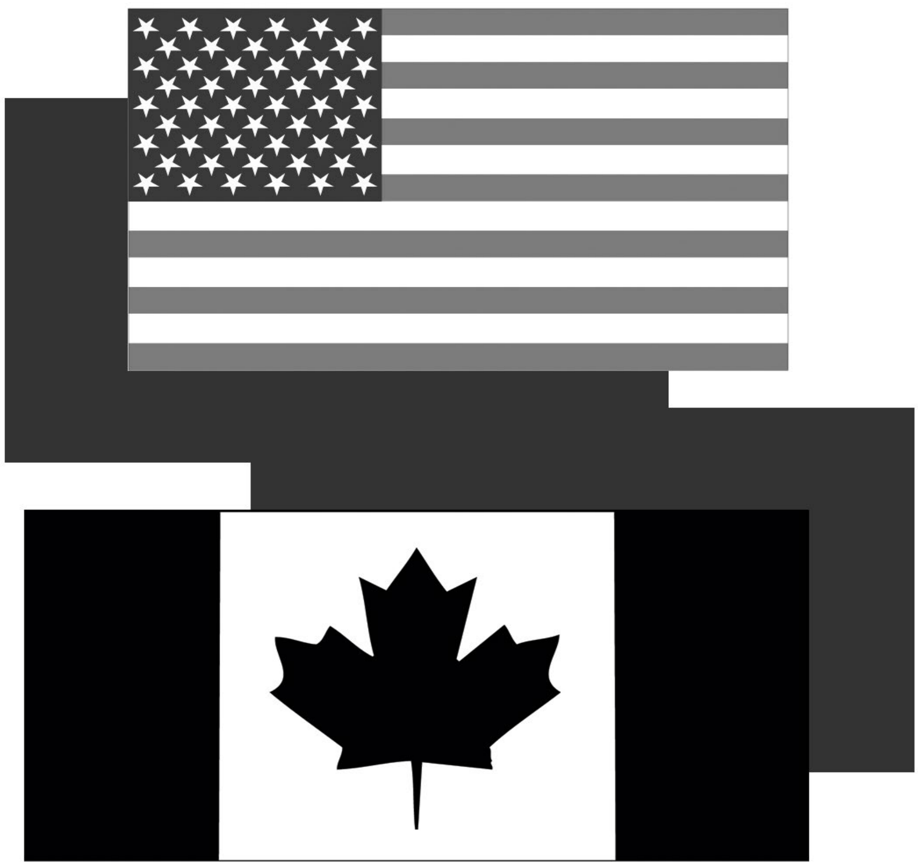
Report of the Technical Subcommittee
of the
Canada-United States Groundfish Committee

Annual Meeting of the TSC

April 19-20, 2022
Remote via Zoom



Appointed by the Second Conference on Coordination of Fisheries Regulations between Canada and the United States

Compiled by the Pacific States Marine Fisheries Commission

History of TSC Meeting Locations, Hosts and Chairs

YEAR	DATES	LOCATION	HOST	CHAIR
1984	June 20-22	British Columbia	Westrheim	Rigby
1985	June 25-27	Juneau, AK	Morrison	Westrheim
1986	June 19-19	Ashland, OR	Demory	Westrheim
1987	June 9-11	Seattle, WA	Jagielo	Demory
1988	June 7-9	Carmel, CA	Henry	Demory
1989	June 6-9	Ladysmith, BC	Saunders	Jagielo
1990	June 5-7	Sitka, AK	Bracken	Jagielo
1991	June 4-6	Newport, OR	Barss	Wilkins
1992	May 5-7	Seattle, WA	Jagielo	Wilkins
1993	May 5-7	Point Lobos, CA	Thomas	Saunders
1994	May 3-5	Nanaimo, BC	Saunders	Saunders
1995	May 2-3	Seattle, WA	O'Connell	Bracken
1996	May 7-9	Newport, OR	Barss	O'Connell
1997	May 6-8	Tiburon, CA	Thomas	Barss
1998	May 5-7	Olympia, WA	Jagielo	Barss
1999	May 4-6	Seattle, WA	Methot	Barnes
2000	May 9-10	Nanaimo, BC	Saunders	Barnes
2001	May 8-10	Newport, OR	Schmitt	Schmitt
2002	May 7-8	Point Lobos, CA	Barnes	Methot
2003	May 6-7	Sitka, AK	O'Connell	Jagielo
2004	May 4-5	Coupeville, WA	Wilkins	Jagielo
2005	May 3-4	Parksville, BC	Stanley	Stanley
2006	May 2-3	Otter Rock, OR	Parker	Stanley
2007	April 24-25	Santa Cruz, CA	Field	Brylinsky
2008	May 6-7	Seattle, WA	Wilkins	Brylinsky
2009	May 5-6	Juneau, AK	Clausen	Clausen
2010	May 5-6	Nanaimo, BC	Stanley	Clausen
2011	May 3-4	Astoria, OR	Phillips	Clausen
2012	May 1-2	Newport Beach, CA	Larinto	Clausen
2013	April 30-May 1	Seattle, WA	Palsson	Larinto
2014	April 29-30	Seattle, WA	Dykstra	Larinto
2015	April 28-29	Sidney, BC	Yamanaka	Larinto
2016	April 26-27	Newport, OR	Whitman	Yamanaka
2017	April 25-26	Juneau, AK	Heifetz	Yamanaka
2018	April 24-25	Santa Cruz, CA	Field	Lowry
2019	April 23-24	Olympia, WA	Lowry	Lowry
2020	Cancelled	Due to COVID-19		
2021	April 20-21	Remote Meeting	via Zoom	Whitman
2022	April 19-20	Remote Meeting	via Zoom	Whitman

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A. History and Purpose

Purpose:

The Technical Subcommittee of the Canada-U.S. Groundfish Committee (TSC) was formed in 1960 out of a need to coordinate fishery and scientific information resulting from the implementation of commercial groundfish fisheries operating in US and Canadian waters off the West Coast. Today, representatives from Canadian and American state and federal agencies meet annually to exchange information and to identify data gaps and information needs for groundfish stocks of mutual concern from California to Alaska. Each agency prepares a comprehensive annual report highlighting survey and research activities, including stock assessments. These reports are compiled into an annual TSC report that is published online (www.psmfc.org/tsc2). The TSC reviews agency reports and recommends collaborative work or plans workshops on topics of shared interest. Historically, the TSC has prepared catch databases that led to the development of the Pacific Fisheries Information Network (PacFIN) catch reporting system, hosted 24 scientific/management workshops, organized 25 working groups, and created the Committee for Age Reading Experts (CARE). Each year the TSC discusses and recommends actions to improve and coordinate groundfish science among agencies, and these recommendations are sent to agency heads and managers to inform research and management priorities.

History:

Before the U.S. and Canada implemented exclusive domestic fisheries off their respective coasts, commercial fishers from either country could fish in both American and Canadian waters. In 1959, an International Trawl Fishery Committee (later renamed the Canada-U.S. Groundfish Committee) was established by groundfish management and research agencies to track transboundary fisheries and examine biological questions pertinent to the stocks and fisheries. This committee established the Technical Subcommittee (TSC), which held its first meeting in 1960 and has held annual meetings ever since. Initial activities and concerns focused on reporting and resolving catch estimates, stock identification and assessment, tagging, aging techniques, and hydroacoustic techniques. These earlier studies focused on Petrale, Rock, and English Soles; Lingcod; Pacific Ocean Perch; and Sablefish. The TSC has fostered new science and improved methodologies by forming workgroups to focus on specific problems and by holding workshops to bring scientists and managers together to discuss aspects of groundfish science that are of mutual concern. Some recent workshops include Trawl and Setline Survey Methods, Catch Reconstruction, Visual Survey Methods, Developing Electronic Data Capture Systems, and Descending Device Policy and Science (see the TSC website for these reports: http://www.psmfc.org/tsc2/).

Evolution:

Over time, the TSC's role has changed with the implementation of new management and legislative authorities but the annual reports provide a common and concise forum to both disseminate information on current groundfish science and to learn about agency programs and activities. The TSC continues to highlight timely research topics, hold workshops, and establish workgroups, as well as send their recommendations to agency directors, fishery managers, and program managers to lay the foundation for trans-boundary coordination through open communication.

B. Executive Summary

With uncertainty in the ability of members to travel to an in-person meeting with the ongoing COVID-19 pandemic, the TSC met remotely on April 19 - 20, 2022. A list of attendees is included in the minutes (Appendix A). Alison Whitman (ODFW) chaired the meeting. As is done each year at the meeting, participants reviewed previous year (2021) research achievements and projected current year (2022) research for each agency. Each agency also submitted a written report summarizing groundfish accomplishments for the previous year. Based on feedback from the 2021 remote TSC meeting, the agenda for the 2022 meeting was modified to include more opportunity to connect and develop collaborations among TSC members. As with last year's meeting, the Chair also directed each agency to select multiple projects to highlight in more detail to the group. These highlighted projects formed the main basis of the TSC discussions. In addition to the highlighted projects, the agenda included two breakout sessions for members to reconnect and to discuss potential collaborations, a Meet and Greet with members of TSC's sister organization CARE, and a guest speaker.

The TSC again noted the valuable ongoing work of the CARE (http://care.psmfc.org/), a long-standing TSC Working Group that was originally created by the TSC in 1982. The purpose of CARE is to facilitate among agencies the standardization of groundfish age determination criteria and techniques. The TSC thanks Delsa Anderl (AFSC) and Andrew Claiborne (WDFW), the current CARE chair and vice chair, for taking the time to attend the 2022 TSC meeting, present CARE's highlighted projects, and organize the CARE meet and greet.

Alison Whitman (ODFW) agreed to continue as Chair of the TSC for 2023. If an in-person meeting is possible next year, the next TSC meeting will be held in Victoria, British Columbia, on April 18 - 19th, 2023, as confirmed after the meeting, and will be hosted by the Department of Fisheries and Oceans, Canada.

Meeting Notes
Sixty-Second Annual Meeting of the Technical Subcommittee (TSC) of the Canada - U.S. Groundfish Committee
April 19-20, 2022
Remote (Zoom)
Chair: Alison Whitman (ODFW)

I. Call to Order (8:30 am (PST) Tuesday April 19th)

Melissa Monk (SWFSC), Kathryn Meyer (WDFW), and Lara Erikson (PSMFC) agreed to act as rapporteurs. The Chair thanks these members for their assistance.

Stephen Phillips (PSMFC) introduced Ms. Erikson as the new PSMFC coordinator. Mr. Phillips indicated that he would be stepping back from the TSC to focus on other duties. The TSC thanks Mr. Phillips for his many years of service and contributions to the TSC. There were also multiple new members to the TSC. Traci Larinto (CDFW) also announced that this will be her last TSC meeting, as she is retiring at the end of the year. The TSC congratulated her on her retirement and thanked her for her contributions to the TSC over the years.

The Chair substantially modified the TSC agenda (Appendix B) from previous years based on feedback from last year's meeting. The TSC approved the new agenda and the 2021 TSC Report. The Chair also encouraged members to contribute to a word cloud that asked for descriptors for the TSC organization. This word cloud is included in Appendix C.

II. Breakout session 1: Reconnecting

Acknowledging that professional connections are one way for TSC members to realize value from the TSC, members were randomly sorted into four smaller groups for a virtual breakout session to get to know each other better. Several trigger questions were provided by the Chair to stimulate conversation (see Appendix B: 2022 TSC Meeting Agenda). General feedback provided by members indicated this was a worthwhile addition to the agenda, particularly with the turnover in membership in the last several years and the virtual setting in both 2021 and 2022.

III. Progress on Previous Year's Recommendations

The Chair detailed progress made on last year's TSC recommendations in three parts: TSC to CARE, TSC to Itself, and TSC to the Parent Committee.

TSC recommendations to CARE were deferred to the planned fall 2022 CARE meeting, with an anticipated report back to TSC in 2023.

The bulk of the presentation focused on the six recommendations from TSC to Itself and are summarized below.

> 1.) *Value of In-Person Meetings* – While an in-person TSC meeting was not possible in 2022, there were changes to the meeting agenda and structure to make the most of meeting time in a virtual setting. These included not doing the traditional round robins, breakout sessions, and focusing on highlighted projects. The Chair was hopeful that next year's 2023 meeting could be in-person.

2.) *Sponsor a WGC Session* – The TSC has previously sponsored and organized sessions at the WGC. Last year's recommendation included a suggested session topic on the potential long-term impacts of COVID on sampling, survey, data collection, and how that may impact management. The WGC was considering a 2022 meeting, but currently, the WGC is planning on an April 2023 meeting in Alaska. The Chair has touched base with the WGC planning committee and will pitch the TSC recommendation at their May 2022 planning meeting. Cara Rodgveller (AFSC), a member of TSC and the WGC planning committee suggested that the TSC provide multiple session topics for consideration. Members agreed to discuss this during the recommendation development agenda item at the end of the meeting.

3.) *Recommendation to develop a draft Terms of Reference (TORs)* – At last year's meeting there was some general confusion regarding what to include in the agency annual report. At that time, a recommendation was made to create a TOR for the annual report to streamline and clarify content expectations. This recommendation also included expansion of the distribution list to a couple of additional groups, including NPRB and PICES. There was also a suggestion to clarify the role and expectations of the Chair to provide additional guidance. There was no progress made and the Chair suggested rolling this recommendation over to this year.

4.) *Draft letters of recognition for retiring TSC members* – There was progress made on this recommendation, including drafting letters and developing a framed certificate of appreciation, which are ready to be mailed to TSC retirees. The Chair requested help finding addresses for these past members.

5.) *Review TSC minutes and finalize Agency reports within two months and provide TSC minutes in Google Docs within two weeks* - The Chair admitted that this was not achieved in 2021 but will prioritize this in 2022. She suggested retaining this suggestion as a goal, potentially in the TORs, rather than a hard recommendation.

6.) *Develop a subcommittee to identify data sharing mechanisms across agencies and countries, create a list of how each Agency is sharing data, and explore (some examples provided) how international agreements are set up.* No progress was made on this recommendation and the Chair suggested rolling this recommendation over to next year. Ms. Whitman also noted this was a relatively ambitious recommendation.

There were two recommendations from TSC to the Parent Committee (PC). There was a brief discussion of the role of the PC. The PC has been more active in recent years and its role has changed over the years. The PC includes representation from both the U.S. and Canada. The recommendations for the PC included advocating for additional survey effort, clarifying goals for ecological monitoring for closed areas, sending a letter commending agency efforts during the COVID pandemic, and prioritizing calibrating surveys to be more easily integrated. There was no progress on these to date. The Chair suggested discussing these recommendations again at a later date, and to further consider the role of the PC.

The Chair asked for any further feedback from the group. Ms. Larinto (CDFW) thanks Ms. Whitman for putting together this presentation and reviewing the recommendations from last year. There is a great deal that can be rolled over to this year as recommendations. Ms. Larinto has some recommendations from her time as TSC chair that could be passed along for TORs or guidelines. As for the other recommendations, she hoped that there will be enough time to discuss these issues/recommendations at the end of the meeting. The Chair confirmed that she prioritized this in the development of this year's agenda.

IV. Agency Overviews Round Robin

The TSC received high level overviews from: Traci Larinto (CDFW), Melissa Monk (SWFSC), Ali Whitman (ODFW), Kat Meyer (WDFW), Keith Bosley (NWFSC), Dana Haggerty (DFO), Ned Laman (AFSC; Seattle), Cara Rodgvellar (AFSC; Juneau), Rhea Ehresmann (ADF&G), and Brianna King (ADF&G). This information is also summarized in the agency overview section of each agency's annual report.

V. Highlighted projects

Highlighted projects were taken up intermittently throughout the meeting. Each agency also provided their powerpoint slides as reference material in the meeting's Google drive. Prior to the meeting, the Chair provided direction to each agency to present three to five projects that they wish to "highlight" for the group in a 20-30 minute presentation. These presentations replaced the traditional round robin that was previously central to the TSC annual meeting.

a. Alaska Department of Fish and Game

The first highlighted project presentation was provided by Rhea Ehresmann (ADF&G). She first discussed the Statewide Rockfish Initiative (SRI). This program started in 2017 to improve management, research, and outreach and focused on rockfish because of their vulnerability to overfishing. This group meets twice per year and has 30-40 participants. There are subgroups that tackle specific projects. These include Communication and Outreach, Harvest Reconstructions, Population Structure and Genetics, Stock Assessments, and MSE Development (after stock assessments are in place). For Communication and Outreach, there were several specific examples detailed. In 2020, deepwater release mechanisms were mandated (>100ft). This group provides descending devices directly to anglers and educational materials, like a popular deck of cards to help with species identification. They also share information through local advisory groups, ADF&G Board of Fisheries, and stakeholder workshops. For the Harvest Reconstructions subgroup, there has been progress made on historical catch reconstructions. These are based on data from logbooks and fish tickets back to 1880's. A challenge of the data reconstruction is to spatially standardize the commercial catch management areas with sport harvest management areas. Using a Bayesian framework similar to Hower et al., these data include catch from domestic, joint venture and other fisheries. Ms. Ehresmann presented figures of estimated catch reconstructed from 1998-2019. The goal of this work is to use these data in stock assessments to estimate total removals (including release mortality).

There is also a project focusing on estimating Yelloweye Rockfish bycatch and discards in the commercial Pacific Halibut fishery. The data are from the IPHC longline surveys and the NOAA observer program (since 2007). Methods are from Tribuzio et al 2014 using the biomass ratio of Yelloweye to Halibut in IPHC survey, and specifically, expands bycatch by applying ratio to Halibut harvests. There was generally good agreement between the observed bycatch from NOAA and the WCPUE from the IPHC survey, as shown in a figure in the presentation. Expected bycatch is roughly equal to landed bycatch, and IPHC rates are similar to NOAA observer program rates. ADF&G is also developing life history and maturity estimates for species under this initiative. Length at Age and maturity schedules for Black and Yelloweye rockfishes have been assessed using histological methods and researchers are looking at differences by region and latitude to inform assessments. There is a genetics study to look at population structure for Black and Yelloweye Rockfishes. Phase 1 includes the development of markers via RADseq and Phase 2 is a population structure examination. Differences were found between inside and outside waters of southeast Alaska and for Yelloweye Rockfish. There is also a project that uses otolith morphology to confirm and correct rockfish species identification. Specific factors evaluated include otolith roughness, thickness, shape and weight. Outliers below prediction intervals for a particular species are flagged for further evaluation. Otolith weight models have proven most useful for species identification; however, only a subset of data can be evaluated via this method. In the future, genetic samples will be used to confirm identifications, and shape and machine learning analyses could narrow the variables.

A new submergence study tracks survival after deepwater releases for rockfishes. Fish are tracked for 15 minutes and then followed for two days. Non-pelagic and pelagic rockfish species were compared and tracked by capture depth, sex, length, and species. Pelagic rockfish (Black) had a better success rate but there was a net gain across all species for deepwater release versus surface release. Finally, Ms. Ehresmann also provided a recorded presentation from Philip Tseresch (ADF&G) that detailed the ADF&G hydroacoustic and dropcam surveys in the Kodiak management area. Split beam hydroacoustics counts individual fish, which are then apportioned by species based on underwater video sampling data. The use of consistent survey locations provides estimates for abundance and density monitoring over time. Rockfish density for four districts has had a slight downward trend (all rockfish combined) since 2007, with tight confidence intervals, except one district. The proportion of Black Rockfish is going up across regions, except in the Northeast district, where the trend is flat. Dropcam density shows Black Rockfish density increasing in all districts except the Northwest.

b. Alaska Fishery Science Center

Ned Laman (AFSC) presented the highlighted projects for the AFSC, covering multiple departments within the AFSC in Seattle. For RACE, large-scale fishery independent surveys resumed in 2021. Bottom trawl surveys in the Gulf of Alaska (GOA) and the Eastern Bering Sea (EBS), which were the 11th and 40th standardized surveys in these series, respectively. In total, there were 550 stations planned in the GOA and 529 stations were completed by two vessels. In general, temperatures in the GOA were cooler than in recent years and warmer than average in the Bering Sea. In Groundfish Assessment Program (GAP), an article was published on the availability of transboundary fishes (O'Leary et al. 2021; cecilia.oleary@noaa.gov), which was an ICES journal editors choice article. This study estimated Walleye Pollock, Pacific Cod and Alaska Plaice abundance across the entire North Pacific region, including the EBS and Russian waters. Results suggest that a growing proportion of the stocks were located in the Western and Northern Bering Sea, in areas where they would traditionally be unavailable to the EBS bottom trawl survey. The cold pool in the EBS was included as a covariate in this exercise and there are implications for stock assessment. There is also a project that details a Pacific Cod satellite tagging effort by Susanne McDermott (susanne.mcdermott@noaa.gov). Twenty-five tags were released in the Western GOA, and more than half moved into the EBS and Northern Bering Sea. Thirty-eight tags were released in the NBS during the summer of 2021. It is possible that movement is related to recent oceanographic variability. A recent paper by Ingrid Spies showed that the genetic population structure of Pacific Cod is similar from Kodiak to the Northern Bering Sea. The satellite tags also provided physical oceanographic data (ingrid.spies@noaa.gov). Finally, Mr. Laman detailed a federal effort to update essential fish habitat (EFH) for all species in Alaskan waters. Species Distribution Model (SDM) ensembles have been developed to describe habitat maps for different life history stages for all fishery management plan species in Alaska using the relationship between abundance and habitat covariates (megsie.siple@noaa.gov). Model predictions and the resulting EFH maps are compilations of numerical abundance, which is converted to quantiles and corresponds to the current definition of EFH in Alaska (top 95%). There is ongoing work and brainstorming to combine movement and genetic stock structure to create an ecosystem-based fisheries management approach.

Cara Rodgveller (AFSC) presented on multiple projects for the AFSC in Juneau. Her presentation focused on Sablefish in Alaska because there has been a great deal of recent discussion surrounding Sablefish management. The first project details a tagging study investigating population dynamics project on Sablefish in Alaska. The longest tag at liberty was 42 years and the furthest traveled was 4200 nautical miles (Aleutian Islands to Oregon). The age structure of Sablefish has shifted dramatically since 2014 and has become truncated recently, dominated by young fish. The 2014 year was the biggest recruitment event in approximately 40 years, perhaps due to warmer water temperatures in the North Pacific. Several more large recruitments have occurred since 2014 as well. These events are a positive development for Sablefish, but these fish are not marketable at their current size and there are concerns about harvesting too many immature fish. Overall, Sablefish biomass is up dramatically as a result of these recent recruitments, but the population is largely immature. Pot gear has recently been allowed in the Sablefish fishery in the GOA in 2017. This has been great for fishermen because the use of pot gear greatly reduces whale depredation, as opposed to the traditional longline gear. Many fishermen are quickly transitioning to pots, "slinky" pots especially. Both landings and effort are increasing. Currently, it is unknown what proportion of the fishery is using slinky versus conventional pot gear. The AFSC is now collecting data on pot type in fishery logbooks, electronic monitoring, and fish tickets. Also, the AFSC is planning to determine the characteristics of the different types of pot gear, as a goal for 2022. As the fishery is transitioning very quickly to this new gear type, this will be an important consideration for future stock assessments.

VII. CARE Highlighted Projects

The highlighted projects for the Committee for Age Reading Experts (CARE) were presented by CARE Chair, Delsa Anderl (AFSC) and the CARE Vice Chair, Andrew Claiborne (WDFW). First, Ms. Anderl presented on the new CARE website, hosted by PSMFC. The website has information on what CARE is about, as well as minutes from past meetings. There is a page that has a list of species to find information on what agencies have been aging each species, aging methodology, and any validation work that has been done. There is also a page on aging exchanges, which contains a list of species, with information on where and when structures were aged by more than one agency. There is a reference page with published papers on age and growth on fish and a forum where any CARE member can initiate a discussion on any relevant topic. Ms. Anderl is anticipating a CARE meeting later this year (Fall 2022) and noted that CARE is made up of 11 total groups or agencies, with 60 members, the largest CARE committee to date. In terms of documenting the aging of species, the AFSC has an electronic aging manual where they continually add species on the new website. Also, AFSC has a reference collection with roughly 100 otoliths where new age readers can be tested for quality control. These also include annotated images with ages.

Mr. Claiborne continued the presentation by providing more detail on the new CARE structure exchange and invoice forms, which includes an exchange tracker. There were only two exchanges in 2021, and one so far in 2022. These are much reduced prior to the pandemic, likely due to the lack of access to the agency's aging laboratories during the pandemic.

Finally, Ms. Anderl provided an update on the Lingcod working group. She noted that it is a very labor-intensive process to prepare Lingcod fin rays for aging, and there has been interest in designating otoliths as the primary structure for aging, or at the least, an alternative structure. A strong validation study comparing the two types of structures has been initiated which uses a paired sample collection with spatial coverage from Alaska to California. The working group determined that there would be one primary reader for the paired samples (~2,700 paired samples collected). At this time, 72% of fin rays have been aged, but paired samples will need to be subset, and they are hoping to make progress this summer.

There were a number of questions for the presenters. Matt Siegle (DFO) asked Ms. Anderl if she was aware of any efforts to age Lingcod otoliths. Ms. Anderl said that she was not aware of any but assumed that samplers would prefer to collect otoliths. She also noted that Sablefish otoliths are aged and are purportedly no more difficult than Lingcod. Rhea Erhesmann (ADF&G) commented on the Lingcod otolith collection procedures in Alaska. She stated that often Lingcod come into port with their heads off, preventing otolith collection in most fishery-dependent samples and noted that cutting through a Lingcod head is very difficult and the heads, when present, are often damaged. Ms. Anderl commented on the difficulty of aging Lingcod with fin rays due to a missing area in the core where there is reabsorption. Mr. Claiborne added that the annuli tend to stack up on the outside of the fin ray. These can result in an age estimate up to three lost annuli. Older fish are more difficult and run the risk of under-aging.

Maria Conrthwaite (DFO) thanked the CARE Chair and Vice Chairs and noted her appreciation for the new website. Ms. Anderl requested feedback for the website, or otherwise, and specifically whether or not the exchanges were working well. Ali Whitman (ODFW) noted that she recently used CARE exchange data to develop an aging error matrix for an Oregon stock assessment on Quillback Rockfish using the exchange information on the website.

Finally, Josep Planas (IPHC) had a question regarding other methods for aging fish, for example, genetic methods (e.g. DNA methylation patterns) where it is unnecessary to collect otoliths or rays. Ms. Anderl noted that investigations are always ongoing into new methodologies, but she didn't have anything specific to note at this time.

IX. Meet and Greet with Committee for Age Reading Experts (CARE) Representatives

The Meet and Greet was opened by the TSC Chair, Ali Whitman, and the CARE Chair, Delsa Anderl. Each group introduced their members. Stephen Phillips (PSFMC) provided a brief presentation on the background and history of the relationship between CARE and TSC. CARE was formed in 1983, based on a recommendation from the TSC that a subgroup be formed to investigate the best practices for aging groundfish. Mr. Philips noted that TSC does not dictate terms to CARE, but coordination and collaboration is encouraged through the recommendations that TSC makes to CARE at their annual meeting and from CARE to the TSC through their annual report to the TSC. Ms. Anderl asked what the goal of the TSC originally was. Mr. Philips stated that the origins of the subcommittee are coordinated management of the Pacific Whiting fishery, which has traditionally spanned the U.S. West coast and British Columbia. Mr. Philips also noted that this was the 62nd annual TSC meeting, and its goals have changed over time with an expansion of its focus to all groundfish species. Attendees agreed that there is a good working relationship between the TSC and CARE, and there were brief discussions on how the process for recommendations to each other could be improved. One CARE member noted a desire to increase the ability of the two groups to rapidly communicate, but also to improve long-term coordination. A mechanism to provide research recommendations for CARE or the TSC through stock assessments would be helpful. A TSC member asked if there were CARE protocols established for aging juvenile fishes. Ms. Anderl noted that there were no CARE specific protocols but, as an example, AFSC has a group of researchers in FOCI that look at daily increments. Leif Rasmusson (CARE representative from ODFW) noted that there were researchers at OSU that use daily increments to age juvenile fish in a research setting and another group in Spain that have automated reading of daily increments.

For the second half of the Meet and Greet, a guest presentation by Tom Helser (AFSC) was provided on the recent advancements in FT-NIRS aging. His presentation was titled "FT-NIRS; aging fish at the speed of light using fourier transform near infrared spectroscopy?" This emerging technology was a topic of discussion at the 2021 TSC meeting.

Dr. Helser's presentation focused on the central question of whether the new technology could age fish with as good or better precision and accuracy than traditional methods. With FT-NIRS, molecular bonds vibrate and are visible in the near-infrared spectrum, with spectra as a multivariate response along the spectral profile. This is used as a tool to maximize the correlation between the spectra and the age (traditional age). There is a need to calibrate and validate the model for each species. However, once a model is available, an unknown sample can be scanned, and an age estimated from the spectra. Results of a published case study on Walleye Pollock were presented that indicated close agreement between the FT-NIRS estimates and traditional methods. With Pacific Cod, which is currently at lowest biomass seen in the Bering Sea, growth and abundance are spatially structured and results from this case study showed higher precision within FT-NIRS than traditional age readers. Finally, Dr. Helser detailed the NFMS Strategic Initiative related to the use of FT-NIRS technology. There are seven laboratories involved and their current focus is determining how to integrate these data into stock assessments.

There were a number of questions from TSC members following Dr. Helser's presentation. First, when is calibration of a model needed, particularly with regard to the need for a reference dataset with traditional ages? Dr. Helser replied that if the estimated ages are within two standard deviations of the expectation, then traditional ages are not usually needed, but it is a complicated question to definitively answer and based on the species-specific spectra. In response to a question regarding the use of other age structures, Dr. Helser noted that they have successfully aged vertebrae and published those results but have not tried fin rays yet. The cost of the equipment was brought up. Larger, lab-based units are several hundred thousand dollars; however, there is a smaller unit for approximately $60,000 that can be brought on larger research vessels. There are a lot of considerations when trying to integrate this technology to age in real-time onboard a vessel, but it is possible. There is time required to prepare otoliths for traditional aging methods that are saved using this technology.

XI. Highlighted Projects (cont.)

a. Department of Fisheries and Oceans, Canada

Sean Anderson (DFO) and Dana Haggarty (DFO) presented their agency's highlighted projects. Dr. Anderson began with a project on automated synopses for groundfish species. Dr. Anderson noted that there are more than 100 groundfish species in Canadian waters that are not always assessed with regular frequency. The goal of the project was to create a reproducible report every year for each species that was only two pages per species. This approach facilitates regular review, generates standard information, and increases data transparency. These synopses highlight uncertainties in the data available for each species and uses the same colors for fisheries and surveys across species. Graphs include blank plots where data are unavailable for a particular species. There are relative biomass indices for surveys, maps of relative biomass using a geostatistical model for biomass density, length and age compositions, length-at-age and length-weight relationships and include tables of number of available biological specimens by species. Documents and the R code are available on their Github page as well as an updated document available with data through 2021. Much of the data are available publicly through Open Canada or DFO websites.

Dr. Anderson also presented a publication evaluating trends in Pacific Canadian groundfish stock status with survey data. On average, there was a long-term decline in abundance of groundfish stocks until 2000 and has since been stable following substantial changes in management and surveys. There were four surveys included, and these were standardized and combined surveys for all stocks using sdmTMB R package. This project also compared stock assessment outputs with the survey trends. It was notable that all shelf and some slope rockfish have seen strong increases in the past five or six years.

Finally, Dr. Haggarty presented on DFO's research related to inshore rockfish and Lingcod stocks. There has been interest in research related to descending devices and she has a graduate student, Ms. Hailey Davies,working on the project. There were nine species tagged with video of the releases, including 352 rockfish, in this tag-recapture project. Only one fish has been recaptured, a Copper Rockfish. A photographer who worked as a research assistant documented barotrauma symptoms. Dr. Haggarty also stated that her staff are participating in the Lingcod fin ray and otolith comparison working group with CARE. Finally, she noted that all of the planned 2020 surveys were carried out in 2021, making for a busy survey field season.

b. Northwest Fishery Science Center

Keith Bosley (NWFSC) presented on several projects from the NWFSC. First, the hook and line survey took place in 2021 in Southern California. This was an annual survey from 2004 – 2019 and resumed in 2021. Second, there was a project that evaluated the limitations of macroscopic maturity analysis for three species and compared macroscopic and histological methods for assessing maturity. There has also been a focus on geographic variability in Lingcod demography, including Laurel Lam's master's work that examined Lingcod growth along the West coast and a new genetic study (Long et al. 2021) that shows a genetic break near Point Reyes. Mr. Bosley presented a study on food habit variability of Arrowtooth Flounder that indicated a varied diet that changed throughout their life history. Smaller fish ate euphausiids and other shrimp, whereas larger fish ate mostly fish. Finally, the NWFSC is testing a dual sorting grid system to reduce juvenile Sablefish catches in the West coast bottom trawl fishery.

c. International Pacific Halibut Commission

Josep Planas (IPHC) and Basia Hutniczak (IPHC) presented their agency's highlighted projects. First, the IPHC continues with its reproductive assessment of Pacific halibut using microscopic maturity staging. Female development phases progress through the year starting in spring, and this schedule determines the ideal time of the year to collect samples for revising current maturity estimates by histological assessment. A population genomics study is ongoing that includes low-coverage whole-genome resequencing at a 3X individual genomic coverage. Dr. Hutinczak presented an economic impact assessment on the Pacific halibut fishery. This study evaluates economic interdependence among sectors, including commercial, processing and recreational fisheries, across the US West Coast, British Columbia and Alaska. Finally, a brief review of the most recent Pacific halibut stock assessment was provided. Mortality limits for 2022 up by 5.7% across management areas. Indices of abundance increased in 2021, with younger fish from the 2012 year-class increasingly important.

XIII. Highlighted Projects (cont.)

a. Washington Department of Fish and Wildlife

Highlighted projects from WDFW were presented by Jen Blaine (WDFW). First, she provided an overview of the Marine Program's organizational structure, with supervisor Theresa Tsou leading the program. The first project Ms. Blaine focused on were the 2021 Pacific Herring spawn surveys in the Southern Salish Sea. These are rake surveys in 21 spawning areas in Puget Sound. She noted the Cherry Point and Squaxin Pass stocks are genetically distinct from the other areas, which exhibit mixed migratory behavior. The estimated regional spawning biomass estimate for Puget Sound saw a large decrease in 2021 from 2020 but was still near the 10-year average. Overall, 2021 spawn was down 43% from 2020, mainly due to lower abundance at two specific areas. Ms. Blaine noted that the recent decline appears worse than it is, since 2020 was such a strong year in terms of biomass, but the 2021 total spawning stock biomass is only about 2.5% below the 10-year average. There were notable decreases in Discovery Bay and SHC dropped to zero spawning biomass, but increases in Holmes and Semiahmoo, where estimated biomass more than doubled. In summary, most stocks declined from the recent high spawning stock biomass observed in 2020, but the total SSB still remains within 3% of the 10-year average. Despite spawning stock biomass contracting spatially in 2021, some stocks expanded into new areas, or returned to areas where spawning hasn't been observed for years. No spawn was observed in South Hood Canal for the first time since the stock has been monitored. Further questions can be directed to Phill Dionne (Phillip.Dionne@dfw.wa.gov).

The 2021 WDFW Coastal Rockfish surveys were reviewed. This is a standardized rod-and-reel CPUE survey of Washington's nearshore waters (less than 40 fathoms) that provides a relative index of abundance for all nearshore rockfish species, Kelp Greenling, and Cabezon. It also provides data to describe migration, life history, and distribution of minor nearshore groundfish. Three recreational charter vessels are contracted for each survey annually with five professional anglers each. There are four eight-minute drifts at each station and the boat can drift or fish within a 50-yard radius from the station's GPS location. Fishermen can retrieve gear as needed and individual angler times are recorded with a stopwatch to document time gear is in the water. The spring survey (a.k.a. "Black Rockfish Survey") was completed in March – May and included 21 survey days and 124 total stations. Fishermen can fish anywhere in the water column but the focus is on Black Rockfish and other schooling mid-water rockfish species using shrimp flies. The fall survey (a.k.a. "Demersal Groundfish Survey") occurs in September – October and includes ten survey days and 56 total stations. Fishermen fish on or near the bottom, focusing on demersal species using a mooching rig or artificial worms. All fish are measured and tagged with a Floy T-bar Anchor tag that is color-coded by angler. Genetics samples and structures are collected. Finally, a CTD deployment at central survey stations measures conductivity, temperature, dissolved oxygen, and chlorophyll a. Preliminary results for 2021 include almost 4,000 fish caught in the 31 total days. Black Rockfish had the highest catch rate in both surveys, followed by Deacon Rockfish. CPUE comparisons across years will be available soon. Questions can be directed to Rob Davis (Robert.Davis@dfw.wa.gov)

Ms. Blaine also presented on the 2019-2021 Puget Sound Remotely Operated Vehicle (ROV) Survey from the WDFW ROV Program. This tool is used for deeper habitats and is best for complex substrates between 30-900 feet (10 to 275 m). This survey is generally focused on rockfish and Lingcod but all fish recorded and enumerated. This survey was meant to cover the entire Puget Sound, with a primary target of rockfish, especially those that are ESA-listed. The original scope was all Washington's inside marine waters using the MaxEnt Model to target high probability habitat. This model utilizes known species locations combined with multiple GIS layers (bathymetry, rugosity, slope, environmental, etc.) to develop layers for ArcGIS. Its spatial coverage is somewhat limited due to low-resolution bathymetry outside of San Juan Islands, but each survey will improve this. There is a stereo-camera on the ROV to collect fish lengths. Random stations were selected within the high probability habitat and the ROV conducts 30 minute transects, which equates to about 500 meters traveled, depending on habitat. Unfortunately, the timeline of this project has changed over time, due to vessel difficulties and the COVID pandemic. The scope of the project was also reduced. The reduced footprint survey was completed in September 2021. There were 184 stations completed, and rockfish were observed at 91 stations. Video review is underway and expected to be completed in the Fall of 2022. The program also has a new ROV with a high-definition camera and a fiberoptic cable.

The final project detailed by Ms. Blaine was the results from the 2021 Puget Sound bottom trawl survey. WDFW has conducted bottom trawl monitoring of bottomfish populations since 1987. This survey has been annual since 2000 and sound-wide sampling at the same 51 index stations since 2008. All fish and invertebrates are identified, counted, and weighed. Some samples have genetic and age samples taken as well. In terms of the benthic invertebrates, metridium anemones and Dungeness crab dominated the invertebrate biomass but shrimp dominated the abundance. There are 15 species of shrimp, but pink shrimp comprised 55% of shrimp abundance. In terms of the bottomfish species, Ratfish were the most dominant species by both biomass and abundance. Most were found in the central Sound (Admiralty Inlet to Vashon Island). English Sole were the second-most dominant species overall and the most dominant flatfish species. Overall, the 2021 survey estimated the lowest total biomass since 2016. Abundance has been relatively consistent since 2017. The largest changes in species included a significant decline in Ratfish biomass, and also declines in both Ratfish and flatfish abundance. There were large increases in cods, sculpins and other fish abundances. The Pacific Cod catch was much higher than in the past. There were 154 total Pacific Cod captured, which was the highest since 2013. Sea star populations showed a slight biomass increase but a decrease in abundance. Ms. Blaine noted that Pycnopodia is under review for an ESA-listing. Overall, the 2002-2019 bottomfish communities within regions have remained relatively consistent over time. There are no major shifts in community composition within a region among year groupings (due to changes in survey methodology) and the regions are mostly unique from each other. There is a rough relationship in the community compositions among regions between depth and the proximity to the open ocean.

There were several questions for Ms. Blaine. Keith Bosley (NWFSC) asked whether there were any adjustments in the footrope that they towed, but Ms. Blaine responded that there were no adjustments, and they did not have ticklers like the NWFSC does. Mr. Bosley also asked about northern Puget Sound surveys and WDFW staff responded that they have been working along the border and coordinating with DFO. Josep Planas (IPHC) asked about the timing for Herring rake surveys and the fishery. Ms. Blaine responded that the fishery was just finishing up and ran from January to March. The surveys were executed concurrently.

b. Oregon Department of Fish and Wildlife

Highlighted projects from ODFW were presented by Ali Whitman (ODFW). First, she described the Marine Reserves Synthesis Report, which is a check-in following a decade of implementation, research and monitoring at Oregon's marine reserves network. The report details results from ecological and socioeconomic monitoring programs at each site and includes a section on "lessons learned" from the implementation of the program. These include continued state funding is necessary for core functions, additional staff capacity is needed, and partnering with academia is fundamental but comes with challenges for an agency focused on applied science. For further information, contact Cristen Don (cristen.don@odfw.oregon.gov).

Ms. Whitman also presented on the first statewide hydroacoustic survey, which uses a combination of hydroacoustic and a specialized drop camera for length/species compositions. There are also fishing stations to verify species compositions and collect biological samples. The survey was completed in 2021. The first pass was from August 1 – October 9, during which severe hypoxia was observed in a significant portion of the surveyed waters. Consequently, a second pass was completed from October 17 – November 27. Data are being analyzed currently and ODFW is planning on a PFMC SSC methodology review in Fall 2022. For more information, contact Leif Rasmusson (leif.rasmusson@odfw.oregon.gov).

Another project presented evaluated the effectiveness of stereo landers during day and night. The development of demersal survey techniques remains a high priority for ODFW and stationary video "landers" provide species counts and compositions in rocky habitats. These landers have been used at ODFW for many years, but scaling up to a standardized survey requires information on how the gear will perform at night to evaluate how best to design a survey. Drops for this project will be conducted in three locations – nearshore, mid- shelf and near-shelf break reefs and the lander will sample systematically five hours before and after sunset. Fieldwork for this project will continue into 2022, and for more information, contact Leif Rasmusson (leif.rasmusson@odfw.oregon.gov).

Finally, Ms. Whitman detailed ODFW efforts during the 2021 federal stock assessment cycle. ODFW staff co-authors on four federal groundfish stock assessments in 2021, including Copper, Quillback, and Vermilion rockfishes and the northern Lingcod assessment. Staff are continuing to work on operationalizing data products for federal assessments and using the results from the 2021 assessments, there are several projects evaluating alternative fleet structures and the addition of age data to these assessments. For more information, please contact Ali Whitman (alison.d.whitman@odfw.oregon.gov).

There were several questions for Ms. Whitman. Kat Meyers (WDFW) asked for more detail on the differences seen in the video lander study, to which Ms. Whitman noted that the differences between day and night seem to be very strong for Quillback Rockfish, but she is not aware of any other species for which there are large differences. She noted that she was not conducting this research and that fieldwork was ongoing. Brianna King (ADF&G) asked for more information on the comparison areas in the marine reserve networks. Ms. Whitman responded by stating that most comparison areas are very close to their companion marine reserves, but not always directly adjacent. Comparison areas were selected to be as similar as possible in terms of habitat and oceanography, and of course, the comparison areas are completely open to fishing. She noted that there are great maps of each of the reserves and comparison areas on the ODFW marine reserves website. Ms. King followed up by asking if there were any comparative studies prior to these reserves becoming off limits to fishing, and Ms. Whitman confirmed that each site was monitored for 18 months to two years before fishing regulations were changed, so that before and after comparisons would be possible. This was partially resulting from a staggered and grassroots implementation of the reserves. Basia Hutniczak (IPHC) inquired about socioeconomic data on the marine reserves and Ms. Whitman referred Ms. Hutniczak to Tommy Swearingen at ODFW. She also noted that ODFW contracts out a great deal of its socioeconomic research, but in general, ODFW wanted to characterize social and economic composition of the marine reserves before and after implementations. Some of the results include an attitude and perceptions survey and an assessment of non-market values. Finally, Matt Siegle (DFO) asked what the drop duration of the video landers was, to which Ms. Whitman replied that it was a short drop, less than 10 minutes.

c. Southwest Fishery Science Center

Melissa Monk (SWFSC) presented the SWFSC highlighted projects. First, she presented on a project on rockfish barotrauma and release device research at SWFSC La Jolla (Contact: Nick Wegner, nick.wegner@noaa.gov). An acoustic array was established at "43 Fathom Bank", which is an isolated bank where fish are expected to remain post-release. The focus of this work is on Cowcod and Boccaccio but also tagged Bank and Sunset rockfishes. The fish were tagged and released at 32 m-91 m and the time at the surface was 2.7 +/-1.3 minutes. Analysis of acoustic tagging long-term survival rates showed that rates were 50.0% for Cowcod (n=46, CI= 35.7-70.5%) and 89.5% for Bocaccio (n=41, CI 80.2-99.8%). Both species were affected for at least 30 days post-release, according to the rate of decline in mortality. Dissolved oxygen was found to significantly affect post-release mortality. This study was published in the ICES Journal of Marine Science.

A second project detailed efforts to develop a California Current Trophic Database (Contact: Joe Bizzarro, joe.bizzarro@noaa.gov). Predator data sources include groundfish, California sea lions, salmon, tunas, squid, and others. The database allows for delineation of samples by spatiotemporal factors. There are 24 datasets contributed by 16 collaborators consisting of 105,728 individual stomach or scat samples.

Finally, Dr. Monk reported on the Rockfish Recruitment and Ecosystem Assessment Survey in 2021 (Contact: John Field, john.field@noaa.gov). The successful 2021 survey completed 140 tows. The survey began in 1983, samples from San Diego, CA to the Columbia River, OR, and uses a modified-Cobb midwater trawl on the NOAA Ship Reuben Lasker. The 2022 survey starts soon. Highlights from the 2021 survey include that for the first time since 2014, pelagic red crabs were not observed. Young of the year

(YOY) rockfish catches were average in central and southern California, but higher in the northern areas. YOY Lingcod in the north central region (near point Reyes to Cape Mendocino) were the second highest ever observed and above average in central California. Relative abundance of adult Northern Anchovy remained high as in recent years, and no Pacific Sardine were observed in the core (central California) area. Pyrosome catches remained high, continuing a trend observed the last 10 years. YOY rockfish, sanddabs and Pacific Hake increased from 2020, but are still below average.

There were several questions for Dr. Monk. Ali Whitman (ODFW) asked how they identified YOY rockfish to species. Ms. Monk replied that 80% of samples are Shortbelly Rockfish but there is a NOAA technical memo that details species identification that she could share. Genetic clips are also an option post-survey. Keith Bosley (NWFSC) asked if the mid-water trawl was towed near the bottom, given the number of flatfish. Dr. Monk responded that it was not and the fish were coming off the bottom at night. Finally, Matt Siegle (DFO) thought it was interesting to conduct bird surveys concurrent to the trawl surveys and asked if there were challenges with that pairing. Dr. Monk responded they are done during the day when the trawl crews are sleeping and noted that the bird surveys were more observational and the SWFSC has always had bird and mammal people on the bottom trawl survey.

d. California Department of Fish and Wildlife

The final highlighted projects presentation was by Traci Larinto (CDFW). She provided a presentation on CDFW's recreational fisheries survey as well as the ROV surveys that inform their groundfish work. Ms Larinto also brought up California's network of marine protected areas, which, similar to Oregon, is undergoing its first decadal review. This is a highly collaborative effort involving many different stakeholders, from NGOs to the fishing industry. There is more detail in the CDFW annual report.

There were some questions for Ms. Larinto. Matt Siegle (DFO) asked how the recreational fishery is regulated. Ms. Larinto responded that at each PFMC meeting in-season monitoring is an agenda item and given the lag time between when fish are caught and when data are available to evaluate catch, CDFW tries to project catch. CDFW has an overall bag limit of 10 rockfish and some sub-bag limits, all based on the PFMC process. Brianna King (ADF&G) asked about the in-season monitoring project and whether the unguided and guided catches were combined, to which Ms. Larinto responded that CDFW combines those types of trips. CDFW, like the other west coast states, used the West coast RecFIN network to report their catch. CDFW provides the data, which are included in the RecFIN online data portal. Finally, Keith Bosley (NWFSC) asked what the proposed timeframe for MPAs and RCAs. Ms. Larinto responded that the PFMC is going to select a preferred alternative at the June 2022 meeting and hopes to have it adopted in 2023 and implemented by 2024.

XIV. Breakout Session 2: Collaboration

Members were broken into four groups with varied agency representation. The focus of this breakout session was to promote collaborative efforts among the TSC agencies and to determine how the TSC could facilitate those collaborations. The report from this session was removed from the agenda to retain agenda time for discussion of the current year's recommendations from the larger group. The Chair recognizes that some of the value of this breakout was lost due to the lack of a breakout report.

XVII. Current Year (2022) Recommendations

Recommendations were developed in real-time using a consensus style approach. There were also some changes to recommendations from 2021 that were rolled over to 2022. There were also additional recommendations proposed. Recommendations from 2021 that were rolled over are italicized and recommendations or portions of a recommendation that has been removed are crossed out.

a. TSC to CARE

1) *Consider aging lingcod structures using FT-NIR spectronomy ~~to eliminate need to collect fin rays~~*

2) *Create a record of aging methods as learning tool*

   a. *Library of video instructions to be housed on CARE website*

3) The TSC expresses its appreciation to the CARE members for attending the TSC-CARE meet and greet during this annual TSC meeting. The TSC appreciated the positive comments by attendees on the relationship between CARE and the TSC and concurs that the current cooperative approach is working well for both committees. The TSC also commends CARE on their updated website as a resource for aging information, publications, and communication. Finally, the TSC would like to thank Tom Helser (AFSC) for his presentation on FT-NIR advancements and his responsiveness to the questions posed by TSC members.

4) The TSC requests that CARE consider methods to advance communication between CARE and the TSC, particularly mechanisms to be able to respond more quickly to emerging issues. The use of virtual platforms might be a potential mechanism, in addition to the forum on the CARE website.

b. TSC to Itself

1) *Emphasize the value of in-person meetings to connect and discuss research opportunities*

2) *Sponsoring a WGC session topic on COVID impacts and opportunities, such as survey, catch monitoring, work-life balance, and inter-agency collaboration, and including ~~comparison and~~ discussion of short-term and potential long-term changes and impacts.* The TSC recognizes that hosting a session or workshop at the WGC is a great mechanism to increase awareness of the TSC. The TSC recommends that discussions for the 2025 WGC begin at next year's TSC meeting.

3) *Develop additional guidance for agency reports, including developing draft TORs and report timing*

   a. *Add NPRB and PICES to distribution list*

   b. *Add guidance for Chair*

   c. Traci Larinto (CDFW) will send information on Chair guidance from previous years

4) ~~*Review TSC minutes and finalize Agency reports within two months, including having the minutes in google docs for review within two weeks and agency reports final by end of June*~~

5) *Draft letters of recognition to recent retirees (Yamanaka, Heifetz, Wilderbuer, Palsson, Workman, Ormseth)*

   a. Add Traci Larinto (CDFW) to this list

   b. Add this to the Chair duties in perpetuity (potentially in the draft TORs) and remove as a recommendation

6) ~~*Create a TSC subcommittee to*~~ *Identify data sharing mechanisms across agencies and countries*

   a. *Add section to agency annual report on data sources (any open sources and other datasets) on data sharing mechanisms*

   b. ~~*Explore*~~ *Include any international fishery data sharing efforts, such as OBIS.org or OpenCanada (which DFO is already utilizing)*

   c. *Consider creating a list of how each agency is sharing data in the updated TSC website (TBD)*

7) The TSC should consider mechanisms to enhance communications with CARE, in particular those that might allow the TSC and CARE to respond to emerging issues more quickly than our respective meeting cycles allow.

   a. The TSC recommends that the TSC Chair or an alternate attend the biennial CARE meeting.

   b. The use of virtual platforms might be a potential mechanism, in addition to the forum on the CARE website.

8) The TSC recommends that PSMFC update the TSC website with input from the TSC. This updated website could be modeled after the new CARE website and could include a forum for intra-meeting communication.

9) The TSC discussed the addition of a section in the TSC reports to describe socioeconomic information or sampling efforts directly related to groundfish fisheries. The TSC recognizes that including this information facilitates cross-disciplinary action and aligns with its earlier recommendation on data sharing mechanisms. At this time, the TSC will clarify the inclusion of these data sources and information in the draft TORs (see other rec.) and determine at future meetings if more action is necessary.

10) The TSC recommends that if the highlighted projects continue at future meetings, the connections of the research to management context and results be included in guidance from the Chair.

c. TSC to Parent Committee

1) *Advocate for maintaining and increasing survey effort by member agencies*

2) *Reach out to member agencies to clarify the management disadvantage of not allowing for ecological monitoring in closed areas*

3) *Send letter to member agencies commending them for staff efforts during COVID*

4) *Advocate for an investigation into calibrating different gear used by agencies on their surveys with goal of being able to use multi-agency surveys when looking at coastwide populations*

5) The TSC sees an opportunity to reinvigorate the Parent Committee with the turnover in senior leadership at PSMFC and DFO. The TSC recommends that DFO and PSMFC coordinate to determine the best staff composition of that committee moving forward.

6) There seems to be a common theme across agencies that hiring qualified staff has become particularly difficult in recent years. The TSC recommends that the Parent Committee consider different mechanisms to improve the ability of agencies to hire personnel, such as mentorship programs, undergraduate research opportunities, or communication mechanisms for job vacancies.

d. Additional Discussion of Current Year Recommendations

The group discussed if there were other topics to propose to the WGC planning committee. However, members felt strongly that a session on COVID impacts remains highly relevant. There was a desire to reframe this recommendation in a more positive light and include potential opportunities that have results from the pandemic. *(TSC to Itself - Recommendation 2).*

Traci Larinto (CDFW) noted that the Chair is doing much of the heavy lifting to make progress on the TSC recommendations, whereas the TSC used to do more as a group in the past. As the TSC transitions back to an in-person format, she suggested that the TORs specifically address this workload issue. Ms. Whitman noted that the recommendation for the TORs indicated that this was originally intended to be more focused on the development of the agency annual reports, rather than what occurs at the annual TSC meeting, but this could be re-evaluated when the draft TORs are brought forward. *(TSC to Itself - Recommendation 3).*

There was a great deal of discussion regarding a suggested recommendation on the inclusion of a specific section with socioeconomic information relevant to groundfish fisheries in the annual reports. Members noted that fishery-dependent surveys for socio-economic information specifically are rare and agencies have limited capacity to do this. Some members were amenable to including this in general guidance on the annual report, as a part of the TORs. Basia Hutniczak (IPHC) added she considers socioeconomic information as a part of ecosystem-based fisheries management approach. Ms. Whitman suggested that this be called out as a separate section, under the Survey section towards the beginning of the report. Maria Cornwaithe (DFO) agreed that it would make sense if the group desired a separate section. Keith Bosley (NWFSC) noted that the NWFSC has an economics team that conducts a variety of related groundfish socioeconomic work, which would make for an easy addition to their annual report. It was noted that if an agency wasn't conducting any socioeconomic work, that could just be stated in the report. However, other members found this concept of a separate section to be untenable and thought it would be difficult to tease apart from other data collection or research efforts. Several were concerned that this would be a large endeavor and would make the already-large annual reports much longer. At the end of this discussion, the Chair suggested that this discussion simply be noted, and the group could consider it further once a draft set of the TORs was available. *(TSC to Itself - Recommendation 9).*

XVIII. 2023 TSC Meeting Planning

Members noted that the WGC might overlap with next year's TSC meeting, and members agreed to adjourn without setting the 2023 meeting date, with the understanding that the Chair would finalize the dates over email after touching base with the WGC planning committee. After the meeting, the Chair set the 2023 TSC meeting dates as April 18 – 19th, 2023. Members expressed an interest in going to Victoria, B.C. and DFO agreed to host the meeting. Ali Whitman (ODFW) also agreed to continue to act as Chair and thanked everyone for their participation this year.

Appendix A: List of Attendees at the 2022 TSC Annual Meeting

TSC Members

1. Rhea Ehresmann (ADF&G)
2. Brianna King (ADF&G)
3. Ned Laman (AFSC)
4. Cara Rodgeveller (AFSC)
5. Delsa Anderl (AFSC)
6. Dana Haggarty (DFO)
7. Maria Cornthwaite (DFO)
8. Lorri Granum (DFO)
9. Sean Anderson (DFO)
10. Matt Siegle (DFO)
11. Keith Bosley (NWFSC)
12. Basia Hutniczak (IPHC)
13. Josep Planas (IPHC)
14. Andrew Claiborne (WDFW)
15. Jen Blaine (WDFW)
16. Kat Meyer (WDFW)
17. Stephen Philips (PSMFC)
18. Lara Erikson (PSMFC)
19. Alison Whitman (ODFW)
20. Melissa Monk (SWFSC)
21. Diana Watters (SWFSC)
22. Traci Larinto (CDFW)

TSC/CARE Meet and Greet (Additional attendees during this part of the agenda)

1. Chris Johnston (IPHC)
2. Andrew Chin (AFSC)
3. Audrey Ty (DFO)
4. Austin Anderson (WDFW)
5. Beth Matta
6. Betty Kamikawa (Toledo Council)
7. Brenna
8. Barb Campbell (DFO)
9. Chris
10. Chris Hind (ADF&G)
11. Crmattson
12. Denise
13. Diana
14. Joan Forsberg (IPHC)
15. John Brogan
16. Julie Pearce

17. Kevin McNeel (ADF&G)
18. Leif Rasmusson (ODFW)
19. Mark Terwilliger (ODFW)
20. Mel Mandrup (CDFW)
21. Morgan Arrington
22. Nikki
23. Patrick McDonald (NWFSC)
24. Robert Tobin (IPHC)
25. Sandi
26. Stephen Wischniowski (DFO)
27. Theresa Tsou (WDFW)
28. Toppijat

Appendix B: 2022 TSC Agenda

Agenda

Sixty Second Annual Meeting of the Technical Subcommittee (TSC) of the Canada - U.S. Groundfish Committee
April 19 - 20, 2022

Tuesday, April 19th: 8:30am - 4:30pm (PST)
Wednesday, April 20th: 8:30am - 1:00pm (PST)

Remote Meeting via Zoom

Join Zoom Meeting

Chair: Alison Whitman (ODFW)

I. 8:30 am: Call to order (30 mins)
   a. Introductions
   b. Housekeeping (Breaks, lunch etc.)
   c. Approval of Agenda
   d. Approval of 2021 Report

II. 9:00 am: Breakout Session 1 (30 mins)
   a. Reconnecting!
      i. What do you like about working for your agency?
      ii. What sparked your interest in groundfish or marine science?
      iii. What do you enjoy in your spare time?
   b. Randomly sorted 3 - 4 groups

III. 9:30 am: Progress on Previous Year's Recommendations (30 mins)
   a. From TSC to Itself
   b. From TSC to Parent Committee

IV. 10:00 am: Agency Overviews Round Robin (30 mins)

V. 10:30 am: BREAK (15 mins)

VI. 10:45 am: Highlighted projects from each Agency (1.25 hours)

VII. 12:00 pm: CARE Highlighted projects (30 mins) * time certain

VIII. 12:30 - 1:30pm: LUNCH

IX. 1:30 pm: Meet and greet with CARE Representatives, followed by a presentation from Tom Helser (AFSC) (1.25 hours) * time certain

X. 2:45 pm: BREAK (15 mins)

XI. 3:00 pm: cont. with Highlighted projects (1.5 hours)

XII. 4:30 pm: Adjourn for the day.

XIII. 8:30 am (Wed. 20th): Cont. with Highlighted projects (1 hour)

XIV. 9:30 am: Breakout session 2 (45 mins)

  a. 30 minute discussion; 4 groups
  b. Focus on potential collaborative research among TSC agencies
    i. What type of research or projects would benefit from involvement from multiple agencies or regions?
    ii. Are there specific projects your agency could collaborate with other TSC member agencies on?
    iii. How can the TSC help or facilitate this research?

XV. 10:15 am: Report from Breakout sessions (15 mins)

XVI. 10:30 am: BREAK (15 mins)

XVII. 10:45 am: Current Year Recommendations (1.5 hours)

  a. From TSC to CARE
  b. From TSC to Itself
  c. From TSC to Parent Committee

XVIII. 12:30 pm: Schedule time and location of the Next Meeting (selection of next Chair, if needed)

XIX. Adjourn when completed (no later than 1:00 pm Wed. 20th).

Appendix C: Word Cloud describing the TSC

Report of the Technical Subcommittee
of the
Canada-United States Groundfish Committee

AGENCY REPORTS

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1. ALASKA FISHERIES SCIENCE CENTER, NATIONAL MARINE FISHERES SERVICE
2. CANADA, BRITISH COLUMBIA GROUNDFISH FISHERIES
3. INTERNATIONAL PACIFIC HALIBUT COMMISSION (IPHC)
4. NORTHWEST FISHERIES SCIENCE CENTER, NATIONAL MARINE FISHERIES SERVICE
5. SOUTHWEST FISHERIES SCIENCE CENTER, NATIONAL MARINE FISHERIES SERVICE
6. STATE OF ALASKA – ALASKA DEPARTMENT OF FISH AND GAME
7. STATE OF CALIFORNIA – DEPARTMENT OF FISH AND GAME
8. STATE OF OREGON – OREGON DEPARTMENT OF FISH AND WILDLIFE
9. STATE OF WASHINGTON – WASHINGTON DEPARTMENT OF FISH AND WILDLIFE
10. COMMITTEE OF AGE READING EXPERTS (CARE)

Alaska Fisheries Science Center of the National Marine Fisheries Service
2021 Agency Report to the Technical Subcommittee of the Canada-US Groundfish Committee
April 2022

Compiled by Ned Laman, Cara Rodgveller, and Olav Ormseth

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VIII. REVIEW OF AGENCY GROUNDFISH RESEARCH, ASSESSMENTS, AND MANAGEMENT IN 2021

I. Agency Overview

Groundfish research at the Alaska Fisheries Science Center (AFSC) is conducted within the following Divisions: Resource Assessment and Conservation Engineering (RACE), Resource Ecology and Fisheries Management (REFM), Fisheries Monitoring and Analysis (FMA), the Auke Bay Laboratories (ABL), and the Habitat and Ecological Processes Research program (HEPR). All Divisions work closely together to accomplish the mission of the Alaska Fisheries Science Center.

In 2021, our activities were guided by our Strategic Science Plan with annual priorities specified in the FY21 Annual Guidance and priorities. A review of pertinent work by these groups during the past year is presented below. A list of publications relevant to groundfish and groundfish issues is included in Appendix I. Lists of publications, posters and reports produced by AFSC scientists are also available on the AFSC Publications Center website, where you will also find a link to the searchable AFSC Publications Database.

Lists or organization charts of groundfish staff of these four Center divisions are included as Appendices II - V.

A. RACE DIVISION

The Resource Assessment and Conservation Engineering (RACE) Division conducts quantitative fishery-independent surveys and related research on groundfish and crab in Alaska. Our efforts support implementation of the U.S. Magnuson-Stevens Fishery Conservation and Management Act and other enabling legislation for stewardship of living marine resources. Surveys and research are principally focused on species from the five large marine ecosystems (LMEs) of Alaska (Gulf of Alaska, Aleutian Islands, eastern Bering Sea, northern Bering and Chukchi Seas, Beaufort Sea). The range of surveys conducted by RACE encompass the entire life history of the focal species, from egg to adult. All surveys provide a suite of environmental data supporting an ecosystem approach to fisheries management (EBFM)[1]. In addition, RACE works collaboratively with Industry to investigate ways to reduce bycatch, bycatch mortality, and the effects of fishing on habitat.

RACE staff are composed of fisheries ecologists and oceanographers, geneticists, technicians, IT Specialists, fishery equipment specialists, administrative support staff, and contract research associates. The status and trend data derived from regular surveys are used by AFSC stock assessment scientists to develop our annual Stock Assessment & Fishery Evaluation (SAFE) reports for 46 unique combinations of species and regions. The research conducted by RACE on our bottom trawl surveys develops our understanding of groundfish population fluctuations and provides environmental data used in stock assessments, Ecosystem Status Reports (ESRs) and Ecosystem Socioeconomic Profiles (ESPs) for selected species. These products and related research communicate explanations for groundfish population trajectories to our stakeholders. The RACE Division science programs include: Fisheries Behavioral Ecology (FBE), Groundfish

[1] https://www.fisheries.noaa.gov/insight/understanding-ecosystem-based-fisheries-management

Assessment Program (GAP), Midwater Assessment and Conservation Engineering (MACE), Recruitment Processes Program (RPP), Shellfish Assessment Program (SAP), and Research Fishing Gear/Survey Support. These Programs operate from three locations: Seattle, WA; Newport, OR; and Kodiak, AK.

The Fisheries Behavioral Ecology Program (FBE) conducts laboratory experimental studies and field studies on the ecology, energetics, behavior, habitat associations, and climate responses of the early life stages of groundfish and crab species including walleye pollock, Pacific cod, Arctic cod, sablefish, northern rock sole, yellowfin sole, Tanner crab, and snow crab. Laboratory studies are performed at NOAA's Newport Research Station in Newport, OR. Areas of investigation include the effects of temperature, elevated CO_2, and oil exposure on the survival and growth performance of eggs, larvae and juveniles. In addition to targeted field studies on habitat associations, FBE performs an annual beach seine and camera survey of age-0 and age-1 Pacific cod in the central Gulf of Alaska.

The primary mission of RACE GAP is the continued fishery-independent stock assessment surveys of groundfish and crab species of the northeast Pacific Ocean and Bering Sea. Regularly scheduled bottom trawl surveys in Alaskan waters include an annual survey of the crab and groundfish resources of the eastern Bering Sea shelf and biennial surveys of the Gulf of Alaska (odd years) and the Aleutian Islands (even years). The upper continental slope of the eastern Bering Sea was quasi-biennial in even years, but has not be conducted since 2016. RACE GAP and SAP scientists also conduct bottom trawl surveys of Alaskan groundfish and invertebrate resources over the eastern and northern Bering Sea shelf. RACE GAP personnel continue to conduct cooperative Pacific cod satellite tagging studies in the Western Gulf of Alaska and the Bering Sea as well as cooperative surveys of locations untrawlable by the RACE GAP surveys of the Gulf.

The Midwater Assessment and Conservation Engineering (MACE) Program conducts echo integration-trawl (EIT) surveys of midwater pollock and other pelagic fishes in the Gulf of Alaska (winter) and the western and central Gulf of Alaska (summer). MACE and GAP continue to collaboratively design an acoustical-optical survey for fish in grounds that are inaccessible to fisheries research trawls in the Gulf of Alaska and Aleutian Islands. Once implemented, survey results will reduce bias in our survey assessments of fishes found in these untrawlable areas.

The Recruitment Processes Alliance (RPA: RACE RPP and ABL Ecological and Monitoring Assessment (EMA) Programs) conducted Gulf of Alaska surveys on the early life history stages of groundfish species in the spring and summer, as well as the environmental conditions necessary to explain growth and mortality of fish. Spring surveys focus on winter and early spring spawners such as Walleye Pollock, Pacific cod, Arrowtooth Flounder, and Northern and Southern Rock Sole. Summer surveys concentrate on the age-0 and age-1 juvenile stages of the winter/spring spawners as well as summer spawners (e.g. forage fishes including Capelin, Eulachon, and Pacific Herring). This survey also estimates whether or not age-0 fish have sufficient energy reserves to survive their first winter.

Research on environmental effects on groundfish and crab species such as the impacts of ocean acidification on early life history growth and survival continue at our Newport, Oregon, and Kodiak facilities. Similarly the Newport lab is engaged in a novel line of research to examine oil toxicity for arctic groundfish (e.g. arctic cod). This effort is to understand risks associated with oil and natural gas extraction as well as increased maritime traffic across the Arctic Ocean.

In 2021, RACE scientists continued research on essential habitats of groundfish, identifying suitable predictor variables for building quantitative habitat models and developing tools to map species distributions and abundances throughout Alaska. For the first time, these scientists have mapped essential fish habitat (EFH) in nearshore nursery areas for early life stages of fishes in Alaska. Independent but related EFH projects have estimated habitat-related survival rates based on individual-based models;, investigated activities with potentially adverse effects on EFH, and determined optimal thermal and nearshore habitat for overwintering juvenile fishes. Juvenile fish growth and condition research characterizing groundfish habitat requirements is ongoing as well.

RACE GAP surveys continue to demonstrate changes to groundfish distribution and abundance related climate-mediated ocean warming and loss of sea ice. In 2021, the cold pool was slightly larger than in 2019, but was still almost entirely restricted to the area north of St. Matthew Island. Shifts in fish distribution due to these phenomena can lead to significant fractions of their populations relocating outside of our historical survey boundaries which violates our assumptions that our indexes of abundance represent a constant proportion of the population from one year to the next. These distributional changes are occurring at exactly the same time as our survey and science resources are declining. The RACE Division is collaborating with an international team of scientists to examine the impacts of reduced survey effort on the accuracy and precision of survey biomass estimates and stock assessments. AFSC hosted an ICES workshop on the impacts of unavoidable survey effort reduction (ICES WKUSER) in the winter 2019/2020. Work on the topic began in late 2018 and substantial progress was made before the 2020 meeting (Kupschus et al. 2020). In a related effort, ongoing research by RACE and other Center scientists is examining the efficacy of model-based abundance estimates to supplement our current design-based estimates.

The FBE conducts laboratory, experimental and field studies on the ecology, energetics, behavior, habitat associations, and climate responses of the early life stages of groundfish and crab species including walleye pollock, Pacific cod, Arctic cod, sablefish, northern rock sole, yellowfin sole, Tanner crab, and snow crab. Laboratory studies are performed at NOAA's Newport Research Station in Newport, OR. Areas of investigation include the effects of temperature, elevated CO_2, nutritional conditions, and oil exposure on the survival and growth performance of eggs, larvae and juveniles. In addition to targeted field studies on habitat associations, FBE performs an annual beach seine and camera survey of age-0 and age-1 Pacific cod in the central Gulf of Alaska.

For more information on overall RACE Division programs, contact Division Director Lyle Britt at (206) 526-4501 or Deputy Director Michael Martin at (206) 526-4103.

Literature Cited:

Kupschus, S., S. Kotwicki, and W. Palsson. 2020. ICES Workshop on unavoidable survey effort reduction (WKUSER). ICES Scientific Reports. 2:72. 92pp. http://doi.org/10.17895/ices.pub.7453

B. REFM DIVISION

The research and activities of the Resource Ecology and Fisheries Management Division (REFM) are designed to respond to the needs of the National Marine Fisheries Service regarding the conservation and management of fishery resources within the US 200-mile Exclusive Economic

Zone (EEZ) of the northeast Pacific Ocean and Bering Sea. The activities of REFM are organized under several programs that have specific responsibilities but also interact:

- The **Age and Growth Studies** program performs production ageing of thousands of otoliths each year and performs research regarding new technologies, reproductive biology, and enhancing age and growth data for less well known species.
- **Economics and Social Sciences Research** (ESSR) performs analyses of fisheries economics as well as sociological studies of Alaska fishing communities, and produces an annual economic report on federal fisheries in Alaska.
- **The Resource Ecology and Ecosystem Modeling** (REEM) program maintains an ever-growing database of groundfish diets, constructs ecosystem models, and produces an extensive annual report on the status of Alaska marine ecosystems.
- **Status of Stocks and Multispecies Assessmen**t (SSMA), in collaboration with the Auke Bay Laboratories, prepares annual stock assessment documents for groundfish and crab stocks in Alaska and conducts related research. Members of REFM provide management support through membership on regional fishery management teams.

For more information on overall REFM Division programs, contact Division Director Ron Felthoven (ron.felthoven@noaa.gov).

C. AUKE BAY LABORATORIES

The Auke Bay Laboratories (ABL), located in Juneau, Alaska, is a division of the NMFS Alaska Fisheries Science Center (AFSC). ABL's Marine Ecology and Stock Assessment Program (MESA) publishes groundfish stock assessments for rockfish in the Gulf of Alaska, and sharks, sablefish, and grenadiers for all of Alaska and conduct management strategy evaluations (MSEs). MESA also conducts biological research, such as movement, growth, stock structure, ageing, and maturity. Presently, the program is staffed by 10 full time scientists and 1 term employee. ABL's Ecosystem Monitoring and Assessment Program (EMA) capture groundfish in their surveys in the Bering Sea and the eastern Gulf of Alaska and conduct research on impacts of the environment on groundfish. The Recruitment Energetics and Coastal Assessment Program (RECA) studies the energetics and diet of juvenile groundfish and the Genetics Program conducts research on cod, pollock, sablefish, shark, and forage fish stock structure and distribution.

Projects at ABL included: 1) ageing and movement studies of sharks, 2) predicting pollock recruitment from a temperature change index, 3) researching copepods as an indicator of walleye pollock recruitment, 4) whole genome sequencing of multiple groundfish, 5) population structure and distribution of pollock and cod species, 6) tagging juvenile sablefish nearby Sitka, AK, 7) the continuation of the long-term groundfish tagging program, 8) the continuation of a sablefish coast-wide assessment and research group (OR, WA, BC, AK), 9) conducting the AFSC's annual longline survey throughout Alaska, and 10) the continuation of the northern Bering Sea ecosystem survey.

In 2021 ABL prepared 9 stock assessment and fishery evaluation reports for Alaska groundfish: Alaska sablefish, Gulf of Alaska (GOA) Pacific ocean perch, GOA northern rockfish, GOA dusky rockfish, GOA rougheye/blackspotted rockfish, GOA shortraker rockfish, GOA and Bering Sea/Aleutian Islands "Other Rockfish", and GOA thornyheads.

For more information on overall programs of the Auke Bay Laboratories, contact the ABL

Laboratory Director Dana Hanselman at (dana.hanselman@noaa.gov). For more information on the ABL reports contact Cara Rodgveller (cara.rodgveller@noaa.gov).

D. FMA DIVISION

The Fisheries Monitoring and Analysis Division (FMA) monitors groundfish fishing activities in the U.S. Exclusive Economic Zone (EEZ) off Alaska and conducts research associated with sampling commercial fishery catches, estimation of catch and bycatch mortality, and analysis of fishery-dependent data. The Division is responsible for training, briefing, debriefing and oversight of observers who collect catch data onboard fishing vessels and at onshore processing plants and for quality control/quality assurance of the data provided by these observers. Division staff process data and make it available to the Sustainable Fisheries Division of the Alaska Regional Office for quota monitoring and to scientists in other AFSC divisions for stock assessment, ecosystem investigations, and an array of research investigations. For further information please contact Jennifer Ferdinand, (206) 526-4194.

E. HEPR

The Habitat and Ecological Processes Research Program focuses on integrated studies that combine scientific capabilities and create comprehensive research on habitat and ecological processes. The HEPR Program focuses on four main research areas.

Loss of Sea Ice

Climate change is causing loss of sea ice in the Bering, Chukchi and Beaufort Seas. Addressing ecosystem-related shifts is critical for fisheries management, because nationally important Bering Sea commercial fisheries are located primarily within the southeastern Bering Sea, and for successful co-management of marine mammals, which at least thirty Alaska Native communities depend on.

Essential Fish Habitat

Alaska has more than 50 percent of the U.S. coastline and leads the Nation in fish habitat area and value of fish harvested, yet large gaps exist in our knowledge of Essential Fish Habitat (EFH) in Alaska.

Habitat Research in Alaska

Major research needs are

1. to identify habitats that contribute most to the survival, growth, and productivity of managed fish and shellfish species; and
2. to determine how to best manage and protect these habitats from human disturbance and environmental change.

Essential Fish Habitat Research Plan in Alaska

Project selection for EFH research is based on research priorities from the EFH Research Implementation Plan for Alaska. Around $300,000 is spent on about six EFH research projects each year. Project results are described in annual reports and the peer-reviewed literature. Study results contribute to existing Essential Fish Habitat data sets.

For more information, contact Dr. James Thorson (james.thorson@noaa.gov).

II. Surveys

2021 Eastern Bering Sea Continental Shelf and Northern Bering Sea Bottom Trawl Surveys – RACE GAP

The thirty-ninth in a series of standardized annual bottom trawl surveys of the eastern Bering Sea (EBS) continental shelf was completed in 2021 aboard the AFSC chartered fishing vessels *Vesteraalen* and *Alaska Knight*, which together bottom trawled at 376 stations over a survey area of 492,898 km^2. Researchers processed and recorded the data from each trawl catch by identifying, sorting, and weighing all the different crab and groundfish species and then measuring samples of each species. Supplementary biological and oceanographic data were also collected during the bottom trawl survey to improve the understanding of groundfish and crab life histories and the ecological and physical factors affecting their distribution and abundance.

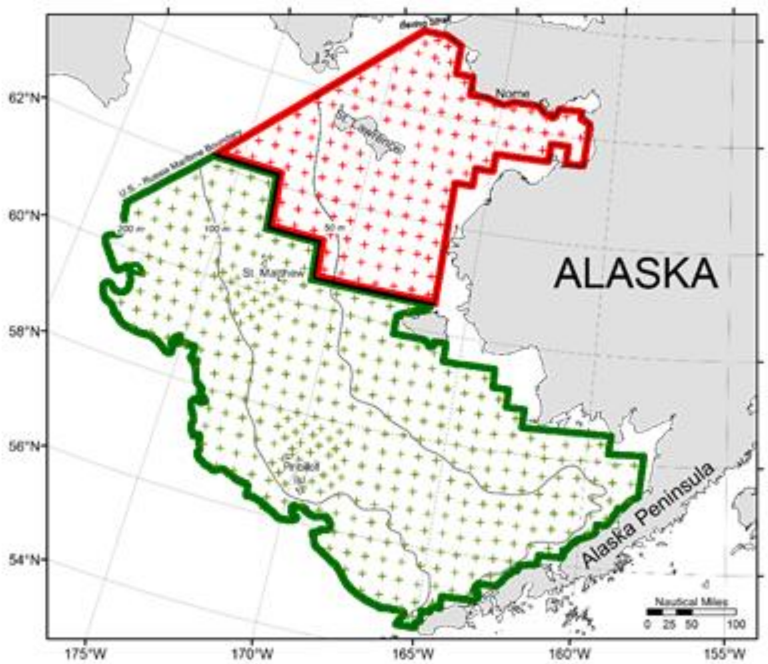

Fig. 1. Map showing survey stations sampled during the 2021 eastern and northern Bering Sea shelf bottom trawl survey.

Survey estimates of total biomass on the eastern Bering Sea shelf for 2021 were 3.0 million metric tons (mt) for walleye pollock, 616.3 thousand mt for Pacific cod, 162.2 thousand mt for yellowfin sole, 1.0 million mt for northern rock sole, 10.7 thousand mt for Greenland turbot, and 131.4 thousand mt for Pacific halibut. Approximately half of the commercially important fish species showed increases in estimated survey biomass compared to 2019 levels. Pacific cod biomass increased 19%, Pacific halibut 15%, Bering flounder 15%, flathead sole 11%, and northern rock sole 6%. Walleye pollock biomass decreased 44%, Greenland turbot 33%, Kamchatka flounder 26%, arrowtooth flounder 21%, yellowfin sole 19%, and Alaska plaice 9%.

The summer 2021 survey period was warmer than the long-term average for the seventh consecutive year. The overall mean bottom temperature was 3.34°C in 2021, which was slightly colder than 2019 (4.34 °C); the mean surface temperature was 7.23°C in 2021, which was almost two degrees colder than 2019 (9.24°C).

After the completion of the EBS shelf survey, which started for both vessels in Dutch Harbor on 29 May 2021, both vessels transitioned into sampling survey stations in the southwest corner of the NBS survey region. After a crew change, the F/V *Alaska Knight* sampled the stations west of Norton Sound moving to the Bering Strait and working south. The F/V *Vesteraalen* conducted sampling in the Norton Sound area traveling east to west. The F/V *Vesteraalen* and the F/V *Alaska Knight* conducted sampling in the NBS from 22 July to 13 August. A total of 520 20 x 20 nautical mile sampling grid stations in the combined EBS and NBS were successfully sampled in 2021.

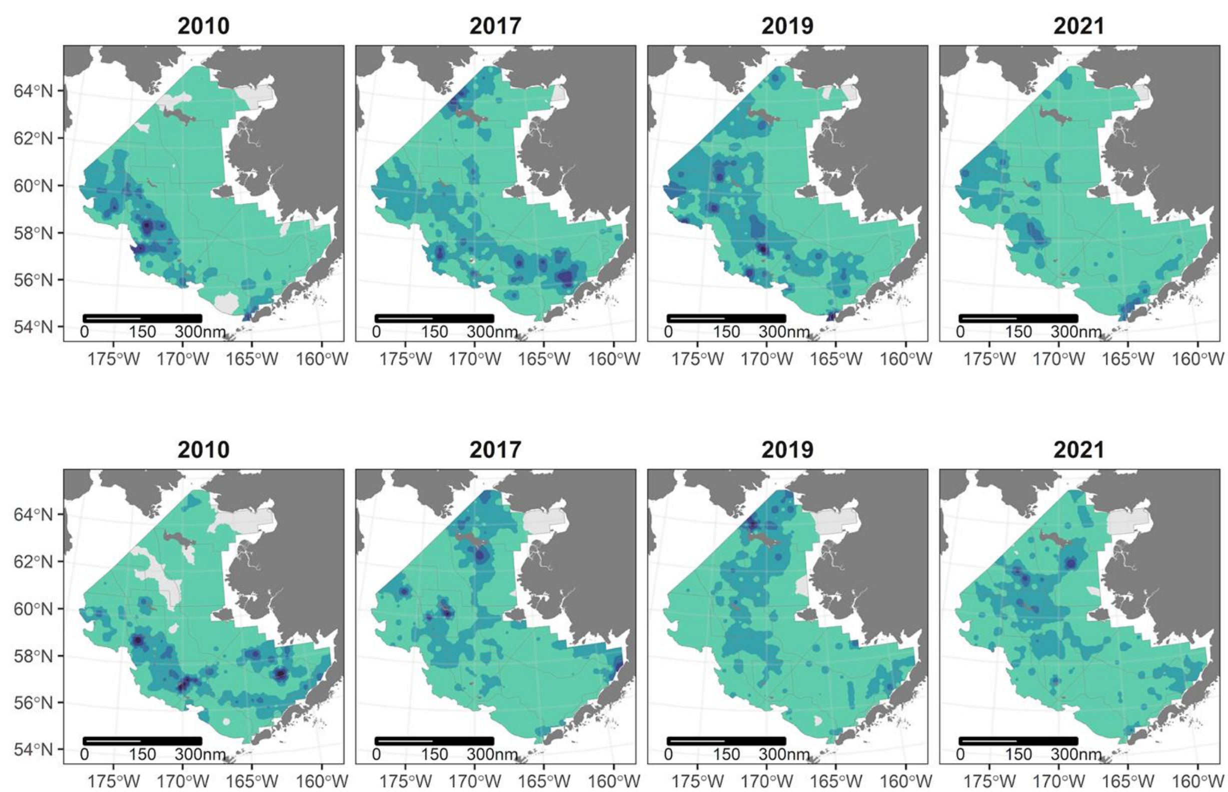

Fig. 2. Spatial distribution of large gadids, in terms of mean CPUE (kg/ha), observed during the 2010, 2017, 2019, and 2021 bottom trawl surveys of the EBS and NBS: Top panel is walleye pollock in (left to right) 2010,2017, 2019, and 2021; bottom panel is Pacific cod in (left to right) 2010, 2017, 2019, and 2021.

The NBS region was fully surveyed using the same standardized protocols and sampling resolution as the EBS survey in 2010, 2017, and 2019. The 2017 distributions of walleye pollock and Pacific cod were completely different than those observed in 2010. In 2010, pollock was mostly concentrated on the outer shelf at depths of 70–200 m north of 56°N (Fig. 2, top left). Pollock biomass was consistently low on the inner and middle shelf, and pollock were almost completely absent from the NBS.

In 2017, pollock biomass in the EBS was concentrated mostly on the middle shelf. In the NBS, there was a high concentration of pollock biomass to the north of St. Lawrence Island (Fig. 2, top middle). The total pollock biomass in 2018 from the EBS was 3.11 million mt. Pollock biomas from the NBS in 2017 was 1.32 million mt. In 2019, pollock distributions were quite different to 2017, 2018 and 2010. In 2018, the EBS pollock were densest in the south east corner of Bristol Bay, in small clusters along the Aleutian chain, and near the shelf break between 59°N and 60°N. During the 2019 EBS, pollock were densest north and west of the Pribilof Islands and the north west survey area In the NBS, pollock were concentrated directly south of St. Lawrence Island and north of the island near the Bering Strait (Figure. 2, top right). The total pollock biomass from EBS was 5.5 million mt, while pollock biomass from the NBS was 1.2 million mt in 2019.

In 2010, Pacific cod biomass in the EBS was concentrated in Bristol Bay and on the middle and outer shelf from the Pribilof Islands north to St. Matthew and cod biomass was low throughout the NBS (Fig. 2, bottom. left). Total cod biomass from the EBS was 8.7 thousand mt, while biomass from the NBS was only 2.9 thousand mt. In contrast, the 2017 Pacific cod densities in the NBS were high both to the north and south of St. Lawrence Island. The 2018 Pacific cod biomass was again concentrated in only a few areas of the EBS. Total estimated cod biomass from the EBS was 5.1 thousand mt during 2018 and biomass from the NBS during 2017 was 2.9 thousand mt. In 2019, Pacific cod biomass was again concentrated in only a few areas of the EBS, but the majority of the biomass was concentrated to the north, east, and south of St. Lawrence Island in the NBS (Fig. 2, bottom. right). Total estimated cod biomass from the EBS was 517 thousand mt, while biomass from the NBS was 365 thousand mt in 2019. In all survey years, Pacific cod were concentrated in areas with bottom temperatures >0°C.

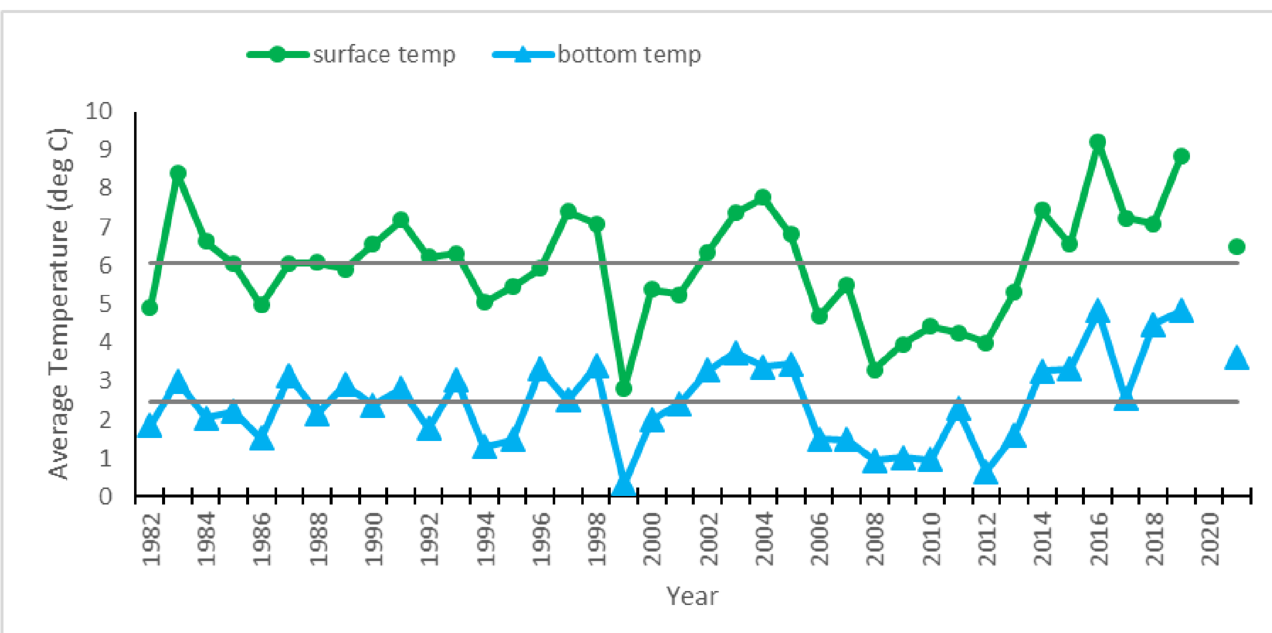

Figure 3: Average annual surface and bottom temperature during the survey period for the eastern Bering Sea shelf survey with the survey mean temperature (1982-2021).

The surface and bottom temperature mean for 2019 eastern Bering Sea shelf increased from 2018 estimates. Both were warmer than the long-term time-series mean (Fig. 3). The 2019 mean surface temperature was 9.2°C, which was 1.6°C higher than 2017 and 2.5°C above the time-series mean (6.7°C). The mean bottom temperature was 4.4°C, which was 0.2°C above the mean bottom temperature in 2018, but 1.6°C above the time-series mean (2.8°C). The 'cold pool', defined as the area where temperatures <2°C, appeared in stations to the west and southwest of St. Lawrence Island (Figure 4). The southern extent in 2019 reached to just south of St. Matthew Island. However, bottom temperatures along the entire length of the inner shelf from Bristol Bay to Chirikov Basin were warm (>6°C) and more developed than in 2017 when the cold pool only reached into a few stations west of St. Lawrence Island.

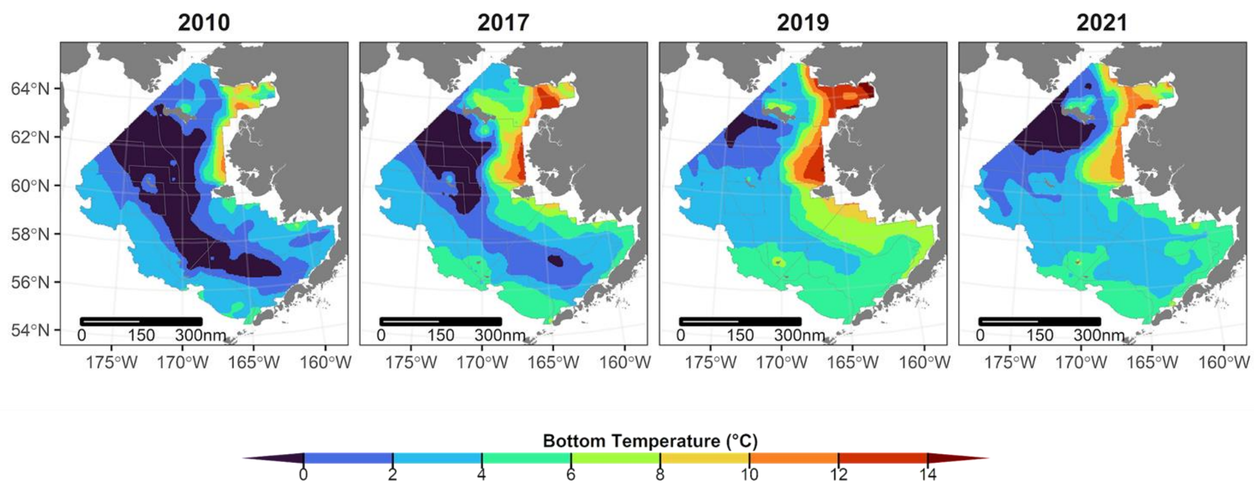

Figure 4: Distribution of survey bottom temperatures for (left to right) 2010, 2017, 2019, and 2021 - the four years that the EBS survey was expanded to comprehensively include the northern Bering Sea shelf.

2021 Gulf of Alaska Biennial Bottom Trawl Survey- RACE GAP

AFSC's RACE Division chartered the fishing vessels *Ocean Explorer* and *Alaska Provider* to conduct the 2021 Gulf of Alaska Biennial Bottom Trawl Survey of groundfish resources. This was the seventeenth survey in this series which began in 1984, was conducted triennially for most years until 1999, and then biennially since. The two vessels were each chartered for 75 days. The cruise originated from Dutch Harbor, Alaska in May and concluded at Ketchikan, Alaska in August. The survey began near the Island of Four Mountains (170° W longitude) and proceeded eastward through the Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern management zones trawling in depths between 15 and 700 m.

During these surveys, we measure a variety of physical, oceanographic, and environmental parameters while identifying and enumerating the fishes and invertebrates collected in the trawls. Specific objectives of the 2021 survey included: defining the distribution and estimating the relative abundance of principal groundfishes and important invertebrate species that inhabit the Gulf of Alaska, measuring biological parameters for selected species, and collecting age structures and other samples. The survey design is stratified-random sampling utilizing 54 strata of depths and regions applied to a grid of 5 km^2 cells. Stations that have been identified as untrawlable were excluded from the sampling frame. Stations were allocated amongst the strata using a Neyman optimal sampling scheme weighted by stratum areas, stratum variance, and the ex-vessel values of key species. Stations were trawled with the RACE Division's standard four-seam, high-opening Poly Nor'Eastern survey trawl equipped with rubber bobbin roller gear. This trawl has a 27.2 m headrope and 36.75 m footrope consisting of a 24.9 m center section with adjacent 5.9 m "flying wing" extensions. Accessory gear for the Poly Nor'Eastern trawl includes 54.9 m triple dandylines and 1.8 ´ 2.7 m steel V-doors weighing approximately 850 kg each. The charter vessels conducted 15-minute trawls at pre-assigned stations. Catches were sorted, weighed, and enumerated by species. Biological information (sex, length, age structures, individual weights, stomach contents, etc.) were collected for selected groundfish species. Specimens and data for special studies (e.g., maturity observations, tissue samples, photo vouchers) were collected for various species, as requested by researchers at AFSC and other cooperating agencies and institutions. Specimens of rare fishes or invertebrates, including corals, sponges, and other sessile organisms were collected on an opportunistic basis and accessioned into the AFSC voucher system.

A total of 550 stations were planned across the shelf and upper slope of the Gulf of Alaska to a depth of 700 m (Figure 1). A total of 668 unique taxa were encountered in the 529 trawls completed; 180 of those were fishes and the remainder were invertebrates ranging from decapods to sponges. The total catch of all fish taxa from the survey was around 275 mt and of invertebrates was around 6 mt. A total of 47 taxa were accessioned to the AFSC RACE voucher collection from the 2021 survey, around 180,000 fish lengths were collected, and close to 11,500 otolith pairs were extracted for ageing. A variety of special collections for ecological and environmental studies were also completed A validated data set was finalized on 30 September and estimates of abundance and length composition of managed species and species groups were delivered to the Groundfish Plan Team of the North Pacific Fisheries Management Council (NPFMC); data and estimates have also been made available through the AKFIN system (www.psmfc.org). The Plan Team incorporated these survey results directly into Gulf of Alaska stock assessment and ecosystem forecast models forming the basis for groundfish harvest advice for ABCs and TAC in 2021. Biomass estimates for Pacific ocean perch, Pacific cod, and arrowtooth flounder all remained relatively stable in 2021 compared to 2019 estimates while walleye pollock abundance appeared to increase slightly.

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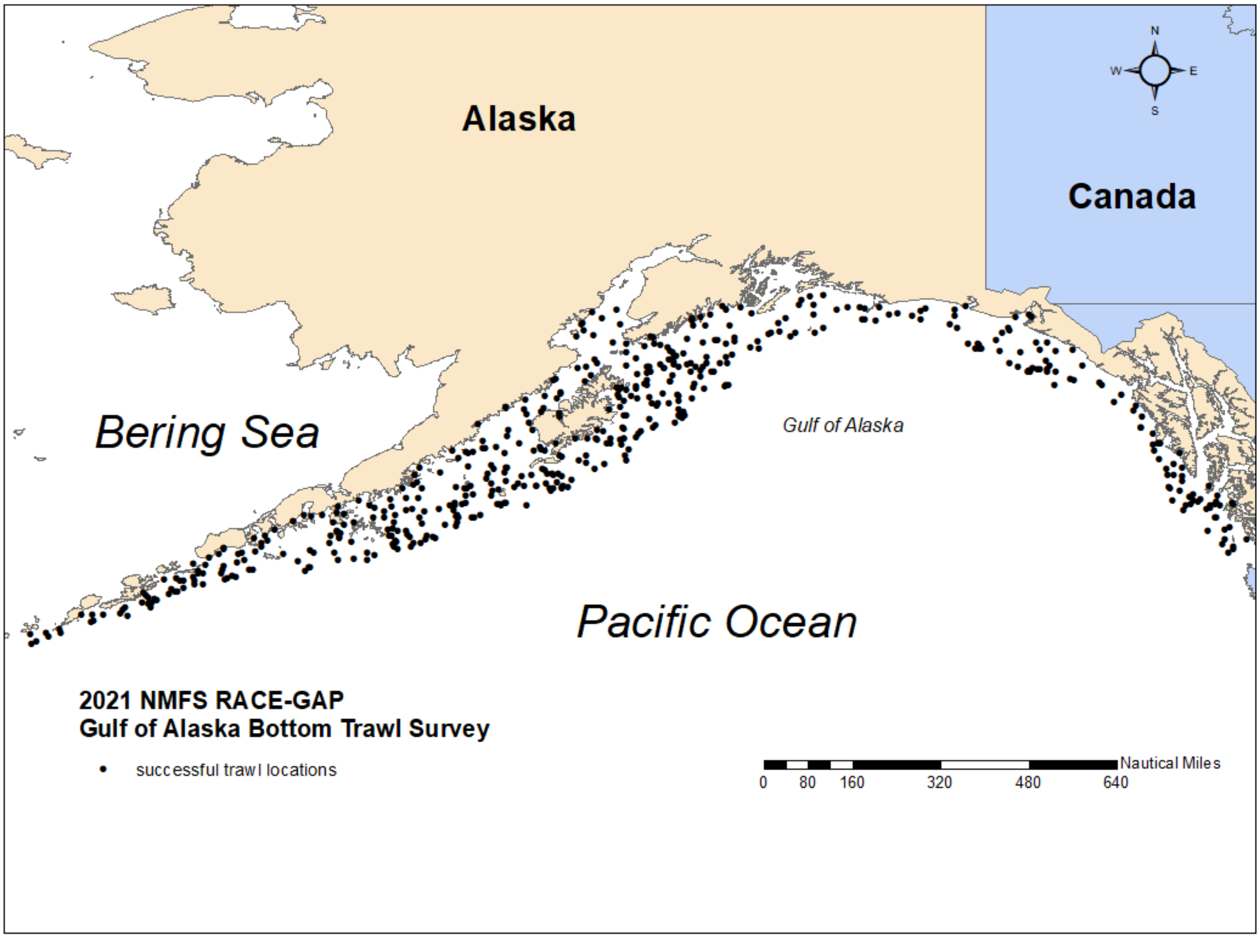

Figure 1. Stations successfully trawled (N = 529) during the 2021 Gulf of Alaska Biennial Bottom Trawl Survey by vessel.

GOA Nearshore age-0 seine survey - RACE FBEP and Alaska Coastal Observations and Research (ACOR)

An extensive nearshore survey was conducted between 2 July and 8 August, 2020. Beach seines were the primary sampling method. A total of 75 beach seine sets were made in 14 different bays on Kodiak Island, the Alaska Peninsula, and the Shumagin Islands (Fig. 1). For each set, habitat information, temperature, and salinity were recorded. In addition, a CTD cast was made in each study bay to record temperature and salinity profiles.

The primary target for the seine survey is age-0 Pacific cod, as this age class is most abundant in shallow coastal nursery areas where environmental conditions (e.g., temperature and food availability) are optimal. As a result age-0, and to some degree age-1, GOA Pacific cod are present in very shallow (0-4 m) nearshore habitats at densities several orders of magnitude higher than found in offshore habitats (Abookire et al. 2007, Laurel et al. 2007, 2009). These nursery habitats are accessible by inexpensive beach seine sampling gear, and beach seine and inexpensive camera gear are currently the only effective means for studying age-0 and age-1 gadids in the Gulf of Alaska. AFSC biologists have conducted post-settlement beach seine surveys for Pacific cod at two Kodiak Island bays during July and August since 2006, and have expanded the survey across 14 more bays along Kodiak and the Alaska Peninsula (Fig. 1). This time series is the only long-term directed program for studying juvenile Pacific cod in the Central and Western GOA and invaluable data on juvenile growth and condition across warm and cold environmental stanzas. The time series demonstrates strong links between age-0 and age-1 abundances in consecutive years, indicating that it may provide an early indication of the strength of recruitment to the adult population, and recently, these data are included in the stock assessment process for GOA Pacific cod. In addition, the survey also catches high abundance of age-0 walleye pollock and pink salmon that may also be useful to management.

In 2020, a total of 27,992 individuals of 47 fish species were captured in beach seines. Pacific cod and walleye pollock were the most common species. All Pacific cod and pollock captured were young of the year. The abundance of the age-0 2020 cohort was nearly 2 orders of magnitude higher than average CPUE observed in the heatwave years of 2019 and 2014-16. Detailed demographic information was collected on 2,219 Pacific cod (length, weight, condition) and ~1,400 of these fish were retained for a variety of laboratory studies, including analysis of body condition, diets, lipid profiles, otolith microchemistry, and otolith reading to infer hatch phenology and daily growth increments. An additional 642 fin clips were retained for genetic studies.

Sampling at 10 m was also conducted using baited cameras. The camera survey is designed to sample age-1 Pacific cod that are typically beyond the maximum depth range of the beach seine, but too shallow to be available to trawl gear. A total of 40 camera sets were conducted in 12 bays in 2020.

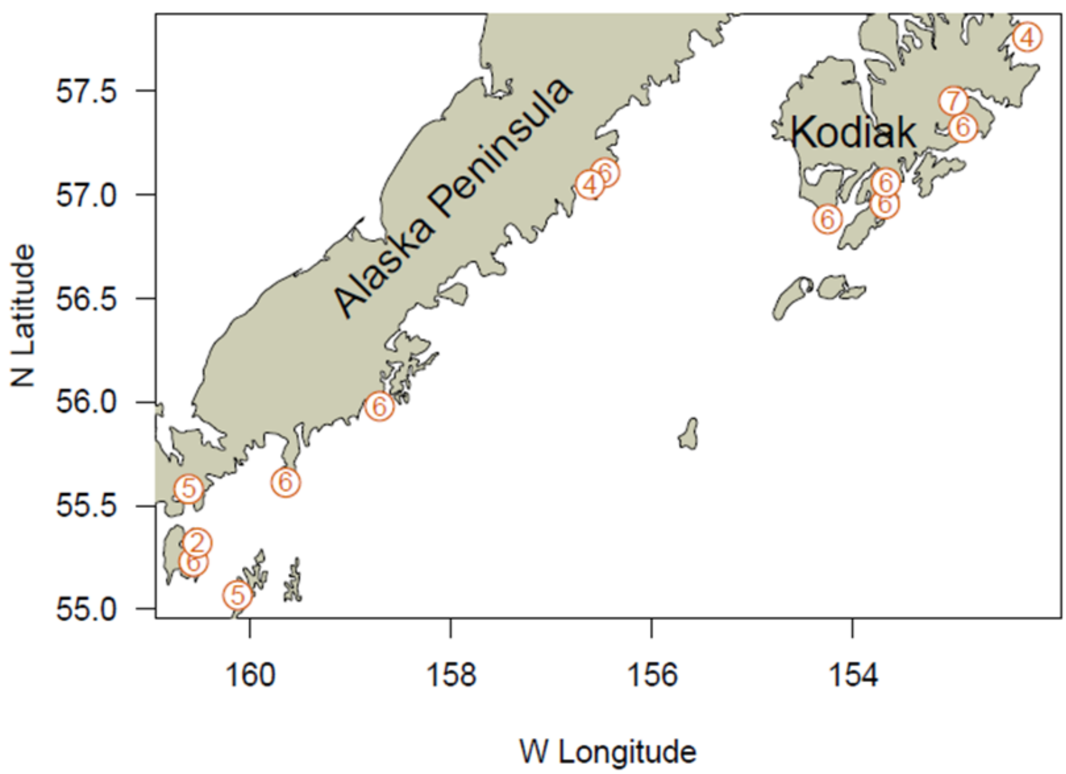

Figure 1: Beach seine sampling locations. Numbers inside circles indicate the total number of seine sets in each bay. A total of 27,992 individuals of 47 species of fish were captured, with age-0 Pacific cod and walleye pollock ranking most common. An additional 40 baited camera sets were also conducted across bays.

Benjamin J. Laurel and Mike Litzow

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Winter Acoustic-Trawl Surveys in the Gulf of Alaska - MACE

Scientists from the Alaska Fisheries Science Center conducted an acoustic-trawl survey in the Shelikof Strait area during late winter 2021 to estimate the distribution and abundance of pre-spawning walleye pollock (*Gadus chalcogrammus*). Winter Gulf pre-spawning pollock surveys have typically included the Shumagin Islands, including Sanak Trough, Morzhovoi Bay, and Pavlof Bay since 2002, and the continental shelf break near Chirikof Island, and Marmot Bay as part of the Shelikof survey. Additionally, the Kenai/Prince William Sound area has been surveyed occasionally and is currently scheduled for odd-year winters. Shelikof and Marmot Bay were the only areas surveyed in winter 2021 due to impacts of the global COVID-19 pandemic. Shelikof Strait and Marmot Bay were surveyed 2-15 March.

The survey was conducted with the NOAA ship *Oscar Dyson*, a 64-m stern trawler equipped for fisheries and oceanographic research. Midwater and near-bottom acoustic backscatter at 38 kHz was sampled to estimate the abundance of walleye pollock using an LFS1421 trawl. Backscatter data were also collected at 4 other frequencies (18-, 70-, 120-, and 200-kHz) to support multifrequency species classification techniques.

In Shelikof Strait, acoustic backscatter was measured along 1735.2 km (937 nmi) of transects spaced mainly 13.9 km (7.5 nmi) apart with spacing varying from 11.3 km to 15.6 km (6.1 to 8.4 nmi) in the survey area. Biological data and specimens were collected from 24 LFS1421 hauls targeted on backscatter attributed to pollock. Pollock and eulachon were the most abundant species in the catch by weight (contributing 68.3% and 24.7%, respectively) and also by numbers (contributing 52.1% and 40.9%, respectively). Pollock observed in Shelikof Strait were generally in pre-spawning (females) or spawning (males) maturity stages. The maturity composition of females > 40 cm fork length (FL; n = 219) was 1% immature, 8% developing, 88% pre-spawning, 2% spawning, and 0% spent. Most females were in the pre-spawning stage of maturity, substantially fewer were spawning and none was spent, which suggests that the timing of the 2021 Shelikof Strait survey relative to the spawning period was appropriate.

Pollock were detected throughout the main body of Shelikof Strait from roughly the Semidi Islands to north of Cape Nukshak. Most of the fish were distributed along the west side between Cape Nukshak and Cape Kekurnoi, and in the center of the sea valley south of Cape Kekurnoi, as is typical for previous Shelikof surveys. Most adult pollock were detected in a thick, uniform layer in water column depths between 205 and 275 m. Most juveniles <= 30 cm FL (largely comprising 8-16 cm FL, age-1 pollock) were between depths of 165 and 265 m. Juveniles were often observed in relatively shallow layers in the middle and eastern portion of the Strait, and would typically disperse at night.

A total of 8,364.7 million pollock weighing 526,974 t were estimated to be in the Shelikof Strait at the time of the survey. The 2021 biomass was 14.7% higher than that observed in 2020 (459,399 t) and 27.1% lower than the historic mean of 715,570 t. The relative estimation error of the 2021 biomass estimate based on the 1-D geostatistical analysis was 2.9%.

Pollock biomass at age in Shelikof Strait was marked by three modes at age-9, age-4, and age-1. Walleye pollock between 44 and 65 cm FL were primarily composed of the age-9 (2012) year class (2% of numbers, 27% of the biomass) with additional biomass contributed by the surrounding year classes. Pollock between 24 and 43 cm FL consisted primarily of the age-4 (2017) year class (2% of numbers, 14% of the biomass). The 8 to 16 cm FL age-1 (2020) year-class dominated the Shelikof Strait population numerically (92%) and contributed 13% of the biomass.

Acoustic backscatter was measured along 312.1 km (168.5 nmi) of transects spaced mainly 1.9 km (1 nmi) apart with spacing varying from 1.9 km to 3.7 km (1 to 2 nmi) in the Marmot Bay area. Biological data and specimens were collected in the Marmot Region from 6 LFS1421 hauls targeted on backscatter attributed to pollock. Pollock and eulachon were the most abundant species in the catch by weight, (contributing 98.1% and 1.2%, respectively) and by numbers (contributing 83.9% and 10.8%, respectively). Pollock observed in the Marmot Region were generally in developing (females) or spawning (males) maturity stages. The maturity composition of females > 40 cm FL (n = 19) was 30% immature, 44% developing, 25% pre-spawning, 0% spawning, and 1% spent. As most females were in the developing or pre-spawning stage of maturity and substantially fewer were spawning or spent, the timing of the 2021 Marmot Region survey relative to the spawning period was likely to have been appropriate.

Adult pollock were detected throughout Marmot Region, but were primarily found in Spruce Gully. Most adult pollock (75% of the biomass) were detected between depths of 135 and 265 m. Most juvenile pollock were detected between depths of 85 and165 m.

A total of 180.5 million pollock weighing 7,400.9 t were estimated to be in the Marmot Region at the time of the survey. The 2021 biomass was 17.9% higher than was observed in 2019 (6,275 t), the last time we surveyed that area. The relative estimation error of the 2021 biomass estimate based on the 1-D geostatistical analysis was 5.8%.

Pollock biomass at age in Marmot Bay was marked by three modes at age-9, age-4, and age-1. In contrast to Shelikof Strait, the age-4 (2017) year class made up the highest percentage of pollock biomass (2% of numbers, 28% of biomass) in the Marmot area, whereas the age-9 (2012) year class pollock were relatively less abundant (< 1% of numbers, 11% of the biomass). Age-1 pollock (9-16 cm FL, 2020 year class) accounted for 92% of the numbers and 17% of the pollock biomass.

For more information, contact MACE Program Manager, Sandra Parker-Stetter, sandy.parker-stetter@noaa.gov.

Summer acoustic vessel of opportunity (AVO) index for midwater Bering Sea walleye pollock-MACE

Acoustic backscatter data (Simrad ES60, 38 kHz) were collected aboard two fishing vessels chartered for the AFSC summer 2021 bottom trawl surveys (F/V *Alaska Knight*, F/V *Vesteraalen*). These Acoustic Vessels of Opportunity (AVO) data were processed according to Honkalehto et al. (2011) to provide an index of age-1+ midwater pollock abundance for summer 2021 (Stienessen et al. 2022, in review). The 2021 AVO index of midwater pollock abundance on the eastern Bering Sea shelf increased by 37.6 % from the 2019 index value, and is the second highest value on record, only 1.8% less than the value recorded in 2015. The percentage of pollock backscatter east of the Pribilof Islands was 16%. This is on the low end of the range observed during the more recent summers between 2013 and 2019 (ca. 15% to 25%).

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Stienessen, S.C., T. Honkalehto, N.E. Lauffenburger, P.H. Ressler, and L. Britt. 2022. Acoustic Vessel-of-Opportunity (AVO) index for midwater Bering Sea walleye pollock, 2021. *In review.*

For more information, contact MACE Program Manager, Sandra Parker-Stetter, sandy.parker-stetter@noaa.gov.

Summer acoustic-trawl survey of walleye pollock in the Gulf of Alaska- MACE

The MACE Program completed a summer 2021 acoustic-trawl (AT) survey of walleye pollock (*Gadus chalcogrammus*; hereafter referred to as pollock) across the Gulf of Alaska (GOA) shelf from the Islands of Four Mountains eastward to Yakutat Trough aboard the NOAA ship *Oscar Dyson*. The summer GOA shelf survey also included smaller-scale surveys in the Shumagin Islands, Shelikof Strait, Barnabas Trough, and Chiniak Trough regions. Previous acoustic-trawl surveys of the GOA have also been conducted during the summers of 2003 (partial), 2005 (partial), 2011 (partial), 2013, 2015, 2017, and 2019. In 2021, the Covid-19 pandemic affected survey participation and logistics such that staffing could only support 2 - 20 day legs (40 day survey) instead of 3 (60 day survey). In response, many smaller bays and troughs surveyed since 2013 were not surveyed in 2021; analysis suggested that this will have little impact on the survey estimate as 92% - 98% of the survey biomass from 2013-2019 was within the areas surveyed in 2021.

The primary survey objective was to collect daytime 38 kHz acoustic backscatter and trawl data to estimate the abundance of pollock. Midwater and near-bottom acoustic backscatter was sampled using an LFS1421 trawl. A trawl-mounted stereo camera ("CamTrawl") was used during LFS1421 trawls to aid in determining species identification and size of animals encountered by the trawls at different depths. A poly Nor'eastern (PNE) bottom trawl was used for sampling near-bottom organisms. Midwater macro-zooplankton were sampled using a Methot trawl. Additionally, the survey collected physical oceanographic data. Water temperature profiles were obtained with a temperature-depth probe attached to LFS1421, PNE and Methot trawls, as well as with conductivity-temperature-depth (CTD) collections at calibration sites, at several predetermined stations, and at nightly opportunistic sites. Sea surface temperatures were continuously measured using the ship's flow-thru sea surface temperature system.

Biological data and specimens were collected from 58 LFS1421, 4 Methot, and 5 PNE hauls. Pollock and Pacific ocean perch were the most abundant species by weight in LFS1421 trawls, contributing 51.5% and 36.3% of the catch, respectively. Pollock and eulachon were the most abundant species by number, contributing 44.8% and 18.2% of the catch. In the PNE bottom trawls, Pacific ocean perch and pollock were the most abundant species by weight, contributing 34.8% and 23.8% of the catch. Pacific glass shrimp and pollock were the most abundant species by number, contributing 68.7% and 7.7% of the catch. Euphausiids were the most abundant species by weight (82.9%) and number (99.1%) in Methot trawls.

The estimated abundance of age-1+ pollock for the entire surveyed area was 4,307.6 million fish weighing 431,053 metric tons (t), a decrease of 7.6% by numbers and 27.5% by weight from the 2019 estimated abundance. The majority of the pollock biomass was observed in the GOA Shelf (60%) and Shelikof Strait (28%) regions. In GOA surveys conducted from 2013 to 2019, the historically large 2012 year class was responsible for the bulk of the observed pollock biomass and numbers. Although the pollock from the 2012 year class were still observed by the survey in summer 2021, age-4 pollock dominated by weight, and age-1 pollock dominated numerically: 28% of the total pollock biomass was attributed to age-4 fish from the 2017 year class, and 84% of the total pollock numbers were attributed to age-1 fish from the 2020 year class.

Abundance estimates were also calculated for Pacific ocean perch (*Sebastes alutus*) and Pacific capelin (*Mallotus catervarius*). Pacific ocean perch ranged from 16 cm to 47 cm fork length (FL), with a mode at 39 cm. The estimated amounts of POP for the 2021 GOA survey area were 386.0 million fish weighing 277,941 t, 77% higher by numbers and 93% higher by biomass than the 2019 estimate. Pacific capelin ranged from 7 cm to 15 cm standard length, with a mode at 9 cm. The estimated amounts of Pacific capelin for the 2021 GOA survey area were 1,563.7 million fish weighing 8,593 t, 63% lower by numbers and 41% lower by biomass than the 2019 estimate. Since 2011, an estimate of the distribution and abundance of backscatter attributed to euphausiids (or 'krill,' primarily consisting of *Thysanoessa inermis*, *T. spinifera*, and *Euphausia pacifica*) has also been provided; work to produce this estimate in 2021 is ongoing.

Since 2013, 5 survey areas have been consistently sampled in all summer GOA surveys: the GOA shelf, Shumagin Islands, Shelikof Strait, Barnabas Trough, and Chiniak Trough regions. Within this consistently sampled region and time period, average surface temperatures in previous surveys have ranged from 10.2°C (2013) to 12.0°C (2015). In 2021, the surface temperature was 9.0°C, 1.2°C cooler than in the coolest previous survey (2013). Surface temperatures became progressively warmer from west to east; however, this is confounded with survey timing, as water temperatures increased to seasonal highs during the survey period. Similarly, differences in survey timing confound any inter-annual comparisons of surface temperature, as survey regions were not always sampled at the same time within each survey year and the 2021 survey concluded approximately 20 days earlier than other summer GOA surveys. The mean temperature at 100 m depth in 2021 was 5.4°C, within the range of previous surveys, which have ranged from 5.1°C (2013) to 6.5°C. The mean bottom temperature, as measured during 31 CTD deployments, was 5.0°C, 0.1°C cooler than in the coolest previous survey (mean bottom temperatures in previous surveys have ranged from 5.1°C in 2013 to 6.0°C in 2019).

The GOA Shelf from the Islands of Four Mountains eastward to Yakutat Trough was surveyed between 4 June and 8 July. Acoustic backscatter was measured along 1,415 nmi of trackline on 30 transects spaced 30.0 nmi (west of Kodiak Island) or 40.0 nmi (east of Kodiak Island) apart. Age-1+ pollock ranged in length from 12 to 67 cm FL with modes at 16, 31, and 41 cm FL. Pollock ranged in age from 1 to 12, with age-1 fish comprising the majority by number (74%) and age-4 fish comprising the majority of the biomass (31%). The estimated amounts of age-1+ pollock for the GOA Shelf were 1,653.9 million fish weighing 260.1 thousand tons, 60.3% of the total pollock biomass observed in this survey and 62.4% of the estimate in 2019.

The Shumagin Islands region was surveyed between 9 June and 12 June. Acoustic backscatter was measured along 211 nmi of trackline on 26 transects primarily spaced 3.0 nmi apart. Age-1+ pollock observed on the Shumagin Islands ranged in length from 13 to 62 cm FL with a mode at 15 cm FL. Pollock ranged in age from 1 to 12, with age-1 fish comprising the vast majority by number (98%) and age-1 fish comprising the majority of the biomass (63%). The estimated amounts of age-1+ pollock for the Shumagin Islands were 131.5 million fish weighing 5.5 thousand tons, approximately 1.3% of the total pollock biomass observed in this survey and 28.5% of the estimate in 2019.

The Barnabas Trough region was surveyed between 17 June and 20 June. Acoustic backscatter was measured along 165 nmi of trackline on 12 transects spaced 6.0 nmi apart. Age-1+ walleye pollock observed on the Barnabas Trough ranged in length from 13 to 65 cm FL with modes at 15 and 39 cm FL. Pollock ranged in age from 1 to 12, with age-1 fish comprising the majority by number (54%) and age-3 fish comprising the majority of the biomass (40%). The estimated amounts of age-1+ pollock for the Barnabas Trough were 174.7 million fish weighing 36.0 thousand tons, approximately 8.4% of the total pollock biomass observed in this survey and nearly identical to the estimate in 2019.

The Shelikof Strait region was surveyed between 24 June and 28 June. Acoustic backscatter was measured along 357 nmi of trackline on 12 transects predominantly spaced mainly 20.0 nmi apart. Age-1+ walleye pollock observed on the Shelikof Strait ranged in length from 12 to 62 cm FL with modes at 15 and 39 cm FL. Pollock ranged in age from 1 to 12, with age-1 fish comprising the vast majority by number (93%) and age-1 fish comprising the majority of the biomass (40%). The estimated amounts of age-1+ pollock for the Shelikof Strait were 2,228.4 million fish weighing 119.6 thousand tons, approximately 27.7% of the total pollock biomass observed in this survey and an increase of 12% from the estimate in 2019.

The Chiniak Trough region was surveyed between 29 June and 30 June. Acoustic backscatter was measured along 121 km (65 nmi) of trackline on 7 transects spaced 6.0 nmi apart. Age-1+ walleye pollock observed on the Chiniak Trough ranged in length from 14 to 64 cm FL with modes at 15 and 37 cm FL. Pollock ranged in age from 1 to 12, with age-1 fish comprising the vast majority by number (88%) and age-1 fish comprising the majority of the biomass (29%). The estimated amounts of age-1+ pollock for the Chiniak Trough were 119.1 million fish weighing 9.9 thousand tons, approximately 2.3% of the total pollock biomass observed in this survey and twice the estimate in 2019.

For more information, contact MACE Program Manager, Sandra Parker-Stetter, sandy.parker-stetter@noaa.gov.

Longline Survey – ABL

The AFSC has conducted an annual longline survey of sablefish and other groundfish in Alaska from 1987 to 2021. The survey is a joint effort involving the AFSC's Auke Bay Laboratories and Resource Assessment and Conservation Engineering (RACE) Division. It replicates as closely as practical the Japan-U.S. cooperative longline survey conducted from 1978 to 1994 and samples gullies not previously sampled during the cooperative longline survey. In 2021, the 44th annual longline survey sampled the upper continental slope of the Gulf of Alaska and the eastern Bering Sea. One hundred and fifty-two longline hauls (sets) were completed during May 30 – August 26 by the chartered fishing vessel *Alaskan Leader*. Total groundline set each day was 18 km (9.7 nmi) and consisted of 180 skates and a total of 8,100 hooks.

Sablefish (*Anoplopoma fimbria*) was the most frequently caught species, followed by giant grenadier (*Albatrossia pectoralis*), Pacific cod (*Gadus macrocephalus*), rougheye/blackspotted rockfish (*Sebastes aleutianus/S. melanostictus*), shortspine thornyhead (*Sebastolobus alascanus*), and Pacific halibut (*Hippoglossus stenolepis*). A total of 169,613 sablefish, with an estimated total round weight of 392,897 kg (866,189 lb) were caught during the survey. This represents increases of 14,774 fish and 50,296 kg (110,884 lb) of sablefish over the 2020 survey catch. Sablefish (6,156), shortspine thornyhead (312), and Greenland turbot (*Reinhardtius hippoglossoides*, 27) were tagged with external Floy tags and released during the survey. Length-weight data and otoliths were collected from 3,480 sablefish. Killer whales (*Orcinus orca*), depredating on the catch, occurred at 10 stations in the eastern Bering Sea and one station in the western Gulf of Alaska. Sperm whales *(Physeter macrocephalus)* were observed during survey operations at 10 stations in 2021 and were observed depredating on the gear at 5 stations in the central Gulf of Alaska, one station in the West Yakutat region, and 2 stations in the East Yakutat/Southeast region.

In 2021, the number of AFSC staff that participated on the survey was reduced for COVID-19 precautions. AFSC permanent staff participated on 4 out of 6 legs of the survey. An experienced contractor participated on all legs and served in the role of Chief Scientist for the two legs not supervised by AFSC staff. With reduced scientific staff onboard, special projects were curtailed but did include the collection of sablefish eyeballs for examining stable isotope ratios in eye lenses for tracking trophic level changes through development.

Longline survey catch and effort data summaries are available through the Alaska Fisheries Science Center's website: https://apps-afsc.fisheries.noaa.gov/maps/longline/Map.php. Full access to the longline survey database is available through the Alaska Fisheries Information Network (AKFIN). Catch per unit effort (CPUE) information and relative population numbers (RPN) by depth strata and management regions are available for all species caught in the survey.

For more information, contact Pat Malecha (pat.malecha@noaa.gov). For data access, contact Cara Rodgveller (cara.rodgveller@noaa.gov).

Northern Bering Sea Surface Trawl and Ecosystem Survey - ABL

The 2021 survey occurred at standard stations in the northern Bering Sea in 2021. Station sampling included phytoplankton, zooplankton, invertebrate nekton, fish, seabird, and marine mammals. The average surface temperature (9.4°C) in 2021 was just above the overall average annual temperature (8.8°C) recorded during the survey from 2003 to 2021. The most abundant benthic fish species captured was yellowfin sole and they were present at nearshore stations throughout the survey. We plan to continue the survey on an annual basis to provide scientific support for salmon, groundfish, and crab resources in the northern Bering Sea.

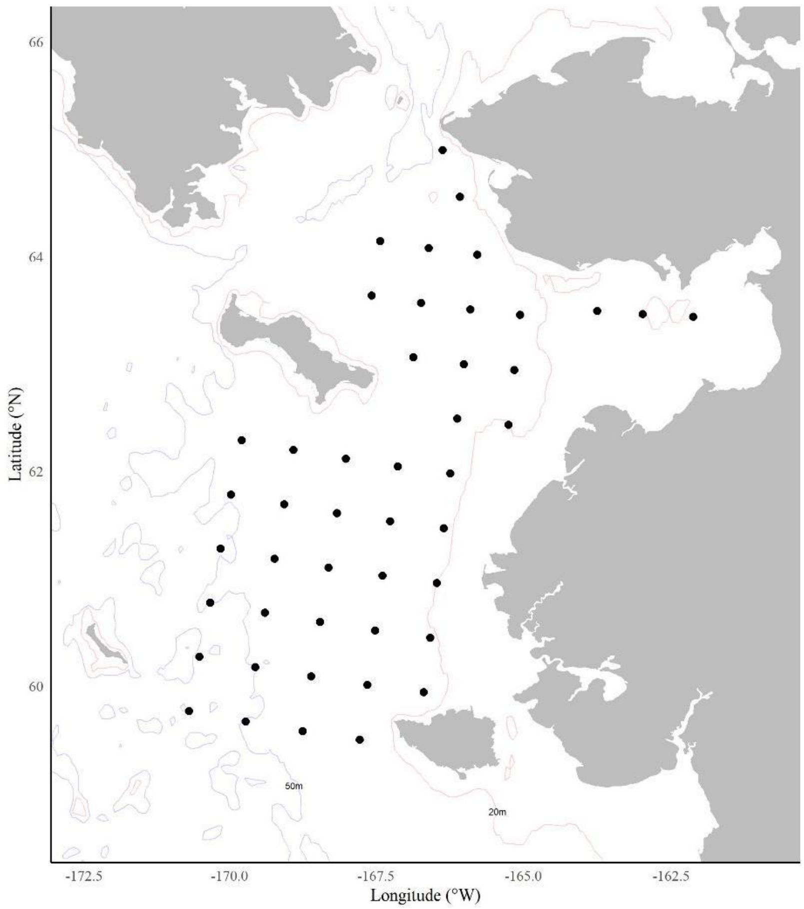

Figure 1. Standard stations sampled during 2021 Northern Bering Sea Surface Trawl and Ecosystem Survey, August 27 to September 20, 2021.

North Pacific Groundfish Observer Program (Observer Program) - FMA

The Fisheries Monitoring and Analysis (FMA) Division administers the North Pacific Observer Program (Observer Program) and Electronic Monitoring (EM) Program which play a vital role in the conservation and management of the Bering Sea, Aleutian Islands, and Gulf of Alaska groundfish and halibut fisheries.

FMA observers and EM systems collect fishery-dependent data onboard fishing vessels and at onshore processing plants that is used for in-season management, to characterize interactions with protected resources, and to contribute to assessments of fish stocks, provide data for fisheries and ecosystem research and fishing fleet behavior, and characterize fishing impacts on habitat. The Division ensures that the data collected by observers and through EM systems are of the highest quality possible by implementing rigorous quality control and quality assurance processes.

During 2020 the FMA Division was faced with enormous challenges in facilitating observer training and deployment. Data from observers is essential for managing federal fisheries and choosing to not deploy them was simply not an option. Training and equipping observers from the Seattle campus was challenging because the campus was closed to all but essential staff, and multiple layers of precaution were necessary due to the pandemic. Deployment of observers was difficult due to limits on travel, quarantine requirements, and the risk of infection. In addition, the challenges varied considerably during the year as the assessment of the pandemic, the state and national standards for preventing infection, and the fishing industry's implementation of those standards changed. For further information regarding FMA activities please access the AFSC website or contact Jennifer Ferdinand at Jennifer.Ferdinand@noaa.gov.

III. Reserves

IV. Review of Agency Groundfish Research, Assessment, and Management

Note: Management of federal groundfish fisheries in Alaska is performed by the NPFMC with scientific guidance (research and stock assessments) from the AFSC and other institutions. Assessments are conducted annually for major commercial groundfish stocks, with biennial or quadrennial assessments for most of the other stocks. Groundfish populations are typically divided into two geographic stocks: Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA). Some BSAI stocks are further divided into Eastern Bering Sea (EBS) and Aleutian Islands (AI). In the GOA, assessment and management for many stocks is structured around large-scale spatial divisions (western, central, and eastern GOA) although the application of these divisions varies by stock. Current and past stock assessment reports can be accessed on the AFSC website (https://www.fisheries.noaa.gov/alaska/ population-assessments/north-pacific-groundfish-stock-assessments-and-fishery-evaluation).

A. Hagfish

There are currently no state or federal commercial fisheries for hagfish in Alaska waters. However since 2017 the Alaska Department of Fish & Game has been conducting research to explore the potential for small-scale hagfish fisheries.

B. Dogfish and other sharks

1. Research

Population Genetics of Pacific Sleeper Sharks - ABL

The purpose of this study is to investigate the population structure of Pacific sleeper sharks (*Somniosus pacificus*) in the eastern North Pacific Ocean. Tissue samples have been opportunistically collected from ~400 sharks from the West Coast, British Columbia, the Gulf of Alaska, and the Bering Sea. Samples of Greenland shark (*S. microcephalus*) and southern sleeper sharks (*S. antarcticus*) were also used in this study. We generated next-generation sequencing data using the reduced representation library method RADseq and conducted phylogenomic and population genomics analyses to provide novel information for use in stock assessments. Our results strongly support the species status of *S. microcephalus* (n = 79), but recover *S. antarcticus* (N = 2) intermixed within the *S. pacificus* (N = 170) clade. Population genomic analyses reveal genetic homogeneity within *S. pacificus* and *S. microcephalus*, and estimates of effective population size suggest populations of hundreds of individuals. Kinship analysis identified two first-degree relative pairs within our dataset (one within each species). Overall, our research provides insight into the evolutionary relationships within the Somniosus Somniosus subgenus. A manuscript is currently in review.

For more information, contact Cindy Tribuzio at (907) 789-6007 or cindy.tribuzio@noaa.gov.

Ageing of Pacific Sleeper Sharks – ABL

A pilot study is underway by staff at ABL, REFM, the Lawrence Livermore National Laboratory and the American River College to investigate potential ageing methods for Pacific sleeper sharks. A recent study suggested extreme longevity in a closely related species by examining the levels of bomb-derived radiocarbon (14C) in the eye lens. The eye lens is believed to be a metabolically inert structure and therefore the levels of 14C could reflect the environment during gestation, which may be used to compare to existing known age 14C reference curves to estimate either a rough age, or a "at least this old" age estimate. For the pilot study, eyes from six animals were removed whole and stored frozen until lab processing. One lens from each shark was excised and lens layers were removed and cleaned by sonication and dried. For larger sharks, both the lens core (earliest deposited material) and outer layer (most recently deposited material) were saved for analysis. Dry samples were sent to an accelerator mass spectrometry (AMS) facility for carbon isotope analyses (^{14}C, ^{13}C), measurement error, and conventional radiocarbon age, when applicable (pre-bomb (<1950); Gagnon et al. 2000) — it was expected that all outer layer samples would be modern and that some cores could have pre-bomb or early bomb ^{14}C rise levels based on rough estimates of age. Preliminary results demonstrate that ^{14}C is measurable in the eye lens cores and outer layers, and two of the PSS had values that could be correlated with the ^{14}C rise period (late 1950s to mid-1960s; Figure 1). Specifically, results from the largest shark sampled (310 cm TL) indicate the age was not older than 50 years. This observation is in contrast to the Nielsen et al. (2016) study, which estimated an age of 105 years for a Greenland shark of the same length. Further, our results suggest that the growth rate of PSS could be twice as high as that of the Greenland shark (Figure 1, inset). For the pilot study, we assumed that the regional bomb ^{14}C reference curve was from two long-lived teleost fishes from the GOA and that exposure and uptake of ^{14}C by PSS was similar. Proposals are pending which would further fund this study and address the concerns and assumptions highlighted by the pilot study work.

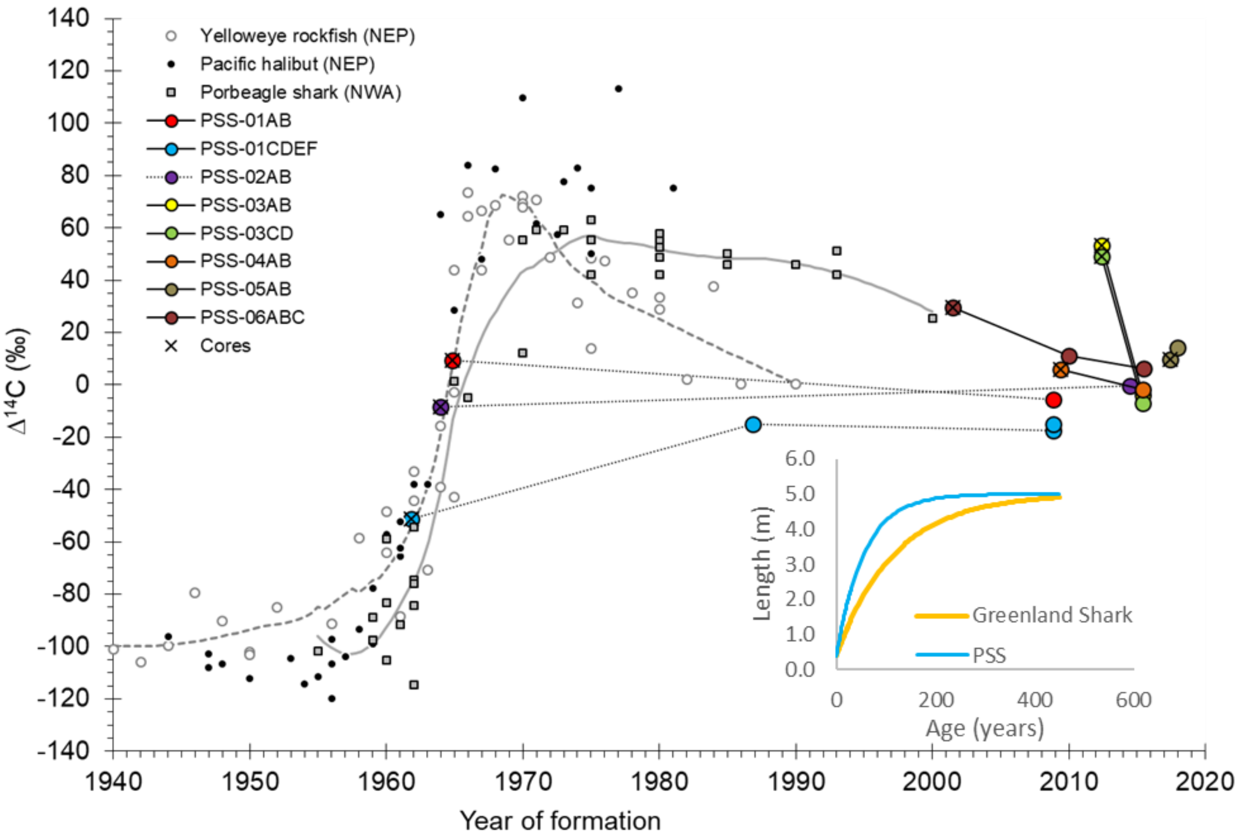

Figure 1. Pacific sleeper shark (PSS) eye lens 14C values from the pilot study plotted as estimated year of formation relative to regional 14C references. Data from six sharks are shown as a series of samples from the core to the outer eye lens. Both eye lenses were sampled in two sharks (PSS-01 and PSS-03). Core ("birth year") layers are indicated with an X over the colored specimen symbol. Published bomb 14C chronologies were used as temporal references from the northeastern Pacific Ocean (yelloweye rockfish (Kerr et al. 2004) and Pacific halibut (Piner and Wischniowski 2004). A shark chronology from the northwestern Atlantic Ocean is shown for comparison (porbeagle shark; Campana et al. 2002). (inset) Von Bertalanffy growth curves based on pilot study results. The PSS growth curve is adjusted from the Greenland shark curve to intersect the data for the largest fish in our pilot study, resulting in the blue curve. These results suggest that the PSS growth coefficient (k) is roughly two times greater than that of the Greenland shark.

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Shark tagging – ABL

Staff at ABL, UAF, the Alaska Sea Life Center, Kingfisher Marine Research, and Wildlife Technology Frontiers have begun a collaborative tagging project on Pacific sleeper shark. This NPRB funded project will apply modern modeling techniques to historical PSAT data, as well as deploy and analyze data from recent and future tags.

Staff at ABL are collaborating with ADF&G, UAF, and Kingfisher Marine Research to deploy tags on salmon shark in the GOA. To date, four male salmon shark have been tagged in the Northern Bering Sea, each with both a SPOT (i.e., GPS) and PSAT tag. The SPOT tags provide multiple years of position data when the shark is at the surface, while the PSAT provides detailed temperature and depth movement. The two data sets will be combined to validate the HMM model. This study is unique in that nearly all previous tagging on the species was on females captured in Prince William Sound. Early results suggest seasonal migration to/from the Northern Bering Sea, but not necessarily the same movement pattern between years.

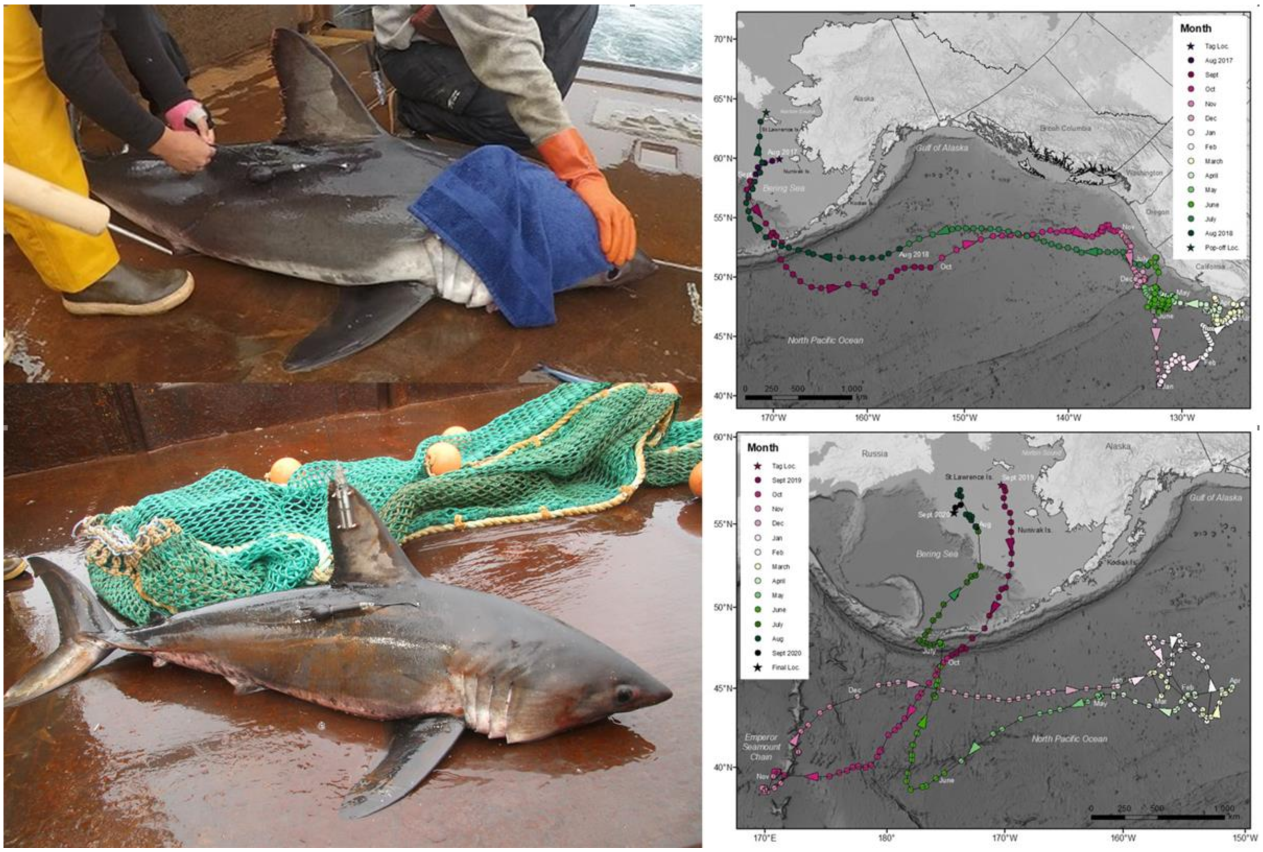

Figure. (Left) Shark A (top) being tagged with a PSAT using two tethers on August 27, 2017. The harness of the second tether attachment is being looped around the body of the tag. Shark B (bottom) with a SPOT-257 tag affixed to the dorsal fin and a PSAT attached with two tethers in the musculature beneath the dorsal fin. Data from Shark B's PSAT are not reported here. (Right) Monthly HMM-derived locations from August 27, 2017 – August 28, 2018 for Shark A (top) and best daily locations transmitted by a SPOT tag carried by Shark B (bottom) from September 7, 2019 through September 6, 2020. Arrows depict swim direction.

For more information, contact Cindy Tribuzio at (907) 789-6007 or cindy.tribuzio@noaa.gov.

2. Stock Assessment

Sharks - ABL

The shark assessments in the Bering Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA) are on biennial cycles in even years. There were no assessments in 2021.

C. Skates

1. Research

2. Assessment

Bering Sea and Aleutian Islands (REFM)
re-insert 2020 text here since it's a rollover - only assessed in even years

Gulf of Alaska (REFM)
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here: https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

For more information contact Ron Felthoven or Stephani Zador at Ron.Felthoven@NOAA.gov or Stephani.Zador@NOAA.gov .

D. Pacific Cod

1. Research

Multiple AFSC research activities regarding Pacific cod- REFM, RACE, ABL
There have been dramatic developments regarding the Pacific cod populations in Alaskan waters over the last few years. In the BSAI region, there is strong evidence that cod moved north in the Bering Sea when temperatures were warm and ice cover was reduced. In the GOA region, the mid-decade marine heat wave appears to have negatively impacted the cod stock with lingering aftereffects. For these reasons and others, Pacific cod have become a major research focus for the AFSC.

Cod appear unique in their spatial distribution, migration patterns, and sensitivity to temperature. The projects outlined here are designed to test and implement the performance of an ecosystem-based fisheries management approach for Pacific cod in the eastern Bering Sea (EBS), Aleutian Islands (AI), and GOA and to examine key mechanisms governing the past, current, and future role of climate variability and change on the distribution and abundance of Pacific cod stocks. Tagging work conducted in 2021 has shown that a large proportion of cod tagged in the western Gulf of Alaska moved as far north as the northern Bering Sea. More work is needed to understand spawning and migration patterns and responses to climate change that can be integrated into model projections.

The research activities listed below are designed to provide resolution to pressing issues related to Pacific cod:

a. Pacific cod juveniles in the Chukchi Sea-RPP

Dan Cooper, Kris Cieciel, Louise Copeman, Libby Logerwell, Pavel Emelin, Robert Levine, Robert Lauth, Lyle Britt, Rebecca Woodgate, Jesse Lamb, Ben Laurel, Nissa Ferm, Johanna Vollenweider, and Alexei Orlov.

Past data have shown that the spatial distribution of Pacific cod shifted northward in the Bering Sea between 2010 and 2017, during the recent warm period (Stevenson and Lauth, 2019). In the Chukchi Sea, however, although Pacific cod juveniles have historically been present in some years, there are no known (to us) records of adults. From 2010 to 2019, we surveyed the eastern and western Chukchi Sea using a variety of trawl gears. We use length modes of juvenile Pacific cod to assign fish to age-0 and age-1 age classes. Age-0 Pacific cod were present in the eastern Chukchi Sea in 2017 and 2019, but were absent in 2012. Our data show that age-0 fish in the eastern Chukchi Sea use both pelagic and benthic habitat to feed on different prey resources, however fatty acid analysis indicates that the fish may move between pelagic and benthic habitat, and poor lipid accumulation by juvenile fish may lead to high mortality. Age-1 fish were present in the eastern Chukchi Sea in 2012, and in the western Chukchi Sea in 2018 and 2019, suggesting that the 2011, 2017, and 2018 year classes either successfully recruited to the Chukchi Sea and overwintered, or moved into the Chukchi Sea from the northern Bering Sea. We suggest that age-0 recruitment to the eastern or western Chukchi Sea is associated with warm temperatures and increased northward transport through the Bering Strait in the spring, when Pacific cod larvae are present in the northern Bering Sea. We found no evidence that Pacific cod juveniles in the Chukchi Sea survive past age-1. The first known (to us) adult Pacific cod were present in the western Chukchi Sea in 2018 and 2019, although estimated densities were very low. One adult Pacific cod was caught in the eastern Chukchi Sea in 2019, however estimated densities in the eastern Chukchi Sea are unknown due to lack of monitoring with a benthic trawl capable of catching adult fish. It is unknown whether the Pacific cod observed in the Chukchi Sea will perish, migrate somewhere else, or survive in the Chukchi Sea as part of a further northward range expansion.

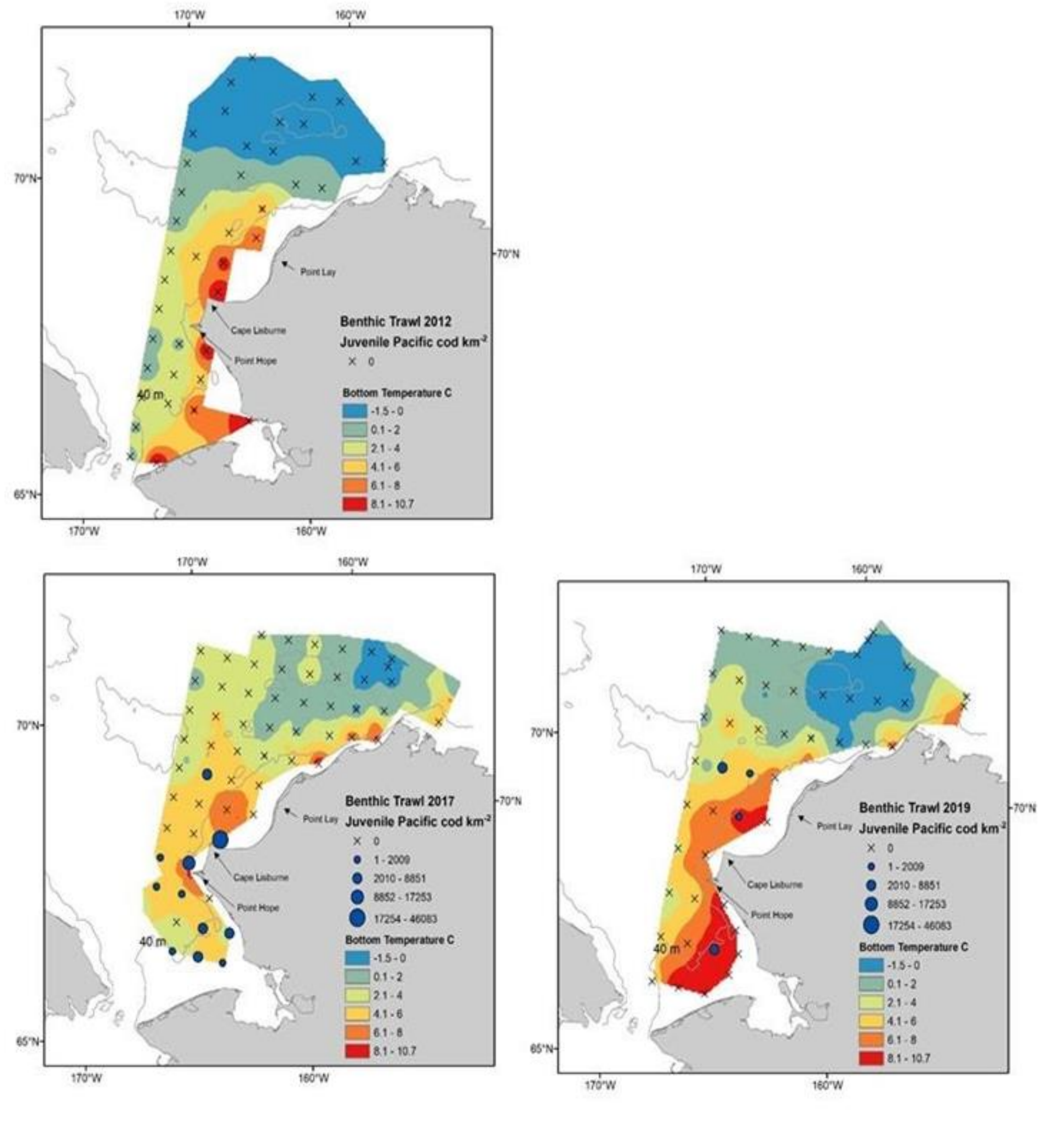
170°W
160°W
70°N
65°N
Point Lay
Cape Lisburne
Point Hope
40 m
Benthic Trawl 2012
Juvenile Pacific cod km-2
× 0
Bottom Temperature C
-1.5 - 0
0.1 - 2
2.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10.7
Benthic Trawl 2017
Juvenile Pacific cod km-2
× 0
1 - 2009
2010 - 8851
8852 - 17253
17254 - 46083
Bottom Temperature C
-1.5 - 0
0.1 - 2
2.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10.7
Benthic Trawl 2019
Juvenile Pacific cod km-2
× 0
1 - 2009
2010 - 8851
8852 - 17253
17254 - 46083
Bottom Temperature C
-1.5 - 0
0.1 - 2
2.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10.7

Figure 1. Age-0 Pacific cod catch per unit effort and bottom temperature interpolations from 2012, 2017, and 2019.

b. Bioinformatics support to prepare GTseq panel for rapid identification of spawning population of origin of Pacific cod: Ongoing work since 2017 (funded by a Saltonstall-Kennedy grant and AFSC) has successfully sequenced the whole genome of 384 cod throughout their range in Alaska and development of a genotyping-by-sequencing panel (GTseq) is underway. The GTseq panel will incorporate several hundred SNPs that identify Pacific cod to their spawning population of origin.

c. Maturation studies: This project was initiated in 2019, and in 2021 will prioritize sampling and rocessing efforts towards developing region-specific maturity curves to be used in stock assessments.

d. Incorporating Pacific cod novel spatial dynamics in the stock assessment model: During recent years, Pacific cod movement patterns have changed in the EBS, increasing the displacement northwards into the NBS. These patterns are expected to persist in future due to global climate change, and will cause changes in several aspects of the cod population dynamics such as spawning and recruitment areas and natural mortality rates, aspects that need to be considered in the assessment. The Pacific cod stock assessment is implemented in Stock Synthesis (SS), a flexible modeling platform that allows for a wide range of data types, including movement patterns. Using SS and information from previous and ongoing studies, we evaluate the effects of observed spatial patterns on stock assessment outputs by simulating: i) spatial changes in spawning grounds and recruitment areas, and ii) variations in survival and growth of new recruits. Also, we will evaluate effective ways to incorporate this complex spatial dynamic into the stock assessment model. The results of this effort will provide an important improvement to the current assessment and plan for future consequences to the productivity of the stock.

e. Understanding Pacific cod availability to survey vs. fishery: This work will analyze existing fishery and survey catch data from EBS and Aleutian Islands including spatial and temporal comparison of catch rates and length distribution and existing tag data (conventional, PSAT, and archival) to better understand cod availability to the survey vs. fishery. Project will incorporate existing selectivity ratio estimation methodology developed by Kotwicki and will result in a peer-reviewed publication and priors for stock assessment. Further, this study will incorporate food habits data to identify occurrences of midwater species prey.

f. Assessment of age-0 juvenile cod in the Western GOA: This is the 3rd year of annual sampling using a beach seine in 0-3 m water along 13 different bays from the east side of Kodiak Island, the Alaska Peninsula, and into the Shumagin Islands. Sampling covers 72 fixed-site locations and 36 non-fixed sets of video surveys (baited cameras, 5 - 20 m). The project provides CPUE data for age-0 Pacific cod and other key species. Age-0 Pacific cod length, weight, condition, diet, and tissue samples (for lipids and genetics) are also obtained from each of the 13 bays. This survey, along with a smaller-scale Kodiak survey, provides direct observations on the lingering effects of marine heatwaves on Pacific cod populations in the GOA at a spatial scale that overlaps with the presumed main spawning area of the region. This work is also a sampling platform for a funded genetics project to identify the natal spawning area of sampled juveniles.

g. Can cod spawn North? Pacific cod larval and juvenile dispersal from the NBS: Using retrospective analyses on Pacific cod larval and juvenile distribution in the Bering Sea, we will: 1) statistically determine phenology and habitat features that correlate with Pacific cod larvae and juveniles, and 2) simulate larval dispersal trajectories, foraging, and growth, from newly putative spawning areas, using IBM and hindcast/forecast of existing ocean circulation models. Simulations will include scenarios to address potential adaptive strategies, such as change in phenology and pelagic larval duration (PLD). These simulations will reveal whether new spawning activity northward of current spawning grounds is likely to be successful, given the foraging and nursery requirements of larval and juvenile cod, and whether there is adaptive potential (phenology, PLD) for establishing new spawning areas. Specifically this project will fund a post-doc for 1 year.

h. PSAT #2 - Gulf of Alaska (Winter 2021); EBS and Chukchi, Summer 2021: Continuation of Pacific cod Satellite tagging project to examine annual variation of migratory movement patterns including tagging in the Western Gulf of Alaska, over the EBS shelf, NBS, and southern Chukchi using pop-up satellite archival tags. In 2021, scientist from the RACE GAP group released 25 satellite tagged Pacific cod in March in the Gulf of Alaska and 26 satellite tagged Pacific cod in the EBS and NBS during the summer. These tagging studies were cooperative projects with the commercial fisheries and the Aleutian East borough. From the Gulf of Alaska study, 19 satellite tags have successfully popped up and 4 conventional tags were recovered by the fishery. Locations of tags recovered in March, April, and May were largely in the vicinity of the release area but fish with tags recovered in June, July, and August had moved west toward the Aleutian Islands region and north into the EBS, NBS, and Russia. More than half of the tag recoveries (9 of 16) between the beginning of June and the end of August were located in the Bering Sea, indicating substantial seasonal connectivity between the Gulf of Alaska and Bering Sea management regions. One tag recovery in September had moved into the southern Chukchi Sea. We are in the process of modeling the movement path of the tagged fish using a geospatial model developed from previous tag releases. This will make it possible to estimate the percentage of time fish spent in each management area over the course of a year and help inform stock assessment and management.

For more information please contact Steve Barbeaux (steve.barbeaux@noaa.gov) or Ingrid Spies (ingrid.spies@noaa.gov).

i. Tracking age-1 Pacific cod across thermal habitats with acoustic transmitters - RACE-GAP – There is growing evidence that seasonal metabolic stress influences the growth and survival of Pacific cod though little information has been gathered on the use of habitat during the early life stages. To link age-1 Pacific cod with their use of nearshore nursery habitats a study was developed using telemetry, bio-loggers, diet analysis, and bioenergetic modeling. The study was conducted in a semi enclosed bay that is known nursery habitat for Pacific cod, Anton Larson Bay (57° 53' 05" N; 152° 47'03" W) on Kodiak Island, Alaska.

A passive acoustic array was established to track the movement of P. cod in the bay. The array was comprised of 15 moorings equipped with Vemco VR2W-69 kHz receivers. Three gates were deployed across the mouth of the bay and at natural choke points in/out of the bay. Additionally, a number of non-overlapping receivers were set to monitor movements within bay (**Figure 1**). A network of thermographs recorded water temperature across a range of locations and depths.

Twenty age-1+ P. cod were implanted with Vemco V7-4TP multi-sensor tags (location & temperature). The average size of the tagged fish was 281.0 ± 20.5 mm TL. Movements of tagged fish were monitored from July - October, 2021. Individual fish were detected an average of 46 days out of the 92 day study (min 5 and max 89 days). In general early in the study (July & Aug) fish detections predominantly occurred in the inner bay near their initial point of release. Later in the study fish detections tended to occur at outer bay stations. Analysis of the tagging data is currently underway.

Baited cameras were used to monitor changes in fish abundance over time. Sampling was conducted monthly (July-Oct) at 3 depths (10’, 30’, and 50’, with 10 replicates each). During the initial review of large numbers age-0 and 1+ P. cod were observed in both July and August. Additional analysis of the video data is underway.

To assess temporal variation in diets, stomach contents were collected monthly (n=>20 per/period). While the target number of fish were sampled in both July & August, no fish were caught in either September or October, suggesting that they may have moved out of the bay. In the lab, their stomach contents were analyzed to determine their diet composition. This information along with data on fish movements and their thermal environment will be input into existing Wisconsin bioenergetics models (Holsman & Aydin, 2015). The models attempt to develop bioenergetics estimates for: metabolic demand, relative foraging rate (RFR), prey energy density, and growth potential (G’).

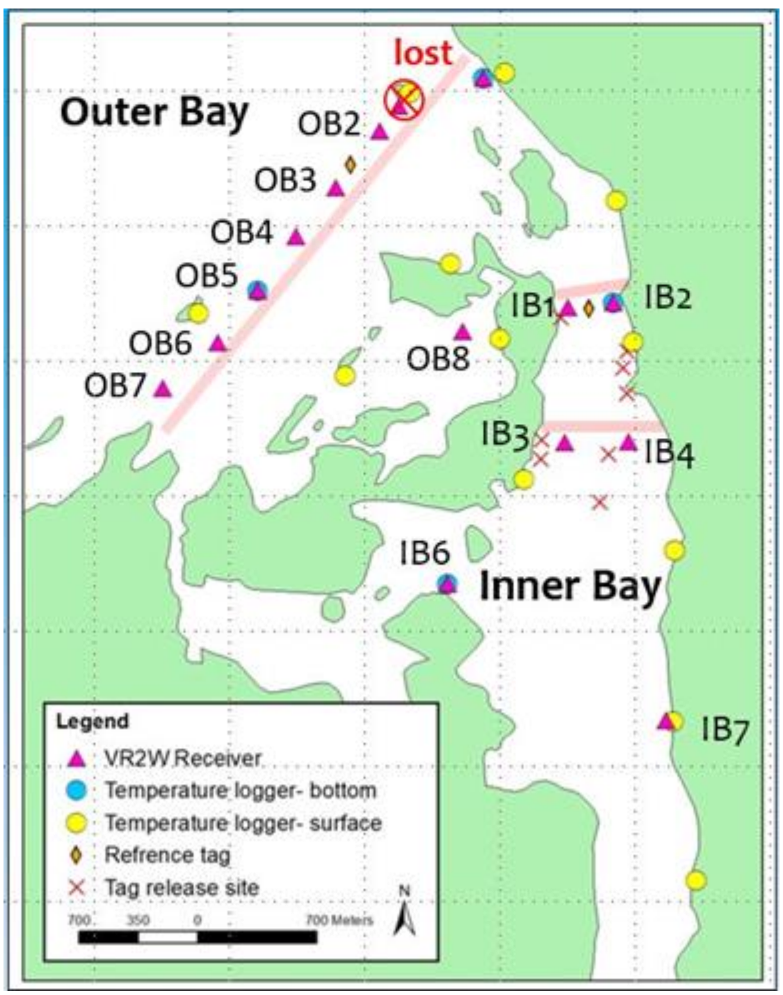

Figure 1: Anton Larson Bay study site showing locations of VR2W acoustic receivers, temperate loggers, and fish release sites. Release sites indicate where fish implanted with Vemco V7-4TP multi-sensor tags were returned to the bay.

For more information contact Sean Rooney (Sean.Rooney@NOAA.GOV)

2. Stock Assessment

Eastern Bering Sea (REFM)

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, ranging from Santa Monica Bay, California, northward along the North American coast; across the Gulf of Alaska and Bering Sea north to Norton Sound; and southward along the Asian coast from the Gulf of Anadyr to the northern Yellow Sea; and occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34 N latitude, with a northern limit of about 65 N latitude. Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. Tagging studies have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA). However, recent research indicates the existence of discrete stocks in the EBS and AI. Research conducted in 2018 indicates that the genetic samples from the NBS survey in 2017 are very similar to those from the EBS survey area, and quite distinct from samples collected in the Aleutian Islands and the Gulf of Alaska. Although the resource in the combined EBS and AI (BSAI) region had been managed as a single unit from 1977 through 2013, separate harvest specifications have been set for the two areas since the 2014 season.

The EBS Pacific cod model has undergone numerous model changes and refinements over the last decade. Preliminary models are reviewed in the spring of each year. The model uses the Stock Synthesis 3 framework. A major issue in recent years has been an apparent shift in the distribution of EBS Pacific cod into the northern Bering Sea (NBS), an area which historically has not been surveyed. Surveys in the NBS were conducted in 2010 and during 2017-2019, and regular NBS surveys are likely to be conducted into the future as EBS groundfish stocks experience changes in distribution. The lack of survey data in the NBS has caused assessment difficulties for Pacific cod and other stocks.

Many changes have been made or considered in the stock assessment model since the 2018 assessment. Seven models (including the current base model) were presented in this year's preliminary assessment. After reviewing the preliminary assessment, the SSC and Team requested that all of the models from the preliminary assessment be presented in the final assessment. In addition, the SSC requested three more new models. Following further explorations by the senior author and consultation with the SSC co-chairs and the Team and SSC rapporteurs assigned to this assessment, a compromise set of ten models (including the current base model) are included here. The nine new models are treated both individually and as an ensemble, with results for the latter presented as both weighted and unweighted averages.

Female spawning biomass for 2020 and 2021 is estimated by ensemble weighted average to be 259,509 t and 211,410 t, respectively, both of which are below the B40% value of 266,602 t. Given this, the ensemble weighted average estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2020 and 2021 as follows: in 2020 OFL is 185,650 t and maxABC is 155,873 t ; in 2021 OFL is 123,331 t and maxABC is 102,975 t.

Aleutian Islands (REFM)
This stock has been assessed separately from Eastern Bering Sea Pacific cod since 2013, and managed separately since 2014. The stock has been managed under Tier 5 (OFL = F * biomass, where F = M) since it was first assessed separately. No changes were made to assessment methodology, but data were updated with recent observations. Catch data from 1991-2018 were updated by including updated catch for 2017 and preliminary catch data for 2018, and the 2018 biomass point estimate and standard error were added to the survey time series. A random effects model using Aleutian Islands trawl survey biomass observations from 1991 to 2018 was used to estimate the biomass and provide management advice.

After declining by more than 50% between 1991 and 2002, survey biomass has since stayed in the range of 50-90 kilotons. The 2018 Aleutians survey biomass estimate (81,272 t) was down about 4% from the 2016 estimate (84,409 t). The estimate of the natural mortality rate is 0.34, which was taken from the 2018 EBS Pacific cod assessment model. For 2020 and 2021, the recommended ABC is 20,600 t, and OFL is 27,400 t.

Gulf of Alaska (REFM)
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

For further information, contact Dr. Grant Thompson at (541) 737-9318 (BSAI assessment) or Dr. Steve Barbeaux (GOA assessment) (206) 526-4211.

F. Walleye Pollock

1. Research

Winter acoustic-trawl surveys of pre-spawning walleye pollock in the Gulf of Alaska (MACE)

Scientists from the Alaska Fisheries Science Center conducted 2 acoustic-trawl surveys in the Gulf of Alaska during late winter and early spring 2020 to estimate the distribution and abundance of walleye pollock (Gadus chalcogrammus) at several of their main spawning grounds. These pre-spawning pollock surveys covered the Shumagin Islands (202001; Feb. 11-18) and Shelikof Strait (202003; March 2-16) areas. Historical surveys also frequently included Sanak Trough, Morzhovoi Bay, and Pavlof Bay since 2002 as part of the Shumagins survey, and the continental shelf break near Chirikof Island, and Marmot Bay as part of the Shelikof Survey. None of these ancillary areas were surveyed in 2020 due to 1) time constraints in February because vessel departure from winter repairs was delayed and 2) a necessity of ending the March survey early due to increased concerns about the growing global COVID-19 pandemic.

The surveys were conducted with the NOAA ship Oscar Dyson, a 64-m stern trawler equipped for fisheries and oceanographic research. Midwater and near-bottom acoustic backscatter at 38 kHz was sampled to estimate the abundance of walleye pollock using an LFS1421 trawl and an Aleutian Wing 30/26 Trawl (AWT). This is the first winter survey where the LFS1421 replaced the AWT as the primary sampling trawl. Backscatter data were also collected at 4 other frequencies (18-, 70-, 120-, and 200-kHz) to support multifrequency species classification techniques.

In the Shumagin Islands acoustic backscatter was measured along 882.8 km (476.7 nmi) of transects spaced an average of 4.3 km (2.3 nmi) apart with spacing varying from 1 to 5 nmi in the survey area. Pollock and eulachon were the most abundant species by weight in the 5 LFS1421 hauls, contributing 94.5% and 3.1% of the catch by weight. Pollock and eulachon were also the most abundant species by numbers with 62% and 25.6%, respectively. Pollock were observed throughout the surveyed area and were most abundant to the northwest and southwest of Korovin Island. Adult pollock were detected in both of these regions, but not in the Shumagin Trough. Juveniles (< 30 cm FL) were concentrated in the areas directly north and south of Korovin Island and were rare elsewhere in the survey area. Adult pollock were detected at 100 m depth, 50 m from the seafloor, and juvenile pollock were similarly distributed but slightly higher in the water column. Pollock with lengths 10-15 cm FL, age-1 pollock, accounted for 48.3% of the numbers and 3.2% of the biomass of all pollock observed in the Shumagin Islands. Pollock 16-29 cm FL, indicative of age-2s, accounted for 14.9% by numbers and 11.5% by biomass. Pollock ≥ 30 cm FL accounted for 36.8% and 85.2% of the numbers and biomass, respectively. Both male and female pollock observed in the Shumagin Islands were predominately in the pre-spawning maturity stage. The maturity composition of males > 40 cm FL (n = 40) was 0% immature, 1% developing, 52% pre-spawning, 42% spawning, and 0% spent. The maturity composition of females > 40 cm FL (n = 30) was 0% immature, 35% developing, 49% pre-spawning, 0% spawning, and 11% spent. The abundance estimate of 28.8 million pollock weighing 4,798t (relative estimation error of 12.2%) was 27.6% of that observed in 2019 (17,390 t) and 7 % of the historic mean of 68,375 t . Survey biomass estimates in 2017, 2018, and 2019 are the smallest since the mid-1980s, and the 2020 biomass estimate continues this downward trend.

In the Shelikof Strait, acoustic backscatter was measured along 1425 km (769.5 nmi) of transects spaced mainly 13.9 km (7.5 nmi) apart with spacing varying from 6.1 to 15 nmi in the survey area. Due to the emergence of the global COVID-19 pandemic, management determined that the survey should be completed as quickly as possible, so once backscatter amounts decreased near the Semidi Islands (where backscatter amounts have historically decreased) transect spacing was doubled to 27.8 km (15 nmi) for the final two transects. Pollock and eulachon were the most abundant species by weight in the 23 LFS1421 hauls, contributing 91.5% and 7.8% of the catch by weight respectively. Eulachon and pollock were the most abundant species by numbers with 46.2% and 38% of total catch numbers, respectively. Adult pollock were detected throughout the Strait, with most distributed along the west side from Cape Nukshak to Cape Kekurnoi and in the center of the sea valley south of Cape Kekurnoi, as is typical for most previous Shelikof surveys. Most pollock were detected between depths of 200-250 m with juveniles (< 30 cm FL) also found in a layer at 50-100 m depth.

Pollock 10-16 cm FL, indicative of age-1 pollock, accounted for 1.7 % of the numbers and ≤ 0.1% of the biomass of all pollock observed in Shelikof Strait. Pollock 17-29 cm FL, indicative of age-2s, accounted for 30.5% by numbers and 8% by biomass of all pollock . Pollock ≥ 30 cm FL accounted for 67.8% and 92% of the numbers and biomass, respectively. The maturity composition in the Shelikof Strait of males>40 cm FL (n = 312) was 0% immature, 0% developing, 3% pre-spawning, 85%spawning, and 5% spent. The maturity composition of females > 40 cm FL (n = 258) was 6% immature, 0% developing, 88% pre-spawning, 1% spawning, and 5% spent. The abundance estimate of 978 million pollock weighing 456,713 t (relative estimation error 4.9%) was 35.7% of that observed in 2019 (1,281,083 t) and 63.18% the historic mean of 722,885 t.

For more information, contact MACE Program Manager, Sandra Parker-Stetter, sandy.parker-stetter@noaa.gov.

Winter acoustic-trawl surveys of pre-spawning walleye pollock near Bogoslof Island

An acoustic-trawl survey of walleye pollock (Gadus chalcogrammus) in the southeastern Aleutian Basin near Bogoslof Island was conducted 19-23 February, 2020 aboard the NOAA Ship Oscar Dyson. The survey covered 1,449 nmi2 of the Central Bering Sea Convention Specific Area. Acoustic backscatter was measured at 38 kHz along 26 north-south parallel transects, which were spaced 3-nmi or 6-nmi. The wider 6-nmi spacing was strategic to conserve transecting time in areas where low pollock density was observed in 2016 and 2018, when 3-nmi transect spacing was used throughout the survey. The survey was divided into two regions, Umnak (transects 1-10), and Samalga (transects 11-26). Survey operations were conducted 24 hours/day, from east to west. Midwater acoustic backscatter was sampled using midwater trawl hauls to identify the species composition and to provide biological samples. The LFS1421 trawl (LFS) was the primary sampling tool for analysis, while the Aleutian Wing 30/26 trawl (AWT) provided additional samples. Pollock dominated the trawl catches in both midwater nets by weight and number, representing 99.2% of the total catch by weight for the 6 AWT hauls, and 96.8% of the total catch by weight for the 8 LFS hauls. Lanternfishes were the second most numerous group captured in the AWT hauls (8.8%), whereas shrimp species were the second most numerous group captured in the LFS hauls (14.9%). Pollock lengths ranged from 27 to 69 cm fork length (FL), with a primary mode at 52 cm, and a secondary mode at 38 cm FL.

Pollock specimens were visually examined for maturity stages. The maturity compositions here are for female pollock that were at least 40 cm in length. For the Umnak region (n = 195), the maturity composition was 3% immature, 31% developing, 50% pre-spawning, 10% spawning, and 6% were in the spent stages. For the Samalga region (n = 169), 0% immature, 1% developing, 98% pre-spawning, and 1% were in the spent stage. The average gonado-somatic-index for pre-spawning mature (i.e., FL≥ 40 cm) female pollock in the Umnak region was 0.15, and in the Samalga region it was 0.17.

Pollock biomass was distributed on all transects with 12% of the biomass distributed in the Umnak region, and 88% of the biomass distributed in the Samalga region. The densest concentration was located on transect 22, within the Samalga region, which represented 44% of the estimated pollock biomass. This layer extended horizontally for about 7.5 nmi with a vertical extent from 260 m down to 600 m below the surface.

The pollock abundance estimate in 2020 was 350 million fish weighing 345 thousand metric tons for the entire surveyed area. The overall size-composition for the pollock was unimodal at 50 cm FL, with an average length at 51.6 cm. The estimates represent an decrease of 64% in abundance and 48% in biomass from the 2018 survey estimates of 964 million fish weighing 663 thousand metric tons. Based on the 1D geostatistical analysis, the relative estimation error for the biomass estimate was 15.8%.

The estimated age-composition for pollock ranged from 2 to 14 years of age. Sixty percent of the estimated biomass were 10-11-year old fish (2010-2009 year classes), and another 15% were 9-year-old fish (2011 year class).

For more information, contact MACE Program Manager, Sandra Parker-Stetter, sandy.parker-stetter@noaa.gov.

Summer acoustic-trawl survey of walleye pollock in the eastern Bering Sea

The COVID-19 pandemic resulted in the cancellation of many fisheries surveys worldwide in 2020. This posed a challenge for fisheries management, which relies on timely and consistent abundance estimates of fish stocks to characterize the state of marine ecosystems to support management decisions (ICES, 2020). This was the case for walleye pollock (Gadus chalcogrammus) in the eastern Bering Sea (EBS), which support the largest fishery in the United States with recent landings of ~1.3 million tons and a value of ~1.4 billion dollars (Ianelli et al., 2020). The research vessel (RV) based surveys of this stock were delayed and subsequently cancelled due to the risk to survey crews and the remote communities where crew exchanges and resupply activities occur. In response, we applied recent advancements in uncrewed surface vehicles (USVs) instrumented with calibrated echosounders (De Robertis et al., 2019) to conduct a USV-based acoustic survey. The goal was to mitigate the loss of information from pollock midwater abundance surveys used to support management of this important fishery.

The 2020 AT survey of pollock in the EBS was cancelled due to safety concerns associated with the COVID-19 pandemic. Instead, three chartered Saildrone USVs were deployed from Alameda, CA, to the Bering Sea to estimate pollock abundance and distribution. The transects covered the same area as previous AT surveys, but were spaced farther apart. The USVs followed a curtailed survey plan designed in case an abbreviated RV-based survey had been possible. The survey consisted of 14 transects spaced 74 km apart with a total length of 4727 km (Fig. 1). This represents half the sampling density of previous RV-based surveys (transects 37 km apart). The USVs measured 38 kHz pollock backscatter, but population biomass (kg) is used in the stock assessment model. Thus, the USV backscatter measurements were converted to biomass units based on an empirical relationship between pollock backscatter and biomass observed in previous surveys. The additional uncertainty introduced by the increased transect spacing and the backscatter-to-biomass conversion was investigated via simple simulations.

Total pollock backscatter in the survey area was 4.32x107 m2, 45.0 % higher than in the last survey in 2018. The spatial distribution of pollock backscatter was consistent with recent surveys, with pollock most abundant in the north-west portion of the survey area. The biomass estimate for 2020 was 3.6 x109 kg of pollock, which represents an increase of 45.0.% relative to the estimate of 2.5x109 kg in the last survey in 2018 (Fig. 2). Adding the USV data to the assessment model provided assurance that the stock status was stable and suggested a slight increasing trend compared to the previous survey and other model scenarios (Ianelli et al., 2020). The USV data were broadly consistent with other data components fit within the assessment model. Furthermore, the pollock spatial pattern depicted by the USV data in 2020 was consistent with the patterns observed in the fishery. The model scenario incorporating the USV data was selected by the North Pacific Management Council as the basis for management advice. Although the EBS pollock USV survey could not produce information on species, size, and age compositions typically collected from research vessels, it allowed the AT survey time series to be extended in a situation when crewed ship-based surveys were not possible.

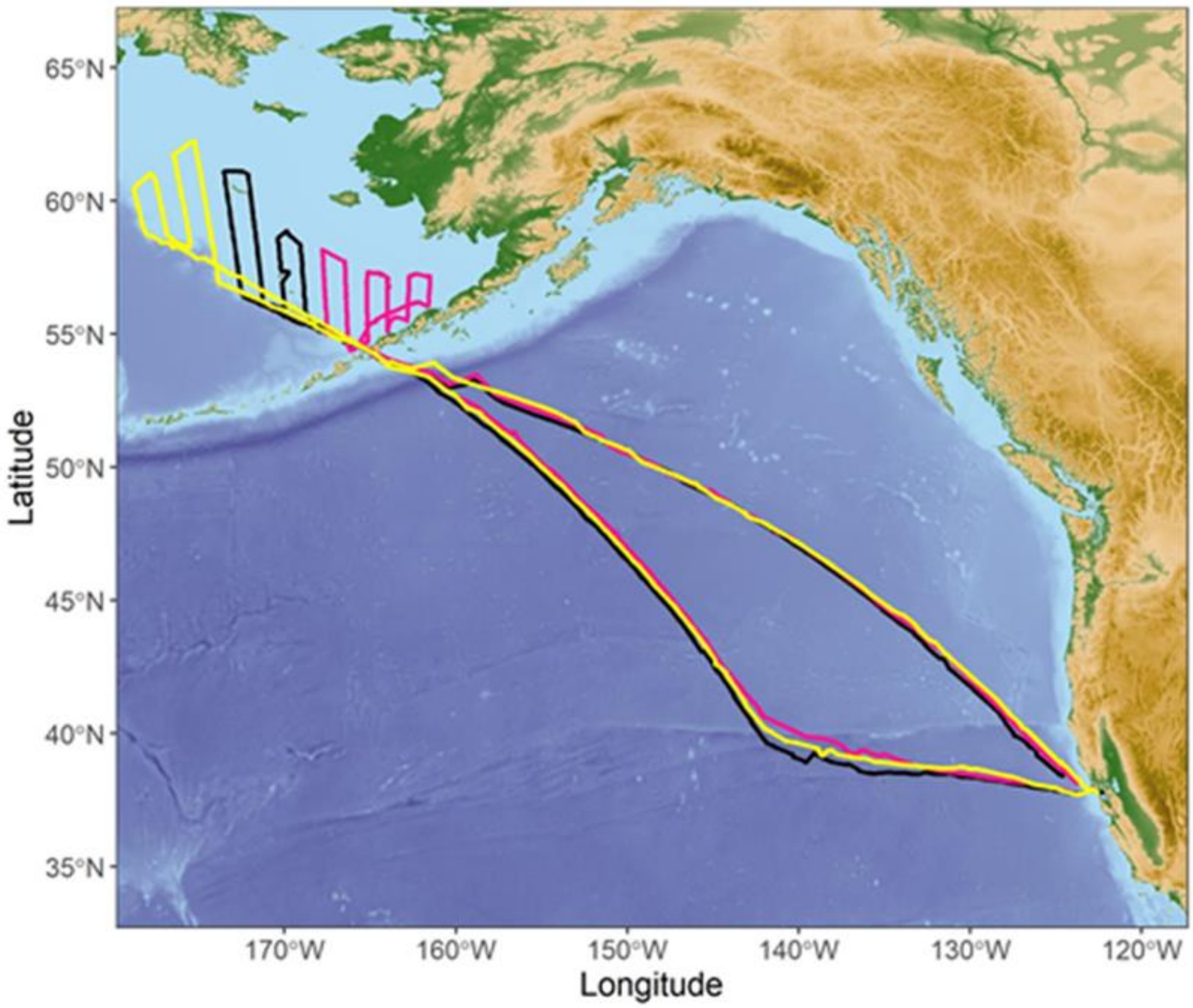

Fig. 1. Path taken by saildrones as they sailed from California across the North Pacific to the survey area in the Bering Sea and returned. Each USV track is depicted in a different color

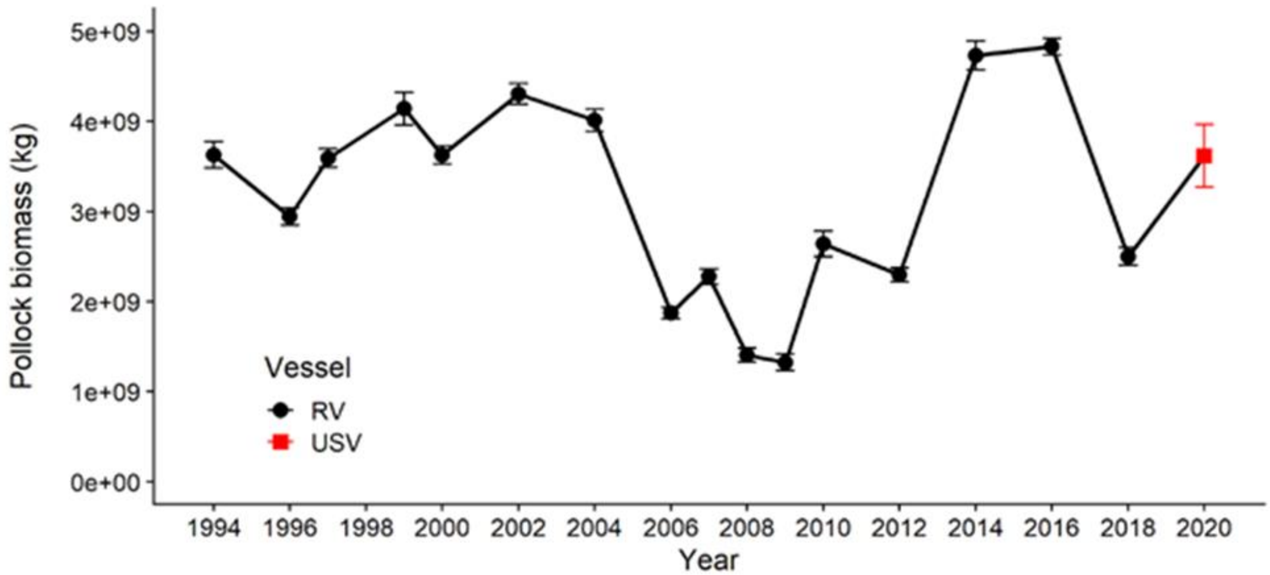

Fig. 2. Time series of EBS pollock acoustic-trawl abundance estimates with error bars showing ± 1 standard deviation of the estimate based on geostatistical 1-D estimates. The 2020 estimate (red square) was conducted with USVs at half the transect spacing of previous surveys. The 2020 uncertainty estimate accounts for the increased uncertainty introduced by the backscatter to biomass conversion.

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ICES 2020. ICES Workshop on unavoidable survey effort reduction (WKUSER). ICES Scientific Reports. 2:72. 92pp. http://doi.org/10.17895/ices.pub.745

For more information, contact MACE Program Manager, Sandra Parker-Stetter, sandy.parker-stetter@noaa.gov.

Summer acoustic vessel of opportunity (AVO) index for midwater Bering Sea walleye pollock

Due to the COVID-19 pandemic, the annual bottom trawl survey of the eastern Bering Sea shelf was cancelled, thus these acoustic data of opportunity were not collected.

For more information, contact MACE Program Manager, Sandra Parker-Stetter, sandy.parker-stetter@noaa.gov.

Pre- and Post-Winter Temperature Change Index and the Recruitment of Bering Sea Pollock - ABL

According to the original Oscillating Control Hypothesis (OCH), warmer spring temperatures and earlier ice retreat led to a later oceanic and pelagic phytoplankton bloom and more food in the pelagic waters at an optimal time for use by pelagic species. The revised OCH indicated that age-0 pollock were more energy-rich and have higher over wintering survival to age-1 in a year with a cooler late summer. Therefore, the warmer later summers during the age-0 phase followed by warmer spring temperatures during the age-1 phase are assumed unfavorable for the survival of pollock from age-0 to age-1.

The temperature change (TC) index is a composite index for the pre- and post-winter thermal conditions experienced by walleye pollock (*Gadus chalcogrammus*) from age-0 to age-1 in the eastern Bering Sea (Martinson et al., 2012). The TC index (year t) is calculated as the difference in the average monthly sea surface temperature in June (t+1) and August (t) (Figure 1) in the southern region of the eastern Bering Sea. Less negative values represent a cool late summer during the age-0 phase followed by a warm spring during the age-1 phase for pollock. The 2020 year class of pollock experienced above average summer temperatures during the age-0 stage and a warm spring in 2021 during the age-1 stage indicating below average conditions for over wintering survival from age-0 to age-1. The 2020 TC index value of -5.37 was below the long-term average of -4.58, therefore we expect below average recruitment of pollock to age-4 in 2024 from the 2020 year class (Figure 2).

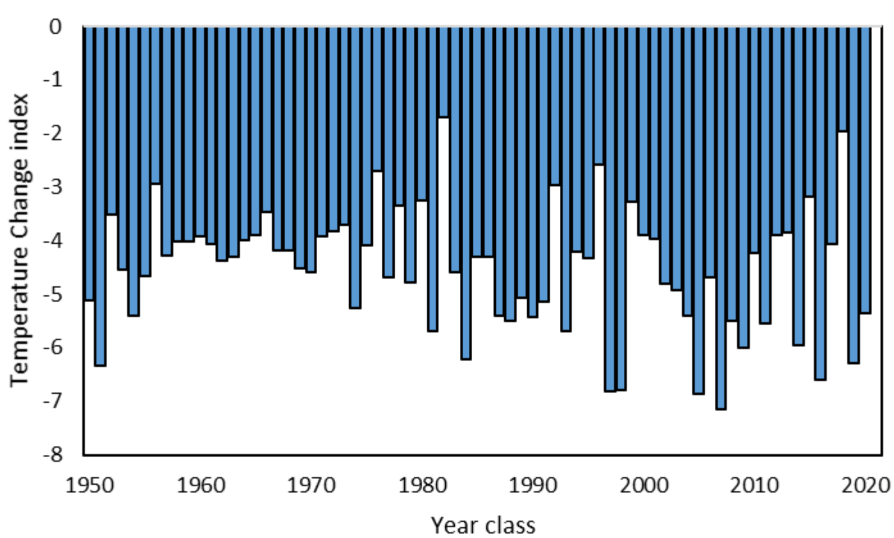

Figure 1: The Temperature Change index values for the 1950 to 2020 year classes of pollock. Values represent the differences in sea temperatures in the south eastern Bering Sea shelf. Less favorable conditions (more negative values) represent a warm summer during the age-0 life stage followed by a relatively cool spring during the age-1 life stage.

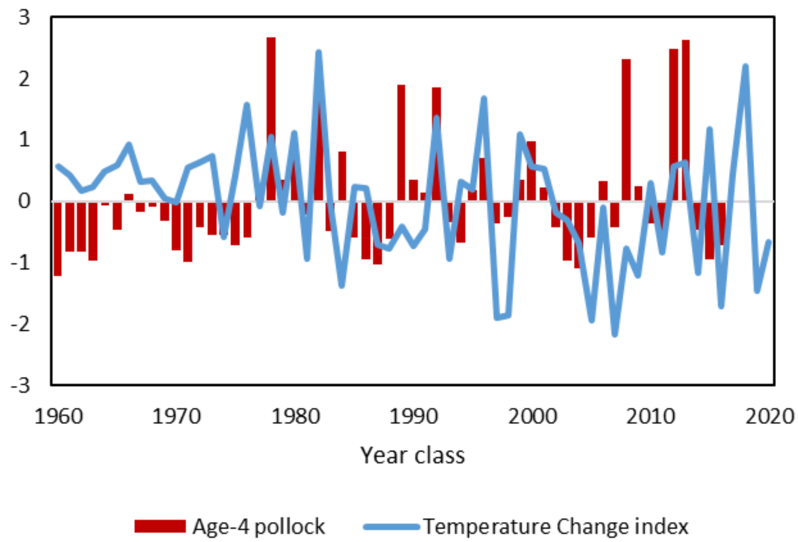

Figure 2: Normalized time series values of the temperature change index indicating conditions experienced by the 1960-2020 year classes of pollock during the summer age-0 and spring age-1 life stages. Normalized values of the estimated abundance of age-4 walleye pollock in the eastern Bering Sea from 1964-2020 for the 1960-2016 year classes. Age-4 walleye pollock estimates are from the Alaska walleye pollock stock assessment (Ianelli et al. 2020).

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Martinson, E. C., Stokes, H. H., & Scarnecchia, D. L. 2012. Use of juvenile salmon growth and temperature change indices to predict groundfish post age-0 yr class strengths in the Gulf of Alaska and eastern Bering Sea. *Fisheries Oceanography*, *21*(4), 307-319.

For more information contact Lisa Eisner at (206) 526-4060, lisa.eisner@noaa.gov or Ellen Yasumiishi at (907) 789-6604, ellen.yasumiishi@noaa.gov.

Large copepod abundance sample-based and modeled) as an indicator of pollock recruitment to age-3 in the southeastern Bering Sea - ABL

Interannual variations in large copepod abundance during the pollock age-0 life stage were compared to age-3 walleye pollock (*Gadus chalcogrammus*) abundance (billions of fish) for the 2002-2018 year classes on the southeastern Bering Sea shelf, south of 60°N, < 200 m bathymetry. The large copepod index sums the abundances of *Calanus marshallae/glacialis* (copepodite stage 3 (C3)-adult), *Neocalanus* spp. (C3-adult), and *Metridia pacifica* (C4-adult), taxa typically important in age 0 pollock diets. Data were collected on the Bering Arctic Subarctic Integrated Survey fishery oceanography surveys and along the 70 misobath during mid-August to late September, for four warm years (2002-2005) followed by one average (2006), six cold (2007-2012), four warm (2014-2016, 2018) and an average year (2017, 70 m isobath only). Zooplankton data were not available for 2013. Age-3 pollock abundance was obtained from the stock assessment report for the 2002-2016 year classes. Two estimates of large copepod abundances were calculated, the first using means among stations (sample-based), and the second using the means estimated from the geostatistical model, Vector Autoregressive Spatial Temporal (VAST) package version 9.4.0.

Positive, significant linear relationships were found between age-3 pollock abundance and the 1) the BASIS sample-based mean abundances and 2) the BASIS VAST-modeled mean abundances of large copepods collected during the age-0 stage for the 2002-2015 year classes (Figure 1). There was a stronger relationship between the VAST model copepod estimates and the age-3 pollock abundance (R^2 = 0.720 vs R^2= 0.43). This appeared to be partially due to the VAST model filling in data for survey areas missed in some years (e.g., 2008). The results show a low availability of large copepod prey for age-0 pollock during the first year of life in 2017 and 2018. The 2020 estimate is larger than the 2021 estimate; however, they are relatively low to other years (Figure 2).

These large zooplankton taxa contain high lipid concentrations (especially in cold, high ice years) which in turn increases the lipid content in their predators such as age-0 pollock and other fish that forage on these taxa. Increases in energy density (lipids) in age-0 pollock allow them to survive their first winter (a time of high mortality) and eventually recruit into the fishery (Heintz et al., 2013). Accordingly, a strong relationship has been shown for energy density in age-0 fish and age-3 pollock abundance (Heintz et al., 2013). This relationship provides further support for the revised oscillating control hypothesis that suggests as the climate warms, reductions in the extent and duration of sea ice could be detrimental to large crustacean zooplankton and subsequently to the pollock fishery in the southeastern Bering Sea.

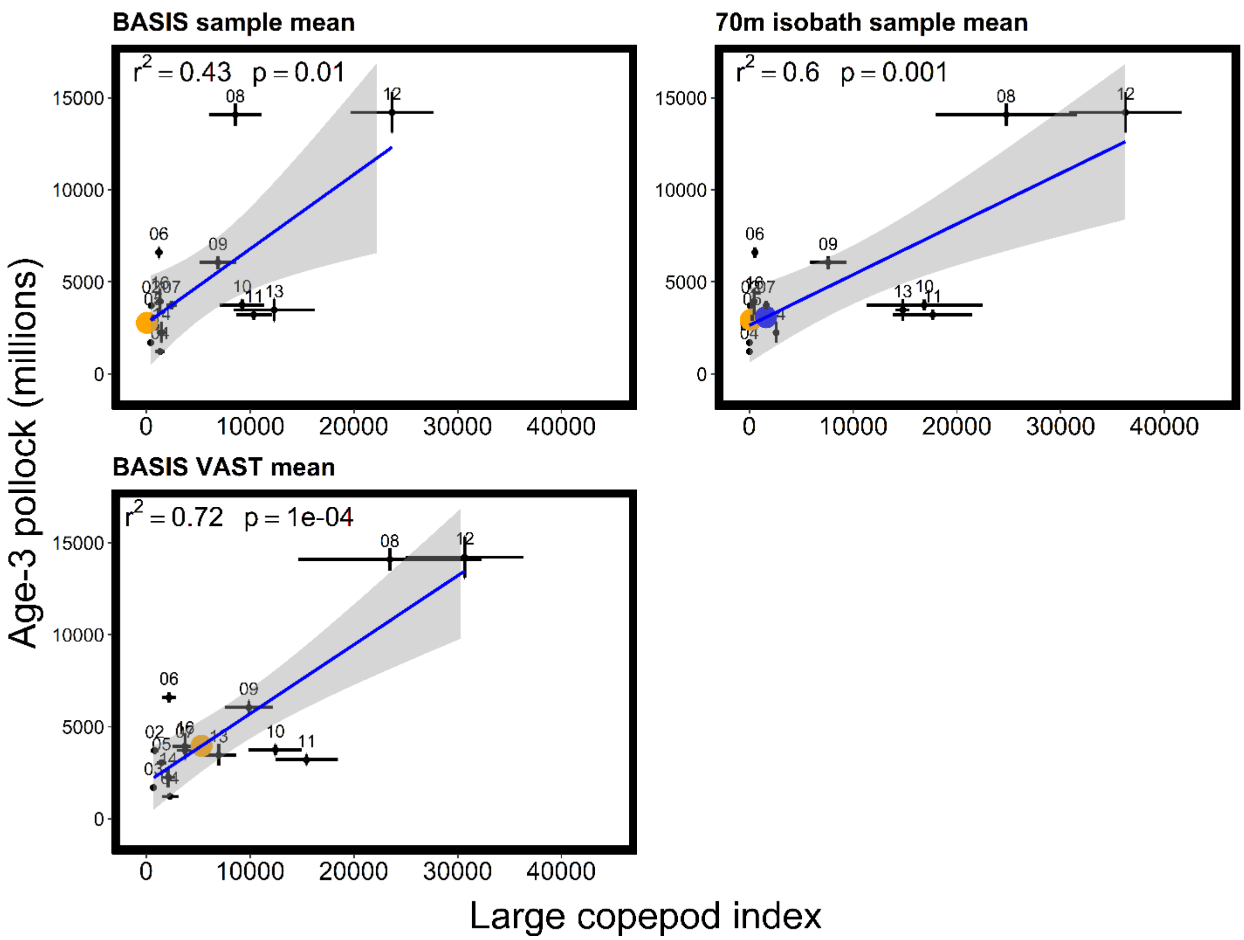

Figure 1. Linear relationships between sample-based (top) from the BASIS and 70 m isobaths surveys and BASIS VAST-model (bottom) estimated mean abundance of large copepods (C+MN, sum of *Calanus marshallae/glacialis, Metridia pacifica* and *Neocalanus* spp.) during the age-0 life stage of pollock, and the estimated abundance (millions) of age-3 pollock from Ianelli et al. (2019) for 2002-2018 year classes. No zooplankton data were available for 2013. The orange dots represents the values for the large copepod index in 2018 and the blue dot for the 2017 year class.

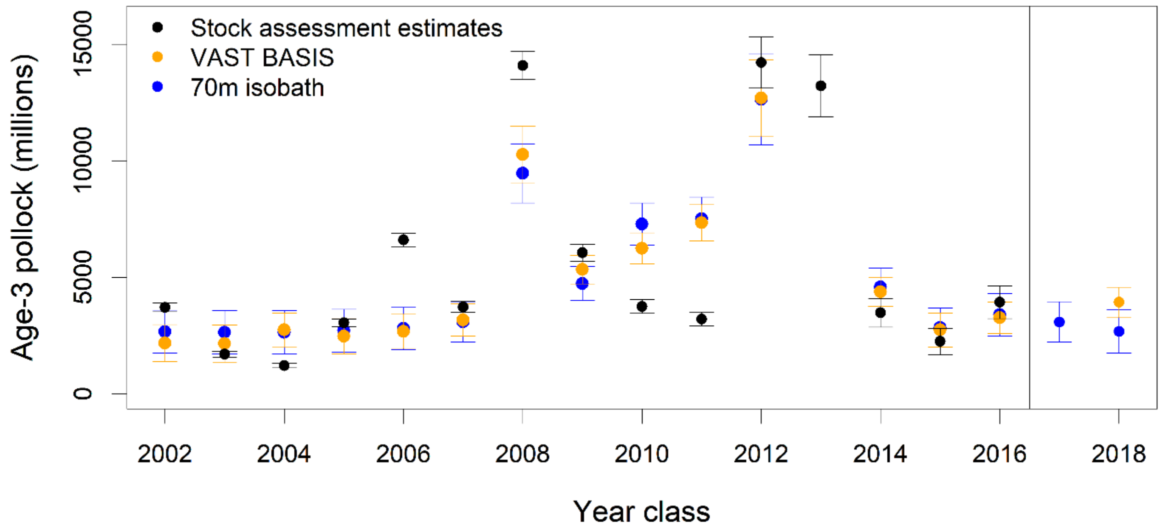

Figure 2. Fitted means and standard errors of the age-3 pollock abundance estimated from the linear regression models using VAST estimates of large copepods (orange), sample mean abundance of large copepods at the 70m isobaths stations (blue), and means from the pollock stock assessment estimates (black) from Ianelli et al. (2019). Predicted estimates of age-3 pollock (recruited into fishery as age 3's in 2021) are shown for the 2017 and 2018 year classes.

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For more information contact Ellen Yasumiishi (ellen.yasumiishi@noaa.gov).

Ocean acidification effects in larval walleye pollock-FBE RACE

Laboratory analyses were conducted to broaden understanding of the effects of increasing oceanic CO_2 levels (ocean acidification) on walleye pollock. This work builds upon an initial work which indicated general resiliency of walleye pollock to high CO_2 levels and the observation of sub-lethal effects of CO_2 on Pacific cod and other gadids. This work examined the effect of CO_2 on aspects of larval development, growth, survival, swimming patterns, and energy storage. Observations on growth rates were consistent with previous work showing little effect on growth rate or condition factor. There was a notable effect of high CO_2 resulting in a reduced rate of swim bladder inflation in larval pollock. Inflation of the swim bladder is an important milestone in the development of the fish and includes both physiological and behavioral components. While these findings generally support the notion that walleye pollock are less sensitive to elevated CO_2 levels than other marine gadids, it is possible that the reduced rate of swimbladder inflation could carry over with negative impacts on growth or survival in later larval stages.

For further information see Hurst et al. 2012, or, contact Tom Hurst, 541-867-0222, *thomas.hurst@noaa.gov*

Literature cited:

Hurst, T.P., L.A Copeman, M. Stowell, J.F. Andrade, C.E. Al-Samarrie, J.L. Sanders, and M.L. Kent. 2021. Expanding evaluation of ocean acidification responses in a marine gadid: elevated CO_2 impacts development, but not size of larval walleye pollock. *Marine Biology* 168:119. doi: 10.1007/s00227-021-03924-w

RACE Recruitment Processes Program (RPP)
The Recruitment Processes Program's (RPP) overall goal is to understand the mechanisms that influence the survival of young marine fish to recruitment. Recruitment for commercially fished species occurs when they grow to the size captured or retained by the nets or gear used in the fishery. For each species or ecosystem component studied, we attempt to learn what biotic and abiotic factors cause or contribute to the observed fishery population fluctuations. These population fluctuations occur on many different time scales (for example, between years, between decades). The mechanistic understanding that results from our research is used to better manage and conserve the living marine resources for which NOAA is the steward.

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Gulf of Alaska

Changes in spawn timing and availability of walleye pollock to assessment surveys in the Gulf of Alaska
Lauren A Rogers, Martin Dorn, Darin Jones, Kresimir Williams, Cole Monnahan

Changes in phenology, or the seasonal timing of events, are a widely-documented response to changes in climate. Spawn timing, in particular, has been shown to be sensitive to temperature in many species, including walleye pollock. Beyond implications for recruitment and survival of offspring, climate-driven changes in the timing of spawning can affect the availability of fish to surveys designed to monitor their abundance, complicating efforts to assess stock status and sustainably manage fisheries.

In recent years, biomass estimates from four surveys used to monitor Gulf of Alaska (GOA) pollock have diverged, giving conflicting estimates of survey biomass and temporal trends. In particular, from 2017-2019, estimates of pollock biomass were record high in the winter pre-spawner survey in Shelikof Strait, while other GOA summertime surveys estimated near record low biomass. These conflicting trends increased uncertainty in the stock assessment and occurred during a time of rapid environmental change in the GOA. Following recent evidence of shifting spawn timing in GOA pollock, we hypothesized that changes in spawn timing relative to survey timing affected availability of pollock to the winter Shelikof survey. To test this, we reconstructed relative spawn timing from estimated hatch dates of larvae collected during spring larval surveys and from observations of spawning state in mature female pollock collected during the winter Shelikof survey. We then compared estimates of spawn timing/survey timing overlap with residual errors from an age-structured stock assessment model to evaluate whether model lack-of-fit to survey biomass estimates was related to the timing of spawning relative to the timing of the survey. Results suggest that changes in spawn timing relative to survey timing can explain a significant portion of recent and historical discrepancies in survey biomass estimates. Based on this, we developed a time series of covariates for survey catchability for the stock assessment model to account for changing availability of pollock to the winter Shelikof survey. As climate change accelerates, changes in phenology may complicate efforts to monitor and assess stock status. We show that knowledge of underlying processes can guide approaches to account for these changes in assessment frameworks, expanding our toolkit for climate-ready fisheries management.

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Bering Sea

Management strategies for the eastern Bering Sea pollock fishery with climate change -- ESSR
Recent studies indicate that rising sea surface temperature (SST) may have negative impacts on eastern Bering Sea walleye pollock stock productivity. A previous study (*Ianelli et al 2011 ICES J Mar Sci 68: 1297–1304*) developed projections of the pollock stock and alternative harvest policies for the species, and examined how the alternative policies perform for the pollock stock with a changing environment. The study, however, failed to evaluate quantitative economic impacts. The present study showcases how quantitative evaluations of the regional economic impacts can be applied with results evaluating harvest policy trade-offs; an important component of management strategy evaluations. In this case, we couple alternative harvest policy simulations (with and without climate change) with a regional dynamic computable general equilibrium (CGE) model for Alaska. In this example we found (i) that the status quo policy performed less well than the alternatives (from the perspective of economic benefit), (ii) more conservative policies had smaller regional output and economic welfare impacts (with and without considering climate change), and (iii) a policy allowing harvests to be less constrained performed worse in terms of impacts on total regional output, economic welfare, and real gross regional product (RGRP), and in terms of variability of the pollock industry output. The results of this project are summarized in Seung and Ianelli (2017), which is currently under review / revision at a peer-reviewed journal. For further information, contact Chang.Seung@noaa.gov

An examination of size-targeting in the Bering Sea pollock catcher processor fishery -- ESSR
Weight-based harvest quota regulations do not restrict the size of individual fish that fill that quota, although fish of different sizes may present varying fishery profit opportunities and have different impacts on the stock's growth potential. This paper empirically links revenue per unit of quota and fish size by investigating the catcher-processor fleet of the U.S. Bering Sea pollock fishery, where larger fish can be made into higher-value fillets, instead of surimi that is lower value on average. We then use a dynamic age-structured model to illustrate how some harvesters target smaller fish to decrease their own harvesting costs, which imposes a stock externality on the fleet. This is a working paper that is being revised for submission to a peer-reviewed journal. We estimate the potential increase in profit if a manager hypothetically controls for the size of fish caught in the pollock fishery. Fishers benefit due to higher prices coming from higher-value products, and greater catches because of a larger biomass. For further information contact Alan.Haynie@noaa.gov.

2. Stock Assessment

Eastern Bering Sea (REFM)
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

Aleutian Islands (REFM)
The Aleutian Islands (AI) pollock stock assessment has changed to a biennial cycle with full assessments in even years timed with the Aleutian Islands bottom trawl survey, and partial assessments in odd years. Partial assessments include updated harvest recommendations; the 2020 OFL is 66,973 t and 2020 maximum ABC is 55,120 t.

Bogoslof Island (REFM)
Assessments for Bogoslof-area pollock are performed in even years and the harvest recommendations are not revised in off years. Harvest recommendations for Bogoslof-area pollock are made by multiplying the biomass estimate from the NMFS acoustic-trawl survey by an estimate of natural mortality. The biomass estimate is made using a random effects model used widely in AFSC assessments. Natural mortality was re-evaluated using the age-structured model presented in previous assessments (unchanged except for new survey, fishery, and age composition data from the survey).

Between 1997 and 2016, biomass estimates varied between 508,051 t and 67,063 t. The most recent acoustic-trawl survey of the Bogoslof spawning stock was conducted in March of 2018 and estimated a biomass estimate of 663,070 t, resulting in a random-effects survey average of 610,267 t. Assuming FOFL = M = 0.3 and FABC = 0.75 x M = 0.225, OFL for 2020 is 183,080 t and the maximum permissible ABC for 2020 is 137,310 t.

Gulf of Alaska (REFM)

The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

For further information regarding BSAI pollock contact Dr. James Ianelli (jim.ianelli@noaa.gov); for further information regarding GOA pollock contact Dr. Martin Dorn (martin.dorn@noaa.gov).

G. Pacific Whiting (hake)

There are no hake fisheries in Alaska waters.

H. Rockfish

1. Research

Rockfish Condition and Reproductive Studies - RACE GAP Kodiak

The development of accurate and logistically feasible methods to assess fish condition and reproductive success across the large spatial scales of the marine ecosystems of Alaska would be a valuable tool for assessing the importance of habitat for commercially important species. This research project is a collaborative effort with researchers from the EBS GAP group, the REFM Age and Growth Program (NOAA Strategic Initiative), and the Deep Sea Coral and Sponge Initiative.

Fish condition is generally thought to be a predictor of fish productivity and has been directly linked to reproductive success for some species (Kjesbu et al. 1991, Lambert and Dutil 2000). By measuring both condition indices and reproductive parameters (maturity, skipped spawning, and fecundity), it is possible to quantify the link between fish condition and reproductive status and success. Reproduction is energetically costly, and there is evidence that fish in better condition or that have higher energy reserves are more reproductively successful. The realization of maturity is related to greater body condition in some species (Henderson and Morgan 2002, Feiner et al. 2019). Improved fish condition is also linked to increased fecundity, earlier spawning, and eggs with larger energy reserves (Gagliano and McCormick 2007, Donelson et al. 2008, Feiner et al. 2019). Spawning omission has also been related to fish condition and low energy reserves (Rideout and Rose, 2006, Skjaeraasen et al. 2012, McBride et al. 2015). Several rockfish species in Alaska waters have been shown to exhibit some reproductive failure or skipped spawning (Conrath 2017, 2019), but it is unknown if body condition relates to this reduction in spawning effort.

Spatial differences in condition have been related to both water temperature and depth (Lloret and Ratz 2000, Chouinard and Swain 2002), but differences due to the presence of different substrate types are not as well documented. Rockfish species are frequently associated with coral and sponge habitat in both the Gulf of Alaska and the Aleutian Islands (Rooper et al. 2007, Rooper and Martin 2011, Conrath et al. 2019). It is often assumed structure-forming invertebrates provide a valuable habitat that results in higher productivity of these species. A previous study in the Gulf of Alaska examining rockfish abundance and community structure in different habitats found that rockfish densities were highest in complex habitat, but additional value of habitat containing structure-forming invertebrates was not shown (Conrath et al. 2019). Similarly, Rooper et al. (2019) found that rockfish in the eastern Bering Sea and the Aleutian Islands had an affinity for coral and sponge habitats, but that any structure is important for rockfish and both abiotic and biotic structure was associated with increased rockfish densities. A more comprehensive examination of fish condition and reproductive success across large spatial scales within the Gulf of Alaska and the Aleutian Islands will support the further examination of the value of coral and sponge habitats within these large marine ecosystems.

Northern Rockfishes and Pacific Ocean Perch - RACE

A project focused on developing an appropriate condition index for use during annual bottom trawl surveys, relating condition to reproductive success, and examining the relationship between these parameters and habitat was initiated in 2021. During 2021, the sampling for this project was focused on developing the best method to examine fish condition during standardized annual bottom trawl surveys. Pacific ocean perch (*Sebastes alutus*) and northern rockfish (*S. polyspinis*) were sampled for this project during the Alaska Fisheries Science Center (AFSC) 2021 Gulf of Alaska Bottom Trawl Survey. Fifty rockfish of each species were sampled throughout the survey area. Each sampled rockfish was measured for length, total weight, liver weight, biological impedance, and water content. These data will be used to calculate length weight residuals, hepatosomatic indices, and lipid/water ratios. These condition indices will be validated using proximate composition and bomb calorimetry to calculate energy density. These results will be used to determine how fish condition will be assessed during the 2022 sampling period and in future years throughout the large marine ecosystems of Alaska.

The focus of sampling in 2022 will be on collecting fish condition and reproductive samples for Pacific ocean perch and northern rockfish in or near areas of high concentrations of structure forming invertebrates and areas without structure forming invertebrates. Sampling will occur during the 2022 Aleutian Islands Bottom Trawl Survey. It is anticipated one sampling day will occur in the Samalga Pass region and one additional sampling day will occur near Seguam Island. Sampling stations will be finalized prior to the onset of the survey based on current sampling maps and additional examination of historical survey and camera data. Current sampling locations are based on 1) initial proposed bottom trawl sampling locations for 2022 2) modeled coral density from Rooper et al. 2018, and 3) differences in model predictions and camera observations from Rooper et al. 2018 (Figure 2).

For further information, please contact Christina Conrath (907) 481-1732

Whole genome resequencing of rockfish, sablefish, and Pacific cod - ABL

The genetics group at Auke Bay Laboratories is using whole genome resequencing to understand population structure in a number of groundfish and crab species including several rockfish, sablefish, king crab, and Pacific cod. The focus of this work will be understanding the population structure of these species. Analysis of sablefish showed no structure, reinforcing results from Jasonowicz et al. 2017. Analyses of other species are in process.

For more information, contact Wes.Larson@noaa.gov.

2. Assessment

Pacific Ocean Perch (POP) – Bering Sea and Aleutian Islands - REFM

In 2005, BSAI rockfish were moved to a biennial assessment schedule with full assessments in even years to coincide with the occurrence of trawl surveys in the Aleutian Islands (AI) and the eastern Bering Sea (EBS) slope. In odd years, partial assessments include revised harvest recommendations. The 2020 OFL is and the 2020 maximum ABC is 58,956 t and the 2020 OFL is

48,846 t.

For more information contact Paul Spencer, (206) 526-4248 or paul.spencer@noaa.gov.

Pacific Ocean Perch - Gulf of Alaska - ABL

In 2021, an assessment was conducted for Gulf of Alaska Pacific ocean perch. New data in the 2021 assessment included updated 2020 catch and estimated 2021 catch, survey biomass for 2021, and fishery age composition for 2020. There were no changes to the model.

Spawning biomass was above the $B_{40\%}$ reference point and projected to be 216,635 t in 2022 and to decrease to 210,257 t in 2023. The SSC has determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, thereby qualifying Pacific ocean perch for management under Tier 3. The current estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ are 132,767 t, 0.10, and 0.12, respectively. Spawning biomass for 2022 is projected to exceed $B_{40\%}$, thereby placing POP in sub-tier "a" of Tier 3. The 2022 and 2023 catches associated with the $F_{40\%}$ level of 0.10 are 38,268 t and 37,104 t, respectively, and were the authors' and Plan Team's recommended ABCs. The 2022 and 2023 OFLs are 45,580 t and 44,196 t.

A random effects model was used to set regional ABCs based on the proportions of model-based estimates for 2022: Western GOA = 2,602 t, Central GOA = 30,806 t, and Eastern GOA = 4,860 t. The Eastern GOA is further subdivided into west (called the West Yakutat subarea) and east (called the East Yakutat/Southeast subarea, where trawling is prohibited) of 140° W longitude using a weighting method of the upper 95% confidence of the ratio in biomass between these two areas. For W. Yakutat the ABC in 2022 is 1,409 t and for E. Yakutat/Southeast the ABC in 2022 is 3,451 t. The recommended OFL for 2022 is apportioned between the Western/Central/W. Yakutat area (41,470t) and the E. Yakutat/Southeast area (4,110 t). Pacific ocean perch is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

For more information contact Pete Hulson, ABL, at (907) 789-6060 or pete.hulson@noaa.gov.

Dusky Rockfish-- Gulf of Alaska - ABL

In 2021, a partial assessment was conducted for Gulf of Alaska dusky rockfish. The input data were updated to include final catch for 2020 and preliminary catch for 2021. Only the projection model was run, no changes were made to the assessment model.

Spawning biomass was above the $B_{40\%}$ reference point and projected to be 38,371 t in 2022 decreasing to 36,853 t in 2023. The SSC has determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, thereby qualifying dusky rockfish for management under Tier 3. With $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ estimated at 24,342 t, 0.114, and 0.093, respectively. Spawning biomass in 2022 is projected to exceed $B_{40\%}$, thereby placing northern rockfish in Tier 3a. The 2022 and 2023 catches associated with an $F_{40\%}$ are 7,069 t and 6,686 t, respectively. A "stair step" methodology was requested by the SSC that specifies the ABC be set halfway between the 2020 ABC (3,676 t) and 2022 model estimated maximum ABC. This results in an adjusted ABC of 5,372 t. and 5,181 t for 2022 and 2023, respectively. These catches were put forward as the authors' and Plan Team's recommended ABCs. The 2022 and 2023 OFLs are 8,614 t and 8,146 t.

A random effects model was use to establish regional ABCs based on the proportions of model-based estimates for 2022 with 269 t allocated to the Western GOA, 4,534 t to the Central GOA, and 569 t to the Eastern GOA. The recommended OFLs for 2022 and 2023 are not regionally apportioned. Dusky rockfish is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

For more information contact Ben Williams, ben.williams@noaa.gov.

Northern Rockfish – Bering Sea and Aleutian Islands - REFM
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

For further information, contact Paul Spencer at (206) 526-4248

Northern Rockfish - Gulf of Alaska - ABL

In 2021, a partial assessment was conducted for Gulf of Alaska northern rockfish. The input data were updated to include final catch for 2020 and preliminary catch for 2021. Only the projection model was run; no changes were made to the assessment model.

Spawning biomass was above the $B_{40\%}$ reference point and projected to be 40,474 t in 2022 decreasing to 37,408 t in 2023. The SSC has determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, thereby qualifying northern rockfish for management under Tier 3. With $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ estimated at 33, 933 t, 0.073, and 0.061, respectively. Spawning biomass in 2022 is projected to exceed $B_{40\%}$, thereby placing northern rockfish in Tier 3a. The 2022 and 2023 catches associated with an $F_{40\%}$ are 5,147 t and 4,921 t, respectively. These catches were put forward as the authors' and Plan Team's recommended ABCs. The 2022 and 2023 OFLs are 6,143 t and 5,874 t.

A random effects model was used to establish regional ABCs based on the proportions of model-based estimates for 2022 with 1,944 t allocated to the Western GOA, 3,202 t to the Central GOA, and 1 t to the Eastern GOA. The Eastern GOA allocation is managed within the "Other Rockfish" complex. The recommended OFLs for 2022 and 2023 are not regionally apportioned. Northern rockfish is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

For more information contact Ben Williams, ben.williams@noaa.gov.

Shortraker Rockfish - - Bering Sea and Aleutian Islands - REFM
The Bering Sea and Aleutian Islands (BSAI) shortraker rockfish stock is classified as a Tier 5 stock for setting the acceptable biological catch (ABC) and overfishing level (OFL). In accordance with

the new assessment schedule frequency, we conducted a full assessment for shortraker rockfish in 2020; however since there were no new surveys for this assessment the ABC and OFL were rolled over from the previous assessment. The recommended 2021 ABC and OFL for BSAI shortraker rockfish are 541 t and 722 t, respectively. The stock is not being subject to overfishing. Please refer to this year's full stock assessment and fishery evaluation (SAFE) report for further information regarding the stock assessment (Shotwell et al., 2020, available online at https://www.fisheries.noaa.gov/resource/data/2020-assessment-shortraker-rockfish-stock-bering-sea-and-aleutian-islands).

For more information, contact Kalei Shotwell at (907) 789-6056 or kalei.shotwell@noaa.gov.

Shortraker Rockfish – Gulf of Alaska – ABL

The Gulf of Alaska (GOA) shortraker rockfish are assessed on a biennial stock assessment schedule with a full stock assessment produced in odd years and no stock assessment produced in even years. For this on-cycle year, we incorporated the 2020 and 2021 Relative Population Weights (RPWs) from the AFSC longline surveys, the 2021 trawl survey biomass estimate, and updated catch.

Shortraker rockfish has always been classified into "tier 5" in the North Pacific Fishery Management Council's (NPFMC) definitions for ABC and overfishing level. Following the recommendation of the NPFMC for all Tier 5 stocks, we continue to use a random effects (RE) model fit to the AFSC longline survey RPW index (1992 – 2021) and the AFSC bottom trawl survey biomass index (1984 – 2021), to estimate the exploitable biomass that is used to calculate the recommended ABC and OFL values for the 2022 fishery. Estimated shortraker biomass is 31,331 mt, which is < 0.5 % decrease from the 2019 estimate. The NPFMC's "tier 5" ABC definitions state that $F_{ABC} \leq 0.75M$, where *M* is the natural mortality rate. Using an *M* of 0.03 and applying this definition to the exploitable biomass of shortraker rockfish results in a recommended ABC of 705 t for the 2022 fishery. Gulfwide catch of shortraker rockfish was 531 t in 2020 and estimated at 532 t in 2021. Shortraker rockfish in the GOA is not being subjected to overfishing. It is not possible to determine whether this stock is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

For more information contact Katy Echave at (907) 789-6006 or katy.echave@noaa.gov.

Other Rockfish – Bering Sea and Aleutian Islands– ABL

The BSAI Other Rockfish complex is currently managed under Tier 5 harvest control rules, which define FOFL and FABC as M and 0.75M, where M is the natural mortality rate. This complex is assessed fully in even years to coincide with the AI groundfish trawl survey. The Other Rockfish complex includes all species of Sebastes and Sebastolobus, except Pacific ocean perch, northern rockfish, rougheye rockfish, and shortraker rockfish. Because of differences in the assumed M among species, the Other Rockfish complex is assessed in two parts: (1) shortspine thornyhead (SST; M=0.03), which comprise approximately 95% of the estimated total Other Rockfish exploitable biomass; and (2) the remaining "non-SST" species, which are dominated by dusky rockfish (M=0.09) but include at least eleven other rockfish species. New data for the stock assessment included 2020 catch and fishery lengths and a zero biomass observation for the non-SST component of the stock in the 2019 EBS shelf trawl survey. The 2020 AI and EBS shelf surveys were canceled due to Covid-19, and there has been no EBS slope survey since 2016. No changes to assessment methodology were made in 2020.

The recommended Tier 5 random effects model was used to estimate exploitable biomass from time series of EBS shelf, EBS slope, and AI trawl survey data. Combined Other Rockfish biomass in 2021/2022 is estimated to be 53,248 t. The recommended BSAI ABC and OFL for 2021/2022 are 1,313 t and 1,751 t, respectively. The area-apportioned ABCs in the AI and EBS for 2021 are 394 t and 919 t, respectively.

The 2020 stock assessment is available online at: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIorock.pdf

For more information contact Jane Sullivan, ABL, at 907 789-6000 or jane.sullivan@noaa.gov

Other Rockfish – Gulf of Alaska – ABL
The Other Rockfish complex in the Gulf of Alaska (GOA) is comprised of 27 species, but the composition of the complex varies by region. The species that are included across the entire GOA are the 17 rockfish species that were previously in the "Other Slope Rockfish" category together with yellowtail and widow rockfish, formerly of the "Pelagic Slope Rockfish" category. Northern rockfish are included in the Other Rockfish complex in the eastern GOA and the Demersal Shelf rockfish species are included west of the 140 line (i.e. all of the GOA except for NMFS area 650). The primary species of "Other Rockfish" in the GOA are sharpchin, harlequin, silvergray, redstripe and yelloweye rockfish; most of the others are at the northern end of their ranges in Alaska and have a relatively low abundance here. Rockfish in the GOA have been moved to a biennial stock assessment and the "Other Rockfish" stock complex is assessed in odds years as per prioritization. The last full assessment was in the fall of 2019 and the next full assessment will be completed in the fall of 2021.

This complex consists of species assessed as Tier 4, Tier 5 or Tier 6, based on data availability. The complex is managed as a whole and the acceptable biological catch (ABC) and overfishing level (OFL) for each species are summed to create the ABC/OFL for the complex. The Tier 4/5 species ABC/OFLs are based on a random effects model applied to the biennial GOA trawl survey data. This results in a current exploitable biomass of 67,325 t for "Other Rockfish" in 2022 and 2023. Applying either an $F_{ABC} \leq F_{40\%}$ rate for sharpchin rockfish or an $F_{ABC} \leq 0.75M$ (*M* is the natural mortality rate) for the tier 5 species to the exploitable biomass for Other Rockfish results in a recommended ABC in the GOA of 2,982 t, which was combined with the tier 6 ABC of 180 t for a total complex ABC of 3,162 t for 2022 and 2023.

Gulfwide catch of Other Rockfish was 882 t and 1,201 t in 2020 and 2021, respectively. Other rockfish is not considered overfished in the Gulf of Alaska, nor is it approaching overfishing status. However, the apportioned ABC for the Western GOA has often been exceeded. Beginning in 2014, the Western and Central GOA apportioned ABCs were combined. This was not deemed a conservation concern because the combined catch of the Western and Central GOA does not always exceed the combined ABC of the two areas, nor is the catch of Other Rockfish approaching the complex ABC. While this GOA-wide ABC was a small reduction from the previous assessment, due to shifts in the trawl survey biomass distribution, and the relative proportional abundance of the component species, the resultant apportioned ABCs were far below historical catch in the Western and Central GOA, and likely not representative of the true abundance. As such, the SSC and

Council opted to roll over the previous assessments' harvest recommendations until further analysis could be completed.

For more information contact Cindy Tribuzio at (907) 789-6007 or cindy.tribuzio@noaa.gov.

Blackspotted/rougheye Rockfish Complex – Bering Sea and Aleutian Islands - REFM

Fish previously referred to as rougheye rockfish are now recognized as consisting of two species, rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*Sebastes melanostictus*). The current information on these two species is not sufficient to support separate assessments, so they are combined as a complex in one assessment. In 2005, BSAI rockfish were moved to a biennial assessment schedule with full assessments in even years to coincide with the occurrence of trawl surveys in the Aleutian Islands (AI) and the eastern Bering Sea (EBS) slope. In odd years, partial assessments include revised harvest recommendations. The 2020 maximum ABC is 817 t and the 2020 OFL is 675 t.

For more information contact Paul Spencer,(206) 526-4248 or paul.spencer@noaa.gov.

Blackspotted/rougheye Rockfish Complex – Gulf of Alaska - ABL

Rougheye (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*) have been assessed as a stock complex since the formal verification of the two species in 2008. The rougheye and blackspotted rockfish (RE/BS) are caught primarily in trawl and longline fisheries and has been a bycatch only fishery since 1991. The GOA RE/BS complex is fully assessed as a Tier 3 stock in odd years to correspond with the GOA trawl survey. In 2021, we presented a full stock assessment with updated data. There were no changes to the assessment model. The 2021 trawl survey biomass estimate decreased 56% from the 2019 estimate and is the lowest in the time series. The 2021 longline survey abundance estimate decreased 36% since 2019, and 2020 was the lowest in the time series. These declines had significant impacts on the parameters that govern the scale of the population, resulting in a significant downgrade in biomass trajectories, recruitment, and estimates of unfished spawning biomass. Despite declines, the stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished.

We recommended the maximum allowable ABC of 788 t from the updated projection model for 2022. This ABC is 35% lower than the 2022 projected ABC of 1,221 t from the 2020 partial assessment. Female spawning biomass is estimated to be decreasing and is projected to be 8,648 t in 2022 and 8,627 in 2023. These estimates are above the $B_{40\%}$ reference point of 5,911 t, thereby placing RE/BS in sub-tier “a” of Tier 3. Area apportionments based on the two survey random effects method are as follows for 2022: Western GOA = 184 t, Central GOA = 235 t, and Eastern GOA = 369 t.

For more information contact Jane Sullivan, jane.sullivan@noaa.gov.

The 2021 stock assessment is available online at: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/GOArougheye.pdf

I. Thornyheads

1. Research

2. Stock Assessment

Gulf of Alaska - ABL

The thornyhead rockfish stock complex remain on a biennial stock assessment schedule with a full stock assessment produced in even years and no stock assessment or document produced in odd years. Because this was an "off year," the 2021 values were rolled over for the 2022 fishery. Estimated thornyhead rockfish biomass is 86,802 t. The NPFMC's Tier 5 ABC definitions state that FABC ≤0.75*M*, where *M* is the natural mortality rate. Using an *M* of 0.03 and applying this definition to the exploitable biomass of thornyhead rockfish results in a recommended ABC of 1,953 t for the 2022 fishery. Gulfwide catch of thornyhead rockfish was 274 t in 2021. This is down from 453 t in 2020.

For more information please contact Katy Echave at (907) 789-6006 or katy.echave@noaa.gov.

J. Sablefish

1. Research

Groundfish Tag Program - ABL

The ABL MESA Tag Program continued the processing of groundfish tag recoveries and administration of the tag reward program and Groundfish Tag Database during 2021. While sablefish is the primary species tagged, tags from shortspine thornyheads, Greenland turbot, Pacific sleeper sharks, lingcod, spiny dogfish, Pacific cod, Pacific ocean perch, and rougheye rockfish are also maintained in the database. Total tag recoveries for the year were ~450 sablefish and 5 thornyhead. Twenty two percent of the recovered sablefish tags in 2021 were at liberty for over 10 years. About 32 percent of the total 2021 recoveries were recovered within 100 nautical miles (nm; great circle distance) from their release location, 33 percent within 100 – 500 nm, 23 percent within 500 – 1,000 nm, and 13 percent over 1,000 nm from their release location (sum will not add to 100 because of rounding). The tag at liberty the longest was for approximately 42 years (15,423 days), and the greatest distance traveled of a 2021 recovered sablefish tag was 2,357 nautical miles from a fish tagged in the northwest Aleutian Islands on 5/25/1982 and recovered off the Oregon coast on 4/18/2021. Two adult and one juvenile sablefish tagged with archival tags were recovered in 2021. Releases in 2021 on the AFSC groundfish longline survey totaled 6,156 adult sablefish, 312 shortspine thornyhead, and 27 Greenland turbot. An additional 143 juvenile (age-1) sablefish were tagged during one juvenile sablefish tagging cruise in 2021.

For more information, contact Katy Echave at (907) 789-6006 or katy.echave@noaa.gov.

The AFSC groundfish tag data can now be viewed online through a series of summary tables and interactive maps, at this location: https://www.fisheries.noaa.gov/resource/map/alaska-groundfish-tagging-map.

Juvenile Sablefish Studies – ABL

Juvenile (age-1) sablefish tagging studies have been conducted by the Auke Bay Laboratories in Alaska since 1984 and were continued in 2021 thanks to the efforts of the Alaska Department of Fish and Game-Sitka and the crew of the R/V Kittiwake. When NMFS staff were unable to perform this fieldwork due to COVID restrictions, ADF&G graciously volunteered their time and service to ensure this historical time series was not interrupted. The ADF&G sampled St. John Baptist Bay near Sitka, AK for three days (Sept. 13, 15, and 17), tagging 143 juvenile sablefish. The CPUE in 2021 was down considerably from 2020. The average length of fish was 360 mm.

Thank you again to the Alaska Department of Fish and Game – Sitka, particularly Rhea Ehresmann for heading up this endeavor.

For more information, contact Katy Echave at (907) 789-6006 or katy.echave@noaa.gov.

Sablefish Point of No Return Studies- RPP

The goal of our research funded by the North Pacific Research Board is to examine factors that may influence recruitment in Sablefish, particularly focusing on prey availability and temperature. During year 1, we focused on starvation resiliency of first feeding Sablefish larvae to low prey conditions at 6°C, an average springtime sea surface temperature in the western Gulf of Alaska. Our rearing work was initially delayed by the lack of spawning individuals at the Manchester Seawater Laboratory (NWFSC) and was, ultimately, unsuccessful due to low egg survivorship for the starvation resiliency experiments. However, we did have some success because our partners in the Fisheries Behavioral and Ecology Program also obtained Sablefish eggs and were able to test tank configurations to determine how best to proceed for year 2 temperature experiments.

For more information, contact Ali Deary at 518-366-6703 or alison.deary@noaa.gov

2. Stock Assessment

Sablefish in the Bering Sea, Aleutian Islands, and Gulf of Alaska - ABL

Moderate changes to the assessment model were implemented for the 2021 sablefish (*Anoplopoma fimbria*) SAFE to address increasing retrospective patterns in recent recruitment estimates over the last few assessments. Model refinements included updated biological inputs, new fishery and survey selectivity and catchability parametrizations, and improved data reweighting approaches, all of which have helped to address retrospective patterns.

New data included in the assessment model were relative abundance and length data from the 2021 longline survey, length data from the fixed gear fishery for 2020, length data from the trawl fisheries for 2020, age data from the longline survey and fixed gear fishery for 2020, updated catch for 2020, and projected 2021 – 2023 catches. Estimates of killer and sperm whale depredation in the fishery were updated and projected for 2021 – 2023. In 2021, there was also a NMFS Gulf of Alaska trawl survey; associated relative abundance indices and length data for the Gulf of Alaska in waters less than 500m were included in the assessment. Due to funding issues and timing constraints, 2020 fixed gear fishery catch-per-unit effort (CPUE) data from logbooks were unavailable. Because logbooks are a major component of the CPUE index, no fishery CPUE data point for 2020 was available. Additionally, revised estimates of growth-, weight-, and maturity-at-age using recently collected data were incorporated in the model.

The longline survey abundance index (relative population numbers, RPNs) increased 9% from 2020 to 2021 following a 32% increase in 2020 from 2019. Similarly, the trawl survey biomass index has increased nearly five-fold since 2013, with a 40% increase from 2019 to 2021. The fishery catch-rate (CPUE) index was at the time series low in 2018, but increased 20% in 2019 (the 2020 data are not available yet). The age and length composition data continue to indicate strong recent year classes in 2014, 2016, 2017, and 2018.

Based on the strength of these recent year classes, biomass estimates have more than doubled from a time series low of 215,000 t in 2015 to 553,000 t in 2021. From the time series low in 2017, SSB has increased by 34% to 108,000 t in 2021, which is 36% of the unfished SSB (i.e., SSB_0). The updated point estimate of $B_{40\%}$, is 118,140 t, while projected female spawning biomass (combined areas) for 2022 is 128,789 t (i.e., equivalent to $B_{44\%}$). The maximum permissible 2022 ABC (combined areas) based on the NPFMC harvest control rule is 34,863 t. After accounting for whale depredation in the fishery, the whale adjusted ABC for 2022 is 34,521 t. The recommended 2022 ABC represents an 18% increase from the 2021 ABC, and a tripling of the quota since 2016 when the lowest ABC on record (11,795 t) was enacted.

Because a single area stock assessment model is utilized, it is necessary to apportion the total ABC to management regions. Based on biological rationale, the NPFMC SSC adopted a five-year average survey apportionment method in 2020, which uses a five-year moving average of the longline survey proportions of biomass in each region to apportion the Alaska-wide ABC to each management region. This method tracks biomass across management regions to the best of our current ability (i.e., by using estimates of regional biomass from the yearly longline survey that targets sablefish in prime adult habitat), while still buffering against variability caused by annual measurement error. The SSC also instituted a four-year stair step approach to move from the fixed apportionment used prior to 2020 towards the five-year average survey apportionment. In 2021, a 50% stair step from the 2020 fixed apportionment values towards the 2021 five-year average survey apportionment values was implemented.

Although modeling updates appear to have addressed the retrospective issues associated with previous sablefish assessments, the exact cause of those retrospective patterns is not certain and it is unclear if these patterns may persist when new data is incorporated in coming years. Additionally, a number of concerns related to the sablefish resource remain, which merit careful monitoring as recent recruitment year classes continue to age and help the resource to rebuild. For instance, sablefish age structure is severely truncated and the SSB relies heavily on recent cohorts (i.e., year classes since 2014 constitute >50% of the SSB) with little contribution from early 2000s year classes. Alternate metrics of spawning potential, which better emphasize fully mature age classes (e.g., the biomass of ages > 10), could help maintain a strong spawning portfolio and avoid future contraction of the age structure, thereby improving resilience of the sablefish resource. From a fishery perspective, there has been a rapid shift in the composition of the fixed gear fleet where pot gear now constitutes more than 50% of sablefish removals, which is not fully accounted for in the assessment. In addition, the rapid decline in overall market conditions, particularly due to the influx of small sablefish, may be contributing to differences in targeting and selectivity in all fisheries. Moreover, the projected maximum ABC would represent the largest catch since the late 1980s, which, due to high catches and extended periods of poor recruitment, was followed by subsequent declines in biomass and SSB. Given that sablefish are such a long-lived species and considering the cyclic nature of sablefish dynamics, exploration of a capped (i.e., implementing a maximum cap on the ABC) management procedure (or an 'inventory management' strategy) for sablefish may be worthwhile. Compared to using a maximum yearly catch strategy, capped HCRs could aid in stabilizing long-term sablefish dynamics (i.e., help to prevent long-term cyclical declines as the resource transitions between high and low recruitment regimes).

For more information contact Dan Goethel (daniel.goethel@noaa.gov).

Coastwide research discussions for sablefish – ABL

The Pacific Sablefish Transboundary Assessment Team (PSTAT), which was established in 2017, is a research collaboration between the Alaska Fisheries Science Center, the Northwest Fisheries Science Center, the Alaska Department of Fish and Game, and the Department of Fisheries and Oceans Canada. The purpose of the PSTAT is to aid collaboration among scientists and managers across jurisdictions to enable wider understanding of Pacific-wide sablefish population dynamics. In the last year, the group has continued work on a tagging model to estimate movement and mortality within and among management regions, which is expected to be completed next year. Similarly, research continued towards developing a spatially explicit coastwide operating model that incorporates movement rates from the tagging model along with spatially-varying demographics (i.e., as identified through earlier PSTAT research) to emulate sablefish dynamics, and is likely to be completed in the next 1-2 years. The operating model will form the basis of a management strategy evaluation, which aims to inform on the potential risks of current independent, regional assessment-management approaches and also identify whether regionwide management strategies might be more robust. In April 2021, the PSTAT held a stakeholder engagement workshop aimed to solicit feedback on the development, assumptions, and desired performance measures of the MSE tool. Workshop outcomes included:

- Participants increased knowledge of sablefish science and management among regions.
- Participants increased knowledge of the development of the sablefish MSE tool.
- Participants provided feedback on inputs for the Sablefish MSE, including objectives, performance metrics, and management procedures.

For more information contact Dan Goethel (daniel.goethel@noaa.gov).

K. Lingcod

There are no federally-managed lingcod fisheries in Alaska waters. Recreational and small-scale commercial fisheries are managed by the Alaska Department of Fish & Game.

L. Atka Mackerel

1. Research

2. Stock Assessment

Bering Sea and Aleutian Islands - REFM
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

Gulf of Alaska (REFM)
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

For more information, contact Sandra.Lowe@noaa.gov.

M. Flatfish

1. Research

Northern rock sole and yellowfin sole growth potential

Laboratory experiments were conducted to compare the age-dependence and temperature-dependence of age-0 and age-1 flatfishes in the shallow-water complex. Fish for the lab experiments were collected from nursery grounds in the Gulf of Alaska and Bering Sea in 2018 and 2019 with the experimental series completed in 2020. In both species, fish were reared for 6-8 weeks at temperatures of 2, 5, 9, 13, and 16°C. Fish were fed ad libitum daily and were measured at bi-weekly intervals for determination of maximum growth potential. Both age classes of yellowfin sole and age-1 northern rock sole exhibited maximum growth potential at 13°C. In contrast, growth rates of age-0 northern rock sole were slightly higher at 16°C than 13°C suggesting higher tolerance of warner temperatures in demersal juveniles of this species. These thermal sensitivities may play a role in habitat suitability for these species as climate conditions change in the Gulf of Alaska and Bering Sea. Samples from these experiments are being examined for lipid composition to determine whether temperature effects on energy storage mirror the patterns observed in growth or if there is a tradeoff between growth and storage in these species.

For further information, contact Tom Hurst, 541-867-0222, thomas.hurst@noaa.gov

Northern rock sole and yellowfin sole feeding in SEBS nursery areas - FBE RACE

Field collections of juvenile northern rock sole and yellowfin sole in nursery areas along the Alaska

Peninsula were used to examine feeding patterns and diet overlap in these co-occurring species. As observed in other parts of their ranges, the diets of both species included polychaetes and amphipods. The primary difference in the diets of these species was that prey of yellowfin sole were almost exclusively endobenthic and epibenthic invertebrates; northern rock sole had more diverse diets and consumed substantial amounts of hyperbenthic mysids and pelagic euphausiids). Overall dietary overlap was low, in part due to differences in microhabitat use. These observations indicate that direct competition for prey resources between juveniles of these co-occurring species is reduced by a combination of differential habitat associations and prey selection. However, this differentiation indicates that climate change in the SEBS may differentially affect the forage base and productivity of these species (Ferm et al. 2021).

For further information, contact Tom Hurst, 541-867-0222, thomas.hurst@noaa.gov

Ferm, N.C., J.T. Duffy-Anderson, T.P. Hurst. 2021. Foraging habits and dietary overlap of juvenile yellowfin sole and northern rock sole in a Bering Sea coastal nursery. *Fishery Bulletin* 120:1-12. doi: 10.7755/FB.120.1.1

2. Assessment

Yellowfin sole - Bering Sea and Aleutian Islands -REFM
The yellowfin sole fishery in the EBS is the largest flatfish fishery in the world. This stock is assessed using an age-structured population dynamics model implemented in the software program AD Model Builder. Survey catchability (q) has been shown to be linked to bottom water temperatures, so in the model q is estimated as a function of an included bottom temperature index. In 2019 a new model was introduced based on the 2018 model that retains female natural mortality fixed at 0.12 while allowing the model to estimate male natural mortality.

The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

Greenland turbot - Bering Sea and Aleutian Islands - REFM
The BSAI Greenland turbot assessment is conducted in even years, with a partial update in odd years that includes revised harvest recommendations. For 2020, the OFL is 11,319 t and the maximum ABC is 9,625 t.

For further information contact Meaghan Bryan (206) 526-4694

Arrowtooth flounder - Bering Sea and Aleutian Islands - REFM
The Bering Sea and Aleutian Islands (BSAI) arrowtooth flounder stock is classified as a Tier 3 stock for setting the acceptable biological catch (ABC) and overfishing level (OFL). In accordance with the new assessment schedule frequency, we conducted a full assessment for arrowtooth flounder in 2020. We use a statistical age-structured model as the primary assessment tool for arrowtooth flounder. New data for this year included estimates of catch through October 25, 2020, updated and new fishery size compositions, new biomass, age and size data for the eastern Bering

Sea shelf bottom trawl survey, and new age data from the Aleutian Islands bottom trawl survey. Additionally, early survey data from 1982-1991 were removed from the eastern Bering Sea trawl survey index as this data occurred when there was low confidence in the identification of arrowtooth flounder.

There were no changes in the assessment methodology as we continue to use the 2018 assessment model (18.9). The 2019 eastern Bering Sea trawl survey estimate increased 13% from the 2018 estimate and is now 27% above average. No 2020 surveys were conducted in the eastern Bering Sea and the Aleutian Islands this year due to Covid-19. Catch for arrowtooth flounder is generally low and has been between 10-18% of the ABC since 2011 when speciation began in the catch accounting system for this stock. Current catch as of October 25, 2020 is at 13.8% of ABC. The total allowable catches (TACs) for arrowtooth flounder are generally set well below ABC and have been between 11- 27% since 2011. The 2020 ratio of TAC to ABC was 14%. For the 2021 fishery, we recommend the maximum allowable ABC of 77,349 t from the 2018 accepted model (Model 18.9). This is an 8% increase from last year's ABC of 71,618 t. The projected female spawning biomass for 2021 is 497,556 t and the projected age 1+ total biomass for 2021 is 923,646 t. Female spawning biomass is well above B40%, and projected to be stable. The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished. Please refer to this year's full stock assessment and fishery evaluation (SAFE) report for further information regarding the stock assessment (Shotwell et al., 2020, available online at https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIatf.pdf).

For more information, contact Kalei Shotwell at (907) 789-6056 or kalei.shotwell@noaa.gov.

Arrowtooth flounder - Gulf of Alaska - REFM
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

For more information, contact Kalei Shotwell at (907) 789-6056 or kalei.shotwell@noaa.gov.

Kamchatka flounder - Bering Sea and Aleutian Islands - REFM
Before 2011, Kamchatka flounder and arrowtooth flounder were managed in aggregate as a single stock. Due to the emergence of a directed Kamchatka flounder fishery and concerns about overharvesting, the stocks were separated in 2011. The BSAI Kamchatka flounder assessment is conducted in even years, with a partial update in odd years that includes revised harvest recommendations. For 2020, the OFL is 11,495 t and the maximum ABC is 9,708 t.

Northern rock sole - Bering Sea and Aleutian Islands - REFM
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:

https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

Northern and southern rock sole - Gulf of Alaska - REFM
Northern and southern rock sole in the GOA are managed as part of the shallow-water flatfish complex, which is discussed below.

Flathead sole - Bering Sea and Aleutian Islands - REFM
The BSAI flathead sole assessment is conducted in even years, with a partial update in odd years that includes revised harvest recommendations. For 2020, the OFL is 82,810 t and the maximum ABC is 68,134 t.

Flathead sole - Gulf of Alaska - REFM
This assessment is conducted using Stock Synthesis on a four-year schedule. 2019 was an off-year thus a partial assessment was presented. The projection model was run using updated catches. The 2019 spawning biomass estimate was above B40% and projected to increase through 2020. Biomass (age 3+) for 2019 was estimated to be 283,285 t and projected to slightly decrease in 2020. For 2019, the authors' recommendation was to use the maximum permissible ABC of 38,196 t from the updated projection. The FOFL is set at F35% (0.36) which corresponds to an OFL of 46,572 t.

For recent stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

For further information contact Carey McGilliard (206) 526-4696

Alaska plaice - Bering Sea and Aleutian Islands - REFM
Alaska plaice are assessed biennially using an age-structured population dynamics model implemented in the software program AD Model Builder. The 2019 assessment indicated that above average recruitment strength in 1998 and exceptionally strong recruitment in 2001 and 2002 have contributed to recent high levels of female spawning biomass. The Alaska plaice spawning stock biomass is projected to decline through 2023 while remaining above B35%.

Rex sole - Gulf of Alaska - REFM
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

For further information contact Carey McGilliard (206) 526-4696

"Other flatfish" complex - Bering Sea and Aleutian Islands - REFM
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation

(SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

For further information contact Meaghan Bryan (206) 526-4694

Shallow-water flatfish complex - Gulf of Alaska - REFM
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

For further information contact Carey McGilliard (206) 526-4696

Deep-water flatfish complex - Gulf of Alaska - REFM
The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the assessment sections in this report were not updated. For stock assessment results please see the assessments in the 2021 Stock Assessment and Fishery Evaluation (SAFE) reports here:
https://www.fisheries.noaa.gov/alaska/population-assessments/2021-north-pacific-groundfish-stock-assessments.

N. Pacific halibut

1. Research

Abundance-based management of halibut bycatch in Alaska's federal fisheries
The NPFMC has been actively working for several years to improve management of halibut bycatch. Following is the purpose and need statement for the Council's current actions:

Halibut is an important resource in the Bering Sea and Aleutian Islands (BSAI), supporting commercial halibut fisheries, recreational fisheries, subsistence fisheries, and groundfish fisheries. The International Pacific Halibut Commission (IPHC) is responsible for assessing the Pacific halibut stock and establishing total annual catch limits for directed fisheries and the North Pacific Fishery Management Council (Council) is responsible for managing prohibited species catch (PSC) in U.S. commercial groundfish fisheries managed by the Council. The Amendment 80 sector is accountable for the majority of the annual halibut PSC mortality in the BSAI groundfish fisheries.

While the Amendment 80 fleet has reduced halibut mortality in recent years, continued decline in the halibut stock requires consideration of additional measures for management of halibut PSC in the Amendment 80 fisheries. When BSAI halibut abundance declines, PSC in Amendment 80 fisheries can become a larger proportion of total halibut removals in the BSAI, particularly in Area 4CDE, and can reduce the proportion of halibut available for harvest in directed halibut fisheries.

The Council intends to establish an abundance-based halibut PSC management program in the BSAI for the Amendment 80 sector that meets the requirements of the Magnuson-Stevens Act, particularly to minimize halibut PSC to the extent practicable under National Standard 9 and to achieve optimum yield in the BSAI groundfish fisheries on a continuing basis under National Standard 1. The Council is considering a program that links the Amendment 80 sector PSC limit to halibut abundance and provides incentives for the fleet to minimize halibut mortality at all times. This action could also promote conservation of the halibut stock and may provide additional opportunities for the directed halibut fishery.

For more information please consult the NPFMC website (https://www.npfmc.org/); you may also contact Jim Ianelli at jim.ianelli@noaa.gov or Carey McGilliard at carey.mcgilliard@noaa.gov.

O. Other Groundfish Species

Other groundfish stocks assessed by the AFSC - REFM

In addition to the assessments described above, the AFSC assesses and provides harvest recommendations for an octopus complex in both the BSAI and GOA. These are non-target species and exploitation rates are low. In addition, the AFSC produces status reports for several species groups included in the FMPs as “Ecosystem Components”. These are stocks for which there are not active conservation concerns, but which have ecosystem roles that warrant some level of monitoring. These groups currently include grenadiers, squids, and a diverse forage fish group (the osmerids capelin and eulachon, as well as Pacific sand lance, are the main species of interest). Sculpins are also included in the FMP as Ecosystem Components but receive no reports.

Estimating spatiotemporal availability of transboundary fishes to fishery-independent surveys - RACE GAP, HEPR, REFM

In the paper ‘Estimating spatiotemporal availability of transboundary fishes to fishery-independent surveys’, we combined United States and Russian data from the northern, eastern, and western Bering Sea to understand the proportion of fish biomass within the extent of the eastern survey (“availability”). Surveys are within close proximity to each other, but with different sampling protocols (hence catch a different proportion of local densities, termed “sampling efficiency ratio”). We used Alaska pollock (*Gadus chalcogrammus*), Pacific cod (*Gadus macrocephalus*), and Alaska plaice (*Pleuronectes quadrituberculatus*) as case studies to calculate survey efficiency ratios and two area-swept estimators, termed local and conventional, to summarize groundfish biomass over various spatial scales across the Bering Sea. We estimated variation in spatial availability of transboundary stocks to the eastern Bering Sea (EBS) survey. In 2017, the most recent available year of survey coverage that included all three Bering Sea regions, estimated availability in the EBS of pollock biomass was ~33%, cod biomass was ~27%, and plaice biomass was ~26%, down from ~58%, ~71%, and ~30% respectively in 2010. This is the first study to provide an empirical way to combine Russian and US data in the Bering Sea to assess changes in the availability of groundfish biomass, which in turn will alter the interpretations and values of population indices used in regional management. We recommend leveraging this approach using existing global fishery-independent data sets that span different spatiotemporal footprints to monitor transboundary stocks, and as a template to initiate international cooperation on the assessment of spatial availability of stocks common to multiple countries. This published study is in the Journal of Applied Ecology (https://doi.org/10.1111/1365-2664.13914).

For further information, contact Cecilia O'Leary (cecilia.oleary@noaa.gov).

Understanding transboundary stocks availability by combining multiple fisheries-independent surveys and oceanographic conditions in spatiotemporal models. RACE GAP, HEPR, REFM

In this study, we illustrate the necessity for novel partnerships in the North Pacific when responding to climate-driven distribution shifts. We specifically develop the first-ever biomass estimate for groundfishes across the North Pacific, combining scientific fishery-independent bottom trawl data from the United States and Russia. We use three groundfish species across the Bering Sea as case studies, estimating biomass across the Bering Sea in a spatio-temporal model using the Vector Autoregressive Spatio-Temporal (VAST) model. We estimated a fishing-power correction as a catchability ratio to calibrate the disparate data sets and also estimated the impact of an annual oceanographic index, the cold pool extent index (CPI), as a covariate to explain variation in groundfish spatiotemporal density. We found that for major groundfish species included in this analysis, 'hot spots' or areas of high density span across the international border, particularly in warmer years when the cold pool extent is lower than the long-term average. We also found that groundfish densities increase throughout the entire Bering Sea region relative to historical densities, and all three groundfish species are shifting northward to varying degrees. The proportion of groundfish biomass found in the eastern and western sides of the Bering Sea is highly variable, but the majority of biomass was consistently found in the eastern Bering Sea until the final few years in this study. In the final year of comprehensive survey data (2017), 49%, 65%, 47% of biomass was in the western and northern Bering Sea for pollock, cod, and plaice, respectively, suggesting that availability of groundfish to the more regular eastern Bering Sea survey is declining. We conclude that International partnerships are key to tracking fish across international boundaries as they shift beyond historical survey areas. Research effort should be directed towards international collaborations to combine and calibrate past data, and to coordinate efforts in future data collection in order to fully understand biomass changes and manage shifting distribution of fish species as ocean conditions change. This work was accepted into ICES Journal of Marine Science and will be available online soon.

For further information, contact Cecilia O'Leary (cecilia.oleary@noaa.gov).

Gulf of Alaska

Establishing groundfish densities estimates in GOA untrawlable habitat with paired lowered stereo-camera system and bottom trawl data – RACE GAP, RACE MACE, REFM, MESA

This newly funded project will collect data from untrawlable (UT) habitats using a lowered stereo-camera system (LSC) and integrate those data with existing bottom-trawl data and bathymetry maps to develop a model-based index of abundance for groundfish that includes UT habitat-specific information. Many groundfish stock assessments in the Gulf of Alaska depend on fishery-independent surveys conducted by the Groundfish Assessment Program (GAP) to provide reliable indices of abundance over time. This work will help to provide more accurate and precise indices to GOA stock assessments for select rockfish species, particularly for those species that rely on rocky habitat, tend to be longer-lived with low fecundity, and thus are particularly vulnerable to overfishing and unfavorable environmental conditions.

For further information, contact Cecilia O'Leary (cecilia.oleary@noaa.gov) or Kresimir Williams (kresimir.williams@noaa.gov).

CONSERVATION ENGINEERING (CE)

The Conservation Engineering (CE) group of the NMFS Alaska Fisheries Science Center (AFSC) (Dr. Noëlle Yochum, lead) conducts cooperative research with Alaska fishing groups and other scientists to better understand and mitigate bycatch, bycatch mortality, and fishing gear impacts to fish habitat. This is done through the evaluation of fish biology and behaviour, and gear design and use. In 2020, CE research focused on evaluating a bycatch reduction device (BRD) designed to reduce Pacific salmon bycatch (primarily chum, Oncorhynchus keta, and Chinook, O. tshawytscha) in the eastern Bering Sea walleye pollock ("pollock", Gadus chalcogrammus) pelagic trawl fishery. Pacific salmon (*Oncorhynchus* spp.) bycatch is a significant driver in the management of pollock trawl fisheries in the North Pacific. In 2019, in collaboration with science and industry partners, CE developed and field tested a novel salmon 'excluder' (a BRD that provides an open area for salmon to escape between the net and codend; Breddermann et al., 2019; Yochum et al., 2021). In 2020, CE aimed to conduct further testing of that excluder to deepen our collective mechanistic understanding of what influences excluder efficacy and to improve the excluder design. In addition, in 2020 CE began developing methods for quantifying target catch loss (i.e., pollock) when using an excluder.

In light of the limitations to conduct field work due to Covid-19, the scope of the 2020 research plan was reduced and data collection was done through a modified approach. CE worked with the fishing company contracted to conduct the field testing, the NOAA observer program, and the observer company to have the on-board observer install the research equipment (cameras, sensors, etc.) into the net (as per the study design) during commercial fishing operations. To accomplish this, CE conducted thorough training with the observer before he boarded the vessel, had discussions with the captain, and produced a detailed manual and datasheets. In addition, locations for installation of the equipment were marked on the trawl in advance. The observer then worked with the fishing crew to attach the equipment and collect the data.

In August 2020, during two commercial fishing trips, the trawl was fished with the CE developed excluder and data were gathered as described above to inform salmon escapement and behaviour, and the loss of pollock. CE is currently conducting analysis on these data. The results will be included with those from a 2021 charter, where more data will be gathered to address questions about drivers of salmon excluder efficacy. This includes: (i) evaluating the potential to increase escapement rates using artificial lights near the escapement area of the excluder; (ii) assessing salmon behavior, and evaluating changes relative to tow period, water flow, tow speed, and ambient light; and (iii) further developing methods to quantify pollock loss.

References:

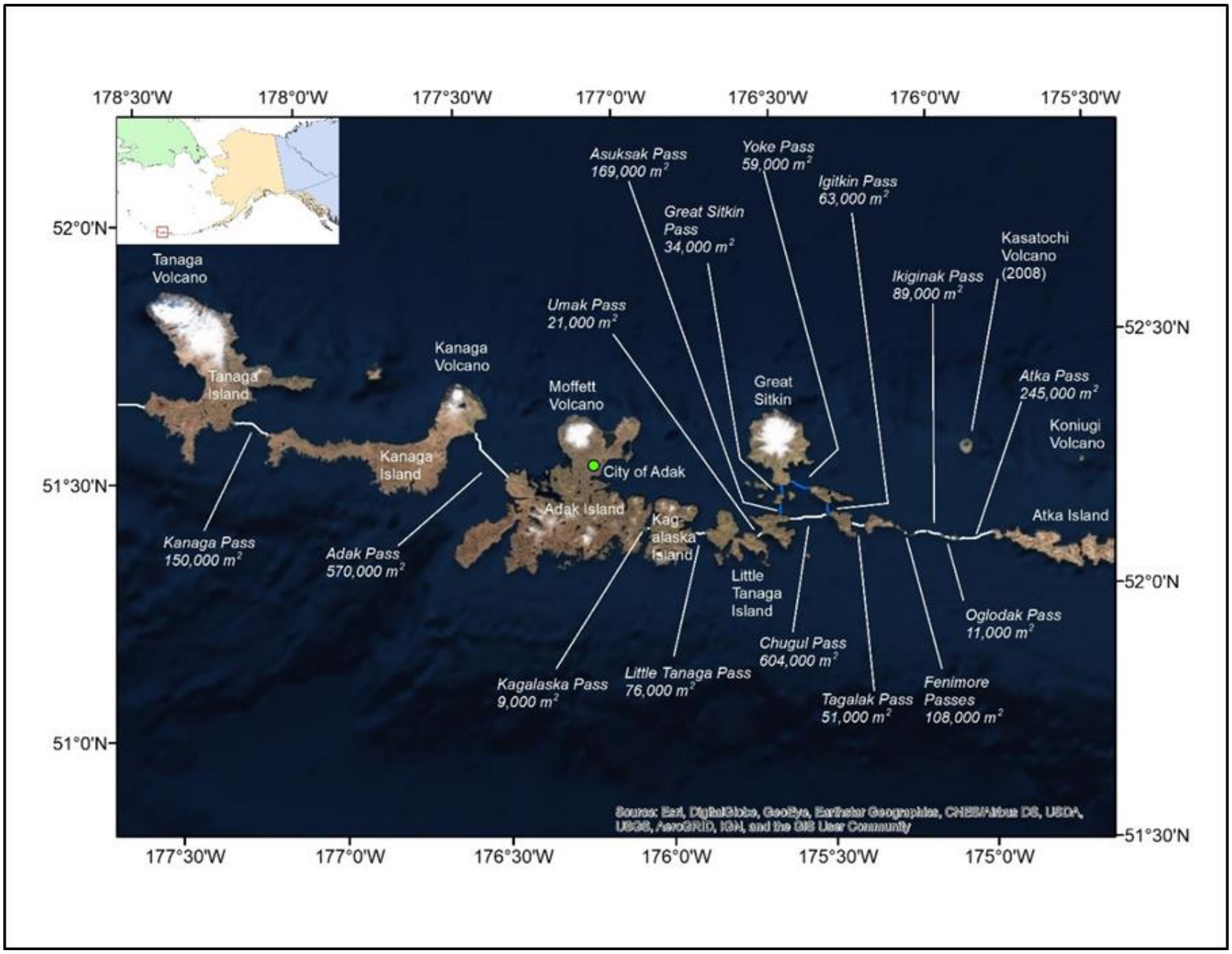
Yochum, N., Stone, M., Breddermann, K., Berejikian, B.A., Gauvin, J.R., and Irvine, D.J. 2021. Evaluating the role of bycatch reduction device design and fish behavior on Pacific salmon (*Oncorhynchus* spp.) escapement rates from a pelagic trawl. Fisheries Research. April 2021.

Breddermann, K., M. Stone, and N. Yochum. 2019. Flow analysis of a funnel-style salmon excluder. In Contributions on the theory of fishing gear and related marine systems. Proceedings of the 14th International Workshop on Methods for the Development and Evaluation of Maritime Technologies (DEMaT), 5-7 November, 2019. Izmir, Turkey, pp. 29- 42. Ed. by M. Paschen and A. Tokaç.

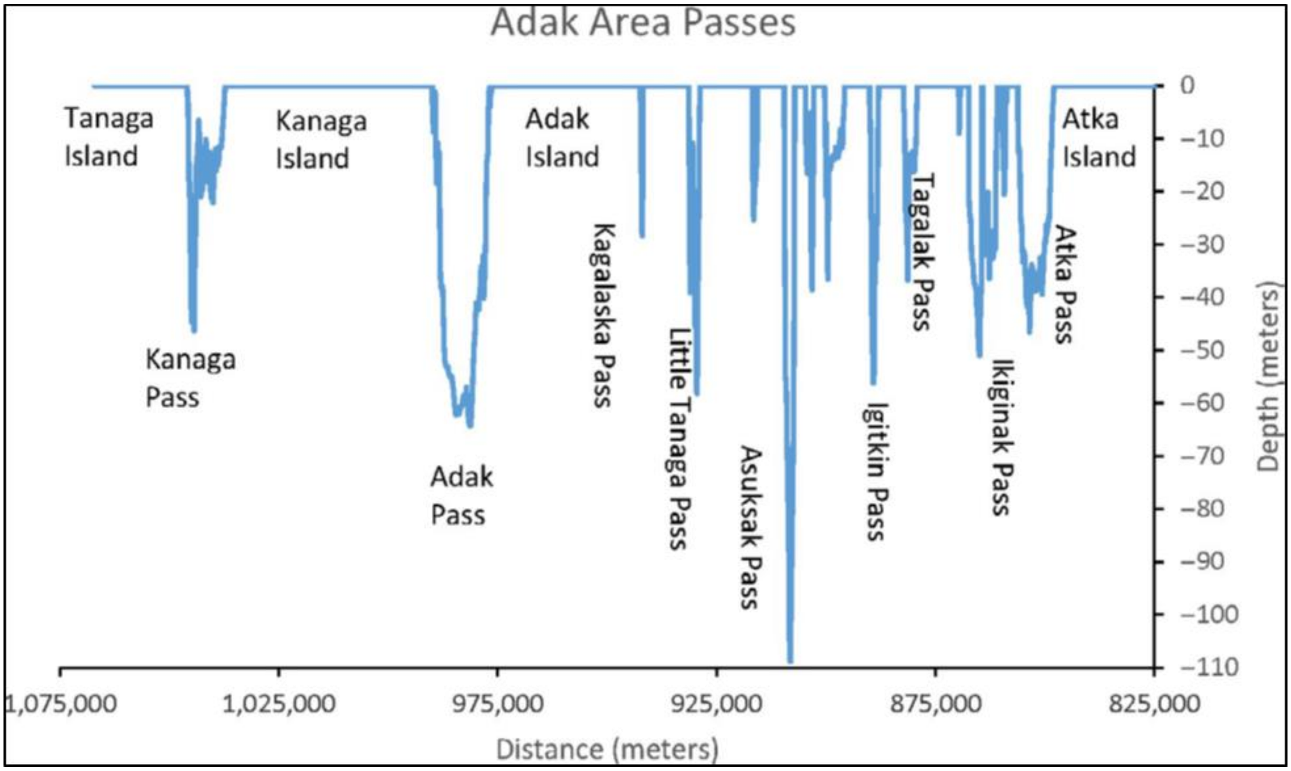
For more information, contact MACE Program Manager, Sandra Parker-Stetter, sandy.parker-stetter@noaa.gov.

Passes of the Aleutian Islands: First detailed description - RACE GAP

We derived the first detailed and accurate estimates of the location, cross-sectional area, length, and depth of the Aleutian Island passes, which are important bottlenecks for water exchange between the North Pacific Ocean and the Bering Sea. Our pass descriptions utilized original bathymetric data from hydrographic smooth sheets, which are of higher resolution than the navigational chart data used for earlier pass size estimates. All of the westernmost Aleutian passes, from Kavalga to Semichi, are larger (18%–71%) than previously reported, including Amchitka Pass (+23%), the largest in the Aleutians. Flow through Chugul Pass, previously reported as the largest pass in the Adak Island area, is blocked on the north side by Great Sitkin and several other islands. Collectively, these smaller passes (Asuksak, Great Sitkin, Yoke, and Igitkin) are only about half the size of Chugul Pass. The important oceanographic and ecological boundary of Samalga Pass occurs in a location where the cumulative openings of the eastern Aleutian passes equal the minimal opening of Shelikof Strait, carrier of the warmer, fresher water of the Alaska Coastal Current that eventually flows northward, through Samalga and the other eastern passes, into the Bering Sea and Arctic Ocean.



Example figures: FIGURE 6. (a) Pass locations and sizes in the Adak area. Pass location as defined by the Cost Distance tool denoted as white line.



Example figures: FIGURE 6. (b) Graph showing horizontal arrangement of islands and passes, with pass depth shown in meters

Zimmermann, M., Prescott, M.M. 2021. Passes of the Aleutian Islands: First detailed description. Fisheries Oceanography, 30(3), pp.280-299. http://dx.doi.org/10.1111/fog.12519

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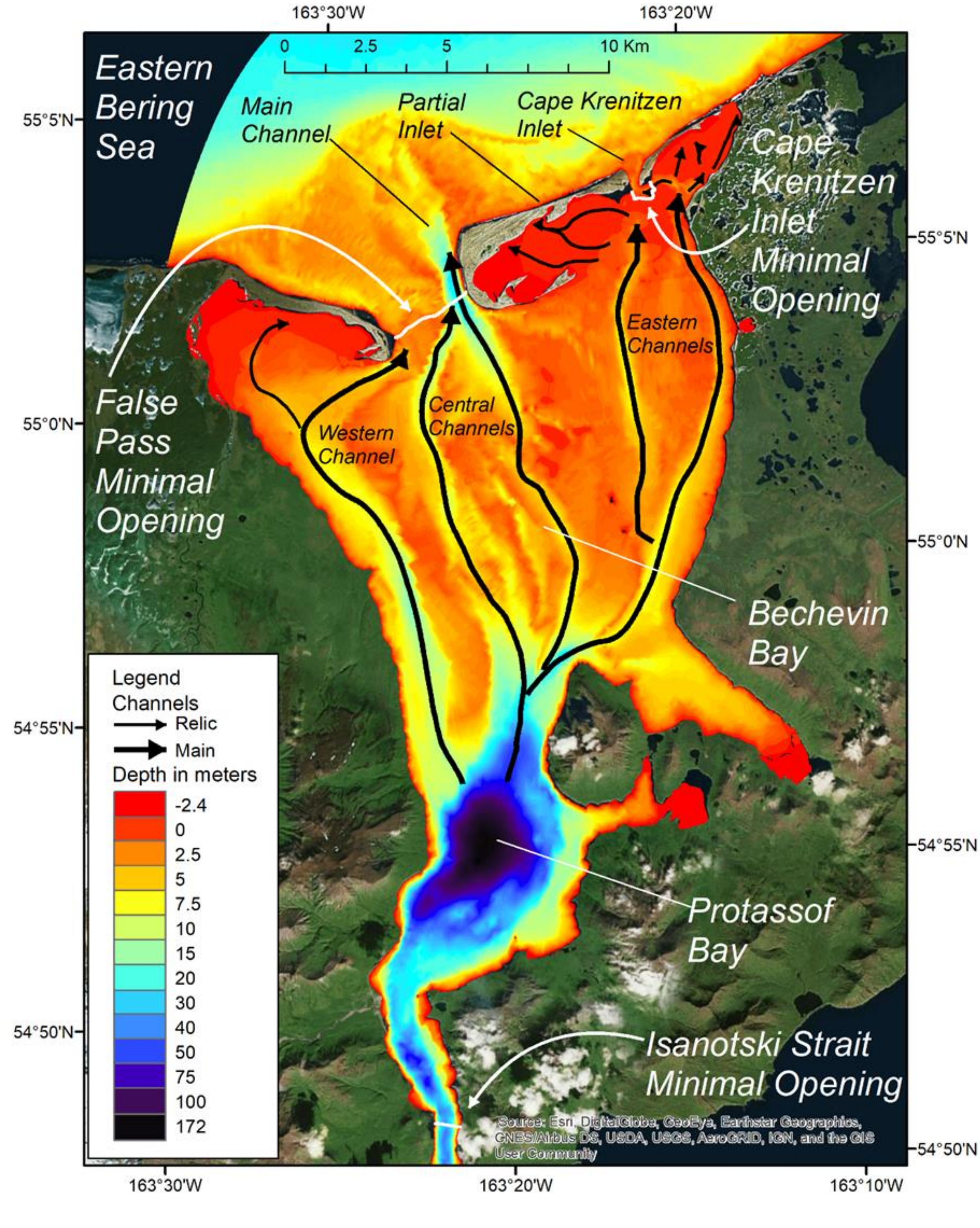
False Pass, Alaska: Significant changes in depth and shoreline in the historic time period- RACE GAP

Global ocean circulation is limited partly by the small passes of Alaska's Aleutian Islands, which restrict North Pacific Ocean water from flowing north into the Bering Sea and eventually to the Arctic, but the size and shape of these Aleutian passes are poorly described. While quantitatively redefining all of the Aleutian passes, we determined that the easternmost pass, with the cryptic name of False Pass, and with an unusual configuration of having both northern and southern inlets, had two or more inlets to the Bering Sea in the recent past, but that it has only a single northern inlet now (15,822 m2), roughly equivalent in size to the southern inlet, Isanotski Strait (15,969 m2). Navigational charts depict the opposite: two inlets to the Bering Sea now, but just one in older charts (1926–43). This discrepancy inspired a thorough review of the hydrographic history from which we concluded that the second northern inlet did exist and hypothesize that it was a remnant of multiple former openings, or a single large opening, potentially allowing greater northward flow of warmer, fresher Alaska Coastal Current water. While the shoreline changes that we document here are often regarded as minor, ephemeral events, we document similar, nearby, permanent shoreline shifts which changed Ikatan Island into a peninsula and which shifted the Swanson Lagoon outlet over 3 km to the east.



Example figure: FIGURE 4. False Pass bathymetry with main channels indicated with thick black arrows and relic mud flat channels indicated with thin black arrows, using the "before" bathymetry

(1924–57). The "after" bathymetry of 2014 was incomplete, without soundings in much of the shallows and without a shoreline.

Zimmermann, M., Prescott, M.M. 2021. False Pass, Alaska: Significant changes in depth and shoreline in the historic time period. Fisheries Oceanography, 30(3), pp.264-279. http://dx.doi.org/10.1111/fog.12517

For further information, contact Mark.Zimmermann@noaa.gov

Accounting for trophic relationships in Essential Fish Habitat designations

This funded proposal will seek to characterize the relationship between satellite chlorophyll a (chl-*a*), zooplankton, and forage fish density. We will accomplish this objective by answering 1) Do dynamic environmental conditions, such as temperature, phytoplankton concentrations, and zooplankton abundances influence the abundance and distribution of forage fish? 2) Is there spatial overlap between chl-a hotspots and forage fish hotspots? The proposed project directly addresses the Alaska Essential Fish Habitat (EFH) Research Plan's Core EFH Research Priority 1: to characterize habitat utilization and productivity, increase the level of information available to describe and identify EFH; and Research Priority 2: apply information from EFH studies at regional scales. The outcomes from this study are intended to advance EFH for forage fish and invertebrate prey species including capelin [*Mallotus villosus*], herring [*Clupea pallasii*], age-0 walleye pollock [*Gadus chalcogrammus*], and large copepods. If possible based on model performance, more spatially and temporally explicit zooplankton biomass estimates from ROMS-NPZ may be incorporated into EFH models. Our proposed work will develop methodology for describing prey habitat and incorporating dynamic environmental covariates in species distribution models. This project involves co-PIs from CICOES, ABL, and EMA and collaborators from EcoFOCI and AKRO.

For more about this project, contact Margaret Siple (margaret.siple@noaa.gov ; RACE) or Jens Nielsen (jens.nielsen@noaa.gov ; CICOES).

Advancing Essential Fish Habitat (EFH) Species Distribution Modeling (SDM) Descriptions and Methods for North Pacific Fishery Management Plan (FMP) Species --GAP, AKR

Councils and NMFS are required to review the essential fish habitat (EFH) components of Fishery Management Plans (FMPs) and revise or amend these components based on available information at least every five years (50 CFR 600.815(a)(10)) in an EFH 5-year Review. This study demonstrates advances in EFH component 1 descriptions and identification (maps) based on refinements to the habitat-based species distribution modeling (SDM) approach to mapping EFH that was established in the 2017 EFH 5-year Review. All of the SDM ensembles constructed for FMP species in three regions in Alaska (GOA, AI, and the Bering Sea) in this present work describe and map EFH Level 2 (habitat related abundance), meeting a key objective of the EFH Research Plan for Alaska. For early juvenile life stages in the GOA, SDMs describe and map EFH Level 1 (distribution) for the first time. Another objective of the Research Plan was met by introducing maps for a subset of species with EFH Level 3 information (habitat related vital rates) for the first time. In this study, 229 new or revised EFH descriptions and maps were generated for 211 species' life stages and 10 stock complexes available across all regions. For the majority of stocks and life stages, 2022 ensemble performance demonstrated clear improvements over the 2017 SDMs. The maps and descriptions here present the best available science to form a basis for assessing anthropogenic impacts to habitats in Alaska and are extensible to other fishery and ecosystem management information needs. This process revealed some recommendations for the next EFH review cycle, including a goal to develop methods for combining disparate data sources to expand spatial and seasonal coverage; and the goal of increasing the scope of EFH research to address rapidly changing environmental conditions in the region. These tech memos contain methodological advancements in species distribution modeling, leading to better species coverage and more robust habitat maps in the 2022 Five Year-Review. In order to make these transparent and available to other scientists and to ensure continuity in the methodology used for EFH, members of the analytical team produced a publicly available R package.

For more about this project, contact Ned Laman (ned.laman@noaa.gov), Margaret Siple (margaret.siple@noaa.gov) or Jodi Pirtle (Jodi.pirtle@noaa.gov).

V. Ecosystem Studies

Ecosystem and Socioeconomic Profiles (ESP) – REFM
Ecosystem-based science is an important component of effective marine conservation and resource management; however, the proverbial gap remains between conducting ecosystem research and integrating with stock assessments. A main issue involves the general lack of a consistent approach to deciding when to incorporate ecosystem and socioeconomic information into a stock assessment and how to test the reliability of this information for identifying future change. Our current national system needs an efficient testing ground and communication tool in order to effectively merge the ecosystem and stock assessment disciplines.

Over the past several years, we have developed a new standardized framework termed the Ecosystem and Socioeconomic Profile or ESP that facilitates the integration of ecosystem and socioeconomic factors within the stock assessment process and acts as a proving ground for use in management advice (Shotwell et al., 2020). The ESPs are a commitment to a process that allows for creating a proactive strategy in response to change. Here we are building on the rich history of identifying ecosystem pressures on stocks in the Alaska region and designing a research template that tests these linkages for providing advice. The ESPs serve as a corollary stock-specific process to the large-scale ecosystem status reports, effectively creating a two-pronged system for ecosystem based fisheries management at the AFSC.

There are four steps to the ESP process. In the first step, we start with a focused effort to review information from national initiatives on prioritization, vulnerability, and classification and combine that with regional priorities to develop a list of priority stocks for producing ESPs. Once an ESP has been prioritized for a stock, we then move to grading a standard set of descriptive stock metrics and then evaluate ecosystem and socioeconomic processes driving stock dynamics to develop a mechanistic understanding of the drivers for the stock. This leads to defining a suite of indicators to monitoring and analyzing trends of these indicators using tests appropriate to the data availability for the stock. The process is completed with a standardized reporting template that is concise and conveys the status of the leading indicators to fisheries managers within the stock assessment cycle (Shotwell et al., In Review).

Three annual workshops planned to fine-tune the ESP framework to the needs of the AFSC have recently been completed. The first data workshop summarized the available data for use in an ESP from a large variety of programs both within and external to the AFSC. This workshop was conducted in May 2019 and results were presented at the Preview of Ecosystem and Economic Considerations (PEEC) meeting in June 2019 and at the Joint Crab and Groundfish September Plan Team 2019. The second model workshop was conducted in March 2020 through two small in-person host sites and large remote participation due to current events regarding COVID-19. The workshop presentations reviewed current progress on the ESPs as well as modeling applications to create value-added metrics or indicators for the ESPs and models to evaluate indicators for use in the ESPs and the operational stock assessments. A one-day follow-up discussion session was conducted in September 2020 to provide a short review of the presentations and engage in-group discussions that were truncated due to the largely remote participation of the workshop.

The third ESP advice workshop was conducted entirely remotely in March 2021 due to the persistence of COVID-19; however, attendance was higher than the previous two workshops. Progress on new ESPs and ESP teams were reviewed as well as presentations on data accessibility and reproducibility and a series of program updates that reviewed avenues for interfacing with the ESPs. Two evaluation gates have now been established for including indicators within an ESP (gate 1) and within a stock assessment model (gate 2). A series of presentations reviewed the types of indicators currently in ESPs and forecasting with climate enhanced single and multispecies models. Two discussion sessions included creating guideline criteria for entering the two ESP gates. The final workshop day included presentations on how the ESPs are currently used for management advice and a discussion session on interfacing more with stakeholders and the public. A one-day ESP session is now scheduled to coincide with the PEEC workshop to review new and upcoming ESPs and have discussions on further developing the ESP process both regionally and nationally.

A methods manuscript detailing the four-step ESP framework, along with technical memorandums of the workshops are planned for 2021. Additional web applications and data repository are also in development to provide access to the data and model output for use in the ESPs. These products will improve communication of the ESP framework and allow timely and consistent access to regional or stock-specific ecosystem and socioeconomic indicators for use in the ESPs. Altogether, the workshops and reports will pave a clear path toward building next generation stock assessments and increase communication and collaboration across the ecosystem, economic, and stock assessment communities at the AFSC. We plan to expand the ESPs to other regions to form a more coordinated national effort of integrating ecosystem information within our next generation stock assessments.

For more information, contact Kalei Shotwell at (907) 789-6056 or kalei.shotwell@noaa.gov.

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Gulf of Alaska Climate Integrated Modeling Project - REFM and other divisions

The Gulf of Alaska ecosystem supports valuable and diverse marine fisheries and most of the human population of Alaska resides in the Gulf of Alaska region. Large changes in climate are expected in the Gulf of Alaska in the coming decades. Scientists are using an integrated modeling approach to identify factors affecting present and future ecosystem-level productivity and to assess the economic and social impacts on Gulf of Alaska fishing and subsistence communities of Climate Change. This is an interdisciplinary collaboration and a complement to a successful project developed for the eastern Bering Sea.

This multidisciplinary modeling effort applies a regional lens to global climate models. Scientists are combining regional socio-economic, oceanographic data and biological models including single-species, multispecies and ecosystem models to develop a regional multi-model (an ensemble model) to provide quantitative advice to support resource management given climate variability and long-term change. One important management application of this research is to evaluate the Optimum Yield (OY) range (160,000–800,000 t) in the Groundfish Fishery Management Plan for the Gulf of Alaska in a changing climate.

Scientists will begin to address the critical need to anticipate those changes and evaluate their impact on the ecosystem and its inhabitants. By providing near-term and long-term projections, scientists hope to help resource managers and local communities anticipate and better plan for environmental and ecological changes due to Climate Change in the Gulf of Alaska. This effort represents a substantial step towards meeting the objectives of Gulf of Alaska Climate Science Regional Action Plan and the NOAA Fisheries Climate Science Strategy. This project will examine how individuals, families, and communities adapt to climate variability and associated changes in fisheries and marine ecosystems. We will also identify the factors underlying adaptation choices, and tradeoffs associated with those adaptations.

Project activities

- Develop and apply the Atlantis model as an element of a multi-model ensemble to evaluate fisheries management strategies in a changing climate.
- Combine oceanographic modeling driven by climate projections of earth system models (ESM) with biological models including single species, multi-species, and ecosystem models. This includes the Atlantis end-to-end ecosystem model, food web models for the Gulf of Alaska (Ecopath and Ecosim) and a Gulf of Alaska multi-species (CEATTLE).
- Explore recent climate change impacts on the Gulf of Alaska social-ecological system (e.g., use the 2013-2016 marine heat wave, PDO variation, and climate projections as natural experiments to explore ecosystem-level and species-specific responses to physical forcing).

- Apply the coupled climate-biological-social multi-model ensemble to explore the implications of long-term changes in physical forcing on various management questions (e.g., current OY range in the Gulf of Alaska; implementation of catch share programs, etc.), taking into account model uncertainty.
- Evaluate performance of management strategies under climate change (e.g., estimate system-level OY for Gulf of Alaska using the multi-model ensemble)
- Evaluate and predict the impacts of major environmental anomalies to an endangered population of Steller sea lions using the 2013-2016 marine heatwave as a natural experiment.
- Model fleet dynamics and fishery landings responses to ecosystem and management change

Greater detail can be found at https://www.fisheries.noaa.gov/alaska/socioeconomics/gulf-alaska-climate-integrated-modeling-socioeconomics-climate-communities. Also , for more information please contact Martin Dorn at Martin.Dorn@noaa.gov.

Resource Ecology and Ecosystem Modeling Program (REEM)

Multispecies, foodweb, and ecosystem modeling and research are ongoing. A detailed program overview is at: https://www.fisheries.noaa.gov/resource/data/alaska-marine-ecosystem-status-reports-interactive-overview.

Ecosystem Status Report 2021: (REFM)
The status of Alaska's marine ecosystems is presented annually to the North Pacific Fishery Management Council as part of the Stock Assessment and Fishery Evaluation (SAFE) report. There are separate reports for each of four ecosystems: the eastern Bering Sea, Aleutian Islands, Gulf of Alaska, and the Arctic. Comprehensive environmental data are gathered from a variety of sources. The goal of these Ecosystem Status Reports is to provide the Council and other readers with an overview of marine ecosystems in Alaska through ecosystem assessments and by tracking time series of ecosystem indicators. This information provides ecosystem context to the fisheries managers' deliberations. The reports are now available online at: https://www.fisheries.noaa.gov/alaska/ecosystems/ecosystem-status-reports-gulf-alaska-bering-sea-and-aleutian-islands#2018.

Groundfish Stomach Sample Collection and Analysis - REFM-REEM
The REEM Program continues regular collection of food habits information on key fish predators in Alaska's marine environment. Much of this information comes from samples collected during standard assessment surveys.

The AFSC, REFM program representative to the TSC left AFSC in Spring 2022. Because of this recent change, some of the sections in this report were not updated.

Contact Kerim Aydin with any questions regarding the REEM program within REFM.

Online sources for REEM data on food habits and fish ecology (*note that the AFSC website hosting these sites has been updated but the links below were not updated before the REFM representative to the TSC retired in Spring 2022*).

- Accessibility and visualization of the predator-prey data through the web can be found at http://www.afsc.noaa.gov/REFM/REEM/data/default.htm.
- The predator fish species for which we have available stomach contents data can be found at http://access.afsc.noaa.gov/REEM/WebDietData/Table1.php.
- Diet composition tables have been compiled for many predators and can be accessed, along with sampling location maps at http://access.afsc.noaa.gov/REEM/WebDietData/DietTableIntro.php.
- The geographic distribution and relative consumption of major prey types for Pacific cod, walleye pollock, and arrowtooth flounder sampled during summer resource surveys can be found at http://www.afsc.noaa.gov/REFM/REEM/DietData/DietMap.html.
- REEM also compiles life history information for many species of fish in Alaskan waters, and this information can be located at http://access.afsc.noaa.gov/reem/lhweb/index.php.

Economics and Social Sciences Research (ESSR)

Annual economic SAFE report - ESSR

The ESSR program annually produces an economic counterpart to the stock assessment and fishery evaluation reports (SAFE) published by the North Pacific Fishery Management Council (NPFMC). Published as an appendix to the omnibus SAFE document, the Economic Status Report presents summary statistics on catch, discards, prohibited species catch, ex-vessel and first- wholesale production and value, participation by small entities, and effort in these fisheries. Because of the lag in data availability and ensuing analysis, the 2021 Economic SAFE largely focuses on the results of the fisheries in 2020. The economic SAFE is part of the larger document and available at: https://www.npfmc.org/safe-stock-assessment-and-fishery-evaluation-reports/.

VI - AFSC GROUNDFISH-RELATED PUBLICATIONS AND DOCUMENTS

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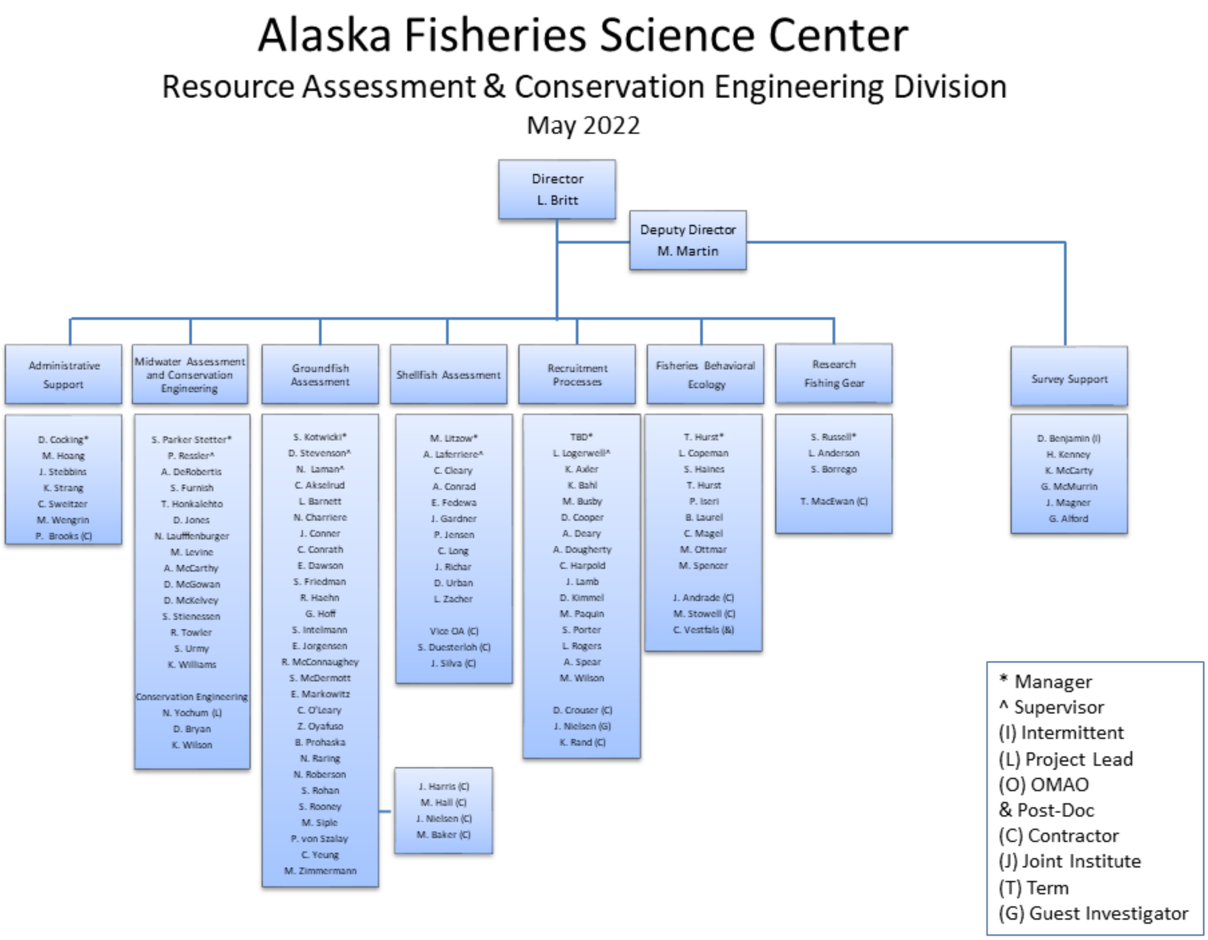
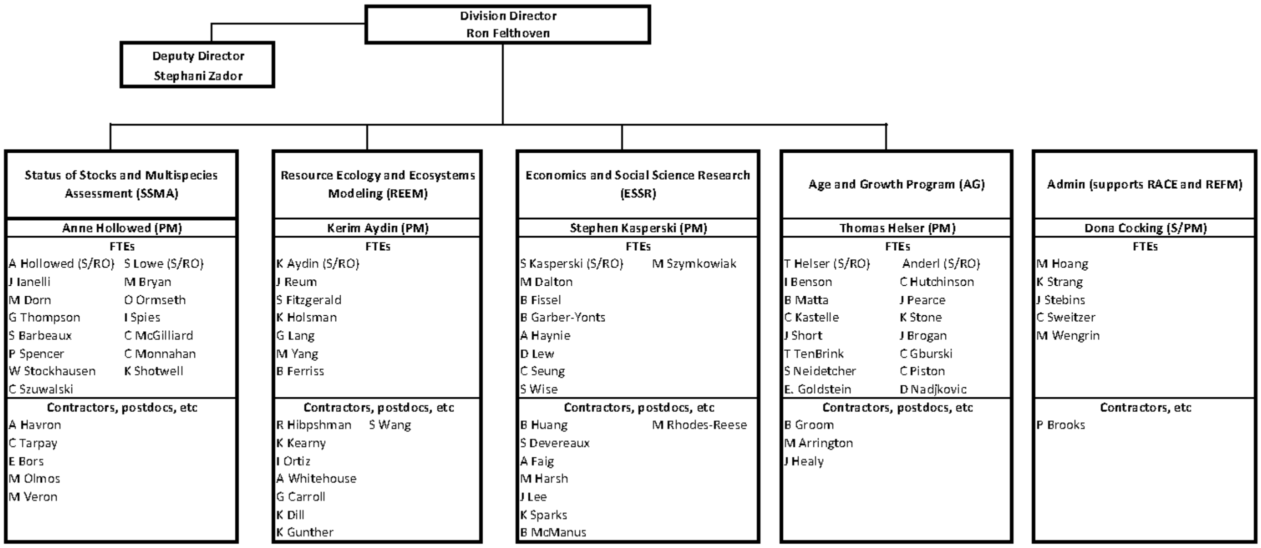
APPENDIX I. RACE ORGANIZATION CHART

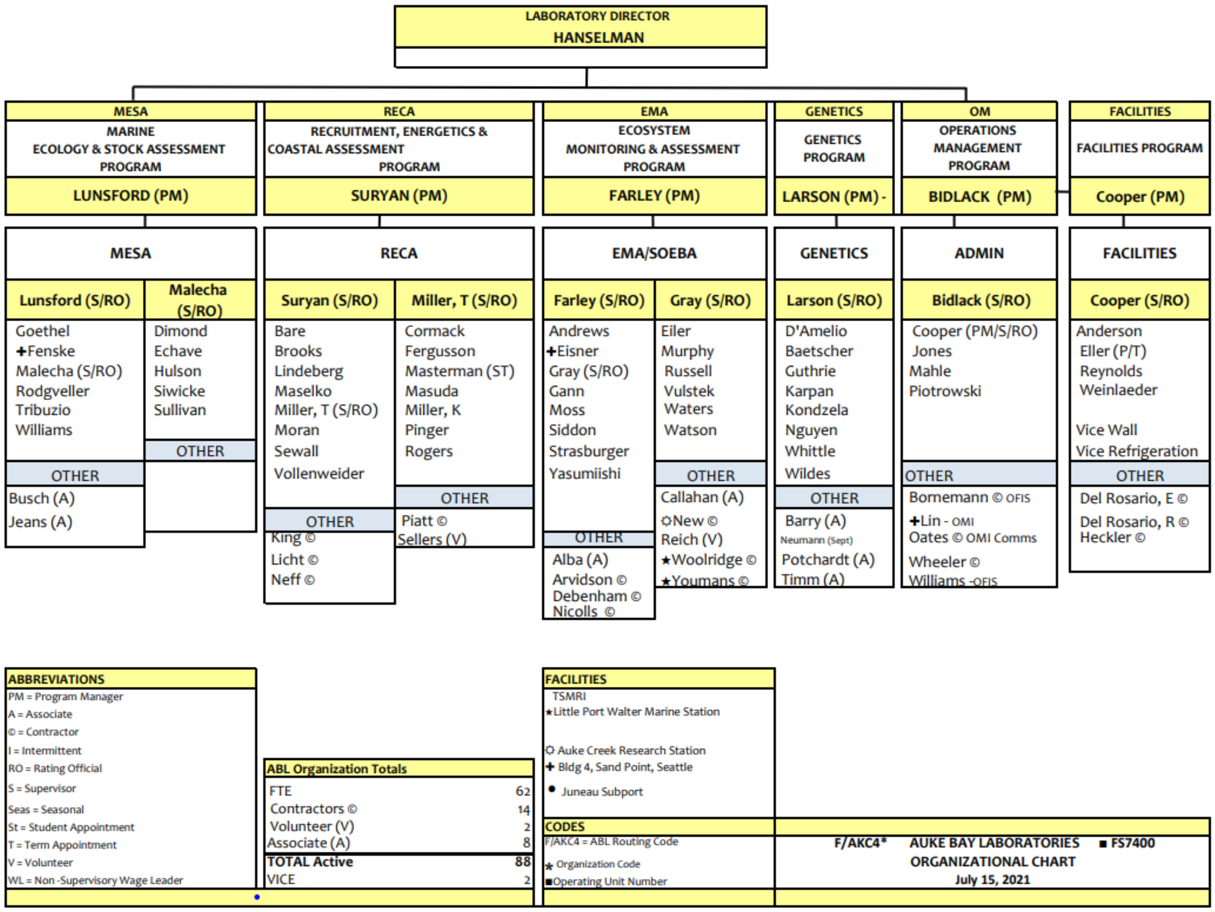


APPENDIX II. REFM ORGANIZATION CHART

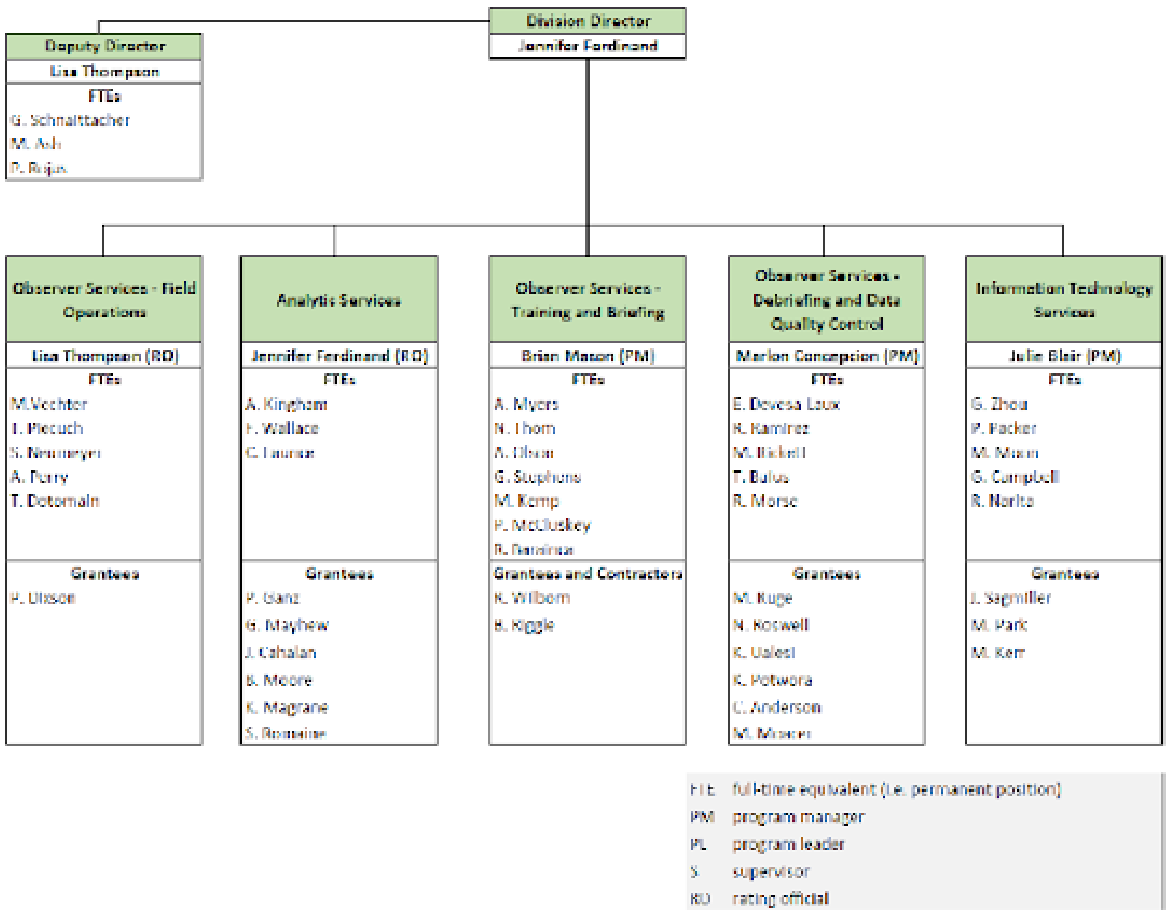


FTE	full-time equivalent (i.e. permanent position)
PM	program manager
PL	program leader
S	supervisor
RO	rating official
vice	vacant position

APPENDIX III. AUKE BAY LABORATORY ORGANIZATIONAL CHART



APPENDIX IV. FMA ORGANIZATIONAL CHART



CANADA

British Columbia Groundfish Fisheries and Their Investigations in 2021

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Prepared for the
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Appendix 1: British Columbia commercial groundfish TACs, landings, and research allocations for 2021 37

I. Agency Overview

Fisheries and Oceans Canada (DFO) has its regional headquarters office (RHQ) for the Pacific Region (British Columbia and Yukon) in Vancouver, British Columbia, with area offices and science facilities at various locations throughout the Region. Groundfish fishery management is conducted by the Groundfish Management Unit within the Fisheries Management Branch at RHQ, while Groundfish stock assessment and research is conducted by Science Branch at the Pacific Biological Station (PBS) in Nanaimo, and at the Institute of Ocean Sciences (IOS) in Sidney. Within Science Branch, a variety of programs are responsible for delivering groundfish stock assessments and research and for providing science advice to fishery managers, species at risk coordinators, marine spatial planners, etc. Directors, division managers, and section heads are as follows:

Fisheries and Oceans Canada Minister: The Honourable Joyce Murray

Regional Headquarters Office (RHQ)

Regional Director General: Rebecca Reid

Fisheries and Aquaculture Management Branch

Regional Director of Fisheries Management:	Neil Davis
Regional Director of Resource Management:	Julia MacKenzie
Regional Manager of Groundfish:	Averil Lamont

Science Branch

Regional Director of Science:	Andrew Thomson
Strategic Science Initiatives Division (SSID):	Al Magnan (Acting)
• Centre for Science Advice – Pacific:	Lisa Christensen
• Strategic Partnerships and Programs:	March Klaver
Stock Assessment and Research Division (StAR):	John Holmes
• Groundfish Section:	Dana Haggarty (Acting)
• Quantitative Assessment Methods Section:	Steve Schut
• Fisheries and Assessment Data Section:	Shelee Hamilton
• Marine Invertebrates Section:	Ken Fong
• Salmon Assessment:	Antonio Velez-Espino
• Salmon Coordinator:	Dawn Lewis
Aquatic Diagnostics, Genomics & Technology Division (ADGT):	Jon Chamberlain (Acting)
• Applied Technology:	Kathryn Berry (Acting)
• Genetics:	John Candy
• Aquatic Animal Health:	Mark Higgins

Ocean Science Division (OSD):	Kim Houston
• Ecology and Biogeochemistry:	Neil Dangerfield
• Modelling & Prediction:	Di Wan (Acting)
• State of the Ocean:	Gwyn Lintern
Ecosystem Science Division (ESD):	Eddy Kennedy
• Marine Spatial Ecology & Analysis:	Miriam O
• Aquatic Ecosystem & Marine Mammals:	Sean MacConnachie
• Freshwater Ecosystems:	Jeffery Lemieux
• Nearshore Ecosystems:	Cher LaCoste
• Regional Ecosystem Effects on Fish & Fisheries:	James Mortimor
Canadian Hydrographic Service (CHS):	Mark LeBlanc

Groundfish research and stock assessment work is conducted amongst the Groundfish, Fisheries and Assessment Data, and Quantitative Methods Sections within StAR. Groundfish specimen ageing and genetics are conducted in the Applied Technologies and Genetics Sections in ADGT. Acoustic fisheries research and surveys are led by the Ecology and Biogeochemistry Section in OSD. Ecosystem studies, marine protected areas research and planning, and habitat research is undertaken in collaboration with staff in the Ecosystems Science Division (ESD).

Fishery Managers and other clients receive science advice from StAR through the Canadian Centre for Scientific Advice Pacific (CSAP) review committee. Groundfish subject matter experts (SMEs) meet periodically throughout the year to provide scientific peer review of stock assessment working papers and develop scientific advice. Every peer review process involves both internal (DFO) and external reviewers. The resulting Science Advisory Report summarizes the advice to Fishery Managers, with the full stock assessment becoming a Research Document. Both documents can be viewed on the Canadian Stock Assessment Secretariat website: http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm. The frequency of review meetings and production of stock assessment advice for fisheries managers varies depending on departmental, branch and regional priorities.

The Canadian Coast Guard operates DFO research vessels. These research vessels include the J.P. Tully, Vector, Neocaligus, and the Sir John Franklin. The Sir John Franklin, replacement for the W.E Ricker, was deployed for its inaugural field season in 2020 but only a limited number of surveys (and no groundfish surveys) were completed due to the COVID pandemic. A full suite of surveys was planned for 2021 but there was a major electrical failure mid-way through the season that sidelined the vessel. A commercial fishing vessel was chartered to complete the remainder of the surveys.

The Groundfish Trawl, Sablefish, Rockfish, Lingcod, North Pacific Spiny Dogfish, and Halibut fishery sectors continue to be managed as an integrated fishery with Individual Vessel Quotas (IVQs). IVQs can be for specific areas or coastwide. Within the general IVQ context, managers also use a suite of management tactics including time and area specific closures and bycatch limits. The 2021 Groundfish Integrated Fisheries Management Plan v.1.3 (IFMP) is available from the Federal Science Library: https://waves-vagues.dfo-mpo.gc.ca/Library/40990151.pdf.

Allocations of fish for financing scientific and management activities are identified in the Groundfish IFMP. Use of Fish Collaborative Agreements were developed for 2021-22 between Fisheries and Oceans Canada and Wild Canadian Sablefish (multi-year agreement to the end of 2023), Pacific Halibut Management Association of BC, and the Canadian Groundfish Research and Conservation Society to support groundfish science activities through the allocation of fish to finance the activities. These agreements will be updated for 2022-23.

Fish stock provisions

Following amendments made to Canada's *Fisheries Act*, new regulations amending the Fishery (General) Regulations, ss. 69-70, were published in *Canada Gazette Part II*, including required contents of rebuilding plans. The Fish Stocks provisions have come into force for 30 prescribed major fish stocks. The date of coming into force was **April 4,** the date in which the regulations were registered. Rebuilding requirements under the Fish Stock Provisions will apply to Inside Yelloweye Rockfish and Bocaccio. Domestic Fisheries Policy is currently finalizing approvals for revised Rebuilding Plan Guidelines to support the development of rebuilding plans to meet these requirements. Other Pacific grooundfish stocks listed as "major stocks" but that don't require rebuilding plans include Outside Yelloweye Rockfish, Pacific Hake and Sablefish. Other Pacific groundfish stocks will be gazetted in following batches in subsequent years. For more information: https://www.gazette.gc.ca/rp-pr/p2/2022/2022-04-13/html/sor-dors73-eng.html

II. Surveys

A. Databases and Data Acquisition Software

GFBioField is a data acquisition software application created in-house by DFO staff in the Groundfish Surveys Program at the Pacific Biological Station in Nanaimo British Columbia. GFBioField was designed for real-time data capture and data entry during at-sea surveys but can also be used for dockside sampling and office-based data entry. Modified versions have been developed by Groundfish Surveys staff for use by other programs such as the Marine Invertebrates Section within the StAR Division, and the Aquatic Ecosystems and Marine Mammals Section and Regional Ecosystem Effects on Fish and Fisheries Section in the Ecosystem Science Division. GFBioField uses a client-server architecture employing Microsoft SQL Server 2016 for the back-end data storage and business logic along with a Microsoft Access 2016 front-end.

GFBio is an oracle database developed in-house by DFO staff in the 1990s, which houses groundfish research survey and commercial biological data collected in British Columbia from the 1940s to the present. GFBio now includes 29,328 trips and approximately 11.9 million individual fish specimens. In 2021, data entry activities concentrated on input of current-year groundfish research cruises, fish ages, and lingcod creel survey biological samples for 2013-2019.

B. Commercial Fishery Monitoring and Biological Sampling

Groundfish commercial fisheries in British Columbia are subject to 100% catch monitoring. This requirement is met either through an at-sea observer program (ASOP) or through the use of an electronic monitoring (EM) system on each trip. In addition, a dockside monitoring program (DMP) validates all commercial landings. EM systems must meet standards specified by DFO, must be functional for the duration of any fishing trip, and are subject to an audit following every trip. The combination of fisher logbooks with ASOP/EM and DMP are intended to provide an accurate and complete record of all fishing that takes place under a commercial groundfish fishing licence.

Prior to the COVID-19 pandemic, Groundfish hook and line and trap fisheries were permitted to use either an ASOP or EM system to satisfy 100% monitoring requirements, while the majority of the groundfish trawl fleet were required to use ASOP. On April 2, 2020 the Minister of Fisheries and Oceans Canada suspended the use of at-sea observers due to the COVID-19 pandemic. On April 10, 2020, an emergency Electronic Monitoring (EM) pilot program was introduced for groundfish trawl trips in order to ensure continued comprehensive and independent catch monitoring of the groundfish trawl fleet. Effective October 29, 2020, the emergency EM measures were expanded to require an upgraded version of the EM system as well as the installation and use of video-monitored fixed measuring grids for all releases of lingcod and sablefish which are subject to size limits. Alternatively, vessels were once again permitted to carry an at-sea observer (subject to availability and applicable COVID-19 guidelines); however, all vessels opted to continue with the EM measures. In consultation with harvesters and service providers, improvements to the EM program were implemented on August 15, 2021 which include enhanced EM equipment standards and an improved audit program to ensure the accuracy of fishing logs. Consequences for non-compliance with EM audit standards began on February 21, 2022 to provide time for fishers to learn the new standards. Consequences may include partial or 100 per cent replacement of fisher logbook data with EM estimates when audits do not meet standards.

Commercial fishery data from observer logs, fisher logs, and DMP are captured electronically in the groundfish modules of the Fishery Operations System (FOS) database, maintained by the Fisheries and Aquaculture Management Branch of DFO. Groundfish Science maintains GFFOS, which contains the groundfish FOS data, reformatted to be useful for scientific purposes.

Prior to the COVID-19 pandemic, in addition to monitoring catches at sea, the ASOP also provided biological samples of halibut, salmonids, and a variety of important commercial groundfish species from the observed trawl fishery. Biological samples were also collected from the hake fishery as part of the DMP. For the duration of the pandemic at-sea sampling has been suspended and minimal sampling has occurred during DMP; however, improved dockside sampling protocols are being implemented in 2022 for Pacific Hake and Longspine Thornyheads. Work is also underway to develop an interim biosampling program for other commercial groundfish species while Science conducts a larger review the numbers and types of biological samples needed to support groundfish stock assessment and research on an ongoing basis. Additional commercial biological samples may also be collected by DFO staff at the dockside from sablefish trips or other trips that would not otherwise be sampled.

Commercial biological samples are uploaded to GFBio on an annual basis, or more frequently as required.

C. Research Surveys

The Fisheries and Oceans, Canada (DFO) Groundfish section of the Stock Assessment and Research Division conducts a suite of fishing surveys using bottom trawl, longline hook, and longline trap gear that, in aggregate, provide comprehensive coverage for all offshore waters of Canada's Pacific Coast. The core surveys include the Multispecies Synoptic Bottom Trawl, Hard Bottom Longline Hook, and Sablefish Longline Trap surveys (Figure 1).

Data from the synoptic bottom trawl surveys and hard bottom longline hook surveys are published annually to the Government of Canada Open Government Portal and to OBIS:

- Open Government Portal
  - Synoptic Bottom Trawl Surveys
  - Hard Bottom Longline Surveys
- OBIS
  - Queen Charlotte Sound Bottom Synoptic Trawl Survey
  - West Coast Vancouver Island Synoptic Trawl Survey
  - Hecate Strait Synoptic Trawl Survey
  - West Coast Haida Gwaii Synoptic Trawl Survey
  - Strait of Georgia Synoptic Trawl Survey
  - Inside North Hard Bottom Longline Survey
  - Inside South Hard Bottom Longline Survey
  - Outside North Hard Bottom Longline Survey
  - Outside South Hard Bottom Longline Survey

All the core surveys follow similar random depth-stratified designs and have in common full enumeration of the catches (all catch sorted to the lowest taxon possible), size composition sampling for most species, and more detailed biological sampling of selected species. Most of the surveys are conducted in collaboration with the commercial fishing industry under the authorities of various Collaborative Agreements. In addition to these randomized surveys, a fixed-station longline hook survey targeting North Pacific Spiny Dogfish in the Strait of Georgia is completed every three years. The Groundfish section also routinely participates in the Canadian portion of the Joint Canada US Hake Acoustic Survey and collects groundfish information from a DFO Small-Mesh Bottom Trawl Survey (Figure 2).

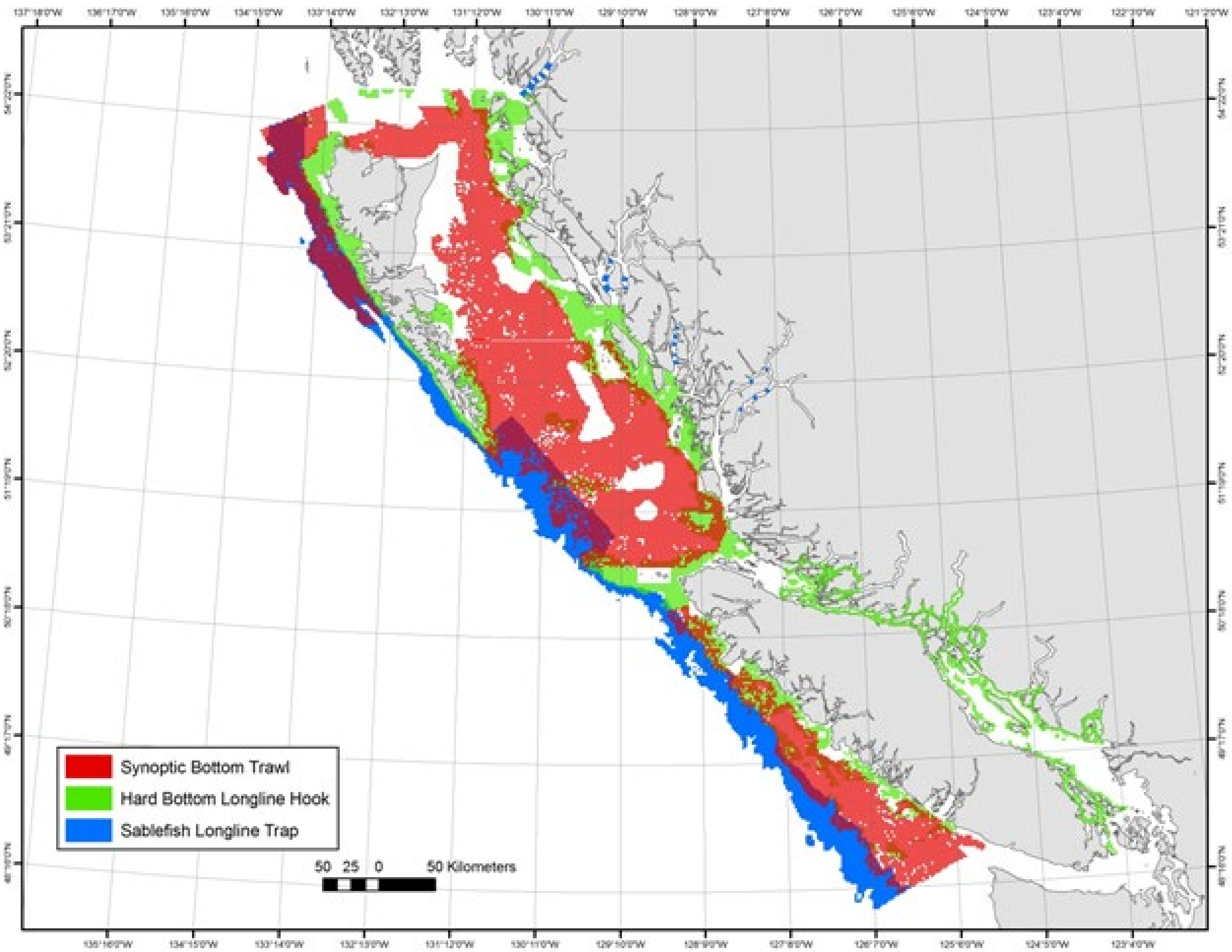

Figure 1. Random depth-stratified survey coverage.

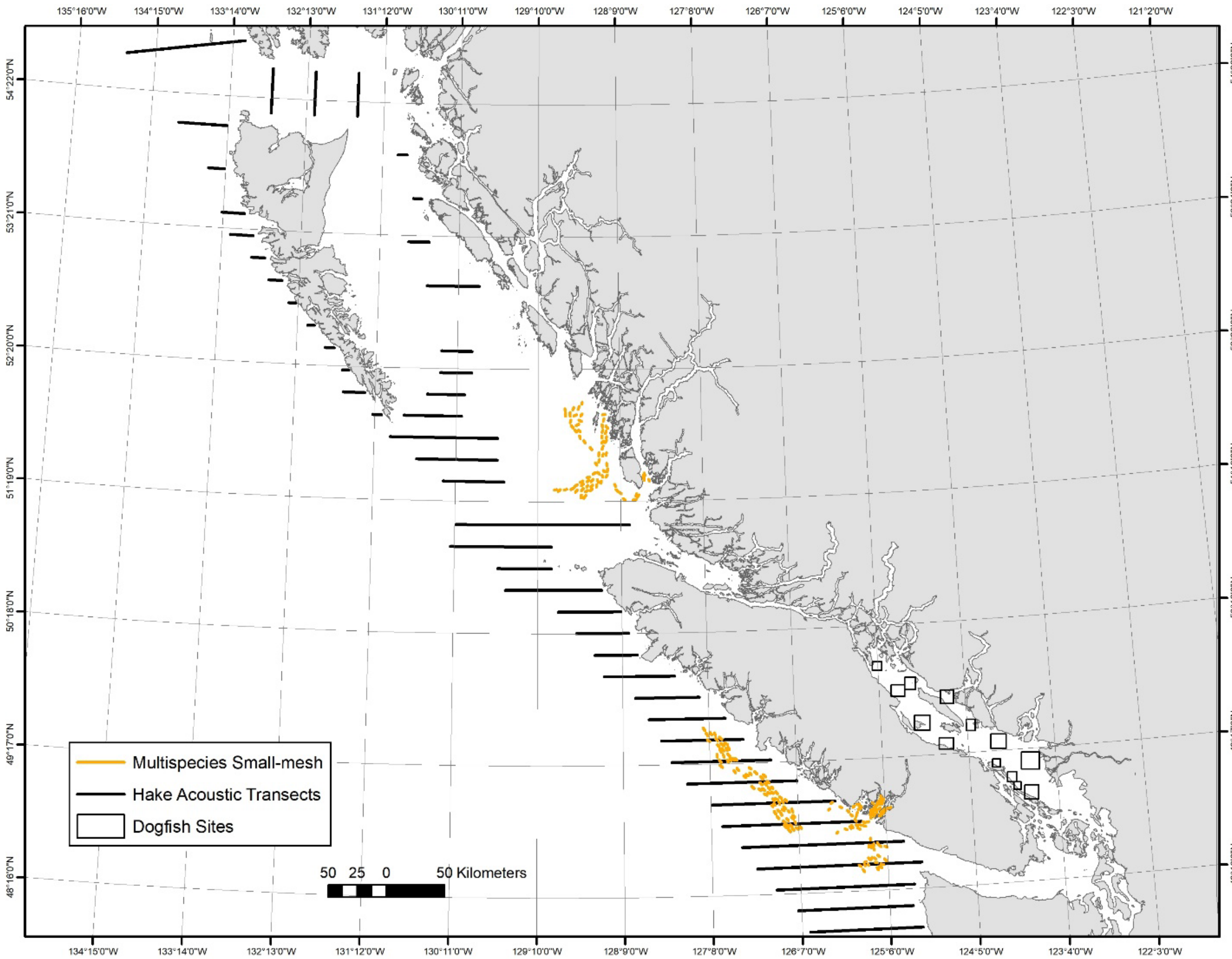

Figure 2. Non-random depth-stratified surveys that form part of the Groundfish fishing surveys program including the Multispecies Small-mesh Bottom Trawl Survey, the Pacific Hake Acoustic Survey, and the Strait of Georgia Dogfish Longline Hook Survey.

The **Multispecies Synoptic Bottom Trawl Surveys** are conducted in four areas of the BC coast with two areas surveyed each year such that the whole coast is covered over a two-year period. Typically, the West Coast of Vancouver Island (WCVI) and West Coast of Haida Gwaii (WCHG) are surveyed in even-numbered years while Hecate Strait (HS) and Queen Charlotte Sound (QCS) are surveyed in odd-numbered years (Figure 3). An additional synoptic bottom trawl survey has been conducted twice in the Strait of Georgia (SOG) but vessel availability and staffing constraints have precluded establishing a regular schedule.

These surveys are conducted under a collaborative agreement with the Canadian Groundfish Research and Conservation Society (CGRCS) and, in typical years, one survey occurs on a Canadian Coast Guard Vessel with DFO staff while one survey occurs on a chartered commercial fishing vessel with a mix of DFO staff and contracted technicians. In aggregate, the surveys provide coast-wide coverage of most of the trawlable habitat between 50 and 500 meters depth.

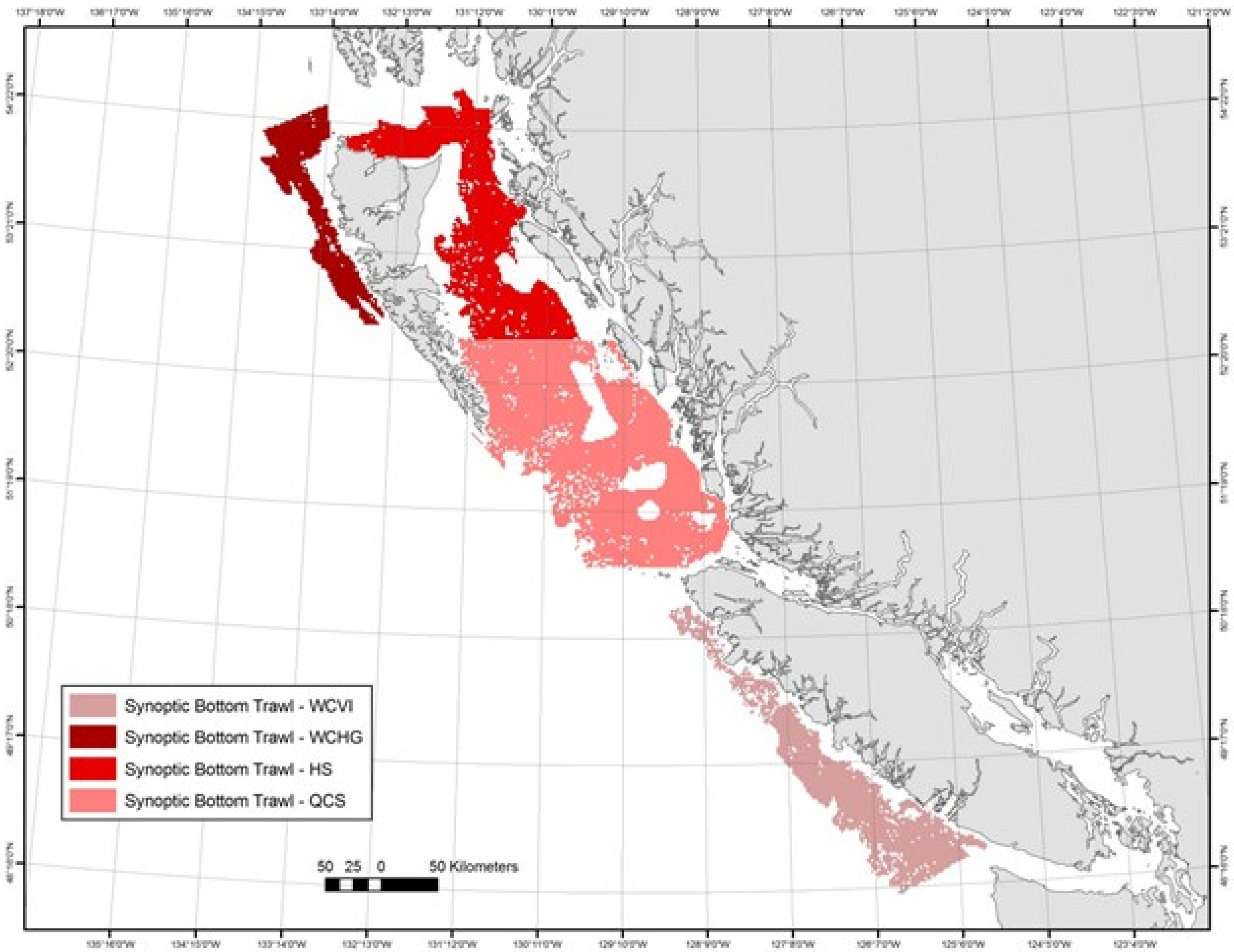

Figure 3. Multispecies Synoptic Bottom Trawl Survey coverage.

The HS, WCVI, and QCS Synoptic Bottom Trawl surveys were all conducted in 2021. The WCVI survey was originally scheduled for 2020 but was postponed to 2021 due to the COVID-19 pandemic. The HS survey was completed on the research vessel Sir John Franklin from mid-May to mid-June while the WCVI and QCS surveys were completed on the chartered commercial trawl vessel Nordic Pearl from mid-May to mid-June and early July to mid-August, respectively. A total of 478 successful tows were completed over the three surveys with 116 in HS, 169 in WCVI, and 193 in QCS (Figure 4). The dominant species in the HS survey catches were Spotted Ratfish (*Hydrolagus colliei*), Dover Sole (*Microstomus pacificus*), Arrowtooth Flounder (*Atheresthes stomias*), and Rex Sole (*Glyptocephalus zachirus*). The dominant species in the WCVI survey catches were Sablefish (*Anoplopoma fimbria*), Sharpchin Rockfish (*Sebastes zacentrus*), Pacific Ocean Perch (*Sebastes alutus*), and Arrowtooth Flounder (*Atheresthes stomias*). The dominant species in the QCS survey catches were Pacific Ocean Perch (*Sebastes alutus*), Silvergray Rockfish (*Sebastes brevispinis*), Arrowtooth Flounder (*Atheresthes stomias*), and Redstripe Rockfish (*Sebastes proriger*).

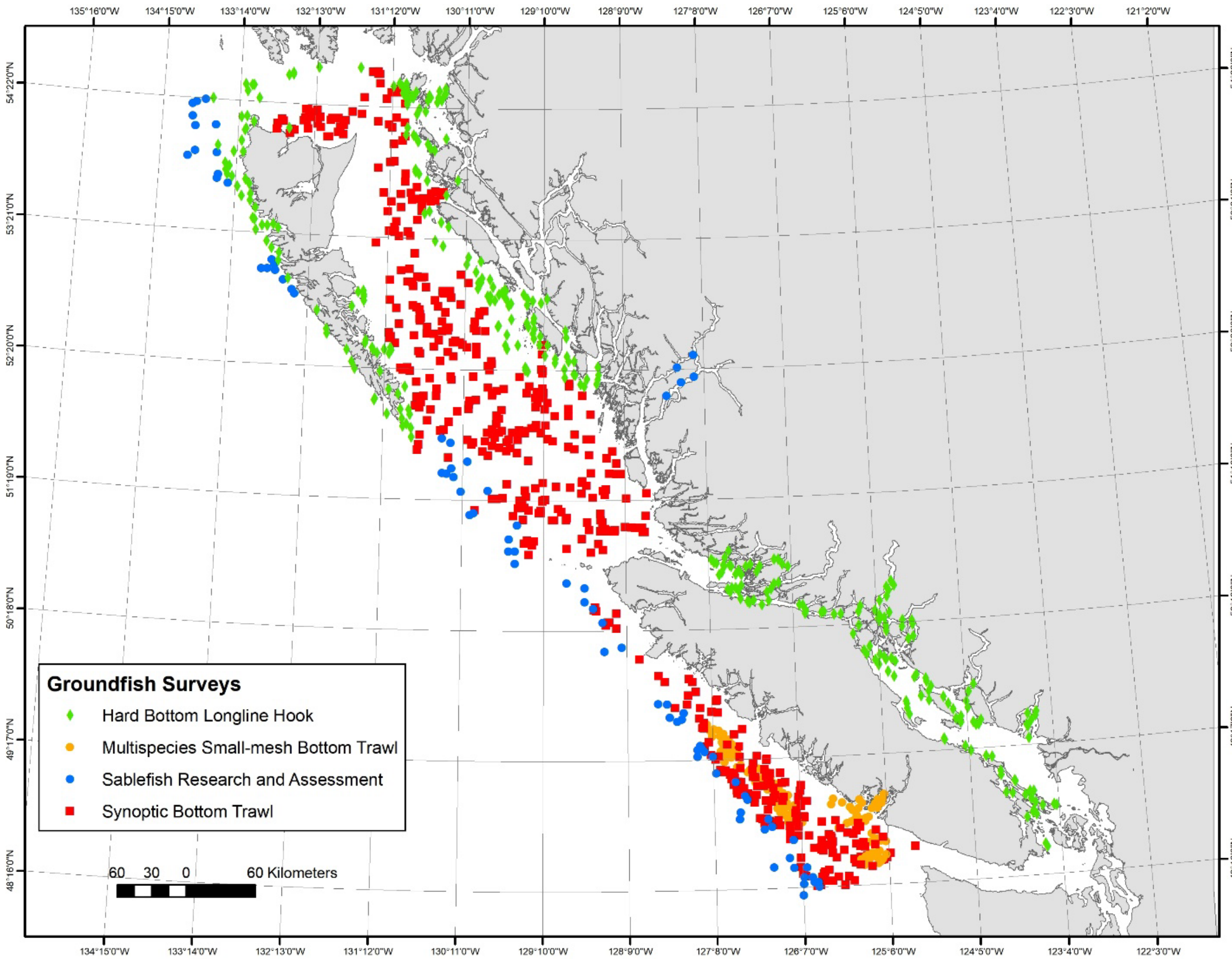

Figure 4. Fishing locations of the 2021 Groundfish surveys.

The **Hard Bottom Longline Hook (HBLL) Surveys** are conducted annually in "outside" waters (not between Vancouver Island and the mainland) and "inside" waters (between Vancouver Island and the mainland). Both the "outside" and "inside" areas are divided into northern and southern regions and surveys annually alternate between the regions such that the whole coast is covered over a two-year period. The outside surveys are conducted under a collaborative agreement with the Pacific Halibut Management Association (PHMA) and occur on chartered commercial fishing vessels with contracted technicians. The inside surveys are conducted by DFO and occur on a Canadian Coast Guard vessel with DFO staff. In aggregate, the HBLL surveys provide coast-wide coverage of most of the untrawlable habitat between 20 and 220 meters depth.

In 2021 the northern region of the outside area and both the northern and southern regions of the inside area were surveyed (Figure 4). The 2020 inside area survey was scheduled for the northern region but was postponed to 2021 due to the COVID-19 pandemic. The outside HBLL survey was conducted on the chartered commercial longline vessels Banker II, Borealis 1, and Western Sunset from late July to mid-August. A total of 197 sets were completed. The data from the outside surveys has not been finalized at the time of writing. The inside surveys were conducted on the research vessel Neocaligus and the northern region was surveyed in August while the southern region was surveyed in September. A total of 144 sets were completed and the dominant species in the catch were North Pacific Spiny Dogfish (*Squalus suckleyi*), Quillback Rockfish (*Sebastes maliger*), and Yelloweye Rockfish (*Sebastes ruberrimus*).

The **Sablefish Research and Assessment Survey** is an annual longline trap survey targeting Sablefish. This survey releases tagged Sablefish at randomly selected fishing locations in offshore waters as well as at fixed stations in four mainland inlets. The survey also provides catch rates and biological data for use in stock assessments. The survey is conducted under a collaborative agreement with the Canadian Sablefish Association and occurs on a chartered commercial fishing vessel by a mix of DFO staff and contracted technicians. This survey covers the depth range of 150 m to 1250 m for the entire outer BC coast as well as a number of central coast inlets.

In 2021, the survey was conducted on the commercial fishing vessel Pacific Viking from early October to late November. The survey experienced an unprecedented number of days lost to poor weather. A total of 72 of the 91 intended sets were completed in the offshore areas while only 5 of the intended 20 sets in the inlet portion of the survey were completed (Figure 4). In addition to the offshore and inlet sets, the survey included a research program designed to investigate gear interactions with the substrate and 4 sets designed to simulate commercial fishing were conducted. The most abundant fish species in the catch were Sablefish (*Anoplopoma fimbria*), North Pacific Spiny Dogfish (*Squalus suckleyi*), and Lingcod (*Ophiodon elongatus*).

The **Multispecies Small-mesh Bottom Trawl Survey** is an annual fixed-station survey of commercially important shrimp grounds off the West Coast of Vancouver Island that was initiated in 1973, and occurs on a Canadian Coast Guard Vessel with DFO staff. Catch rate indices generated by the survey have been used to track the abundances of several groundfish stocks. Groundfish staff provide assistance in catch sorting and species identification and also collect biological samples from selected fish species. The 2021 survey was conducted onboard the research vessel Sir John Franklin from April 26 to May 18, 2021 and a total of 119 usable tows were completed (Figure 4). The most abundant species in the catch were Rex Sole (*Glyptocephalus zachirus*), Pink Shrimp (*Pandalus jordani*), and Eulachon (*Thaleichthys pacificus*).

The **International Pacific Halibut Commission** (IPHC) conducts an annual stock assessment longline survey in waters from California to Alaska, including British Columbia (BC) waters. The survey's main goal is to provide data on Pacific Halibut (*Hippoglosus stenolepis*) for stock assessment purposes. However, data are also recorded on other species caught, making it the longest ongoing groundfish survey in BC waters and hence a valuable source of data for many species. The gfiphc R package (https://github.com/pbs-assess/gfiphc), developed at PBS and updated annually, contains much of the relevant data (and enables extraction from **GFBio** for the rest) It also includes code for deriving relative biomass index trends for non-halibut groundfish species within BC, based on methods that take into account the changing survey methodologies (see Anderson et al., 2019). Results for 113 species are directly viewable at http://htmlpreview.github.io/?https://github.com/pbs-assess/gfiphc/blob/master/vignettes/data_for_all_species.html, and are incorporated into the groundfish synopsis report (see below).

III. Reserves

Canada has surpassed its marine conservation target commitment of protecting 10 percent of coastal and marine areas through effectively managed networks of protected areas and other effective area-based conservation measures by 2020, a commitment made under the United Nations Convention on Biological Diversity (UN CBD) Aichi Target 11. Approximately 14% of Canada's EEZ are now protected. Marine Conservation initiatives in British Columbia are illustrated in Figure 5.

In the Pacific Region, an initiative is underway to develop a network of Marine Protected Areas (MPAs) in BC's Northern Shelf Bioregion (NSB). A draft MPA network scenario was released for comment by stakeholders on the advisory committee on February 28, 2019, and consultation on this plan is ongoing. In 2020, the partners continued to work through outstanding questions including scope and level of detail for the action plan, approach to phased implementation, and principles that will guide future governance and implementation. The Marine Protected Area Technical Team (MPATT) will consider all spatial advice received and work towards a revised network scenario and a socio-economic analysis will be completed on a revised scenario. A revised draft scenario will be shared with stakeholders, local governments and the public for review and comment in 2021.

The Hecate Strait/Queen Charlotte Sound Glass Sponge Reefs MPA that was designated under Canada's Oceans Act in February 2017 to protect glass sponge reefs in Hecate Strait and Queen Charlotte Sound will be part of the NSB MPA network, as will the Gwaii Haanas National Marine Conservation Area Reserve (NMCAR) and Haida Heritage Site. The Scott Islands marine National Wildlife Area (NWA), an area that conserves a vital marine area for millions of seabirds on the Pacific coast, will also be part of the NSB MPA. Fishing activity is currently not prohibited in the NWA.

Parks Canada and the Archipelago Management Board have introduced new zoning to the NMCAR which includes multiple use zones (IUCN protection level IV-VI) as well as high protection zones (IUCN Ib-III) and two small restricted access zones that are intertidal/terrestrial. These zones came into effect on May 1, 2019. The two Rockfish Conservation Areas that were formerly within the NMCAR boundaries have been rescinded and replaced with the new zoning. Parks Canada is also still working to establish an NMCAR in the Salish Sea.

Another major initiative is the designation of the Offshore Pacific Seamounts and Vents Closure. The Area of Interest (AOI) was designated in 2017 and an offshore groundfish fishing closure was put into place to protect seamount and vent communities (Figure 5). The Endeavour Hydrothermal Vents MPA, designated under Canada's Ocean Act in 2003, is within the Offshore AOI. The Endeavour MPA was designated to ensure the protection of hydrothermal vents, and the unique ecosystems associated with them. The regulation to establish the MPA prohibits the removal, disturbance, damage or destruction of the venting structures or the marine organisms associated with them while allowing for scientific research that will contribute to the understanding of the hydrothermal vent ecosystem.

The SGaan Kinghlass-Bowie Seamount MPA, which was designated in 2008, protects communities living on Bowie Seamount which rises from depths to 3000 m to within 24 m of the surface, as well as two other seamounts and adjacent areas (https://dfo-mpo.gc.ca/oceans/mpa-zpm/bowie-eng.html).

The other 162 Rockfish Conservation Areas (RCAs) designated as fishery closures between 2004-2007 (Yamanaka and Logan, 2010), remain in place. The Glass Sponge Reef Conservation Areas are closed to all commercial and recreational bottom contact fishing activities for prawn, shrimp, crab and groundfish (including halibut) in order to protect the Strait of Georgia and Howe Sound Glass Sponge Reefs (http://www.dfo-mpo.gc.ca/oceans/ceccsr-cerceef/closures-fermetures-eng.html).

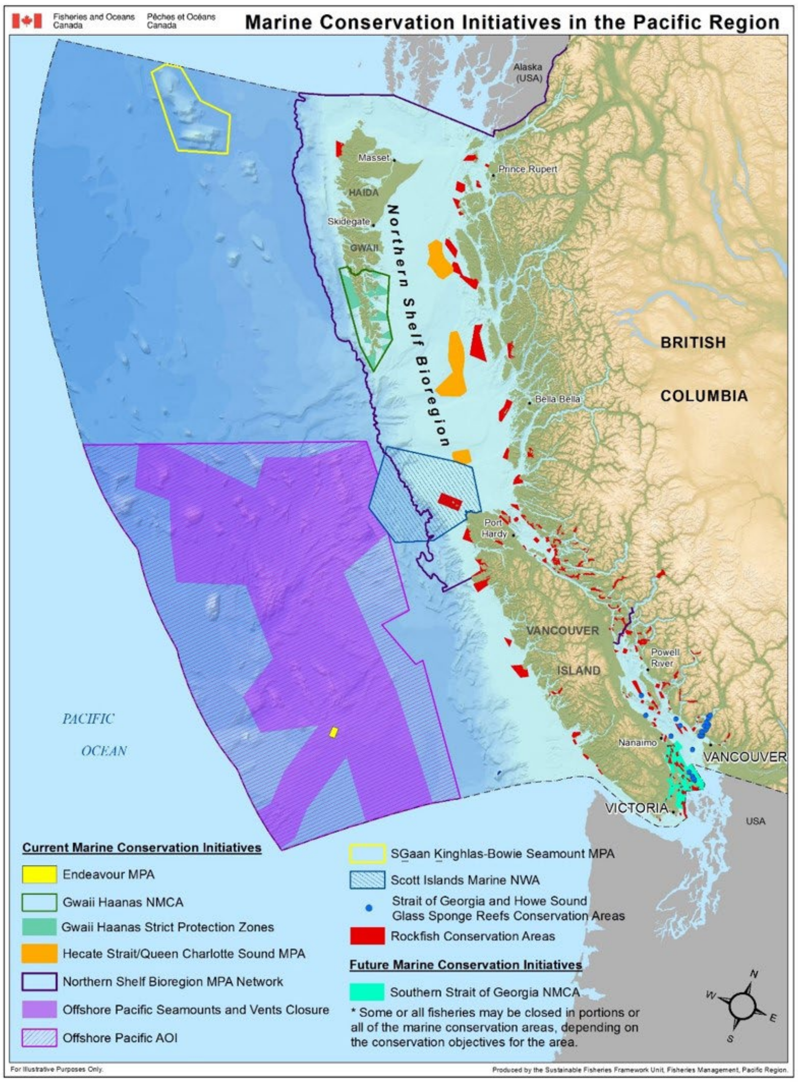

Figure 5. Marine Conservation Initiatives in the Pacific Region (Map by F. Yu).

IV. Review of Agency Groundfish Research, Assessment and Management

A. Hagfish

1. Research

No new research in 2021.

2. Assessment

Nothing to report.

3. Management

There is currently no fishery for Hagfish in BC.

B. Dogfish and other sharks

1. Research

i) North Pacific Spiny Dogfish

Data collection continued in 2021 through the annual groundfish multispecies trawl and longline surveys. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery in 2021. Several indices of relative abundance for North Pacific Spiny Dogfish in BC waters have declined over the last decade despite relatively little catch compared to historical levels and no directed fishery in recent years. Dr. Lindsay Davidson is a postdoc leading a research project (with Drs. Sean Anderson, Philina English, Jackie King, and Paul Grant, and NOAA collaborators Drs. Cindy Tribuzio, Vladlena Gertseva, and Ian Taylor) examining these declines and evaluating the evidence for possible explanations including climate, predator-prey interactions, seasonal distribution shifts, population declines from historical harvesting, or changes to survey timing.

ii) Other Shark Species

Other species of shark are sampled opportunistically during annual groundfish multispecies trawl and longline surveys. In 2021, two Bluntnose Sixgill Shark and three Tope Shark were sampled. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery. Anecdotal information on encounters with other shark species is also collected through the Shark Sightings Network (https://www.dfo-mpo.gc.ca/species-especes/sharks/info/sightings-eng.html).

2. Assessment

i) North Pacific Spiny Dogfish

North Pacific Spiny Dogfish were last assessed in 2010. No new assessment is currently scheduled. However, Dogfish are scheduled to be “batched in” as a Major Stock under the Fish Stocks provisions of the *Fisheries Act* and so an assessment is likely within the next 2-3 years, likely following the research project mentioned above.

In 2011, the Committee on the Status of Wildlife in Canada (COSEWC) assessed the conservation status of North Pacific Spiny Dogfish as Special Concern, citing low fecundity, long generation time (51 years), uncertainty regarding trends in abundance of mature individuals, reduction in size composition, and demonstrated vulnerability to overfishing as the causes for concern. Nevertheless, COSEWIC acknowledged that the population remains relatively abundant, and overfishing is currently unlikely.

COSEWC status reports are available at https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports.html.

ii) Other Shark Species

As no directed commercial fisheries for sharks other than North Pacific Spiny Dogfish exist in British Columbia, there have been no requests for any stock assessments.

The Committee on the Status of Wildlife in Canada (COSEWC) has assessed the conservation status of a number of British Columbia shark species, and three species are listed under the Canadian Species at Risk Act (SARA):

- Basking Shark: Designated Endangered in 2007. Status re-examined and confirmed in 2018. Listed under SARA.
- Bluntnose Sixgill Shark: Designated Special Concern in 2007. Currently being re-examined. Listed under SARA.
- Tope Shark: Designated Special Concern in 2007. Currently being re-examined. Listed under SARA.

Blue Shark (North Pacific population) was examined by COSEWIC in 2016 and designated Not at Risk. White Shark and Brown Cat Shark were considered in 2006 and 2007 and placed in the Data Deficient category.

COSEWC status reports are available at https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports.html.

3. Management

i) North Pacific Spiny Dogfish

North Pacific Spiny Dogfish are managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan (IFMP), and are permitted to be retained in the recreational fishery. There is currently no targeted fishing for Dogfish. Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

ii) Other Shark Species

Currently, there is no directed commercial fishery for other shark in Canadian Pacific waters; only Salmon Shark are permitted to be retained in the recreational fishery. Species at Risk Act prohibitions only apply to species listed as extirpated, endangered or threatened; thus, they do not apply to species of special concern. Nevertheless, commercial fisheries are no longer permitted

be released at sea with the least possible harm. Catch limits for the recreational fishery have been reduced to “no fishing” for all species listed under the Species at Risk Act, and “zero retention” (catch and release) for all other shark species except Salmon Shark. Codes of conduct have been developed for encounters with Basking Sharks (https://www.dfo-mpo.gc.ca/species-especes/publications/sharks/coc/coc-basking/index-eng.html) and other sharks (https://www.dfo-mpo.gc.ca/species-especes/publications/sharks/coc/coc-sharks/index-eng.html).

C. Skates

1. Research

Data collection continued in 2021 through trawl and longline surveys. Most individual skates encountered on groundfish research surveys are sampled (length, weight if feasible, sex) and released alive if possible. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery in 2021.

Species sampled in 2021 through groundfish surveys include Aleutian Skate (n=13), Big Skate (n=180), Sandpaper Skate (n=245), and Longnose Skate (n=862).

2. Assessment

Big Skates and Longnose Skate were assessed in 2013 (King et al 2015). No new assessment is currently planned. No other skate species in British Columbia are assessed.

3. Management

Big and Longnose Skates are currently managed under sector and area TACs. For all other species of skate there are no management measures in place.

Big and Longnose Skates are IVQ (individual vessel quota) species managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan (IFMP). Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

Literature Cited:

King, J.R., Surry, A.M., Garcia, S., and Starr, P.J. 2015. Big Skate (*Raja binoculata*) and Longnose Skate (*R. rhina*) stock assessments for British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/070. ix + 329 p. https://waves-vagues.dfo-mpo.gc.ca/Library/362171.pdf

D. Pacific Cod

1. Research

Data collection continued in 2021 through trawl and longline surveys. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery in 2021.

2. Assessment

The last full assessments of Pacific Cod stocks were done in 2018, using the same delay-difference model that was used in 2013. The Research Document (Res Doc 2020/70) is available at https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2020/2020_070-eng.html. The Science Advisory Report (SAR 2019/008) is available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2019/2019_008-eng.html.

Four stocks are defined for management purposes in BC: Strait of Georgia (4B); West Coast Vancouver Island (3CD); Queen Charlotte Sound (5AB); and Hecate Strait (5CD). Historically, each area has been assessed separately; however, for the 2018 assessment, data from Areas 5AB and 5CD were combined into a single stock assessment due to the lack of biological evidence for separate stocks and improved fits to the combined data compared to data from area 5AB alone. Area 3CD was assessed separately. Area 4B was not assessed as there is no directed commercial fishery there.

Both 3CD and 5ABCD stock assessments were updated in 2020 and published as a Science Response (https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2021/2021_002-eng.html), following an approximate 75% drop in the synoptic survey index in 2018 in 3CD, accompanied by three years of commercial catches well below average. There was an estimated 2-10% probability that the 3CD stock would fall into the Critical Zone in 2022 under a range of 2021 catch levels. There was an estimated < 0.01% probability that the 5ABCD stock will fall into the Critical Zone in 2022.

Groundfish bottom trawl surveys resumed in the West Coast Vancouver Island, Queen Charlotte Sound and Hecate Strait areas in 2021. Compared to the 2019 index, the median swept area survey index increased by 25% in Hecate Strait and by 15% in Queen Charlotte Sound, representing the third year of increases in Hecate Strait and the second year of increases in Queen Charlotte Sound. Although not included in the stock assessment, the West Coast Haida Gwaii index also increased, with a 132% increase in the median swept area index, compared to 2018. However, the stock continued to decline in the West Coast Vancouver Island Survey, with a 22% decrease in the median swept area index compared to 2018.

Given the decreases in the 2018 and 2021 West Coast Vancouver Island survey index, an update to the 3CD stock assessment is scheduled to occur once the 2022 survey data are available in Fall 2022.

3. Management

Pacific Cod is an IVQ (individual vessel quota) species, managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan

(IFMP). Commercial TACs and landings for 2020 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. Following the 2020 assessment update, the commercial TAC in Area 3CD was reduced to 300 metric tonnes. See Appendix 1 for details. In addition, winter spawning closures are in effect in both Areas 3CD and 5CD.

E. Walleye Pollock

1. Research

There was no work conducted directly on Walleye Pollock in 2021 but ongoing data collection continued through the Groundfish Synoptic Surveys. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery in 2021.

2. Assessment

The most recent stock assessment (2017) is publicly available on the CSAS website (Research Document 2021/004, Science Advisory Report 2018/020, Proceeding 2021/048).

3. Management

Walleye Pollock is an IVQ (individual vessel quota) species, managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan (IFMP). Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

F. Pacific Whiting (Hake)

1. Research

There are two commercially harvested and managed stocks of Pacific Hake. The offshore stock is the principal target of the commercial fishery comprising the bulk of landings year over year. A smaller and discrete stock residing within the Strait of Georgia is targeted episodically when market demand is sufficient, and the available fish are large enough for processing.

i) Offshore Hake

Triennial (until 2001), then biennial acoustic surveys, covering the known extent of the Pacific Hake stock have been run since 1995. An acoustic survey, ranging from California to northern British Columbia is currently run in odd-numbered years, to continue the biennial time series. The last survey used in the assessment model took place in 2019. The sail drone survey was run again in 2020, and research is being done to determine appropriateness of using these data to construct a biomass index using commercial trawl samples as the ground truthing method.

In addition to the hake acoustic survey, biological samples were collected in 2021 through groundfish trawl surveys. Due the suspension of the At Sea Observer Program no biological samples were collected at sea from the commercial fishery in 2021. Only five dockside samples were collected.

ii) Strait of Georgia Hake

There has been a biennial acoustic survey for Pacific Hake in the Strait of Georgia since 2011. Methods are currently being developed to calculate a biomass estimate for these surveys, which will then be used as the primary index of abundance for the stock assessment.

2. Assessment

i) Offshore Hake

As in previous years, and as required by the Agreement Between the Government of Canada and the Government of the United States of America on Pacific Hake/Whiting (the Pacific Whiting treaty), the 2021 harvest advice was prepared jointly by Canadian and U.S. scientists working together, collectively called the Joint Technical Committee (JTC) as stated in the treaty. The assessment model used was Stock Synthesis 3 (SS3). The 2021 model had the same model structure used in 2020, with updates to catch and age compositions. Standard sensitivities requested by the Scientific Review Group showed little difference when compared with the base model. The largest cohort caught in the fishery was age-4's, followed by age 6's which represent the large cohorts for 2016 and 2014 respectively.

ii) Strait of Georgia Hake

There has not been an assessment of Pacific Hake in the Strait of Georgia, although the recent increases in catch may warrant one.

3. Management

Canadian commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details

i) Offshore Hake

Management of Pacific Hake has been under a treaty (The Agreement) between Canada and the United States since 2011. The stock is managed by the Joint Management Committee (JMC) which is made up of fisheries managers and industry representatives from both the U.S. and Canada. These managers receive advice from the JTC and the Scientific Review Group (SRG), which is a committee responsible for the scientific review of the assessment.

The final decision on catch advice for the 2021 fishing season was made at the Joint Management Committee (JMC) meeting online on Mar. 15 – Mar. 17, 2021. Despite extensive deliberations, a TAC was not agreed upon by the two countries' JMC members for 2021, so Canadian managers chose a TAC of 104,480 t, which is the same as the TAC for 2020.

The final assessment document and other treaty-related documents are posted at: https://www.fisheries.noaa.gov/west-coast/laws-and-policies/pacific-hake-whiting-treaty.

ii) Strait of Georgia Hake

Management of Strait of Georgia Pacific Hake has been implemented as ad-hoc quota allocation for the history of the fishery. Typical catch for the Strait has been approximately 10 - 40 metric tonnes for many years, but has seen an increase of several orders of magnitude in the last few years.

G. Grenadiers

1. Research

There is no directed work conducted on Grenadiers. Opportunistic sampling occurs on groundfish trawl surveys, but no Grenadiers were encountered in 2021.

2. Assessment

Grenadiers are not commercially harvested in BC and are rarely encountered during commercial fisheries. Consequently, there are no assessment activities planned for these species.

3. Management

There are no management objectives or tactics established for these species. These species are caught incidentally in the deep-water rockfish (Rougheye/Shortraker/Thornyhead) and Dover Sole fisheries and in the Sablefish trap fishery. 100% of the catch is discarded.

H. Rockfish

1. Research

Biological samples are collected on an ongoing basis from annual trawl, longline, and trap surveys. Due the suspension of the At Sea Observer Program no biological samples were collected from the commercial fishery in 2021.

i) Inshore Rockfish

Dr. Dana Haggarty continues to collaborate with other scientists at DFO, Dr. Philina English, Dr. Sarah Dudas and Dr. Stephan Gauthier, as well as external Scientists: Dr. Francis Juanes (UVic), Dr. William Halliday (Wildlife Conservation Society Canada), and Dr. Francis Mouy (NOAA) to continue to develop passive acoustic monitoring (PAM) of rocky reef fishes. Based on the successes of a SPERA funded project, they were awarded Canadian Science Research Funding for three years of study. With this grant, they will support some post-doctoral work of Xavier Mouy who will continue to develop and refine an automatic detector of fish (and hopefully rockfish) calls. They have also brought on a Ph.D. student, Darienne Lancaster, co-supervised by Drs. Francis and Haggarty at UVic who will refine methods to collect passive and active acoustic data of rockfishes.

Dr. Haggarty is also collaborating with colleagues at UVic and Ball State University as well as industry (Angler's Atlas) to improve and monitor compliance in Rockfish Conservation Areas (RCAs) and Marine Protected Areas (MPAs). Angler's Atlas has already upgraded their smart phone app, MyCatch, to include the location of all RCAs and to provide users with warnings when they are in an RCA. The app works by employing the cell phone's internal GPS and with downloaded maps, so users do not need to be on cell networks for it to function. There is also a function to collect data on the use of descending devices for rockfishes and an outreach program associated with this. This project was funded by the BC Salmon Restoration and Innovation Fund (BCSRIF) until the end of 2022-23. We think that the up-take of the MyCatch app by anglers was affected by the COVID19 pandemic; however, we are hoping to increase awareness about the app in 2021. Dr. Paul Venturelli and his students are continuing work that Dana and collaborators have done to assess recreational compliance in RCAs using creel overflight data.

Dana is also working with a graduate student at the University of Victoria, Hailey Davies, with collaborator Dr. Francis Juanes. Hailey is studying survival of rockfish following the use of a descending device by using a tag-recapture experiment as well as the use of camera systems to record the release. Despite tagging a total of 352 rockfishes from 9 species, we have only had two tag recoveries. One recovery was a Copper Rockfish that had been at large for a month, and the other was a Yelloweye Rockfish that was recovered by a recreational angler in late February which had been tagged and released in mid-October. We have collected additional data on barotrauma symptoms by species and are planning on writing a meta-analysis on the subject. A photo essay on the field work is in review in Fisheries.

Dana has also collaborated with DFO iREC (Internet Recreational Effort and Catch) staff to develop a questionnaire on the use of descending devices by anglers. The survey is a voluntary add-on to the annual iARC (Internet Annual Recreational Catch Reporting program) survey. The survey runs April 1-23, 2022.

ii) Offshore Rockfish

The Offshore Rockfish program in 2021 continued with one DFO person working in collaboration with an industry-sponsored scientist. All efforts were devoted to stock assessment. To facilitate stock assessment, the Offshore Rockfish program maintains a suite of PBS R software packages (https://github.com/pbs-software). The Groundfish Surveys program coordinates all sample collections (otoliths, genetic tissues, morphology measurements, etc.) and the Sclerochronology Lab researches ageing protocols and methods, in addition to performing production ageing for BC finfish stock assessments.

2. Assessment

i) Inshore Rockfish

British Columbia (BC) "Inside" stocks are generally those occurring in Area 4B (Queen Charlotte Strait, Strait of Georgia, and Strait of Juan de Fuca), while "Outside" stocks occur outside Area 4B (West Coast Vancouver Island, West Coast Haida Gwaii, Queen Charlotte Sound, Hecate Strait, Dixon Entrance).

Outside Yelloweye Rockfish

The Outside population of Yelloweye Rockfish was designated as Threatened in December of 2020 by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC). DFO is now responsible for completing a Recovery Potential Analysis which will be completed in 2022 drawing from the results presented in the 2019 rebuilding plan analysis (Cox et al 2020).

Cox, S.P., Doherty, B., Benson, A.J., Johnson, S.D., and Haggarty, D. 2020. Evaluation of potential rebuilding strategies for Outside Yelloweye Rockfish in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/041.

Inside Yelloweye Rockfish

The Inside population of Yelloweye Rockfish was designated as Threatened in December of 2020 by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC). DFO is now responsible for completing a Recovery Potential Analysis which will be completed in 2022 drawing from the results presented in the 2020 rebuilding plan analysis (Haggarty et al in press).

Haggarty, D.R., Huynh, Q.C., Forrest, R.E., Anderson, S.C., Bresch, M.J., Keppel, E.A. In press. Evaluation of potential rebuilding strategies for Inside Yelloweye Rockfish (Sebastes ruberrimus) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/nnn. vi + 142 p.

Quillback Rockfish

The Inside and Outside management units of Quillback Rockfish were last assessed in 2010 after the Committee On the Status of Endangered Wildlife In Canada (COSEWIC) designated them as threatened in November 2009.

Quillback is due to be reassessed in 2022-2023 in advance of a COSEWIC reassessment. In preparation to do so, we have begun analyzing data for the inside and outside stocks and have developed initial operating models for the inside stock. We also held a series of workshops to discuss the decision context and to develop objectives to be used for the Quillback Rockfish stocks in a Management Procedure (MP) framework analysis. A technical report describing the workshop results will be available soon. We have applied for funding to continue this work which is being led by Dana Haggarty and Matt Siegle and conducted by consultant Quang Huynh at Blue Matter Science. We expect to complete work on the both stocks in 2022-23. Completion of work on the outside stock is delayed due to the COVID19-related shut-down and subsequent reduced capacity of the PBS Sclerochronology lab as well as delays in establishing a contract with Blue Matter Science.

Yamanaka, K.L., McAllister, M.K., Etienne, M.-P., and Flemming, R. 2011a. Stock assessment and recovery potential assessment for Quillback Rockfish (*Sebastes maliger*) on the Pacific coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/135: vii + 151 p.

Other Inshore Rockfish Species (Copper, China, Tiger, Brown, Black, Deacon Rockfishes).

Inshore Rockfishes were assessed as a group in 2001, but none of these other inshore species have been assessed individually by DFO.

ii) Offshore Rockfish

Bocaccio

Bocaccio was assessed in 2019 (Science Advisory Report 2020/025, Proceedings 2021/014), and a very large 2016 cohort was predicted to elevate the stock from the DFO Critical Zone to the Healthy Zone by 2023. An update of the stock assessment model using new survey and commercial CPUE indices was requested for 2021 (Science Response 2022/001).

The updated model had no difficulty in fitting each survey series, including the new 2020 and 2021 indices. The capacity of the model to fit the four new survey index points indicated that these new observations were consistent among each other and with the model estimates of recruitment strength for the 2016 cohort. The updated length frequency distribution data showed that the 2016 cohort of Bocaccio remained the single dominant year class. Length frequency distributions were available from each survey, independently corroborating the presence on this cohort and demonstrating that the increased Bocaccio abundance in each survey was entirely attributable to this cohort.

The composite base case, comprising three pooled Markov Chain Monte Carlo (MCMC) runs, was used to calculate a set of parameter estimates and derived quantities at equilibrium and those associated with MSY. The composite base case population trajectory from 1935 to 2022 and projected biomass to 2032 (Figure 6), assuming a constant catch policy of 500 t/y, indicates that the median stock biomass exceeded the upper stock reference (USR) in 2022, which was sooner than predicted by the 2019 assessment.

The Bocaccio stock has been in the Critical zone since the late 1990s, but has now moved into a current (2022) position that lies well inside the Healthy zone at $B_{2022}/B_{\mathrm{MSY}}$ = 1.499 (0.625, 3.416), u_{2021}(trawl) /u_{MSY} = 0.24 (0.106, 0.487), and u_{2021}(other) /u_{MSY} = 0.006 (0.003, 0.013).

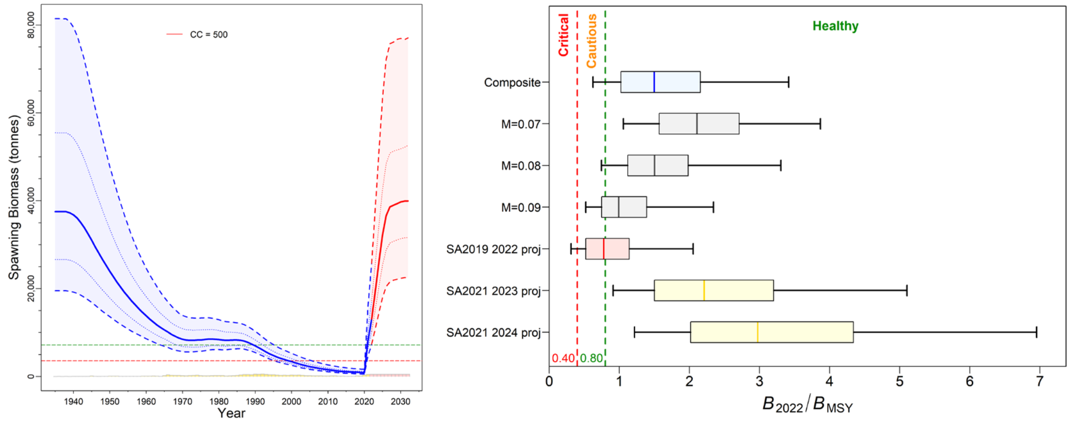

*Figure 6. **Left**: composite estimate of Bocaccio spawning biomass (tonnes) from three model posteriors pooled to form the base case. The median biomass trajectory appears as a solid curve surrounded by a 90% credibility envelope (quantiles: 0.05-0.95) in light blue; projected biomass appears in light red. Also delimited is the 50% credibility interval (quantiles: 0.25-0.75) delimited by dotted lines. The horizontal dashed lines show the median LRP and USR. **Right**: spawning stock status at beginning of 2022 relative to the PA reference points of $0.4B_{MSY}$ and $0.8B_{MSY}$ for the base case. The top quantile plot shows the composite distribution and below are the three contributing runs. Also shown are projected stock status for the composite base case in the 2019 stock assessment (red, assuming constant catch = 200 t/y) and for the current composite base case at the beginning of 2023 and 2024 (yellow, constant catch = 500 t/y). Quantile plots show the 0.05, 0.25, 0.5, 0.75, and 0.95 quantiles from the MCMC posteriors.*

Canary Rockfish

In 2007, Canary Rockfish along the Pacific coast of Canada was designated as ‘Threatened’ by COSEWIC, with commercial fishing identified as the primary threat. The Canary Rockfish stock assessment was last updated in 2009 (Science Response 2009/019). In 2017, DFO prepared a summary of available information on Canary Rockfish in preparation for a re-assessment by COSEWIC. A new full stock assessment by DFO is planned for 2022/23.

Darkblotched Rockfish

In 2009, Darkblotched Rockfish along the Pacific coast of Canada was designated as ‘Special Concern’ by COSEWIC. The last review of this species occurred in 2008 (Research Document 2008/056). Currently, there is no stock assessment planned.

Pacific Ocean Perch

The most recent stock assessment (2017) is publicly available on the CSAS website (Research Document 2018/031).

Redbanded Rockfish

The most recent stock assessment (2014) is publicly available on the CSAS website (Research Document 2017/058, Proceedings 2015/032).

Redstripe Rockfish

The most recent stock assessment (2017) is still awaiting translation; however, a summary report is available (Science Advisory Report 2018/049).

Rougheye/Blackspotted Rockfish

The most recent stock assessment (2020) is publicly available on the CSAS website (Science Advisory Report 2020/047, Proceedings 2022/004).

Shortraker Rockfish

The most recent stock assessment (1998) is publicly available on the CSAS website (Research Document 1999/184).

Silvergray Rockfish

Silvergray Rockfish were last assessed in 2014. The assessment is publicly available on the CSAS website (Research Document 2016/042; Science Advisory Report 2014/028).

Widow Rockfish

The most recent stock assessment (2019) is publicly available on the CSAS website (Research Document 2021/039, Science Advisory Report 2019/044, Proceedings 2021/049).

Yellowmouth Rockfish

The most recent stock assessment (2021) is publicly available on the CSAS website (Science Advisory Report 2022/001, Proceedings 2022/003).

A stock assessment for Yellowmouth Rockfish (YMR) along the BC coast was conducted in 2021. This marked a departure from rockfish stock assessments conducted since 2009 by adopting the Stock Synthesis 3 (SS) generic stock assessment platform maintained by NOAA. This platform provides more flexibility than models used in past BC rockfish assessments despite a time-consuming learning curve.

The SS model was tuned to four fishery-independent trawl survey series, a bottom trawl CPUE series, annual estimates of commercial catch since 1935, and age composition data from survey series (25 years of data from four surveys) and the commercial fishery (28 years of data). The model started from an assumed equilibrium state in 1935, the survey data covered the period 1967 to 2020 (although not all years were represented), and the CPUE series provided an annual index from 1996 to 2020.

The model was implemented in a Bayesian framework (using the Monte Carlo Marko Chain [MCMC] 'No U-Turn Sampling' procedure) to estimate five models which fixed natural mortality (models estimating *M* were not stable) to each of five levels (0.04, 0.045, 0.05, 0.055, 0.06), spanning a range that was considered plausible and which returned acceptable MCMC diagnostics. The parameters estimated by these models included average recruitment and annual year class deviations over the period 1950-2012, and selectivities for the four surveys and the commercial trawl fleet. These five model runs were combined into a composite base case which covered the plausible range of the major axis of parameter uncertainty in this stock assessment. Fourteen sensitivity analyses were performed relative to the central run (M=0.05) of the composite base case to test the effect of alternative model assumptions.

Figure 7 (left) shows the estimated annual spawning biomass (mature females only) relative to spawning biomass at MSY for the coastwide YMR stock depicted by the composite base case. The stock has fluctuated based on four good recruitment years (1952, 1962, 1982 and 2006), increasing to a level above the equilibrium biomass associated with average recruitment (B_0) over four decades (1965-2005) before declining to a low point in 2014. Thereafter, the spawning biomass increased to approximately 15,000 tonnes.

Figure 7 (right) shows the stock status for the YMR composite base case, as well as each base component run, relative to the DFO limit and upper stock reference points of 0.4B_{MSY} and 0.8B_{MSY}, respectively. These reference points define the ‘Critical’, ‘Cautious’ and ‘Healthy’ zones. The YMR composite base case spawning biomass at the beginning of 2022 was estimated to be above the limit reference point (LRP) with probability P(B_{2022} > 0.4B_{MSY}) = 1, and above the upper stock reference (USR) point with probability P(B_{2022} > 0.8B_{MSY}) = 1 (i.e., no probability of being in the Cautious or Critical zones based on the set of MCMC posterior samples).

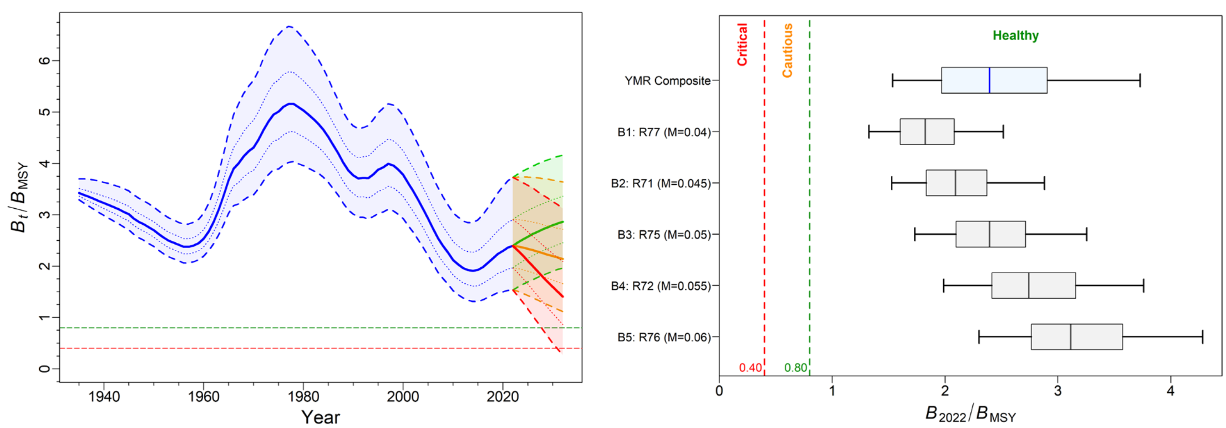

*Figure 7. **Left**: estimates of spawning biomass B_t relative to B_{MSY} from the model posteriors (10,000 samples) of the YMR composite base case. The median biomass trajectory appears as a solid curve surrounded by a 90% credibility envelope (quantiles: 0.05, 0.95) in blue and delimited by dashed lines for years t=1935–2022; projected biomass using constant catch appears in green (no catch), orange (1250 t/y), and red (2500 t/y) for years t=2023-2032 (10 years). Also shown is the 50% credibility interval (quantiles: 0.25–0.75) delimited by dotted lines. **Right**: Stock status of the YMR base case and its component base runs relative to the DFO Precautionary Approach (PA) provisional reference points of 0.4B_{MSY} and 0.8B_{MSY} for t=2022. Boxplots show the 0.05, 0.25, 0.5, 0.75 and 0.95 quantiles from the MCMC posterior projections.*

Yellowtail Rockfish

The most recent stock assessment (2014) is publicly available on the CSAS website (Science Advisory Report 2015/010, Proceedings 2015/020).

3. Management

i) Inshore Rockfish

Inside and Outside Yelloweye Rockfish still fall under a rebuilding plan that is documented in Appendix 9 of the 2020 IFMP (https://waves-vagues.dfo-mpo.gc.ca/Library/40765167.pdf). Most inshore rockfish are managed with Total Allowable Catches under the Individual Transferable Quota system.

Commercial TACs and landings for 2020 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2020 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

Recreationally, the retention of Yelloweye Rockfish in inside and outside waters is prohibited. In outside waters, recreational fishers are limited to 3 rockfishes daily, only 1 of which may be a China, Tiger or Quillback Rockfish; possession limits are twice the daily limits, and the season runs from April 1 – November 15. In inside waters (4B), recreational fishers can take 1 rockfish daily, possession limits are twice the daily limit and the season runs from May 1 – October 1. A condition of the recreational license is that: “Anglers in vessels shall immediately return all rockfish that are not being retained to the water and to a similar depth from which they were caught by use of an inverted weighted barbless hook or other purpose-built descender device.”

ii) Offshore Rockfish

Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

I. Thornyheads

1. Research

Data collection continued in 2021 through trawl and longline surveys. With the suspension of the At Sea Observer program due to COVID-19, there was no commercial sampling.

2. Assessment

Longspine Thornyhead was designated ‘Special Concern’ by COSEWIC in 2007. An assessment has been requested but not yet scheduled. In 2022, the WCVI synoptic survey will be adding 10-20 tows in a deep stratum (800-1300 m), specifically to assess/sample Longspine Thornyhead.

Shortspine Thornyhead was assessed in 2015 (Research Document 2017/015; Science Advisory Report 2016/016; , Proceedings 2016/040).

3. Management

Longspine and Shortspine Thornyhead are both IVQ species. Commercial TACs and landings for 2020 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2020 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

J. Sablefish

The Sablefish management system in British Columbia is an adaptive approach in which three pillars of science – hypotheses, empirical data, and simulation - play a central role in defining management objectives and in assessing management performance relative to those objectives via Management Strategy Evaluation (MSE).

The MSE process is used to provide management advice each year that supplements the stock assessment process by providing a way to explicitly evaluate harvest strategies given a set of stock and fishery objectives and uncertainties/hypotheses about Sablefish fishery and resource dynamics. Fisheries and Oceans Canada (DFO) and Wild Canadian Sablefish Ltd. have collaborated for many years on fisheries management and scientific research with the aim of further supporting effective assessment and co-management of the Sablefish stock and the fishery in Canadian Pacific waters.

1. Research

Collection of biological data continued in 2021 through trawl and trap surveys. With the suspension of the At Sea Observer program due to COVID-19, there has been no commercial sampling from the trawl fishery since March 2020. However, commercial sampling has continued in the directed trap and longline fisheries through a voluntary biosampling program supported by industry. A head-only sampling program was initiated in 2018 whereby commercial fishers follow specific instructions to collect specimens at stepped intervals of their overall cumulative catch for the year (ie., every 50,000 lbs). Males and females are marked by cutting the operculum and then the heads are frozen to be sampled on shore. Unpublished work has shown a strong relationship between head morphometric measurements and fork length, so frozen head samples are measured on shore to collect estimated length data. Otoliths are also retrieved from frozen heads for ageing. A technical report is being developed for 2022 to describe this new sampling procedure and document the relationship between head morphometrics and fork length.

2. Assessment

Sablefish stock status is regularly evaluated via the MSE process. An operating model (i.e., representation of alternative hypotheses about ‘true’ Sablefish population dynamics) is used to simulate data for prospective testing of management procedure performance relative to stock and fishery objectives. The current Sablefish operating model (OM) was revised in 2015/16 to account for potential structural model misspecification and lack-of-fit to key observations recognized in previous models (DFO 2016). Specific modifications included: (i) changing from an age-/growth- group operating model to a two-sex/age-structured model to account for differences in growth, mortality, and maturation of male and female Sablefish, (ii) adjusting model age- proportions via an ageing error matrix, (iii) testing time-varying selectivity models, and (iv) revising the multivariate-logistic age composition likelihood to reduce model sensitivity to small age proportions. These structural revisions to the operating model improved fits to age-composition and at-sea release data that were not well-fit by the previous operating model. Accounting for ageing errors improved the time-series estimates of age-1 Sablefish recruitment by reducing the unrealistic auto-correlation present in the previous model results. The resulting estimates clearly indicate strong year classes of Sablefish that are similar in timing and magnitude to estimates for the Gulf of Alaska. Two unanticipated results were that (i) time-varying selectivity parameters were not estimable (or necessarily helpful) despite informative prior information from tagging and (ii) improved recruitment estimates helped to explain the scale and temporal pattern of at-sea release in the trawl fishery. The latter finding represents a major improvement in the ability to assess regulations (e.g., size limits) and incentives aimed at reducing at-sea releases in all fisheries.

The status of the Sablefish stock is judged on the scale of the OM which was last updated in 2019 (DFO 2019). Based on the 2019 assessment, the current point estimate of Sablefish spawning stock biomass in Canada is 16,300 t. This spawning biomass is at the transition from the Cautious to Healthy zones under the DFO FPA Framework (i.e., $B_{2018}/B_{MSY} = 0.8$). The updated stock status of Canadian Sablefish depended on the absolute size of the 2015-year class, the raw estimate of this which was about eight times the historical average. This created the impression of the largest recorded recruitment from one of the lowest spawning biomasses ever observed in Canada. However, this estimated recruitment is highly uncertain, and both the timing and magnitude of the year-class size should be better estimated as several more years of fishery and survey data accumulate.

In 2019 the updated operating model was used to generate simulated data to test the current and alternative management procedures (MPs). The joint posterior distribution of spawning biomass and stock-recruitment steepness was used to generate five scenarios that captured a range of hypotheses related to current spawning biomass and productivity. These feedback simulations showed that the current MP (no limits on at-sea releases) meets biological objectives but ranked near the bottom in terms of catch performance and revenues compared to MPs with at-sea release management measures. A no size limit (i.e., full retention) MP performed best for both biological and fishery objectives, followed by MPs that included caps on sub-legal releases. These simulations also showed that the largest conservation risk is tuning the maximum target harvest rate in MPs assuming large 2015 recruitment, but then it fails to materialize.

The revised operating model continues to assume that the BC Sablefish stock is a closed population, despite evidence of movements among Sablefish stocks in Alaska and US waters south of BC (Hanselman et al. 2014) and little genetic evidence of population structure across these management regions (Jasonowicz et al. 2017). These movements may have implications for the assumptions made about Sablefish stock dynamics in BC (i.e., recruitment, productivity) that are not currently captured by the revised OM or reflected in MP performance evaluations. The collaboration between DFO, NOAA and ADFG identified above in the research section is working towards the development of a coastwide Sablefish OM to understand the potential consequences of the mismatch between Sablefish stock structure and management by simulation testing current, and potential future, MPs to quantify their performance against a range of conservation and fishery objectives.

The next scheduled update to the BC Sablefish operating model is November 2022, at which time the operating model will be updated with new data and transitioned to a new modelling platform. A comparison of the performance of the current Sablefish management procedure with a re-tuned version of the current procedure given updated estimates of key management parameters (F_{MSY}, B_{MSY}) will also be completed as part of the update. A more thorough simulation-evaluation of a wider range of management procedures based on the updated operating model is scheduled for 2023/24.

Literature Cited:

Cox, S.P., Kronlund, A.R., Lacko, L. 2011. Management procedures for the multi-gear sablefish (Anoplopoma fimbria) fishery in British Columbia, Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/063. viii + 45 p.

DFO. 2016. A revised operating model for Sablefish (Anoplopoma fimbria) in British Columbia, Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/015.

DFO. 2019. DFO. 2019. Evaluating the robustness of candidate management procedures in the BC Sablefish (Anoplopoma fibria) fishery for 2019-2020. DFO Can. Sci. Advis. Sec. Sci. Resp. 2019/999.

Hanselman, D.H., Heifetz, J., Echave, K.B. and Dressel, S.C., 2014. Move it or lose it: movement and mortality of sablefish tagged in Alaska. Canadian journal of fisheries and aquatic sciences, 72(2), pp.238-251.

Jasonowicz, A.J., Goetz, F.W., Goetz, G.W. and Nichols, K.M., 2016. Love the one you’re with: genomic evidence of panmixia in the sablefish (Anoplopoma fimbria). Canadian Journal of Fisheries and Aquatic Sciences, 74(3), pp.377-387.

3. Management

The MP that is currently in place for the Canadian Sablefish fishery was last evaluated in 2019 through the Sablefish MSE (see Assessment section above). This MP is based on a surplus production model fit to time-series observations of total landed catch, and the fishery independent survey CPUE, to forecast Sablefish biomass for the coming year. The surplus production model outputs are then inputs to a harvest control rule to calculate the recommended catch of legal Sablefish in a given year. This MP includes a 3-year phased-in period to a new maximum target harvest rate of 5.5% in 2022.

Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

K. Lingcod

1. Research

Data collection continued in 2021 through trawl and longline surveys and recreational creel surveys. With the suspension of the At Sea Observer program due to COVID-19, there was no commercial sampling. Additional biological samples (length, weight, sex, maturity and fins for ageing) were collected on the Outside HBLL survey done in collaboration with industry. We are currently preparing fins for aging in order to inform survey selectivity in our next stock assessment. We are also collaborating with the Sclerochronology lab at PBS by collecting paired otolith and fin rays on our surveys in order to compare ageing structures.

2. Assessment

Inside, the waters within the Strait of Georgia, and Outside, the rest of the BC Coast, Lingcod populations are assessed and managed as separate units. Outside Lingcod were scheduled to be assessed in the spring of 2019; however, the assessment has been pushed back due to other program demands as well as the desire to have some age-data to inform the catchability of the longline surveys. Fins collected on the IPHC, trawl surveys and Outside HBLL surveys are currently being processed. Inside Lingcod were last assessed in 2014.

3. Management

Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

L. Atka Mackerel

The distribution of Atka mackerel does not extend into the Canadian zone.

M. Flatfish

1. Research

Ongoing data collection in support of the flatfish research program, inclusive of Arrowtooth Flounder, Petrale Sole, Southern Rock Sole, Dover Sole, and English Sole continued in 2021 through surveys. With the suspension of the At Sea Observer program due to COVID-19, there was no commercial sampling after March 2020.

2. Assessment

Arrowtooth Flounder

Arrowtooth Flounder was last assessed in 2016. The final assessment was finalized and published through the Canadian Science Advice Secretariat (CSAS) in 2017. The research document and science advisory report are available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2017/2017_025-eng.html and https://waves-vagues.dfo-mpo.gc.ca/Library/365131.pdf.

Concerns expressed by industry participants regarding localized depletion on several the historic fishing grounds have led to a request from fisheries management for an updated assessment. Efforts are underway to deliver that assessment.

Petrale Sole

Petrale Sole was last assessed in 2007. In response to a request for updated harvest advice from fishery managers, aging of otoliths was completed in 2020. Planning is currently underway to deliver an updated assessment.

Southern Rock Sole

Southern Rock sole was last assessed in 2013. No request for updated advice has been received, but aging of otoliths was undertaken in 2019 in anticipation of an updated assessment.

Dover Sole

Dover sole was last assessed in 1999. Aging of otoliths was completed in 2020 in anticipation of an updated assessment.

English Sole

English sole was also last assessed in 2007. No request for updated advice has been received, but aging of otoliths is scheduled for 2021/22 in anticipation of an updated assessment.

3. Management

Arrowtooth Flounder, Petrale Sole, Southern Rock Sole, Dover sole, and English Sole are all managed by annual coastwide or area specific TACs and harvested primarily by the IVQ multi-species bottom trawl fishery. Commercial TACs and landings for 2021 are provided in Appendix 1. To support groundfish research and account for unavoidable mortality incurred during the 2021 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 1 for details.

N. Pacific Halibut & IPHC Activities

Biological data were collected in 2021 on trawl and longline surveys. With the suspension of the At Sea Observer program (ASOP) due to COVID-19, there has been no commercial sampling since April 2020. Current trawl-based halibut mortality is estimated using area-based average weights that were determined using historical ASOP data. DFO is currently working with industry reps and service providers to develop a biosampling program to address gaps created from the suspension of ASOP; halibut length sampling will be considered along with other species in its development.

Commercial TACs and landings for 2021 are provided in Appendix 1.

O. Other Groundfish Species

Nothing to report at this time.

V. Ecosystem Studies

A. Data-limited Species

The Fisheries and Oceans Canada (DFO) Sustainable Fisheries Framework (DFO 2009) lays the foundation for an ecosystem-based and precautionary approach to fisheries management that enables continued productivity of Canada's fisheries.

In recent decades, DFO groundfish stock assessments have focused on data-rich species, resulting in a subset of stocks with full stock assessments, while many stocks with less informative data remain unassessed. Consequently, quotas assigned to rarely assessed or unassessed stocks may result in catch rates that are too high, may restrict harvesting opportunities to catch target species, or may result in failure for fisheries to meet seafood certification standards.

Starting in 2015, work was initiated to address this gap. Instead of a tiered approach as is used in other jurisdictions around the world, the approach eventually adopted for BC groundfish stocks considers data-richness on a continuous scale and focuses on simulation testing multiple management procedures on a stock-by-stock basis to choose an approach that best meets fisheries risk objectives.

Groundfish Data Synopsis

The first phase consisted of a groundfish data synopsis, as described in the 2019 TSC report. The synopsis provides a visual snapshot of temporal trends and spatial distributions of commercial catches and survey indices, growth and maturity characteristics, and data availability for over 100 BC groundfish stocks. The synopsis was peer reviewed through a Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) process in 2018 and published in 2019 as a Research Document (Anderson et al. 2019). An article described the approach to a wider audience (Anderson et al. 2020). An updated synopsis with all available data since the original Research Document will be published shortly (DFO, in press). The synopsis is available on GitHub: https://github.com/pbs-assess/gfsynopsis.

Management Procedure Framework

The second phase is the development of a framework for applying a management-procedure (MP) approach to data-limited groundfish stocks in British Columbia. Data-limited stocks are defined here as those with insufficient data to reliably estimate stock status or estimate abundance or productivity with conventional stock assessment methods such as statistical catch-at-age models. The MP framework was reviewed through a CSAS RPR process in June 2020. Specifically, the MP framework tests the performance of a suite of data-limited management procedures against conservation and fishery objectives. This is done using an existing closed-loop simulation framework that includes building appropriate operating models, testing suites of management procedures, and determining management procedures that best meet conservation and fishery objectives for one or more case-study stocks. The framework uses the open source R package DLMtool (Carruthers and Hordyk 2018), developed at the University of British Columbia, in partial partnership with DFO.

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VI. Other related studies

Nothing to report at this time.

VII. Publications

A. Primary Publications

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B. Other Publications

C.

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Starr, P.J. and **Haigh, R**. 2021c. Widow Rockfish (Sebastes entomelas) stock assessment for British Columbia in 2019. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/039. vi + 238 p.

Appendix 1: British Columbia commercial groundfish TACs, landings, and research allocations for 2021.

Table 1. British Columbia Groundfish Total Allowable Catch (TAC) and commercial landings in metric tonnes (t) for the 2021 fishing year. Except where noted, TACs are from the 2021 Groundfish Integrated Fisheries Management Plan (https://waves-vagues.dfo-mpo.gc.ca/Library/40990151.pdf). Landings are from the Dockside Monitoring Program.

Species or Species Group	**Trawl Sector (t)**		**Combined Line Sectors (t)**		**Total (t)**	
	TAC	**Landings**	**TAC**	**Landings**	**TAC**	**Landings**
Sharks And Skates						
North Pacific Spiny Dogfish	4,480	88	9,520	0	14,000	88
Big Skate	914	178	118	9	1,032	187
Longnose Skate	195	91	263	54	458	145
Pacific Cod	1,250	708	0	7	1,250	715
Walleye Pollock	4,935	8,588	0	0	4,935	8.588
Pacific Hake [1]	7,000 gulf & 104,480 offshore	64,757	0	0	111,480	64,757
Rockfishes						
Rougheye/Blackspotted Rockfish Complex	614	452	463	165	1,077	617
Pacific Ocean Perch	5,192	2,727	1	0	5,193	2,727
Redbanded Rockfish	295	148	284	180	579	328
Shortraker Rockfish	126	40	111	78	237	118
Silvergray Rockfish	1,945	1,355	254	31	2,199	1,386
Widow Rockfish	2,500	2,264	46	0	2,546	2,264
Yellowtail Rockfish	5,440	5,082	60	4	5,500	5,086
Quillback Rockfish	4	1	147	84	151	85
Bocaccio	414	606	0	8	414	614
Canary Rockfish	965	764	135	9	1,100	773
Redstripe Rockfish	1,550	702	43	0	1,593	702
Yellowmouth Rockfish	2,364	1207	78	5	2,442	1,212
Yelloweye Rockfish	3	6	126	128	129	134
Copper, China, And Tiger Rockfish	1	1	60.3	38	61.3	39

Table 1. Continued.

Species or Species Group	Trawl Sector (t)		Combined Line Sectors (t)		Total (t)	
	TAC	Landings	TAC	Landings	TAC	Landings
Thornyheads						
Shortspine Thornyhead	736	170	34	73	770	243
Longspine Thornyhead	405	6	20	0	425	6
Sablefish	241	253	2,510	2,705	2,751	2,958
Lingcod	2572	514	1168	759	3,740	1,273
Flatfishes						
Arrowtooth Flounder	5000	3,676	0	0	5,000	3,676
Petrale Sole	900	765	0	0	900	765
Southern Rock Sole	1,552	248	0	0	1,552	248
Dover Sole	3,073	1,662	0	0	3,073	1,662
English Sole	822	379	0	0	822	379
Pacific Halibut [2,3]	454	6	2,350	2,396	2,804	2,402

[1] *Hake TAC provided by Chris Grandin and Deirdre Finn*

[2] *Halibut weights are dressed, head-off, where dressed, head-off weight = round weight * 0.75.*

[3]*The groundfish trawl fishery has a bycatch mortality cap of 454 tonnes that is not part of the allocated commercial TAC. Halibut caught while fishing under the authority of a groundfish trawl licence cannot be retained and must be returned to the water as quickly as possible*

Table 2. British Columbia Groundfish research allocations in metric tonnes (t) for 2021. Except where noted, research allocations are deducted from the fish available to the commercial fishery by sector prior to the definition of commercial TACs. Values are copied from the 2021 Groundfish Integrated Fisheries Management Plan (https://waves-vagues.dfo-mpo.gc.ca/Library/40990151.pdf).

Species or Species Group	Trawl surveys (t)	Longline surveys (t)	Sablefish surveys (t)	Total (t)
Sharks And Skates				
North Pacific Spiny Dogfish	1.1	--	--	1.1
Big Skate	0.8	--	--	0.8
Longnose Skate	0.5	--	--	0.5
Pacific Cod	2.1	--	--	2.1
Walleye Pollock	3	--	--	3
Pacific Hake	0.2	--	--	0.2
Rockfishes				
Rougheye/Blackspotted Rockfish Complex	1.0	20.6	--	21.6
Pacific Ocean Perch	20.8	--	--	20.8
Redbanded Rockfish	1.7	11.6	--	13.3
Shortraker Rockfish	0.0	5.4	--	5.4
Silvergray Rockfish	9.5	12.7	--	22.2
Widow Rockfish	0.1	--	--	0.1
Yellowtail Rockfish	2.3	2.0	--	4.3
Quillback Rockfish	0.4	5.8	--	6.2
Bocaccio	0.6	--	--	0.6
Canary Rockfish	1.8	6.5	--	8.3
Redstripe Rockfish	1.1	--	--	1.1
Yellowmouth Rockfish	5.9	3.0	--	8.9
Yelloweye Rockfish	0.0	16.6	--	16.6
Copper, China, And Tiger Rockfish	0.2	2.8	--	3.0
Thornyheads				
Shortspine Thornyhead	1.3	0.9	--	2.2
Longspine Thornyhead	0.0	0.0	--	0.0

Table 2. Continued.

Species or Species Group	**Trawl surveys (t)**	**Longline surveys (t)**	**Sablefish surveys (t)**	**Total (t)**
Sablefish	3	0.4	85	88.4
Lingcod	0.4	3.6	--	4.0
Flatfishes				
Arrowtooth Flounder	12.7	0.0	--	12.7
Petrale Sole	0.7	--	--	0.7
Southern Rock Sole	1.7	--	--	1.7
Dover Sole	5.7	--	--	5.7
English Sole	6.7	--	--	6.7
Pacific Halibut [1]	2.5	27.2	--	29.7

[1] The halibut poundage for the groundfish trawl survey is part of the trawl fishery's halibut bycatch mortality cap. The groundfish trawl fishery has a bycatch mortality cap of 454 tonnes that is not part of the allocated commercial TAC.

TSC Agency Reports – IPHC 2022

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I. Agency Overview

Management of the Pacific halibut resource and fishery has been the responsibility of the International Pacific Halibut Commission (IPHC) since its creation in 1923, see Figure 1 for a map of the IPHC Convention Area. Assessing, forecasting, and managing the resource and fishery requires accurate assessments, continuous monitoring, and research responsive to the needs of managers and stakeholders. The fishery for Pacific halibut (*Hippoglossus stenolepis*) is one of the most valuable and geographically largest in the northeast Pacific Ocean. Industry participants from Canada and the United States of America have prosecuted the modern fishery and have depended upon the resource since the 1880s. Annual removals have been as high as 100 million pounds, and the long-term average of removals is 64 million pounds.

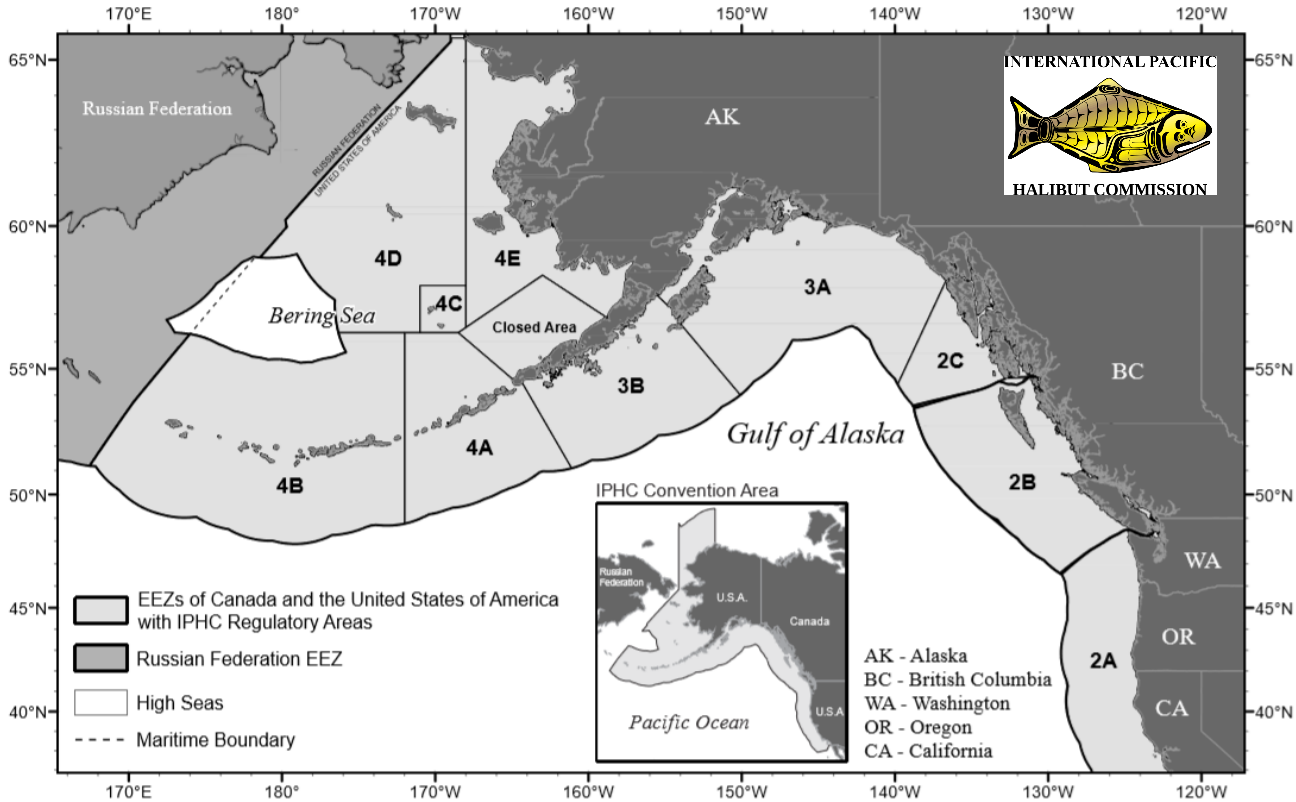


Figure 1. Map of the IPHC Convention Area and IPHC Regulatory Areas.

Staffing Updates: see https://www.iphc.int/locations/map.

II. Fishery-Independent Setline Survey (FISS)

The IPHC's Fishery-Independent Setline Survey (FISS) provides catch information and biological data on Pacific halibut (*Hippoglossus stenolepis)* that are collected independently of the commercial fishery. These data, which are collected using standardized methods, bait and gear during the summer of each calendar year, provide an important comparison with data collected from the commercial fishery. The directed commercial fishery is variable in its gear composition and distribution of fishing effort over time, and presents a broad spatial and temporal sampling of the stock. Pacific halibut biological data collected on the FISS (e.g. the size, age, and sex composition) are used to monitor changes in biomass, growth, and mortality in adult and sub-adult components of the Pacific halibut population. In addition, records of non-target species caught during FISS operations provide insight into bait competition, rate of bait attacks, and serve as an index of abundance over time, making them valuable to the assessment, management, and avoidance of non-target species. In addition, oceanographic data is collected at each station (please see section in Other Ongoing Data Collection Programs).

For details on FISS work conducted in 2021, please refer to the following paper *IPHC Fishery-Independent Setline Survey (FISS) design and implementation in 2021*.

III. Reserves – N/A

IV. Review of Agency Groundfish Research, Assessment, and Management

A. Pacific halibut and IPHC activities

1. Research

The primary biological research activities at the IPHC that follow Commission objectives and selected for their important management implications are identified and described in the IPHC Five-Year Biological and Ecosystem Science Research Plan for the period 2017-21:

Overview of research activities in 2021 and planned for 2022

1. Migration. Knowledge of Pacific halibut migration throughout all life stages is necessary in order to gain a complete understanding of stock distribution and the factors that influence it.

   1.1. Larval distribution and connectivity between the Gulf of Alaska and Bering Sea. Knowledge of the dispersal of Pacific halibut larvae and subsequent migration of young juveniles has remained elusive because traditional tagging methods are not effective on these life stages due to the small size of the animals. This larval connectivity project, in cooperation with NOAA EcoFOCI, used two recently developed modeling approaches to estimate dispersal and migration pathways of larval and young juvenile Pacific halibut in order to better understand the connectivity of populations between the Gulf of Alaska and Bering Sea and within each of these two ocean basins (Sadorus et al. *Fish Oceanogr.* 2021. 30:174-193). Additional studies are currently planned to investigate the potential of Pacific halibut larvae to be successfully delivered from offshore spawning sites to potential inshore settlement habitats identified by the IPHC Secretariat, under different climatic regimes.

   1.2. Wire tagging of U32 Pacific halibut. The patterns of movement of Pacific halibut among IPHC Regulatory Areas have important implications for management of the Pacific halibut fishery. The IPHC Secretariat has undertaken a long-term study of the migratory behavior of Pacific halibut through the use of externally visible tags (wire tags) on captured and released fish that must be retrieved and returned by workers in the fishing industry. In 2015, with the goal of gaining additional insight into movement and growth of young Pacific halibut (less than 32 inches [82 cm]; U32), the IPHC began wire-tagging small Pacific halibut encountered on the National Marine Fisheries Service (NMFS) groundfish trawl survey and, beginning in 2016, on the IPHC FISS. In 2021, 2,534 Pacific halibut were tagged and released on the IPHC FISS but no tagging was conducted in the NMFS groundfish trawl surveys. Therefore, a total of 6,111 U32 Pacific halibut have been wire tagged and released on the IPHC FISS and 126 of those have been recovered to date. In the NMFS groundfish trawl surveys through 2019, a total of 6,536 tags have been released and, to date, 76 tags have been recovered.

2. Reproduction. Efforts at IPHC are currently underway to address two critical issues in stock assessment: updated maturity estimations and new fecundity estimations.

   2.1. Maturity estimations. Recent sensitivity analyses have shown the importance of changes in spawning output due to skip spawning and/or changes in maturity schedules for stock assessment (Stewart and Hicks, 2020). These results highlight the need for a better understanding of factors influencing reproductive biology and success for Pacific halibut. In order to fill existing knowledge gaps related to the reproductive biology of female Pacific halibut, research efforts are devoted to characterize female maturity in this species. Specific objectives of current studies include: 1) accurate description of oocyte developmental stages and their use to classify female maturity stages; 2) characterization of seasonal changes in female reproductive development; 3) revision of current estimates of female age-at-maturity; 4) comparison of macroscopic (based on field observations) and microscopic (based on histological assessment) maturity stages and revision of maturity criteria, and 5) investigations on female fecundity.

   The IPHC Secretariat has described for the first time the different oocyte stages that are present in the ovary of female Pacific halibut and how these are used to classify females histologically to specific maturity stages (Fish et al. *J. Fish Biol*. 2020. 97:1880-1885). In brief, eight different oocyte developmental stages have been described, from early primary growth oocytes until preovulatory oocytes, and their size and morphological characteristics established. Maturity classification was determined by assigning maturity status to the most advanced oocyte developmental stage present in ovarian tissue sections and seven different microscopic maturity stages were established. Analysis of oocyte size frequency distribution among the seven different maturity stages provided evidence for the group-synchronous pattern of oocyte development and for the determinate fecundity reproductive strategy in female Pacific halibut. The results of this study set the stage for recently completed study on temporal changes in maturity through histological assessment of ovarian samples collected over an entire annual reproductive cycle. Our results confirm that the peak period of spawning for Pacific halibut in the central Gulf of Alaska takes place in January and February. Analysis of the temporal changes in female reproductive phase shows that spawning capable females are detected as early as August, therefore marking the beginning of the spawning capable reproductive phase (Fish et al. *Front. Mar. Sci*. 2022. doi: 10.3389/fmars.2022.801759). For stock assessment purposes, the spawning capable reproductive phase comprises females that are considered mature. Importantly, the detection of spawning capable females in July-August is conducive to conducting routine histological assessments of female maturity during the IPHC's FISS sample collection period (i.e. June to late August) that will take place in 2022.

   2.2. Fecundity assessment. The IPHC Secretariat is planning the collection of ovarian samples in 2023 for fecundity assessment using the auto-diametric method.

3. Growth. Research activities conducted in the Research Area on Growth aim at providing information on somatic growth processes driving size-at-age in Pacific halibut. The relevance of research outcomes from these activities for stock assessment resides, first, in their ability to inform yield-per-recruit and other spatial evaluations for productivity that support mortality limit-setting, and, second, in that they may provide covariates for projecting short-term size-at-age and may help delineate between fishery and environmental effects, thereby informing appropriate management responses. The relevance of these research outcomes for the management and strategy evaluation process is in the improvement of the simulation of variability and to allow for scenarios investigating climate change.

   The IPHC Secretariat has conducted studies aimed at elucidating the drivers of somatic growth leading to the decline in size-at-age by investigating the physiological mechanisms that contribute to growth changes in the Pacific halibut. The two main objectives of these studies have been: 1) the identification and validation of physiological markers for somatic growth; and 2) the application of molecular growth markers for evaluating growth patterns in the Pacific halibut population. The IPHC Secretariat has completed a study funded by the North Pacific Research Board (NPRB Project No. 1704; 2017-2020) to identify relevant physiological markers for somatic growth. This study resulted in the identification of 23 markers in skeletal muscle that were indicative of temperature-induced growth suppression and 10 markers in skeletal muscle that were indicative of temperature-induced growth stimulation. These markers represented genes and proteins that changed both their mRNA expression levels and abundance levels in skeletal muscle, respectively, in parallel with changes in the growth rate of Pacific halibut. A manuscript describing the results of this study is currently in preparation (Planas et al., In Preparation).

   In addition to temperature-induced growth manipulations, the IPHC Secretariat has conducted similar studies as part of NPRB Project No. 1704 to identify physiological growth markers that respond to density- and stress-induced growth manipulations. The respective justifications for these studies are that (1) population dynamics of the Pacific halibut stock could be affected by fish density, and (2) stress responses associated with capture and release of discarded Pacific halibut may affect subsequent feeding behavior and growth. Investigations related to the effects of density and stress exposure are still underway.

4. Discard Mortality Rates (DMRs) and Survival Assessment. Information on all Pacific halibut removals is integrated by the IPHC Secretariat, providing annual estimates of total mortality from all sources for its stock assessment. Bycatch and wastage of Pacific halibut, as defined by the incidental catch of fish in non-target fisheries and by the mortality that occurs in the directed fishery (i.e. fish discarded for sublegal size or for regulatory reasons), respectively, represent sources of mortality that can result in significant reductions in exploitable yield in the directed fishery. Given that the incidental mortality from the commercial Pacific halibut fisheries and bycatch fisheries is included as part of the total removals that are accounted for in stock assessment, changes in the estimates of incidental mortality will influence the output of the stock assessment and, consequently, the catch levels of the directed fishery. For this reason, the IPHC Secretariat is conducting investigations on the effects of capture

and release on survival and on providing experimentally-derived estimates of DMRs in the directed longline and guided recreational Pacific halibut fisheries.

4.1. Evaluation of the effects of hook release techniques on injury levels and association with the physiological condition and survival of longline-caught Pacific halibut. The IPHC Secretariat, with funding by a grant from the Saltonstall-Kennedy Grant Program NOAA (NA17NMF4270240; 2017-2020), has conducted studies to evaluate the effects of hook release techniques on injury levels, their association with the physiological condition of captured Pacific halibut and, importantly, has generated experimentally-derived estimates of DMR in the directed longline fishery. Results on individual survival outcomes for Pacific halibut released in excellent viability condition indicate a range of DMRs between 4.2% (minimum) and 8.4% (maximum), that is consistent with the currently-applied DMR value of 3.5% (Loher et al. *North Am. J. Fish. Manage*. 2022. 42:37-49).

4.2. Discard mortality rates of Pacific halibut in the charter recreational fishery. The IPHC Secretariat is conducting a research project to better characterize the nature of charter recreational fisheries with the ultimate goal of better understanding discard practices relative to that which is employed in the directed longline fishery. This project has received funding from the National Fish and Wildlife Foundation (NFWF Project No. 61484) and the North Pacific Research Board (NPRB Project No. 2009). The experimental field components of this research project took place in Sitka, Alaska (IPHC Regulatory Area 2C) from 21-27 May 2021, and in Seward, Alaska (IPHC Regulatory Area 3A) from 11-16 June 2021. In brief, Pacific halibut were captured with the use of 12/0 and 16/0 circle hooks that best reflect the gear currently used and fish sizes were targeted to cover the Pacific halibut size distribution recorded by ADFG on an annual basis. All injuries were documented, along with length, weight, somatic fat measurements (using the Distell Fatmeter), and a blood sample (for measuring the levels of physiological stress indicators in plasma) was collected for each fish, before they were tagged and released. Environmental information on temperature (bottom/surface) and time (fight time, time on deck) was also tracked. Eighty (80) Pacific halibut of Excellent release viability were fitted with satellite pop-up archival tags (sPAT) for near-term survival estimation in IPHC Regulatory Area 3A. Analyses of survival data and levels of blood stress indicators are currently underway.

5. Genetics and genomics. The IPHC Secretariat is conducting studies that incorporate genomics approaches in order to produce useful information on population structure and distribution and connectivity of Pacific halibut.

5.1. Investigate the genetic structure of the Pacific halibut population in the North-eastern Pacific Ocean. Understanding population structure is imperative for sound management and conservation of natural resources. Pacific halibut in Canadian and USA waters are managed by the IPHC as a single coastwide unit stock since 2006. The rationale behind this management approach is based on our current knowledge of the highly migratory nature of Pacific halibut as assessed by tagging studies and of past analyses of genetic population structure that failed to demonstrate significant differentiation in the North-eastern Pacific Ocean population of Pacific halibut by allozyme and small-scale microsatellite analyses. However, more recent studies have reported slight genetic population structure on the basis of genetic analysis conducted with larger sets of microsatellites suggesting that Pacific halibut captured in the Aleutian Islands may be genetically distinct from other areas. These findings of subtle genetic structure in the Aleutian Island chain area are attributed to limited movement of adults and exchange of larvae between this area and the rest of the stock due to the presence of oceanographic barriers to larval and adult dispersal (i.e. Amchitka Pass) that could represent barriers to gene flow. Unfortunately, previous genetic studies suggesting subtle genetic structure were conducted based on a relatively limited set of microsatellite markers and, importantly, using genetic samples collected in the summer (i.e. non-spawning season) that may not be representative of the local spawning population. With the collection of winter (i.e. spawning season) genetic samples in the Aleutian Islands by the IPHC in early 2020, a collection of winter samples from 5 different geographic areas across the North-eastern Pacific Ocean (i.e. British Columbia, Central Gulf of Alaska, Bering Sea, Central and Western Aleutian Islands) is now being used to re-examine the genetic structure of the Pacific halibut population at an unprecedented detail using a low-coverage whole genome resequencing approach and the recently sequenced Pacific halibut genome. The results from these ongoing genomic studies will provide important information on spawning structure and, consequently, on the genetic baselines of source populations. Importantly, the results from these studies will provide management advice regarding the relative justifiability for considering the western Aleutians as a genetically-distinct substock. This work has recently received funding from the North Pacific Research Board (NPRB Project No. 2110).

<u>Other ongoing data collection projects</u>

In addition to specific research projects, the IPHC collects data each year through ongoing data collection projects that are funded separately, either as part of the FISS or as part of the directed commercial fishery data collection program. Ongoing data collections projects include the following:

IPHC Secretariat aboard National Marine Fisheries Service groundfish trawl surveys in the Gulf of Alaska, Bering Sea and Aleutian Islands

The National Oceanic and Atmospheric Administration (NOAA) Fisheries has conducted annual bottom trawl surveys on the eastern Bering Sea continental shelf since 1979 and the IPHC has participated in the survey on an annual basis since 1998 by directly sampling Pacific halibut from trawl survey catches. The IPHC has participated in the NOAA Fisheries Aleutian Islands trawl survey, which takes place every two years, since 2012. Alternating year by year with the Aleutian Islands trawl survey is the NOAA Fisheries Gulf of Alaska trawl survey, which IPHC has participated in since 1996. The IPHC uses the NOAA Fisheries trawl surveys to collect information on Pacific halibut that are not yet vulnerable to the gear used for the IPHC FISS or directed commercial fishery, and as an additional data source and verification tool for stock analysis. In addition, trawl survey information is useful as a forecasting tool for cohorts approaching recruitment into the FISS or directed commercial fishery.

Sampling of directed commercial landings

The IPHC positions Secretariat to sample the directed commercial landings for Pacific halibut in Alaska, British Columbia, Washington, and Oregon. Sampling of commercial landings involves collecting Pacific halibut otoliths, tissue samples (fin clips) for genetic sexing, fork lengths, weights, logbook information, and final landing weights.

The collected data are used in the stock assessment and other research. The collected otoliths provide age composition data and the tissue samples provide sex composition. Lengths and weight data, in combination with age data and sex data, provide size-at-age analyses by sex. Mean weights are combined with final landing weights to estimate catch in numbers. Logbook information provides weight per unit effort data, fishing location for the landed weight, and data for research projects. Finally, tags are collected to provide information on migration, exploitation rates, and natural mortality.

In addition to sampling the catch, other objectives include collecting recovered tags, and copying information from fishing logs along with the respective landed weights, for as many Pacific halibut trips as possible throughout the entire season.

Environmental data collection in the IPHC FISS

Since 2009, the IPHC has been collecting environmental data as water column profiles in each station sampled as part of the IPHC FISS. The data collected includes surface to depth profiles of pressure (depth), temperature, conductivity (salinity), dissolved oxygen, pH, and chlorophyl a concentration. For each year from 2009 until 2021 containing, environmental data, related metadata and maps of profiled FISS stations are publicly available on the IPHC website (https://www.iphc.int/datatest/data/water-column-profiler-data).

2. Assessment

The 2021 stock assessment produced the following scientific advice regarding the Pacific halibut stock:

> ***Sources of mortality****: In 2021, total Pacific mortality due to fishing increased to 37.66 million pounds (17,084 t) but remained below the 5-year average of 38.48 million pounds (17,456 t). Of that total, 88% comprised the retained catch, up from 84% in 2020.*
>
> ***Fishing intensity****: The 2021 fishing mortality corresponded to a point estimate of SPR = 46%; there is a 47% chance that fishing intensity exceeded the IPHC's current reference level of F43%. The Commission does not currently have a coastwide fishing intensity limit reference point.*
>
> ***Stock status*** *(spawning biomass): Current (beginning of 2022) female spawning biomass is estimated to be 191 million pounds (86,600 t), which corresponds to an 45% chance of being below the IPHC trigger reference point of SB30%, and less*

than a 1% chance of being below the IPHC limit reference point of SB20%. The stock is estimated to have declined by 17% since 2016 but is currently at 33% of the unfished state. Therefore, the stock is considered to be 'not overfished'. Projections indicate that mortality consistent with the interim management procedure reference fishing intensity (F43%) is likely to result in further declining biomass levels in the near future.

***Stock distribution**: The proportion of the coastwide stock represented by Biological Region 3 has increased sharply over 2020-21, reversing over a decade of steady decline. This trend occurs in tandem with declines in Biological Regions 2 and 4; however, all regions remain within the historical range observed from 1993-2021. These estimates have been updated and strongly informed by the comprehensive FISS design implemented in 2021.*

***Outlook**:* The projections for this assessment are more optimistic than those from the 2019 and 2020 assessments due to the increasing projected maturity of the 2012 year-class. This translates to a lower probability of stock decline for 2022 than in recent assessments as well as a decrease in this probability through 2023-24. There is greater than a 50% probability of stock decline in 2023 (55-64/100) for the entire range of SPR values from 40-46%, which include the status quo TCEY and the F43% reference level. The 2022 "3-year surplus" alternative, corresponds to a TCEY of 38.0 million pounds (~17,240 t), and a projected SPR of 48% (credible interval 32-63%). At the reference level (a projected SPR of 43%), the probability of spawning biomass decline from 2022 to 2023 is 59%, decreasing to 55% in three years, as the 2012 cohort matures. The one-year risk of the stock dropping below SB30% ranges from 43% at the F46% level to 45% at the F40% level of fishing intensity.*

** TCEY stands for Total Constant Exploitation Yield*

For more information on the 2020 stock assessment and the fishery status, please refer to paper IPHC-2022-AM098-10 at the IPHC website.

3. Management

The IPHC completed the 98th Session of the IPHC Annual Meeting (AM098) on 28 January 2022 with decisions on total mortality limits, fishery limits, fishing period dates, and other fishery regulation changes. A total of 199 individuals attended the meeting via the electronic platform.

Meeting documents, presentations, recordings of the sessions, and the report of the meeting are available on the AM097 meeting page at the IPHC website: 98th Session of the IPHC Annual Meeting (AM098). Decisions arising from this meeting, including management decisions, are documented in the following report: Report of the 98th Session of the IPHC Annual Meeting (AM098).

Mortality limits

Mortality limits adopted for 2022 added up to a 5.7% increase in comparison with the last year (Table 1).

Table 1: Mortality limits for 2021 and 2022.

IPHC Regulatory Area	2021 TCEY (Mlbs)	2022 TCEY (Mlbs)	Change
2A	1.65	1.65	0
2B	7.00	7.56	8.0%
2C	5.80	5.91	1.9%
3A	14.00	14.55	3.9%
3B	3.12	3.90	25.0%
4A	2.05	2.10	2.4%
4B	1.40	1.45	3.6%
4CDE	3.98	4.10	3.0%
IPHC Convention Area	**39.00**	**41.22**	**5.7%**

Other Actions

Management Strategy Evaluation: https://www.iphc.int/the-commission/harvest-strategy-policy

The Management Strategy Evaluation (MSE) at the IPHC completed an evaluation in 2021 of management procedures (MPs) relative to the coastwide scale and distribution of the TCEY to IPHC Regulatory Areas for the Pacific halibut fishery using a recently developed framework. The development of this MSE framework supports the evaluation of the trade-offs between fisheries management scenarios.

Economic research: https://www.iphc.int/management/science-and-research/economic-research

The goal of the IPHC economic research was to provide stakeholders with an accurate and all-sectors-encompassing assessment of the socioeconomic impact of the Pacific halibut resource that includes the full scope of Pacific halibut's contribution to regional economies of Canada and the United States. This research contributes to a wholesome approach to Pacific halibut management that is optimal from both biological and socioeconomic perspective, as mandated by the Convention.

Pacific Halibut Multiregional Economic Impact Assessment (PHMEIA) is a core product of the IPHC economic research. PHMEIA model describes economic interdependencies between sectors and regions to bring a better understanding of the role and importance of Pacific halibut resource in a regions' economies. The model details the within-region production structure of the Pacific halibut sectors (fishing, processing, charter) and accounts for economic activity generated through sectors that supply fishing vessels, processing plants, and charter businesses with inputs to production, by embedding Pacific halibut sectors into the model of the entire economy of Canada and the USA.

The PHMEIA results suggest that the revenue generated by Pacific halibut at the harvest stage accounts for only a fraction of economic activity that would be forgone if the resource was not available to fishers in the Pacific Northwest. In a typical year (based on 2019 data), one USD/CAD of Pacific halibut commercial landings was found to be linked to over four USD/CAD-worth economic activity in Canada and the United States and contributed USD/CAD 1.3 to households. In the recreational sector, one USD/CAD spent by recreational anglers was linked to USD/CAD 4.9 circulating in the economy and USD/CAD 0.7 impact on households. The total economic activity linked to assessed Pacific halibut sectors is estimated at about USD 1.0 billion (CAD 1.3 billion), and contribution to households at over USD 300 million (CAD 400 million), highlighting how important Pacific halibut is to regional economies. However, the 2020 results suggest that Pacific halibut contribution to households' income dropped by a quarter throughout the pandemic, demonstrating Pacific halibut sectors' exposure to external factors beyond stock condition.

V. Ecosystem Studies

[See details in the Research section on ongoing IPHC data collection projects above.]

VI. Publications

Fish, T., Wolf, N., Harris, B.P., Planas, J.V. (2020). A comprehensive description of oocyte developmental stages in Pacific halibut, Hippoglossus stenolepis. Journal of Fish Biology. 97:1880-1885. https://doi.org/10.1111/jfb.14551.

Fish, T., Wolf, N., Smeltz, T.S., Harris, B.P., Planas, J.V. (2022). Reproductive biology of female Pacific halibut (Hippoglossus stenolepis) in the Gulf of Alaska. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2022.801759.

Loher, T., Dykstra, C.L., Hicks, A.C., Stewart, I.J., Wolf, N., Harris, B.P. and Planas, J.V. (2022). Estimation of Postrelease Longline Mortality in Pacific Halibut Using Acceleration-Logging Tags. North American Journal of Fisheries Management. 42:37-49. https://doi.org/10.1002/nafm.10711

Sadorus, L., Goldstein, E., Webster, R., Stockhausen, W., Planas, J.V., Duffy-Anderson, J. (2021). Multiple life-stage connectivity of Pacific halibut (Hippoglossus stenolepis) across the Bering Sea and Gulf of Alaska. Fisheries Oceanography. 30:174-193. doi: https://doi.org/10.1111/fog.12512

Stewart, I., Hicks, A. (2020). Assessment of the Pacific halibut (Hippoglossus stenolepis) stock at the end of 2019. Meeting Doc. IPHC-2020-SA-01, 32 p. Int. Pac. Halibut Comm., Seattle, Washington, USA. [Available from https://iphc.int/uploads/pdf/sa/2020/iphc-2020-sa-01.pdf]

Northwest Fisheries Science Center

National Marine Fisheries Service

Agency Report to the Technical Subcommittee

of the Canada-U.S. Groundfish Committee

April 2022

I. Agency Overview

The Northwest Fisheries Science Center (NWFSC) provides scientific and technical support to the National Marine Fisheries Service (NMFS) for management and conservation of the Northwest region's marine and anadromous resources. The Center conducts research in cooperation with other federal and state agencies and academic institutions. Four divisions, Conservation Biology, Environmental and Fisheries Sciences, Fish Ecology, and Fishery Resource Analysis and Monitoring, conduct applied research to resolve problems that threaten marine resources or that deter their use. The Center's main facility and laboratories are located in Seattle. Other Center research facilities are located in Pasco, Big Beef Creek, and Manchester, Washington; Newport, Hammond, and Clatskanie, Oregon; and Charleston, North Carolina.

The Fishery Resource Analysis and Monitoring Division (FRAMD) is the source for most of the research reported by the NWFSC to the Technical Subcommittee of the Canada-US Groundfish Committee. The FRAMD works in partnership with state and federal resource agencies, universities, and the groundfish industry to achieve a coordinated groundfish program for the West Coast.

FRAMD consists of a multi-disciplinary team with expertise in fishery biology, stock assessment, economics, mathematical modeling, statistics, computer science, and field sampling techniques. Members of this program are stationed at the NWFSC facilities in Seattle and in Newport, Oregon, with some Observer Program staff located in California. Together, they work to develop and provide scientific information necessary for managing West Coast marine fisheries and strive to provide useful and reliable stock assessment data with which fishery managers can set ecologically safe and economically valuable harvest levels. FRAM researchers develop models for managing multi-species fisheries; design programs to provide information on the extent and characteristics of bycatch in commercial fisheries as they look at methods to reduce fisheries bycatch; characterize essential habitats for key groundfish species; and employ advanced technologies for new assessments.

During 2021, FRAMD continued to implement a West Coast observer program and expand its stock assessment, economics, and habitat research. Following the interruption of annual surveys in 2020 due to the global COVID19 pandemic the Pacific hake acoustic survey, southern California hook and line survey, and the coast wide groundfish trawl survey took place in 2021.

For more information on FRAMD and groundfish investigations, contact the Division Director, Craig Russell at Craig.Russell@noaa.gov, (206) 860 – 3402.

Other Divisions at the NWFSC are:

The Conservation Biology Division is responsible for characterizing the major components of biodiversity in living marine resources, using the latest genetic and quantitative methods. It also has responsibility for identifying factors that pose risks to these components and the mechanisms that limit natural productivity. The Division's multi-disciplinary approach draws on expertise in the fields of population genetics, population dynamics, and ecology.

The Environmental and Fisheries Sciences Division conducts research to assess and reduce natural and human-caused impacts on environmental and human health, and to improve methods for fisheries restoration and production in conservation hatcheries and in aquaculture. Environmental health and conservation research examines environmental conditions and the impacts of chemical contaminants, marine biotoxins, and pathogens on fishery resources, protected species, habitat quality, seafood safety, and human health. Fisheries restoration and aquaculture includes research on the challenges associated with captive rearing, nutrition, reproduction, behavior, disease control, engineering, hatchery technology and larval/juvenile quality for protected, depleted and commercially valuable species.

The Fish Ecology Division's role is to understand the complex ecological linkages among important marine and anadromous fishery resources in the Pacific Northwest and their habitats. The Division particularly places emphasis on investigating the myriad biotic and abiotic factors that control growth, distribution, and survival of important species and on the processes driving population fluctuations.

For more information on Northwest Fisheries Science Center programs, contact the Center Director, Dr. Kevin Werner at Kevin.Werner@noaa.gov, (206) 860 – 6795.

II. Surveys

A. U.S. West Coast Groundfish Bottom Trawl Survey

Due to the uncertainties created by the COVID-19 pandemic and the unique challenges those created for NOAA Fisheries, we cancelled the 2020 *West Coast Groundfish Bottom Trawl Survey*. This was a difficult decision for the agency as we strived to meet our core mission responsibilities while balancing the realities and impacts of the 2020 health crisis.

The NWFSC conducted its twenty-third annual bottom trawl resource survey for groundfish off the coasts of Washington, Oregon, and California in 2021. The annual survey was canceled in 2020 due to the COVID-19 global pandemic. The objective of the 2021 survey was to provide information on the distribution and relative abundance of demersal species within this region at depths from 30 to 700 fathoms. Other biological information necessary to assess the status of groundfish stocks (e.g. length, weight, sex and age structures) was collected throughout the survey period.

The NWFSC chartered four commercial fishing vessels to conduct the survey in 2021 using standardized trawl gear. Fishing vessels Last Straw, Ms. Julie, Noah's Ark and Excalibur were contracted to survey the area from Cape Flattery, WA to the Mexican border in Southern California (Figure 1), beginning in the later part of May and continuing through October. Each charter was for a period of 11-12 weeks with the F/V Last Straw and F/V Ms. Julie surveying the coast during the initial survey period from May to July (Pass 1). Pas 1 was subdivided into 3 legs to decrease the number of port calls and reduce the exposure to COVID-19. The F/V Excalibur and F/V Noah's Ark surveyed the coast during a second pass from mid-August to late October. The survey area was partitioned into ~12,000 adjacent cells of equal area (1.5 nm long. by 2.0 nm lat., Albers Equal Area projection) with each vessel assigned a primary subset of 188 randomly selected cells to sample. An Aberdeen-style net with a small mesh (1 1/2" stretch) liner in the codend was used for sampling. The survey followed a stratified random sampling scheme with 15-minute tows within 2 geographic strata (80% N of Pt. Conception, CA and 20% S) and 3 depth strata. The depth strata were: shallow (30-100 fms), middle (100-300 fms), and deep (300-700 fms). The sample design consisted of 752 sampling locations, with a minimum of 30 tows per strata.

In 2021, we continued to utilize an updated back deck data collection system with improved software applications, and wireless networking. Programming used to gather data for the groundfish survey was rewritten so that the various components were fully integrated, updated to include multiple sensor streams, and enhanced to increase flexibility for data input from special projects and future undefined data sources. The changes in the back-deck programming, wheel house programming and data QA/QC process resulted in overall improvements to data collection efficiency and anticipated future decreases in time requirements for data to be made available to the Data Warehouse. Established NOAA national bottom trawl protocols were used throughout the survey. As in prior years, a series of special research projects were undertaken in cooperation with other NOAA groups and various Universities.

Additional data were collected during the trawl survey for collaborative research projects with several NMFS/academic colleagues:

1) Collect whole specimens of Pacific lamprey (*Entosphenus tridentatus*) and take photographs of groundfishes with visible lamprey scars – Laurie Weitkamp, NWFSC, Conservation Division, Newport, OR

2) Identify to species all river Lamprey (*Lampetra ayresii*) then collect and freeze each specimen individually – Laurie Weitkamp, NWFSC, Conservation Division, Newport;

3) Collection whole specimens of all unusual skates, Pacific white skate *(Bathyraja spinossisima)*, fine-spined skate (*Bathyraja microtrachys)* and broad skate (*Amblyraja badia*) – Moss Landing Marine Laboratories;

4) Collect all biological data and specimens of deepsea skate (*Bathyraja abyssicola*) and broad skate (*Amblyraja badia*) – Moss Landing Marine Laboratories;

5) Collect and freeze whole specimens of Pacific black dogfish (*Centroscyllium nigrum*) – Moss Landing Marine Laboratories;

6) Collect whole specimens of any uncommon chimaeras such as *Harriotta raleighana*, *Hydrolagus melanophasma* and *Hydrolagus trolli* (pointy-nosed blue chimaera) – Moss Landing Marine Laboratories;

7) Collection of whole specimens of all unidentified or rare skates, ray, shark or chimaera– Moss Landing Marine Laboratories;

8) Collect fin clips and other tissues from all Pacific sleeper sharks (*Somniosus pacificus*) to examine genetics – NOAA, NWFSC – Cindy Tribuzio, Auke Bay Laboratories, AFSC;

9) Collect DNA and whole specimens of rougheye rockfish (*Sebastes aleutianus*), blackspotted rockfish (*Sebastes melanostictus*), darkblotched rockfish (*Sebastes crameri*) and blackgill rockfish (*Sebastes melanostomus*) to reduce uncertainty in the assessment of morphologically-similar west coast rockfish – CB Division, Northwest Fisheries Science Center;

10) Collection of voucher specimens for multiple fish species – Northwest Fisheries Science Center and University of Washington;

11) Collect voucher specimens for multiple fish species – Oregon State University;

12) Collect sex, total length and photograph dorsal side (including close up of dorsal side of snout) for all big skate (*Beringraja binoculata*), California skate (*Raja inornata*) and starry skate (*Raja stellulata*) captured at depths greater than 300 m – Joe Bizzarro, Institute of Marine Sciences and Fisheries Ecology Division, University of California, Santa Cruz and Southwest Fisheries Science Center;

13) Retain whole specimens of big skate (*Beringraja binoculata*), California skate (*Raja inornata*) and starry skate (*Raja stellulata*) captured at depths greater than 500 m – Joe Bizzarro, Institute of Marine Sciences and Fisheries Ecology Division, University of California, Santa Cruz and Southwest Fisheries Science Center;

14) Collect specimens for multiple fish species for teaching purposes for the West Coast Observer Program;

Several other research initiatives were undertaken by the Survey Team including:

1) Collect up to five stomachs per tow from blackgill rockfish (*Sebastes melanostomus*), canary rockfish (*Sebastes pinniger*), widow rockfish (*Sebastes entomelas*) and yellowtail rockfish (*Sebastes flavidus*)

2) Collect all stomachs per tow from blackspotted/rougheye rockfish (*Sebastes aleutianus / S. melanostictus*), cowcod rockfish (*Sebates levis*) and yelloweye rockfish (*Sebastes ruberrimus*).

3) Collect up to two stomachs per tow and one per size-bin from sablefish (*Anplopoma fimbria*), lingcod (*Ophiodon elongatus*), petrale sole (*Eopsetta jordani*), shortspine thornyhead (*Sebastolobus alascanus*) and longspine thornyhead (*Sebastolobus altivelis*).

4) Collect a tissue sample for stable isotope analysis to examine the feeding ecology of rockfish (darkblotched, canary, blackgill, blackspotted/rougheye, yelloweye, yellowtail rockfishes, widow rockfishes and cowcod) and other species (sablefish, petrale sole, lingcod, longspine thornyhead and shortspine thornyhead);

5) Collect photographs and photographic quality specimens of arbiter snailfish (*Careproctus kamikawai*);

6) Collect photographs and all specimens of sharpnose sculpin (*Clinocottus acuticeps*) for species confirmation;

7) Collect numerous photos and whole specimens of small disk snailfish (*Careproctus gilberti*) and longjaw bigscale (*Scopeloberyx robustus*);

8) Record composition and abundance of benthic marine debris collected during the 2021 West Coast Groundfish Trawl Survey;

9) Continue fin clip collection for DNA analysis of various shelf rockfish species;

10) Collect and/or photograph cold water corals;

11) Photograph, tag, bag and freeze deep-water species such as arbiter snailfish (*Careproctus kamikawi*) and other rare or unidentified deep-water species;

12) Collect near-bottom dissolved oxygen data to examine relation with fish distribution;

13) Collect ovaries and finclips from bank, brown, copper, blackspotted/rougheye, vermilion/sunset rockfishes;

14) Collect whole ovary, finclips (and gonads for males) from selected species;

15) Collect specimens for maturity analysis from selected species.

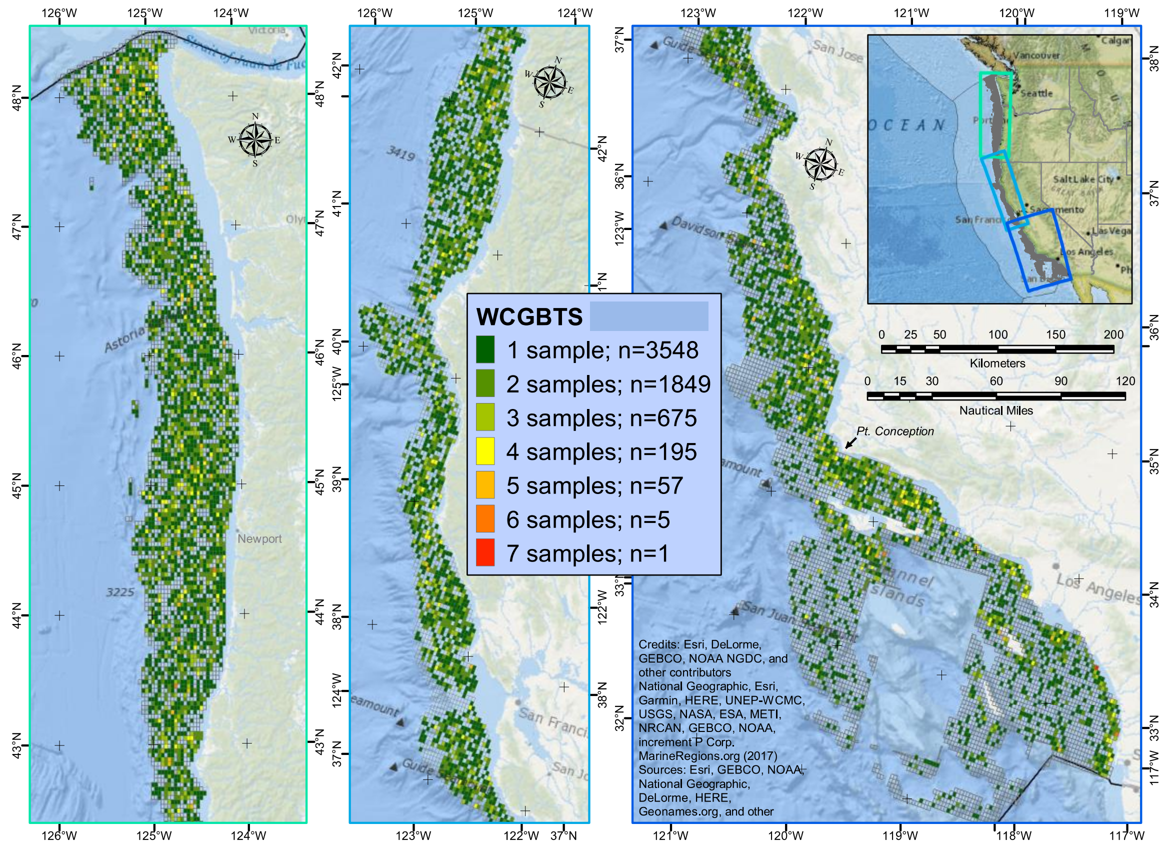


Figure 1. Summary of station locations and frequency for the West Coast Groundfish Bottom Trawl Survey 2003 to 2018.

For more information, please contact Aimee Keller at Aimee.Keller@noaa.gov

B. Southern California shelf rockfish hook-and-line survey

Due to the uncertainties created by the COVID-19 pandemic and the unique challenges those created for NOAA Fisheries, we cancelled the Northwest Fisheries Science Centers' 2020 *Southern California Shelf Rockfish Hook and Line (H&L) Survey.*

In Fall 2021, NWFSC/FRAM conducted the 18th hook and line survey for shelf rockfish in the Southern California Bight (SCB). The survey was not conducted in 2020 due to the COVID-19 pandemic. This survey is a cooperative effort with Pacific States Marine Fisheries Commission (PSMFC) and the southern California sportfishing industry and is aimed at developing a time series of abundance and biological data for structure-associated groundfish species including bocaccio (*Sebastes paucispinis*), bank rockfish (*S. rufus*), copper rockfish (*S. caurinus*), greenspotted rockfish (*S. chlorostictus*), cowcod (*S. levis*) blue rockfish (*S. mystinus*), speckled rockfish (*S. ovalis*), the vermilion rockfish complex (e.g., *S. miniatus* and *S. crocotulus*) and lingcod (*Ophiodon elongatus*) within the SCB.

The F/V *Aggressor* (Newport Beach, CA), F/V *Mirage* (Port Hueneme, CA), and F/V *Toronado* (Long Beach, CA) were each chartered for 14 days of at-sea research, with 17 biologists participating during the course of the survey. During the 2021 survey, the three vessels sampled 198 of the survey's 201 fixed sites which range from Point Arguello in the north to the US-Mexico EEZ boundary in the south and in a depth range of 20 – 125 fth (37 – 229 m) (Figure 2). Sites are located inside and outside the two Cowcod Conservation Areas – two large spatial closures implemented in 2000 to help recover overfished rockfish species including cowcod (*S. levis*). Some experimental re-sampling was conducted at 5 sites.

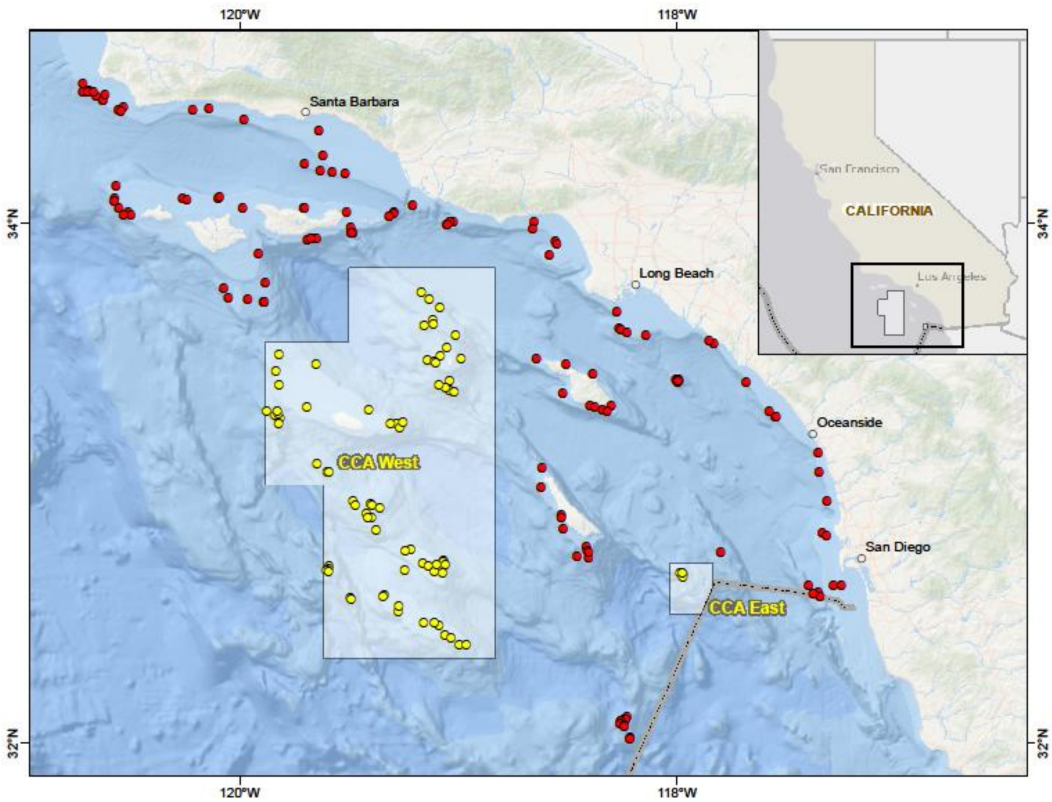


Figure 2. Sampling frame for the NWFSC Shelf Rockfish Hook and Line Survey

For more information, please contact John Harms at John.Harms@noaa.gov

C) 2021 Joint U.S./Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey

Scientists from the Fishery Resource Analysis and Monitoring (FRAM) Division at the NWFSC and the Institute of Ocean Sciences at DFO led the 2021 joint U.S./Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey (IAT). The survey was conducted aboard the NOAA Ship *Bell M. Shimada*—a 209-foot acoustically quieted Fisheries Survey Vessel—and the *Nordic Pearl*, a chartered 115-foot Canadian fishing vessel. Both vessels are stern trawlers equipped for fisheries research, while the *Shimada* is also equipped for oceanographic research. The survey began at Point Conception, California (the current southern extent of the survey area) and proceeded north along the west coast of the U.S. and Canada, surveying Queen Charlotte Sound, Hecate Strait, Dixon Entrance (the northern extent of the survey area), and the west side of Haida Gwaii, which was surveyed from north to south (Figure 3). The *Shimada* surveyed between 1 July and 21 September and the *Nordic Pearl* surveyed between 21 August and 11 September. Acoustic transects were oriented east-west (except for transects in Dixon Entrance, which had a north-south orientation), extended from the 50-m isobath (or as close to shore as was safely navigable) to the 1,500-m isobath, and were spaced 10 nmi apart through Transect 100 (just north of Vancouver Island), after which spacing increased to 20 nmi. Transects were traversed sequentially, usually in alternating directions. If hake were observed on the first transect, the survey area was extended to the south; similarly, if hake were observed on the most northerly transect, the survey area was extended further north. If hake were detected at the offshore end of a transect, the vessel proceeded west to the end of the hake sign and then beyond for an additional 0.5 nmi to ensure that the end of the aggregation was located. This protocol was in place to ensure not only that the full extent of the hake coastal population was accounted for in the survey area, but also that the interpolation algorithm used for calculating hake biomass performed correctly at the offshore ends of transects.

Five Simrad split-beam transducers, operating at 18, 38, 70, 120, and 200 kHz, were mounted on the bottom of the *Shimada*'s retractable centerboard. To reduce interference from bubbles, the centerboard was extended to its maximum depth during the survey, thereby positioning the transducers at a depth of 9.15 m below the water surface. Acoustic data from all five transducers were collected with a Simrad EK80 wideband transceiver (WBT) scientific echosounder system that operated with an EK80 software system (version 2.0.0) in either a CW (continuous wave or narrowband) or FM (broadband or wideband) pulse transmission mode. The *Nordic Pearl* also collected acoustic data with a Simrad EK80 system (version 2.0.1); two Simrad split-beam transducers, operating at 38 and 120 kHz, were mounted on a transducer pod located roughly 1.5 m starboard of the keel. The *Shimada* was equipped with a Teledyne RD Instruments Ocean Surveyor 75-kHz Acoustic Doppler Current Profiler (ADCP) system and a Simrad ME70 scientific multibeam echosounder system, but the ME70 system was not used because of interference with the other acoustic systems. A Simrad K-Sync unit was used to synchronize pulse sequences from the EK80 and ADCP acoustic instruments.

Adult hake were observed on 61 transects, ranging from Transect 14, off Monterey, California (which was the northernmost start of observed adult hake sign since 2011), to the eastern side of Transect 104, off Price Island, British Columbia (Figure 3). The 2021 biomass estimate of adult hake off the west coast of the U.S. and Canada totaled 1.525 million metric tons, with approximately 95.7% (1.459 Mt) of observed biomass located in U.S. waters. Although the 2021 estimate was slightly smaller than the 2019 biomass estimate (a decrease of 0.198 Mt or approximately 11.5%), it was close (4.9% larger) to the average biomass estimate for all surveys conducted since 1995 (1.525 vs. 1.453 Mt). Age-5 and age-7 hake contributed most to the 2021 adult biomass estimate—combining for just under 50%—followed by age-4 (14.6%) and age-11 (10.9%) hake.

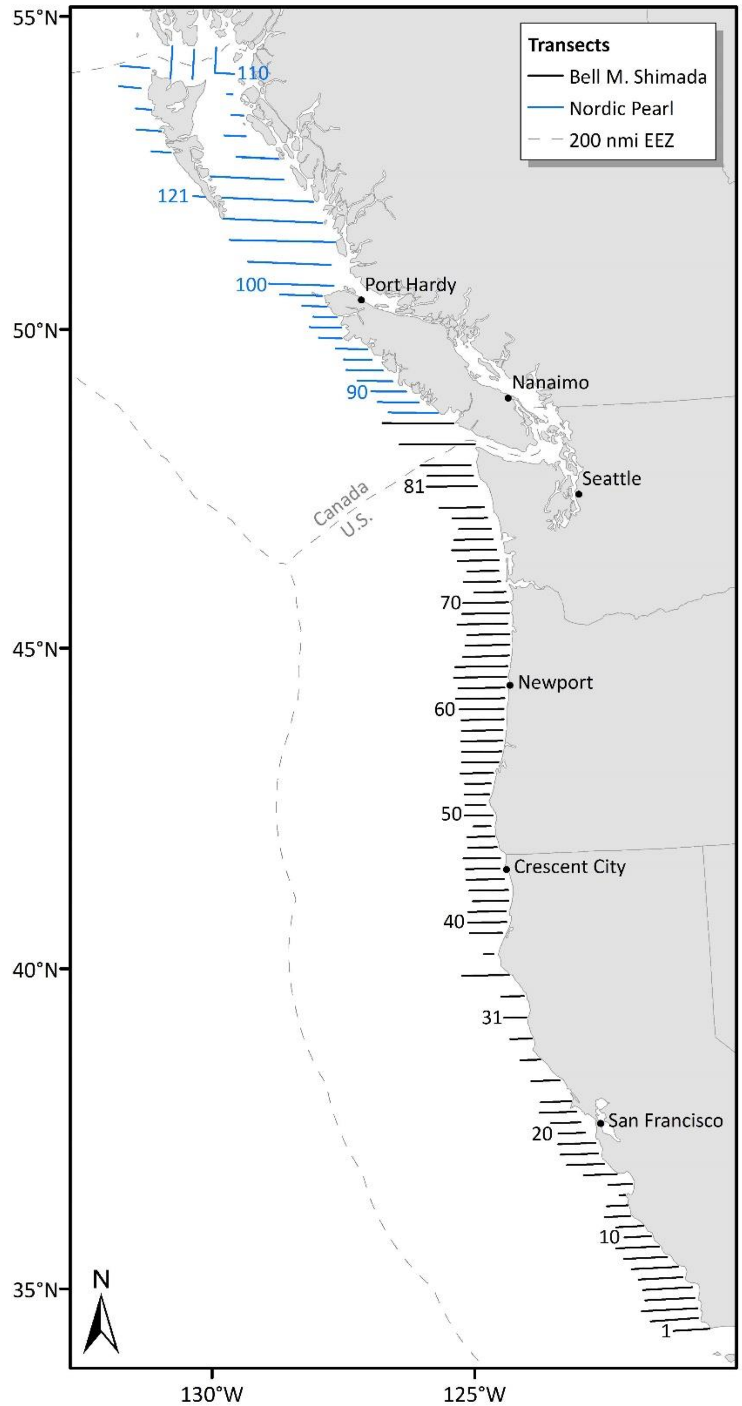


Figure 3. Survey track design used during the 2021 Joint U.S./Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey.

For more information, please contact Julia Clemons at julia.clemons@noaa.gov

III. Reserves

IV. Review of Agency Groundfish Research, Assessments, and Management

A. Hagfish

B. Dogfish and other sharks

1. Research

a) Elasmobranch bycatch in US West Coast groundfish fisheries

Investigators: Jannot J.E., Bjorkland R., Somers K.A., Mitchell T., Tuttle V.J., McVeigh J.

ABSTRACT: Effective management of multispecies fisheries in large marine ecosystems is challenging. To deal with these challenges, fisheries managers are moving toward ecosystem-based fishery management (EBFM). Despite this shift, many species remain outside protective legislation or fishery management plans. How do species that fall outside of formal management structures respond to changes in fisheries management strategies? In 2011, the US West Coast Groundfish Fishery (WCGF) shifted management to an Individual Fishing Quota (IFQ) program. We used data collected by fisheries observers to examine the impact of this shift on elasmobranch catch (sharks, skates, rays). Historically, not all elasmobranchs were included in the WCGF Management Plan, making them vulnerable to fishing mortality. We grouped elasmobranchs into 8 groups based on 14 ecomorphotypes to examine relative catch within groundfish fishing sectors during the period 2002-2014. Of the 22 sharks and 18 skates and rays that these fisheries capture, 9 are listed as Near Threatened or greater on the IUCN Red List and 10 species are listed as Data Deficient by IUCN. The bycatch of 4 non-managed elasmobranch species was reduced under the IFQ program; IFQ management had no significant impact on the remaining 27 species caught by the IFQ fleet. Overall, catch of non-managed elasmobranchs was relatively low. We show that groups of ecomorphotypes co-occur within fisheries, suggesting natural management units for use in EBFM. This work helps identify gaps in monitoring and assessing the impact of management and policy on elasmobranch populations.

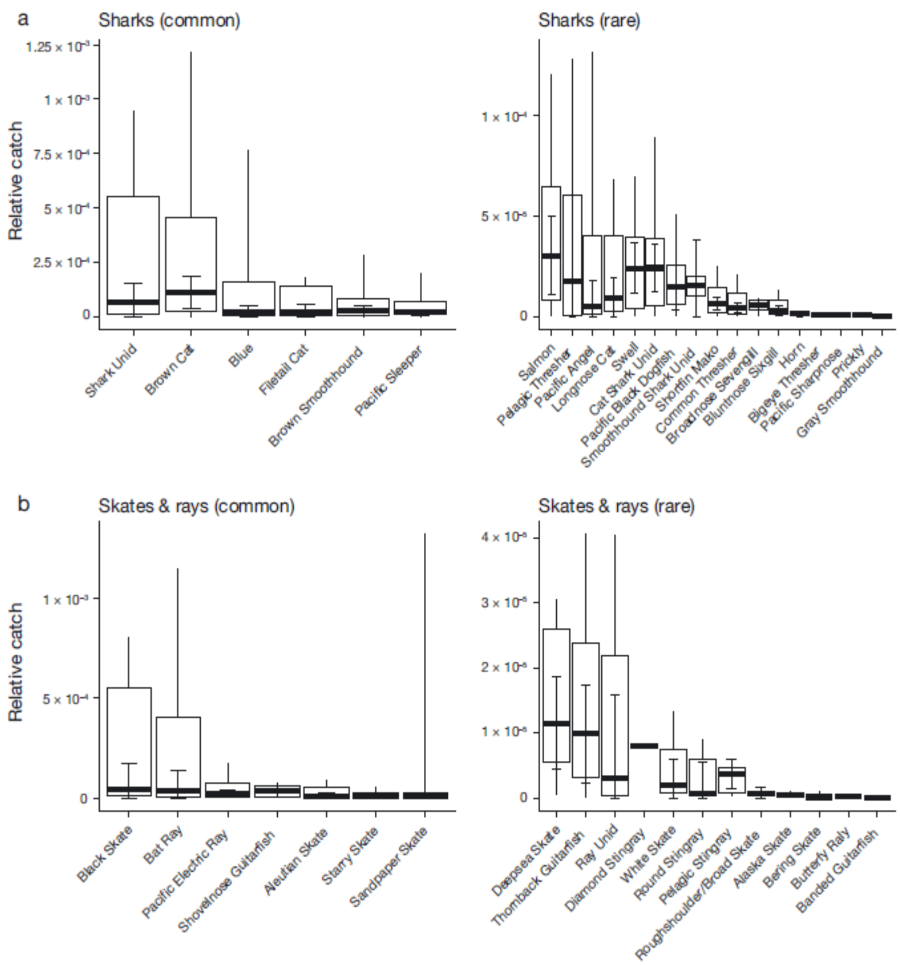


Figure 4. Relative catch (bar: median; box: ±25%; top whisker: 90%; error bar: 95% CI of median) of (a) sharks and (b) skates, rays, and guitarfish in US West Coast groundfish fisheries. Relative catch was calculated as the total catch of the elasmobranchs divided by the total landed catch. For clarity, elasmobranchs are divided into sharks and skates, and within each group, commonly caught species are plotted separately from rarely caught species. Unidentified skates are not shown.

Jannot J.E., Bjorkland R., Somers K.A., Mitchell T., Tuttle V.J., McVeigh J. 2021. Elasmobranch bycatch in US West Coast groundfish fisheries. Endang Species Res 45:109-126.

For more information, please contact Jon McVeigh at jon.mcveigh@noaa.gov.

2. Assessment

a) Status of the Pacific Spiny Dogfish shark resource off the continental U.S. Pacific Coast in 2021.

Investigators: Gertseva, V. Taylor, I.G., Wallace, J.R., Matson, S.E.

Pacific spiny dogfish (*Squalus suckleyi*) in the Northeast Pacific Ocean occur from the Gulf of Alaska, with isolated individuals found in the Bering Sea, southward to San Martin Island, in southern Baja California. They are extremely abundant in waters off British Columbia and

Washington, but decline in abundance southward along the Oregon and California coasts. This assessment focuses on a portion of a population that occurs in coastal waters of the western United States, off Washington, Oregon and California, the area bounded by the U.S.-Canada border on the north and U.S.-Mexico border on the south. The assessment area does not include Puget Sound or any other inland waters.

In the coastal waters of the U.S. west coast, spiny dogfish has been utilized since early 20th century, and are caught by both trawl and non-trawl gears. The history of dogfish utilization included a brief but intense fishery in the 1940s, which started soon after it was discovered that livers of spiny dogfish contain high level of vitamin A. During the vitamin A fishery, removals averaged around 6,821mt per year reaching their peak of 16,876 mt in 1944. The fishery ended in 1950 with the advent of synthetic vitamins. In the mid-1970s, a food fish market developed for dogfish when the species was harvested and exported to other counties, primarily Great Britain. For the last 10 years landings ranged between 482 and 1,908 mt. The landings of spiny dogfish were reconstructed back to 1916 from variety of published sources and databases. Even though spiny dogfish was heavily harvested in the 1940s, this species is not highly prized and is mostly taken as bycatch in other commercially important fisheries.

This assessment, conducted in 2021, estimates that the stock of spiny dogfish off the continental U.S. Pacific Coast is currently at 42 percent of its unexploited level. This is above the overfished threshold of $SB_{25\%}$ and the management target of $SB_{40\%}$ of unfished spawning biomass. The assessment described that the spawning output of spiny dogfish showed a relatively sharp decline in the 1940s, during the time of the intense dogfish fishery for vitamin A. During a 10-year period (between 1940 and 1950), the spawning output dropped from 99% to under 75% of its unfished level. Between 1950 and 1974 the catches of spiny dogfish were minimal, but given the low productivity of the stock, the spawning output continued to slowly decline. Since late 1970s decrease became a bit more pronounced due to fishery removals (an export food fish fishery developed in the mid-1970s) and low productivity of the stock, but in the last decade catches decreased and the stock trajectory flattened.

The time series of total mortality catch (landings plus discards) and estimated depletion for spiny dogfish are presented in Figure 5.

The assessment model captures uncertainty in estimated size and status of the stock through asymptotic confidence intervals estimated within the model. To further explore uncertainty associated with alternative model configurations and evaluate the responsiveness of model outputs to changes in key model assumptions, a variety of sensitivity runs were performed. A major source of uncertainty in the assessment is related to catchability of the West Coast Groundfish Bottom Trawl (WCGBT) Survey, which was found to have a large influence on the perception of current stock size. WCGBT Survey catchability in the assessment is fixed at the value of 0.43, which reasonably represent latitudinal, depth and vertical availably of spiny dogfish to the survey as well as probability of catch in survey net path. Uncertainty from WCGBT Survey catchability is reported via alternate states of nature in the decision table, bracketing the base model results.

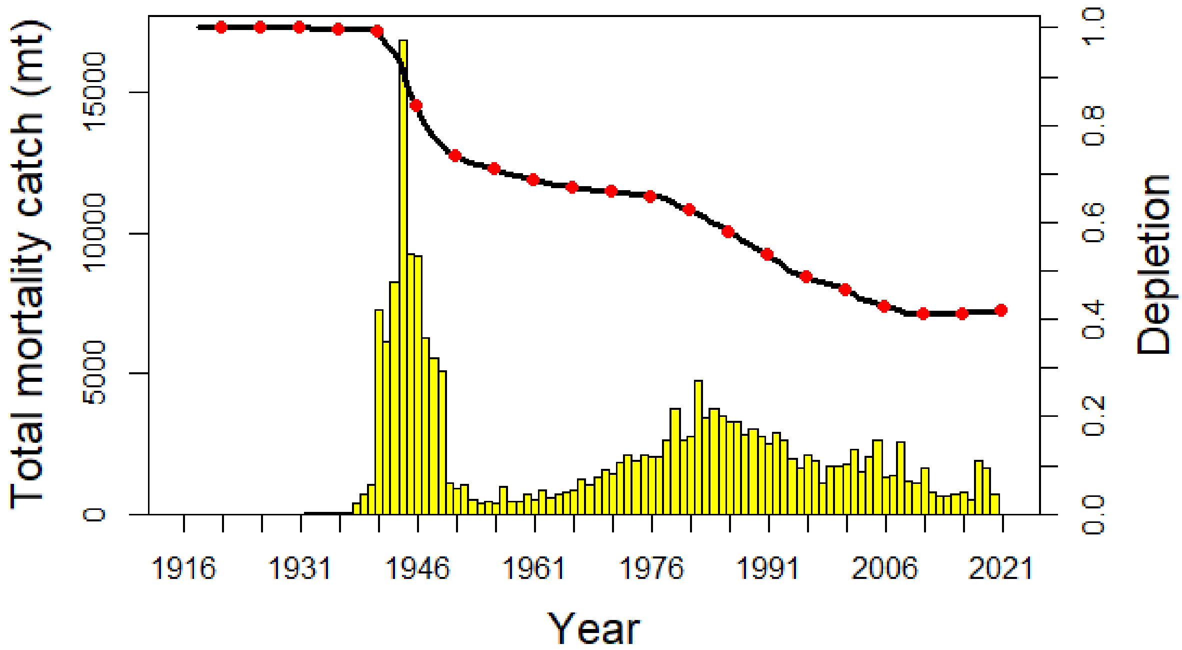


Figure 5. The time series of total mortality catch (bars) and estimated depletion (line) for Pacific spiny dogfish shark.

Gertseva, V. Taylor, I.G., Wallace, J.R., Matson, S.E. 2021. Status of the Pacific Spiny Dogfish shark resource off the continental U.S. Pacific Coast in 2021. Pacific Fishery Management Council, Portland, OR. Available from http://www.pcouncil.org/groundfish/stock-assessments

For more information on the spiny dogfish assessment, contact Dr. Vladlena Gertseva at Vladlena.Gertseva@noaa.gov

C. Skates

D. Pacific cod

E. Walleye Pollock

F. Pacific whiting (hake)

1. Research

a) eDNA research during Joint U.S./Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey

In support of environmental DNA (eDNA) work, Niskin bottle water collections were taken at conductivity-temperature-depth (CTD) stations during the 2021 Joint U.S./Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey and the water extracted from the Niskin bottles was filtered. During Leg 1 of the survey on the *Shimada*, an eDNA autonomous sampler, "SADIE", developed in conjunction with the University of Washington Applied Physics Lab (APL), was attached to the CTD rosette and tested.

For more information, please contact Julia Clemons (julia.clemons@noaa.gov)

b) Unmanned surface vehicle (Saildrone) acoustic survey off the west coasts of the United States and Canada

In 2021, to investigate local movement of hake and the presence/absence of offshore hake, two Saildrones surveyed in tandem with the 2021 Joint U.S./Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey along parallel, extended transects by Cape Mendocino, California. Saildrone 1063 completed 22 lengths of Transect 37 (40.445°N) between 28 August and 2 October (~35 survey days). Saildrone 1064 completed 27 lengths of Transect 38 (40.6117°N) between 27 August and 2 October (~36 days). Length of both transects was 67.5 nmi.

For more information, please contact Julia Clemons at julia.clemons@noaa.gov

Figure 6. Saildrone operating at sea off San Francisco, CA

For more information, please contact Julia Clemons at julia.clemons@noaa.gov

c) Environmentally driven seasonal forecasts of Pacific hake distribution

Investigators: Michael J. Malick1, Samantha A. Siedlecki, Emily L. Norton, Isaac C. Kaplan, Melissa A. Haltuch, Mary E. Hunsicker, Sandra L. Parker-Stetter, Kristin N. Marshall5, Aaron M. Berger, Albert J. Hermann, Nicholas A. Bond and Stéphane Gauthier

Changing ecosystem conditions present a challenge for the monitoring and management of living marine resources, where decisions often require lead-times of weeks to months. Consistent improvement in the skill of regional ocean models to predict physical ocean states at seasonal time scales provides opportunities to forecast biological responses to changing ecosystem conditions that impact fishery management practices. In this study, we used 8-month lead-time predictions of temperature at 250 m depth from the J-SCOPE regional ocean model, along with stationary habitat conditions (e.g., distance to shelf break), to forecast Pacific hake (*Merluccius productus*) distribution in the northern California Current Ecosystem (CCE). Using retrospective skill assessments, we found strong agreement between hake distribution forecasts and historical observations. The top performing models [based on out-of-sample skill assessments using the area-under-the-curve (AUC) skill metric] were a generalized additive model (GAM) that included shelf-break distance (i.e., distance to the 200 m isobath) (AUC = 0.813) and a boosted regression tree (BRT) that included temperature at 250 m depth and shelf-break distance (AUC = 0.830). An ensemble forecast of the top performing GAM and BRT models only improved out-of-sample forecast skill slightly(AUC = 0.838) due to strongly correlated forecast errors between models (r = 0.88). Collectively, our results demonstrate that seasonal lead-time ocean predictions have predictive skill for important ecological processes in the northern CCE and can be used to provide early detection of impending distribution shifts of ecologically and economically important marine species.

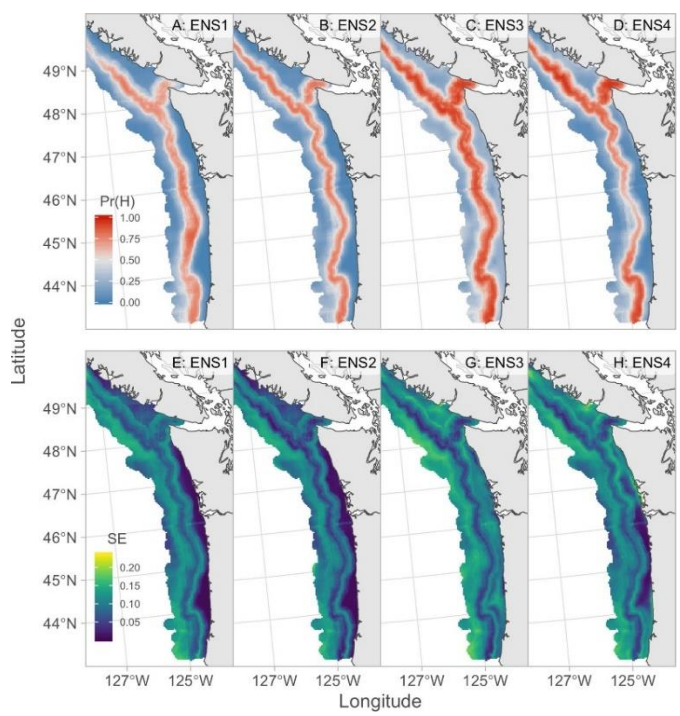


Figure 7. | August 2019 forecasts of hake occurrence from ensemble forecast models. Top row (A–D) shows the probability of hake occurrence where red indicates probabilities greater than 0.5 and blue indicates probabilities less than 0.5. Bottom row (E–H) shows the associated standard errors for each model where brighter colors indicate higher forecast uncertainty.

For more information, please contact Michael Malick michael.malick@noaa.gov)

d) Skill and uncertainty of environmentally driven forecasts of Pacific hake distribution

Investigators: Michael J. Malick, Mary Hunsicker, Melissa Haltuch, Isaac Kaplan, Aaron Berger, Samantha Siedlecki, Nicholas Bond, Albert Hermann, and Emily L. Norton

Changing ecosystem conditions present a challenge for the monitoring and management of living marine resources, where decisions are often made with lead-times of weeks to months. Improvements in the skill of regional ocean models to predict physical ocean states at seasonal time scales provides opportunities to develop early warnings of the biological responses to changing environments and distribution shifts that impact fishery management practices. In this study, we illustrate how regional ocean model predictions can be used in an ecological context using Pacific hake (*Merluccius productus*) summer distribution in the California Current Ecosystem. We used the J-SCOPE regional ocean model to develop 6-8 month lead-time forecasts of thermal conditions at depth, which were then used to force environmentally driven species distribution models for Pacific hake. Using retrospective skill assessments, we show good agreement between hake distribution forecasts and historical observations. Finally, we discuss the utility of using seasonal lead-time ocean predictions in an ecological context to address research questions that can inform current resource management. 2021 and 2022 forecasts are available via NANOOS: http://www.nanoos.org/products/j-scope/forecasts.php

For more information, please contact Mike Malick (Michael.Malick@noaa.gov), Melissa Haltuch (Melissa.Haltuch@noaa.gov), or Mary Hunsicker (Mary.Hunsicker@noaa.gov).

e) Relationships between temperature and Pacific hake distribution vary across latitude and life-history stage

Investigators: Malick M.J., Hunsicker M.E., Haltuch M.A., Parker-Stetter S., Berger A., Marshall K.N.

Environmental conditions can have spatially complex effects on the dynamics of marine fish stocks that change across life-history stages. Yet the potential for non-stationary environmental effects across multiple dimensions, e.g. space and ontogeny, are rarely considered. In this study, we examined the evidence for spatial and ontogenetic non-stationary temperature effects on Pacific hake *Merluccius productus* biomass along the west coast of North America. Specifically, we used Bayesian additive models to estimate the effects of temperature on Pacific hake biomass distribution and whether the effects change across space or life-history stage. We found latitudinal differences in the effects of temperature on mature Pacific hake distribution (i.e. age 3 and older); warmer than average subsurface temperatures were associated with higher biomass north of Vancouver Island, but lower biomass offshore of Washington and southern Vancouver Island. In contrast, immature Pacific hake distribution (i.e. age 2) was better explained by a nonlinear temperature effect; cooler than average temperatures were associated with higher biomass coastwide. Together, our results suggest that Pacific hake distribution is driven by interactions between age composition and environmental conditions and highlight the importance of accounting for varying environmental effects across multiple dimensions.

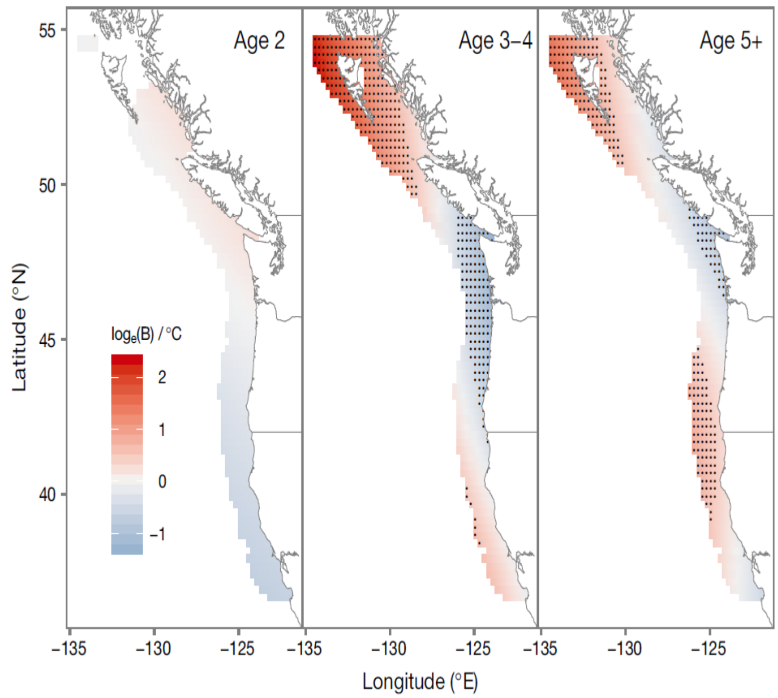


Figure 8. Spatially dependent temperature effect estimated using age-group-specific biomass (B). Shading represents the poste- rior median value for the non-stationary temperature effect on Pacific hake biomass given a 1 unit increase in temperature at a location. Red (blue) shading indicates the linear temperature effect was positive (negative). Black dots indicate locations where the 95% credibility interval for the temperature effect did not include 0. Effects are only shown for locations within 50 km of an age-specific hake biomass observation

Malick M.J., Hunsicker M.E., Haltuch M.A., Parker-Stetter S.L., Berger A.M., Marshall K.N. 2020. Relationships between temperature and Pacific hake distribution vary across latitude and life-history stage. Mar Ecol Prog Ser 639:185-197. https://doi.org/10.3354/meps13286

For more information, please contact Michael Malick michael.malick@noaa.gov)

f) The 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey - NWFSC PROCESSED REPORT, CRUISE NO. SH-21-06

Investigators: Stephen K. de Blois, Ethan M. Beyer,1 Alicia A. Billings, Dezhang Chu, Julia E. Clemons, Stéphane Gauthier, Elizabeth M. Phillips, John E. Pohl, Chelsea P. Stanley, Rebecca E. Thomas

The results presented in the 2021 report are from the 2021 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey. This report provides a brief description of the methods used in the survey and summarizes the distribution, biological composition, and biomass of hake in U.S. and Canadian waters off the Pacific coast. It also summarizes results of acoustic system calibrations and secondary survey objectives.

For more information, please contact Steve de Blois at Steve.DeBlois@noaa.gov.

g) Can spatio-temporal models provide the composition data necessary to estimate fish biomass-at-age with acoustic data collected from autonomous vehicles?

Investigators: D. Bolser, A.M Berger, D. Chu, J. Hastie, J. Clemons, L. Ciannelli

A key limitation of using autonomous vehicles in fishery resource surveys is their inability to collect biological samples. In particular, the lack of size or age composition data makes precise estimation of biomass-at-age difficult, limiting the use of acoustic data collected by autonomous vehicles in stock assessments. To overcome this barrier, we developed an approach that combines age composition information from existing data sources (e.g., fishing fleets, fishery-independent sampling not paired with acoustics) using geostatistics to create spatially and temporally resolved estimates of age compositions across the population domain that then are assigned to autonomous vehicle acoustic data. We examined the validity of this approach using a case study with Pacific Hake (*Merluccius productus*; 'hake'). Specifically, we generated compositional data with a vector-autoregressive spatio-temporal (VAST) model, then estimated biomass-at-age by pairing those estimates with acoustic data from a U.S. West Coast-wide autonomous Saildrone survey. The performance of the VAST model was assessed with simulation testing and comparisons between VAST estimates of age composition and those from midwater trawls in the hake acoustic trawl (AT) survey. VAST-Saildrone biomass-at-age estimates were then compared with those derived from the hake AT survey. The challenges we encountered when fitting the VAST model to a relatively rich dataset (e.g., limited age class resolution, model instability) indicated that this approach may not be suitable in all situations, but our model produced estimates of age composition that were comparable to midwater trawls (~ +/-10%). Ultimately, the difference in acoustic backscatter recorded by the AT and Saildrone surveys influenced biomass-at-age estimates more than the source of compositional data. Leveraging existing compositional data and autonomous vehicle technologies can result in synergies that benefit stock assessment and fisheries management. *Ocean Sciences.*

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

h) Climate-mediated stock redistribution causes increased risk and challenges for fisheries management

Investigators: N.S. Jacobsen, K.N. Marshall, A.M. Berger, C. Grandin, and I.G. Taylor

The environmental conditions that marine populations experience are being altered because of climate change. In particular, changes in temperature and increased variability can cause shifts in spatial distribution, leading to changes in local physiological rates and recruitment success. Yet, management of fish stocks rarely accounts for variable spatial dynamics or changes in movement rates when estimating management quantities such as stock abundance or maximum sustainable yield. To address this concern, a management strategy evaluation (MSE) was developed to evaluate the robustness of the international management system for Pacific hake, an economically important migratory stock, by incorporating spatio-temporal population dynamics. Alternative hypotheses about climate-induced changes in age-specific movement rates, in combination with three different harvest control rules (HCR), were evaluated using a set of simulations that coupled single-area estimation models with alternative operating models representing spatial stock complexity. Movement rates intensified by climate change caused a median decline in catches, increased annual catch variability, and lower average spawning biomass. Impacts varied by area and HCR, underscoring the importance of spatial management. Incorporating spatial dynamics and climate change effects into management procedures for fish stocks with spatial complexity is warranted to mitigate risk and uncertainty for exploited marine populations. *ICES Journal of Marine Science*.

For more information, please contact Kristin Marshall at Kristin.Marshall@noaa.gov

2. Assessment

a) Status of the Pacific (whiting) stock in U.S. and Canadian waters in 2022

Investigators: A. Edwards, A. Berger, C. Grandin, K. Johnson

This stock assessment reported the collaborative efforts of the official U.S. and Canadian Joint Technical Committee members in accordance with the Agreement between the government of the U.S. and the government of Canada to assess the status of the coastal Pacific Hake (or Pacific whiting, *Merluccius productus*) resource off the west coast of the U.S. and Canada for 2022. Coast-wide fishery landings of Pacific hake averaged 241 thousand mt from 1966 to 2021, with a low of 90 thousand mt in 1980 and a peak of 441 thousand mt in 2017. Prior to 1966 the total removals were negligible relative to the modern fishery. Recent coast-wide landings from 2017–2021 have been above the long term average, at 394 thousand mt, with U.S. and Canadian catches averaging 309 thousand mt and 85 thousand mt, respectively. In the 2021 catch, the 2016 cohort was the largest (36%), followed by the 2014 cohort (24%), then the 2017 (14%) and 2010 (10%) cohorts. The Agreement between the U.S. and Canada establishes U.S. and Canadian shares of the coast-wide TAC at 73.88% and 26.12%, respectively.

Data were updated for the 2022 assessment with the addition of the 2021acoustic survey biomass estimate and age-composition data, fishery catch and age-composition data from 2021, weight-at-age data for 2021, the addition of an age-1 index time series (1995–2021), and minor changes to pre-2021 data. The assessment used Bayesian methods to incorporate prior information on two key parameters (natural mortality, M, and steepness of the stock-recruitment relationship, h) and integrate over parameter uncertainty to provide results that can be probabilistically interpreted. The exploration of uncertainty was not limited to parameter uncertainty as structural uncertainty was investigated through sensitivity analyses. Pacific Hake displays the highest degree of recruitment variability of any west coast groundfish stock, resulting in large and rapid changes in stock biomass. This volatility, coupled with a dynamic fishery, which potentially targets strong cohorts resulting in time-varying selectivity, and little data to inform recent recruitment, will, in most circumstances, continue to result in highly uncertain estimates of current stock status and even less-certain projections of future stock trajectory. Uncertainty in the results of this assessment is largely a function of the potentially above-average 2020 year class, the lack of data informing recruitment in 2021, uncertain selectivity, and uncertainty about historical equilibrium conditions prior to or in the absence of fishing. Short-term forecasts are very uncertain because recruitment is a main source of uncertainty in the projections.

Estimates from the 2022 base model indicate that since the 1960s, Pacific Hake female spawning biomass has ranged from well below to near unfished equilibrium biomass. The stock is estimated to have been below the unfished equilibrium in the 1960s before increasing rapidly to near unfished equilibrium after two or more large recruitments occurred in the early 1980s, followed by steady decline through the 1990s to a low in 1999. This long period of decline was followed by a brief peak in 2002 as the large 1999 year class matured and subsequently supported the fishery for several years. Estimated female spawning biomass declined to a time-series low of 0.625 million mt in 2010 because of low recruitment between 2000 and 2007, along with a declining 1999 year class. Spawning biomass esimates peaked again in 2013 and 2014 due to a very large 2010 year class and an above-average 2008 year class. The subsequent decline from 2014 to 2016 is primarily from the 2010 year class surpassing the age at which gains in weight from growth are greater than the loss in weight from mortality (growth-mortality transition). The 2014 year class is estimated to be large, though not as large as the 1999 and 2010 year classes, increasing the biomass in 2017. The estimated biomass was relatively steady from 2017 to 2019, and then declined in 2020 and 2021 due to the 2014 and 2016 year classes moving through the growth-mortality transition during a period of high catches. The 2022 female spawning biomass is estimated to be 65% of the unfished equilibrium level (B_0) with a 95% posterior credibility interval ranging from 31% to 135%. The median estimated 2022 female spawning biomass is 1.17 million mt. Uncertainty in current stock status is considerable, largely due to the lack of information about recent recruitment.

The fishing intensity on the Pacific Hake stock is estimated to have been below the $F_{40\%}$ target in all years, with the median estimate for 1999 being only slightly below (95% of the target). Fishing intensity has been considerably below the $F_{40\%}$ target since 2012 and has been decreasing over the last 5 years (from 74% in 2017 to 53% in 2021). The official coastwide total catch target adopted by the U.S. and Canada has not been exceeded since 2002. Recent catch and levels of depletion are presented in Figure 9.

Management strategy evaluation tools continue to be developed and tested to evaluate major sources of uncertainty relating to data, model structure and the harvest policy for this fishery and compare potential methods to address them. Alternative spatially explicit representations of Pacific Hake population dynamics (i.e., operating models) have been developed, and continued research will focus on how best to model spatial dynamics and include ecosystem information into operation management procedures.

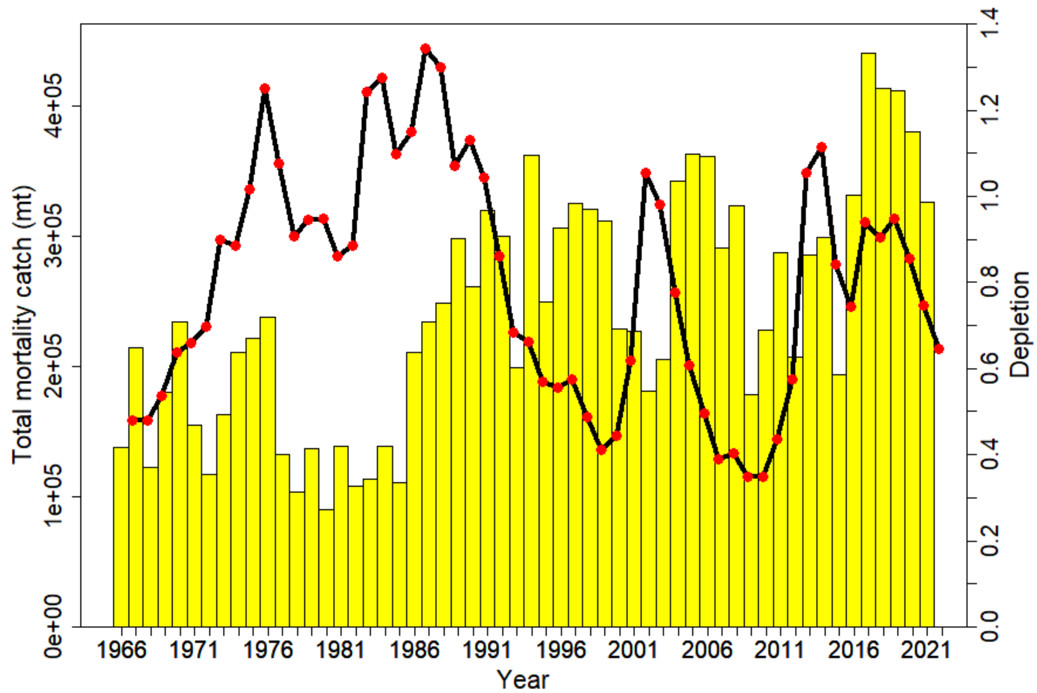


Figure 9. Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for Pacific hake, 1966-2021.

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov or Kelli Johnson Kelli.Johnson@noaa.gov

3. Management

a) Management strategy evaluation of Pacific Hake: exploring the robustness of the current harvest policy to spatial stock structure, shifts in fishery selectivity, and climate-driven distribution shifts

Investigators: N.S. Jacobsen, K.N. Marshall, A.M. Berger, C. Grandin, and I.G. Taylor

The Pacific hake (*Merluccius productus*) management strategy evaluation (MSE) entered a new iteration in mid-2017. This report documents the MSE process and provides technical documentation for a new closed-loop simulation model and scenarios developed to explore key uncertainties. The goals of this iteration of the MSE were to: evaluate the performance of current hake harvest policy under alternative hypotheses about current and future environmental conditions; better understand the effects of hake distribution and movement on the ability of both countries (the United States and Canada) to catch fish; and better understand how fishing in each country affects the availability of fish to the other country in future years. We worked with the Joint Management Committee (JMC) and the MSE Working Group (MSEWG) to develop and refine goals, objectives, and performance metrics used to evaluate performance. These metrics describe performance in terms of stock status, coastwide catch, catch variability, and spatially explicit exploitation rates. A spatially explicit (two-area) operating model was developed, with age-based movement of fish between areas. Other aspects of the operating model closely resemble the current stock assessment model for Pacific hake. The model was conditioned to the coastwide stock assessment and available country-specific data (i.e., survey biomass, survey age compositions, and fishery age compositions). We evaluated the performance of alternative management procedures (MPs) that explored: 1) the implementation of the default harvest policy defined in the Pacific Hake/Whiting Treaty and 2) the consequences of changing the frequency of conducting the Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey. We also developed scenarios to begin to explore how key uncertainties might influence future performance of the current management procedure for hake. These scenarios explored the potential implications of: 1) climate change-driven increases in northward fish movement rates and decreases in southward movement rates; and 2) shifts in selectivity in the United States fishery resulting in changes to the age composition of catch in each country. While each MP and scenario revealed different sensitivities and tradeoffs, the alternative implementations of the harvest policy had the largest influence on projected stock status and catch. Of the performance metrics we examined, variability in catch was the most responsive across all the scenarios and MPs. Assessment error was influenced most by the selectivity scenarios and survey frequency MPs. The technical documentation and model output shown here demonstrate the utility of the closed-loop simulation model framework we developed for future MSE questions and applications. The scenarios we explored provide a foundation of results exploring key uncertainties. However, further testing, additional scenarios, and crosses of scenario types with MPs may be necessary to more fully explore the model dynamics and to address future questions of interest to the Pacific Hake/Whiting Treaty parties. *NOAA Technical Memorandum NMFS-NWFSC-168.*

For more information, please contact Kristin Marshall at Kristin.Marshall@noaa.gov

b) Management of Pacific Hake

Management of Pacific Hake has been under a treaty (The Agreement) between Canada and the United States since 2011. The stock is managed by the Joint Management Committee (JMC), which is made up of fisheries managers and industry representatives from both the U.S. and Canada. These managers receive advice from the JTC and the Scientific Review Group (SRG), which is a committee responsible for the scientific review of the assessment.

G. Grenadiers

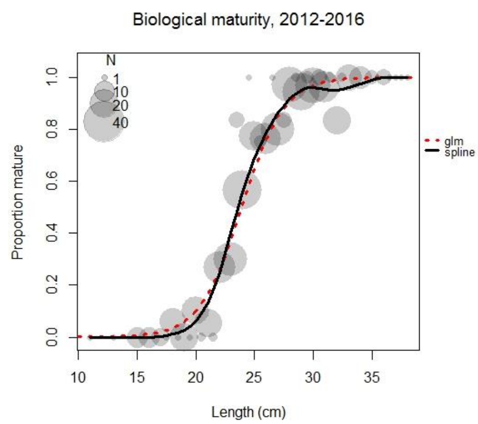
H. Rockfish

1. Research

a) Applying a flexible spline model to estimate functional maturity and spatio-temporal variability in aurora rockfish (*Sebastes aurora*)

Investigators: Melissa A. Head, Jason M. Cope, Sophie H. Wulfing

The authors outlined a new flexible method for estimating maturity that incorporates skip spawning, which can lead to non-asymptotic behavior in the population maturity schedule. This new approach aids fisheries managers who seek to understand marine species' responses to changing oceans. In an effort to assess shifts in maturity and spawning behavior of west coast groundfish, a new method was used to evaluate spatio-temporal trends in length at maturity, the annual reproductive cycle, and spawning behavior of aurora rockfish (*Sebastes aurora*). The authors estimated biological (presence of physiological maturity markers) and functional (potential spawners in a given year) maturity using a standard logistic and the new flexible spline model. The range in lengths at 50% maturity (biological and functional) slightly varied between the two methods (23.66–23.93 and 25.34–25.57 cm). They also investigated spatial trends in maturity and found ~ 2 cm difference in functional maturity between fish sampled north and south of Cape Mendocino, CA (26.22–26.48 and 24.38–24.74 cm). The authors demonstrated model sensitivity by updating the maturity estimates in the 2013 aurora rockfish stock assessment. Absolute, but not relative, spawning output, was sensitive to model choice, spatial resolution, and the updated data. This new flexible spline model can account for skip spawning, capturing potential spawners in a given year, and thus provides accurate measurements for spawning output models.



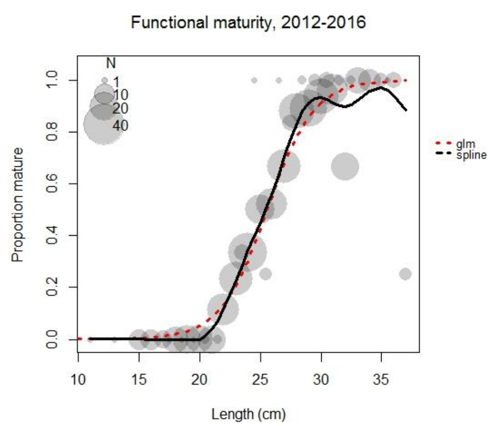


Figure 10. Length (cm) at maturity estimates for Biological maturity coast-wide showing the GLM (red dashed line) and spline (solid black line) fit (upper figure) and Functional maturity coast-wide showing the GLM (red dashed line) and spline (black solid line) (lower figure).

For more information, please contact Melissa Head at Melissa.Head@noaa.gov.

b) Genome-wide markers reveal differentiation between and within the cryptic sister species, sunset and vermilion rockfish

Investigators: Longo, G.C., Harms, J., Hyde, J.R., Craig, M.T., Ramon-Laca, A. Nichols, K.

The vermilion rockfish complex, which consists of the cryptic sister species vermilion and sunset rockfish, is one of themost valuable recreational fisheries on the U.S. West Coast. These species are currently managed as a single complex, and because of uncertainty surrounding the relative contribution of each species within existing data sources, the stock status of each species is not fully known. A reliable and cost-effective method is needed to disentangle these species that will allow for the development of abundance indices, life history profiles, and catch histories that may potentially support species-specific stock assessments. Using restriction-site associated DNA sequence (RADseq) markers we generated 10,003 polymorphic loci to characterize the vermilion rockfish complex. PCA and Bayesian clustering approaches based on these loci clearly distinguished between sunset and vermilion rockfishes and identified hybrid individuals. These loci included 203 highly differentiated ($FST \geq 0.99$) single nucleotide polymorphisms, which we consider candidates in the planned development of a diagnostic assay capable of distinguishing between these cryptic species. In addition to clearly delineating to species, subsets of the interspecific markers allowed for insight into intraspecific differentiation in both species. Population genetic analyses for sunset rockfish identified two weakly divergent genetic groups with similar levels of genetic diversity. Vermilion rockfish, however, were characterized by three distinct genetic groups with much stronger signals of differentiation and significantly different genetic diversities. Collectively, these data will contribute to well informed, species-specific management strategies to protect this valuable species complex.

Longo, G.C., Harms, J., Hyde, J.R., Craig, M.T., Ramon-Laca, A. Nichols, K. 2022. Genome-wide markers reveal differentiation between and within the cryptic sister species, sunset and vermilion rockfish. Conserv Genet 23, 75–89.

For more information, please contact John Harms at john.harms@noaa.gov.

c) Spatiotemporal patterns of variability in the abundance and distribution of winter-spawned pelagic juvenile rockfish in the California Current

Investigators: Field J.C., Miller R.R., Santora J.A., Tolimieri N., Haltuch M.A., Brodeur R.D., Auth T.D., Dick E.J, Monk M.H, Sakuma K.M., Wells, B.K

Rockfish are an important component of West Coast fisheries and California Current food webs, and recruitment (cohort strength) for rockfish populations has long been characterized as highly variable for most studied populations. Research efforts and fisheries surveys have long sought to provide greater insights on both the environmental drivers, and the fisheries and ecosystem consequences, of this variability. Here, variability in the temporal and spatial abundance and distribution patterns of young-of-the-year (YOY) rockfishes are described based on midwater trawl surveys conducted throughout the coastal waters of California Current between 2001 and 2019. Results confirm that the abundance of winter spawning rockfish taxa in particular is highly variable over space and time. Although there is considerable spatial coherence in these relative abundance patterns, there are many years in which abundance patterns are very heterogeneous over the scale of the California Current. Results also confirm that the high abundance levels of YOY rockfish observed during the 2014–2016 large marine heatwave were largely coast wide events. Species association patterns of pelagic YOY for over 20 rockfish taxa in space and time are also described. The overall results will help inform future fisheries-independent surveys, and will improve future indices of recruitment strength used to inform stock assessment models and marine ecosystem status reports.

Field J.C., Miller R.R., Santora J.A., Tolimieri N., Haltuch M.A., Brodeur R.D., Auth T.D., Dick E.J, Monk M.H, Sakuma K.M., Wells, B.K. 2021. Spatiotemporal patterns of variability in the abundance and distribution of winter-spawned pelagic juvenile rockfish in the California Current. PLoS ONE 16(5): e0251638. https://doi.org/ 10.1371/journal.pone.0251638

For more information, please contact Nick Tolimieri at nick.tolimieri@noaa.gov.

d) Diel vertical movement of yelloweye rockfish in Hood Canal, WA

Investigator: Kelly Andrews

Preliminary analyses using data from fifteen Yelloweye Rockfish collected and tagged with acoustic transmitters in Hood Canal, WA showed patterns of diel vertical movement and activity level. Individuals were generally slightly shallower, and more active during the night compared to daylight hours. However, during periods when dissolved oxygen (DO) concentrations were lowest, activity levels at night were reduced compared to periods with higher DO concentrations. If the increased activity level at night is related to increased foraging activity, periods of low DO could significantly reduce foraging and bioenergetic capabilities during these periods.

e) Cross-shelf variability of Deacon Rockfish *Sebastes diaconus* age, growth, and maturity in Oregon waters and their effect on stock status

Investigators: L. Rasmuson, P.S. Rankin, L.A. Kautzi, **A. Berger**, M.T.O. Blume, K.A. Lawrence, and K. Bosley

Understanding the basic biology of exploited fish populations, and how it changes across the waterscape, is essential to sustainable management. Biological features (age, growth, reproductive investment, and fish condition) for the newly described Deacon Rockfish *Sebastes diaconus* were evaluated between two different population segments, an exploited nearshore population and an unexploited offshore population, and were used to parameterize population dynamics models to evaluate how area-specific biological features influence measures of stock status. Monthly hook-and-line sampling was conducted for 1 year, with~50fish collected per area per sampling period. Despite the relatively small (<50 km) distance between the two sampling areas, there were discernible differences in the biology of Deacon Rockfish. When fish of the same size-class were compared between offshore and nearshore segments, the unexploited offshore fish were older, suggesting that fishing may have decreased the overall age structure of the exploited nearshore population segment. Parameters of the von Bertalanffy growth model differed the most between the sexes and secondarily between the nearshore and offshore population segments. Length at 50% maturity was 28cm and age at 50% maturity was 4.1 years for females, which is smaller and younger than previously reported in the literature. Deacon Rockfish were captured in both the nearshore and offshore areas throughout the year, which suggests that at least some component(s) of the population is present in both areas throughout the year. These differences had a nontrivial influence on measures of stock status and will be important to consider during future stock assessments and as management considers the effect of the recent reopening of the offshore population segment to fishing. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*.

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

2. Assessments

a) Stock Assessment of the copper rockfish (*Sebastes caurinus*) along the U.S. West Coast in 2021 using catch, length, and fishery-independent abundance data

Investigators: C.R. Wetzel, B.J. Langseth, J.M. Cope, J.E. Budrick, A.D. Whitman, T.S. Tsou, K.E. Hinton

This assessment reports the status of copper rockfish (*Sebastes caurinus*) off the U.S. West Coast using data through 2020. Copper rockfish is a rockfish that is commonly found of the west coast in nearshore waters with a core distribution off of California. This species was assessed using four separate area-based assessments: south of Point Conception in California, north of Point Conception in California, Oregon, and Washington. This was the second data-moderate assessment of this species and was the first assessment to use length-data.

Relative spawning output declined sharply in both California areas, reaching low biomass levels in the late 1980s. The stock south of Point Conception had an increase in biomass following low biomass levels in the 1980s until recent years (2015) with declines in biomass in recent years. The stock south of Point Conception estimated stock status in 2021 was 18 percent of unfished spawning biomass, below the management threshold (25 percent) due to recent increases in total mortality (Figure 11). The estimated stock status for the portion of the population in California north of Point Conception was estimated to be 39 percent of unfished spawning biomass, just below the management target of 40 percent (Figure 12), with recent above average recruitment driving up the stock at the end of the time series. Overall status determination was summed across both California assessments with a combined stock status of 32 percent.

The overall population size off of Oregon and Washington were relatively low, relative to the California stocks. Both assessment models assumed deterministic stock-recruitment relationship due to limited data. The estimated stock status in Oregon was estimated to be well above the management target at 72 percent of unfished spawning biomass (Figure 13). The estimated stock status off the coast of Washington was near the management target at 42 percent of unfished spawning biomass (Figure 14).

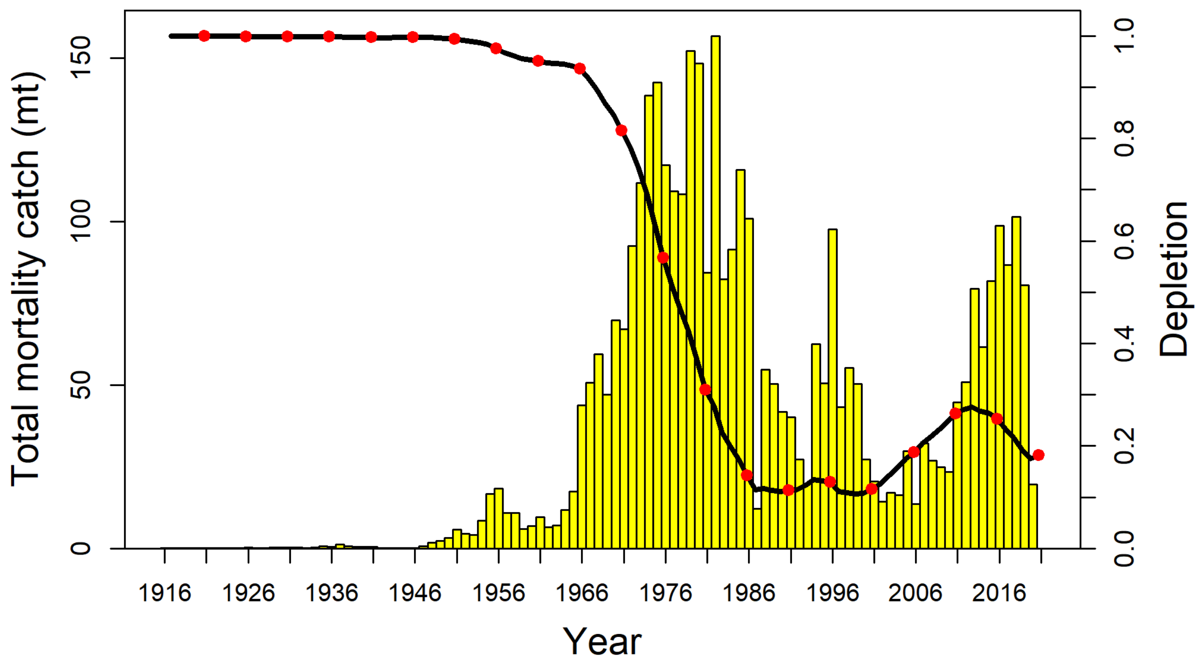


Figure 11. Copper South of Point Conception. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of copper rockfish south of Point Conception for years modeled.

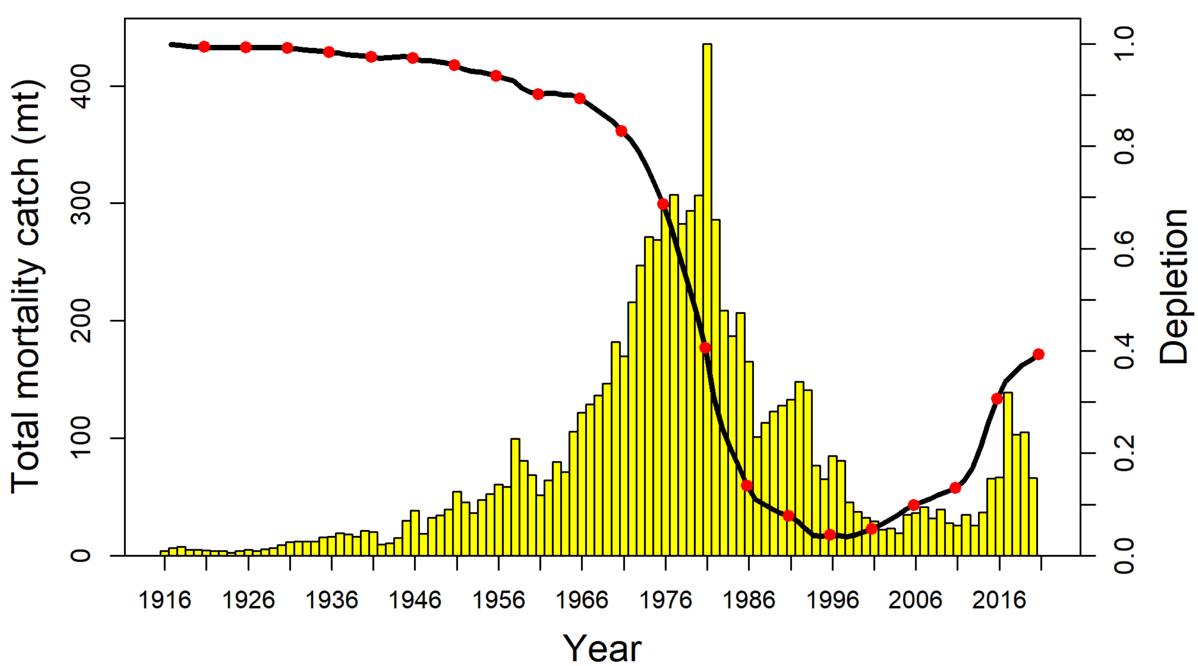


Figure 12. Copper North of Point Conception. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of copper rockfish in California north of Point Conception for years modeled.

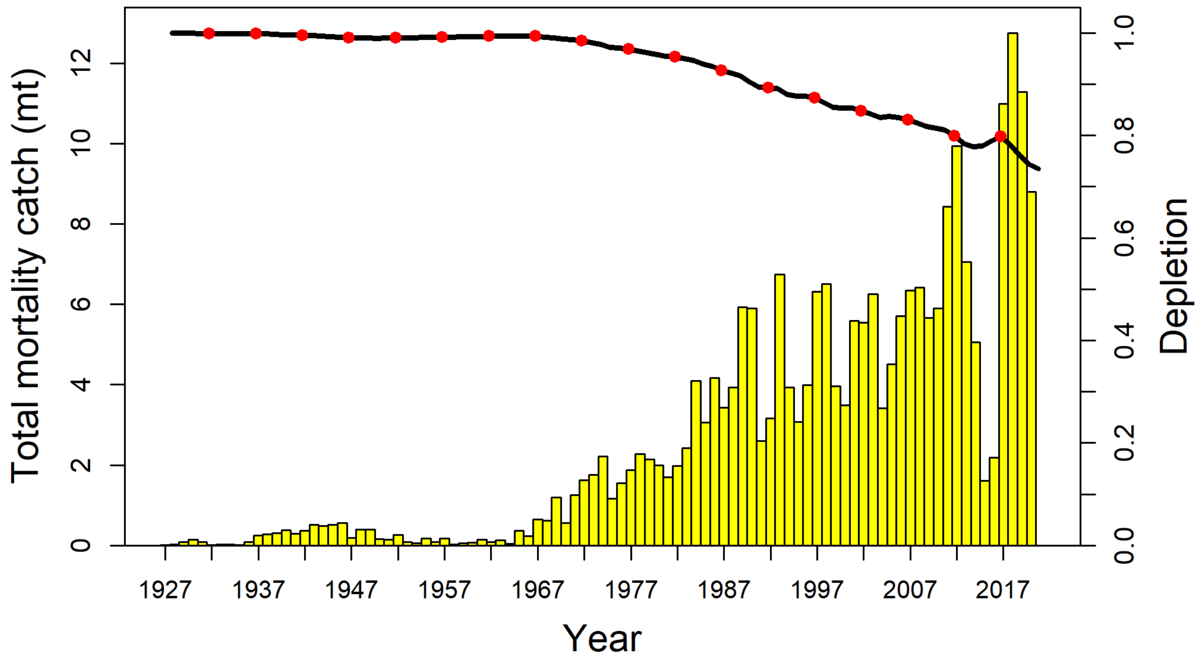


Figure 13. Copper Oregon. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of copper rockfish in Oregon waters for years modeled.

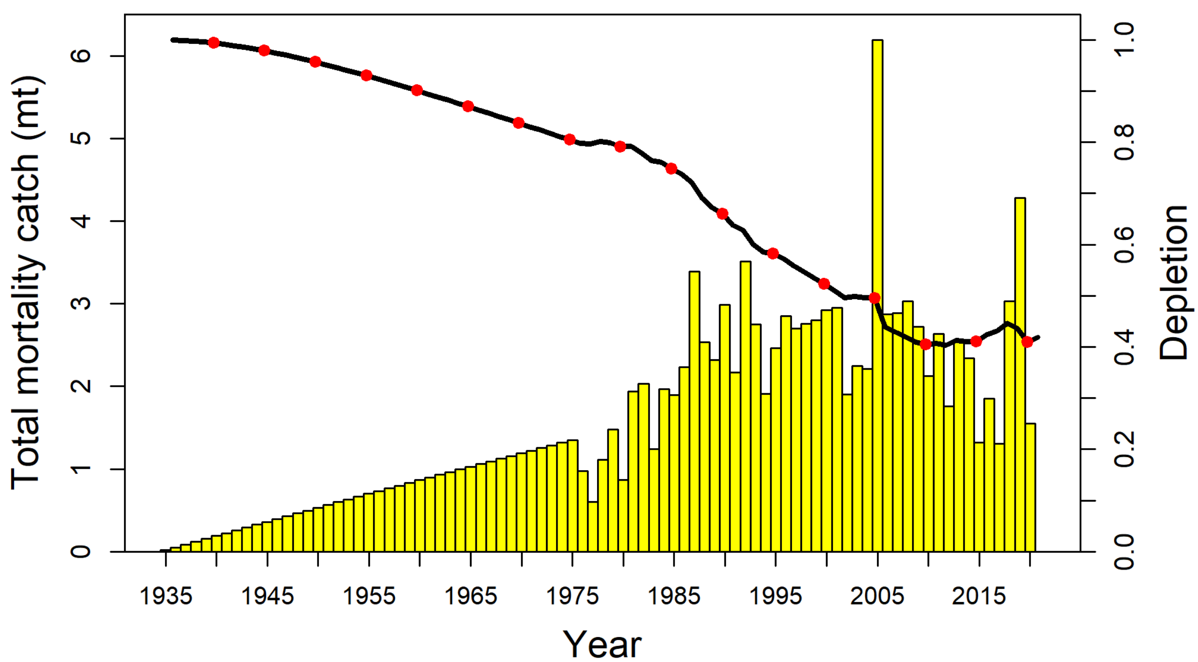


Figure 14. Copper Washington. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of copper rockfish in Washington waters for years modeled.

For more information, please contact Chantel Wetzel at chantel.wetzel@noaa.gov

b) Stock Assessment of the Squarespot Rockfish (*Sebastes hopkinsi*) along the California U.S. West Coast in 2021 using catch, length, and fishery-independent abundance data

Investigators: J.M. Cope, C.R. Wetzel, B.J. Langseth, and J.E. Budrick

This assessment reports the status of squarespot rockfish (*Sebastes hopkinsi*) off the U.S. West Coast using data through 2020. Squarespot rockfish is a relatively small rockfish found from Mexico to southern Oregon, with a core distribution in southern California. This species is treated as one stock, as there is no evidence of population structure. This is the first full assessment for squarespot rockfish.

Squarespot rockfish are generally undesirable in the recreational and commercial fishery due to their small size (Figure A- bars). Females grow larger than males, and only nearing their maximum length do they reach a size that is marginally acceptable to anglers, thus the landings are primarily composed of older females. The commercial removals for squarespot rockfish are extremely sparse throughout the time series. The small size of squarespot rockfish individuals makes squarespot rockfish an undesirable fish to market and to capture by trawl or commercial hook and line gears. The input catches in the model represent total removals: landings plus discards. Discard totals for the commercial fleet from 2002-2019 were determined based on West Coast Groundfish Observer Program (WCGOP) data provided in the Groundfish Expanded Mortality Multiyear (GEMM) product. The historical commercial discard mortality was calculated based on the average discard rates from WCGOP of 28 percent and used to adjust the landings data from 1916 to 2001 to account for total removals. Given the extremely small commercial landings and minimal sampling of lengths (see below), the recreational and commercial catches were combined into a single fleet by aggregating across gear types.

Relative spawning output declined below the management target in the early 1980s and again fell below the target starting in 2019 (Figure 15). The relative stock status at the start of 2021 is estimated to be below the rockfish relative biomass target of 40 percent (37%) but above the management threshold of 25 percent. The very low catches in 2020 (likely attributable to the COVID-19 pandemic) allowed the population to rebound under the assumption of deterministic recruitment,

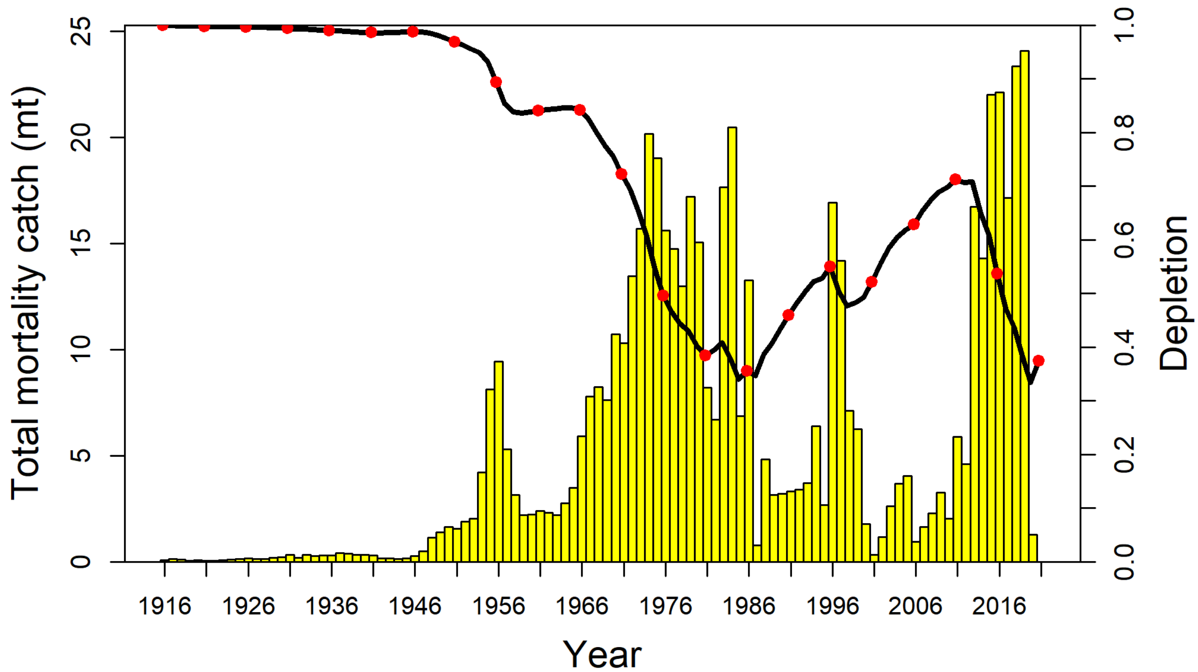


Figure 15. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of Squarespot Rockfish for years.

For more information, please contact Jason Cope at Jason.Cope@noaa.gov

c) Status of Vermilion rockfish (*Sebastes miniatus*) along the US West - Oregon coast in 2021

Investigators: J.M. Cope and A.D. Whitman

This assessment reports the status of vermilion rockfish (*Sebastes miniatus*) off Oregon state using data through 2020. Vermilion rockfish are also found in California (their core range) and Washington waters of the U.S. West Coast, and those are treated in separate stock assessments given different management considerations and exploitation histories. There is substantial biogeographic separation in the populations off Oregon and Washington, thus justifying separation of those populations into different management units and stock assessments.

Vermilion rockfish have been caught mainly by hook and line gear in commercial and recreational fisheries (Figure 16). Commercial catches ramped up in the late 1960s followed by decreasing catches since the mid-1980s. Recreational catches started to increase in the 1980s, fluctuating over time, with high catches over the last several years.

Relative spawning output declined with the onset of increasing commercial removals in the 1960s and continued to decline with the increase in recreational catches through the 1990s, even dropping below the target relative stock size.

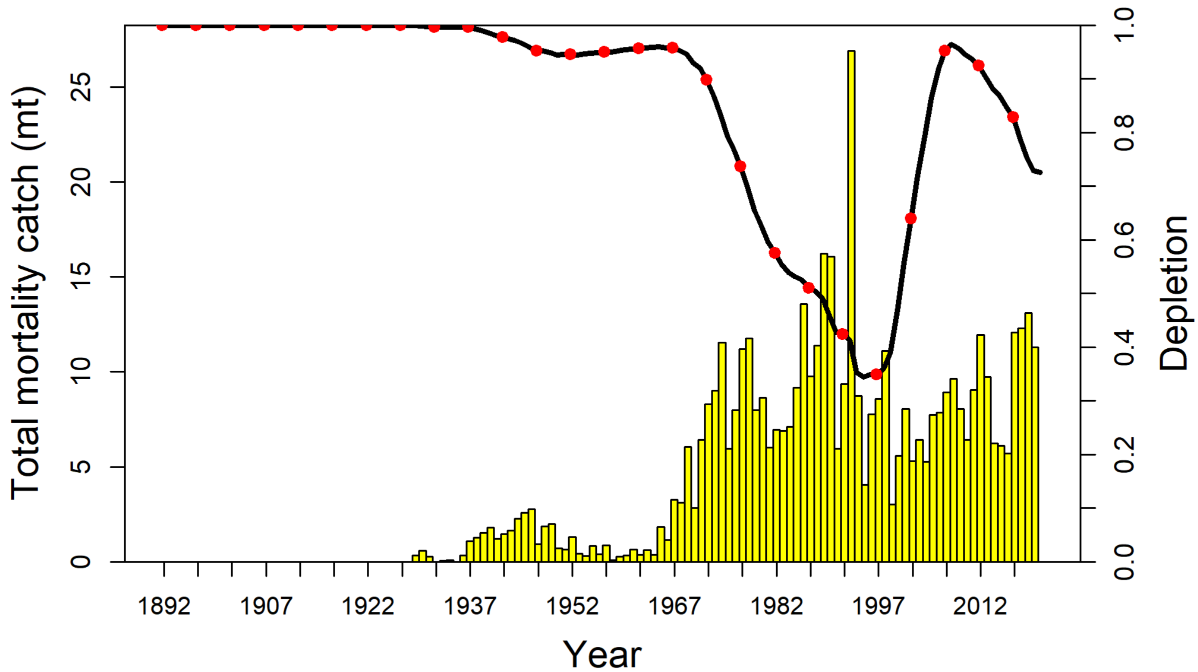


Figure 16. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of Vermilion Rockfish in Oregon.

For more information, please contact Jason Cope at Jason.Cope@noaa.gov

d) Status of Vermilion rockfish (*Sebastes miniatus*) along the US West - Washington State coast in 2021

Investigators: J.M. Cope, T-S. Tsou, K. Hinton, and C. Niles

This assessment reports the status of vermilion rockfish (*Sebastes miniatus*) off Washington state using data through 2020. Vermilion rockfish are also found in California and Oregon waters, but those are treated separately in other stock assessments. The core range of vermilion rockfish are in California, thus outside Washington waters; this assessment thus considers a very small population at the limit of the species range under different management considerations and exploitation histories than vermilion rockfish stocks in either California or Oregon. There is substantial biogeographic separation in the populations off Oregon and Washington, thus justifying separation of those populations into different management units and stock assessments. Vermilion in Canadian waters are also rare and not included in this assessment.

Vermilion rockfish are mainly caught in recreational fisheries by hook and line gear. Recreational catches are generally low, but in relative terms increased in mid-1980s and have fluctuated since to a peak catch in 2019. Vermilion rockfish are not targets in the Washington recreational fishery and are considered rare.

The relative spawning output at the beginning of 2021 56 percent of unfished (Figure 17). Overall, spawning output declined with the onset of increasing recreational removals in the mid-1980s and continued to decline with the increase in recreational catches through the 1990s.

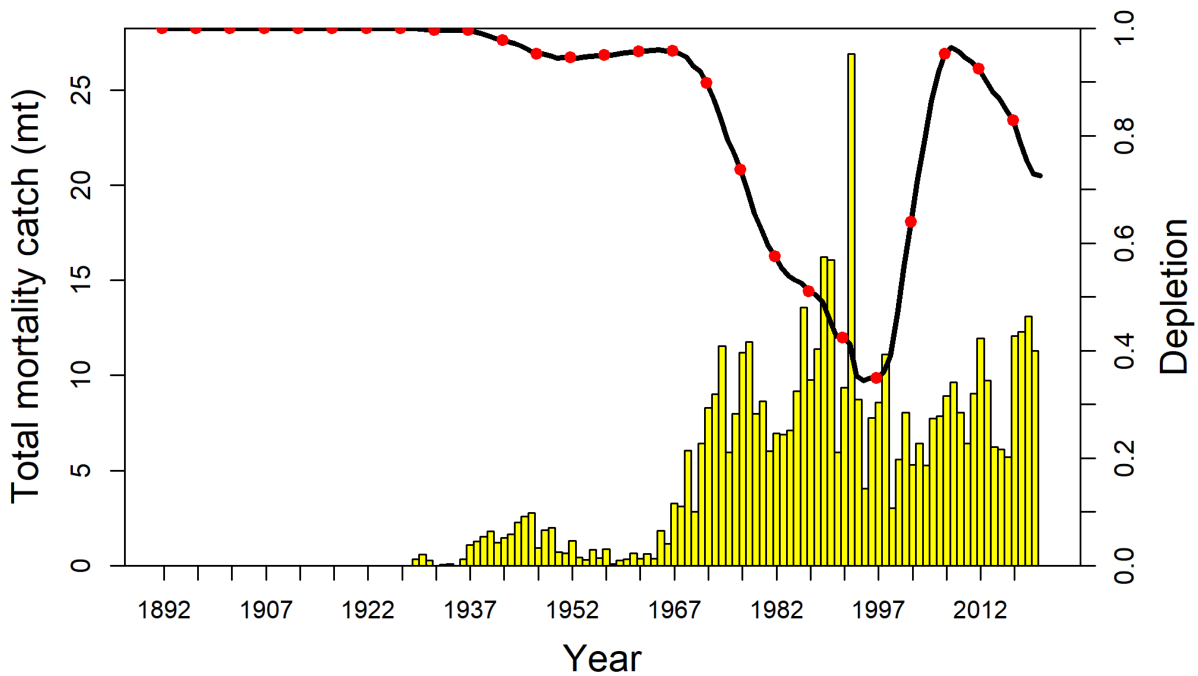


Figure 17. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of Vermilion Rockfish in Washington State.

For more information, please contact Jason Cope at Jason.Cope@noaa.gov

e) Status of quillback rockfish (*Sebastes maliger*) in U.S. waters off the coast of Washington in 2021 using catch and length data

Investigators: B.J. Langseth, C.R. Wetzel, J.M. Cope, T.S. Tsou, and L.K. Hillier

This assessment reports the status of quillback rockfish (*Sebastes maliger*) off the Washington coast using data through 2020. Quillback rockfish are a medium- to large-sized nearshore rockfish found from southern California to the Gulf of Alaska. The stock off the Washington coast was assessed as a separate stock from other populations off the U.S. West Coast because of the fairly sedentary nature of quillback rockfish, and different exploitation history and magnitude of removals off the Washington coast. Populations off Oregon and California are assessed in separate stock assessments. This is the first stock assessment of quillback rockfish using catch and length composition data. Quillback rockfish was last assessed in 2010, coastwide, using Depletion-Based Stock Reduction Analysis.

Quillback rockfish have historically been part of both commercial and recreational fisheries throughout their range. Off the Washington coast, quillback rockfish are primarily caught in the recreational fishery, and in general, are not targeted by either commercial or recreational fleets

(Figure 18 - bars). Recreational removals were specified in numbers of fish (1,000s) but were converted to metric tons internally to the model. The recreational removals generally increased over-time in the early years, spiked in 1990, declined through 2010, and remained level through 2020, with the exception of high removals in 2019. The commercial removals for quillback rockfish are sparse throughout the time series. Washington state waters were closed to commercial fixed gears in 1995 and to trawling in 1999. There are four treaty tribes along the Washington coast that continue to fish under separate commercial rules and are not subject to the state water closure.

Relative spawning output showed a steady decline over the early part of the time series, stabilizing around 2010, and increasing in recent years (Figure 18 – line). The 2021 relative spawning output was just under (39%) the target of 40 percent of unfished spawning output. Recruitment was assumed to be deterministic.

The primary uncertainty for the Washington quillback rockfish model was in the scale of the population. The trajectory of the population was generally consistent across model explorations however there was limited information in the data to inform population scale scale. The ability to estimate additional process and biological parameters for quillback rockfish was also limited by data. Collecting more length and otolith samples from the recreational and commercial fleets would be beneficial to future assessments.

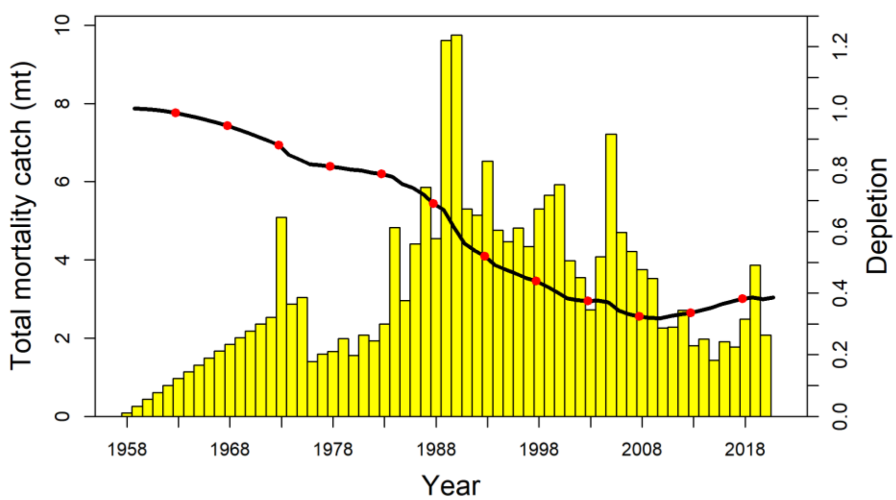


Figure 18. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of quillback rockfish off Washington for years 1958 - 2020.

For more information, please contact Brian Langseth at brian.langseth@noaa.gov

e) Status of quillback rockfish (*Sebastes maliger*) in U.S. waters off the coast of Oregon in 2021 using catch and length data

Investigators: B.J. Langseth, C.R. Wetzel, J.M. Cope, and A.D. Whitman

This assessment reports the status of quillback rockfish (*Sebastes maliger*) off the Oregon coast using data through 2020. Quillback rockfish are a medium- to large-sized nearshore rockfish found from southern California to the Gulf of Alaska. The stock off the Oregon coast was assessed as a separate stock from other populations off the U.S. West Coast because of the fairly sedentary nature of quillback rockfish and different exploitation history and magnitude of removals off the Oregon coast. Populations off Washington and California are assessed in separate stock assessments. This is the first stock assessment of quillback rockfish using catch and length composition data. Quillback rockfish was last assessed in 2010, coastwide, using Depletion-Based Stock Reduction Analysis.

Quillback rockfish off the coast of Oregon are caught in both the commercial and recreational fisheries (Figure 19 - bars). The reported landings from the commercial fishery extend back to 1892 and, other than a small peak in the late 1930s through the 1940s, were minimal until the late-1960s. Commercial landings for quillback rockfish increased from the mid-1960s to 1974 and have since fluctuated between approximately 0.4 and 4.5 mt annually. From 2003 to 2020, landings averaged 1.6 mt annually, and represent approximately one third of the total removals. Landings from the recreational fishery off the coast of Oregon were assumed to begin in 1970 and have generally increased across time and now represent the majority of landings for quillback rockfish off the coast of Oregon. Annual fluctuations in recreational landings were high, ranging from 0.5 to 9.5 mt, and landings since 2017 were some of the highest across the time series.

Relative spawning output declined until 1995, where it steadied due to several above average recruitment events that occurred in the early- to mid-1990s, and then increased dramatically in the early 2000s due to the very large recruitment event in 1995 (Figure 19 – line). The increase slowed in the late 2000s, and then declined in the 2010s due to below average recruitment through the 2000s. The 2021 relative spawning output was above (47%) the target of 40 percent of unfished spawning output.

The important uncertainties for the Oregon quillback rockfish model included selectivity assumptions, the magnitude of recruitment variations, and estimates of growth. The ability to estimate additional process and biological parameters for quillback rockfish was limited by data. Future assessments would benefit from collecting more length and otolith samples from the recreational and commercial fleets, which would also help address the uncertainties described above.

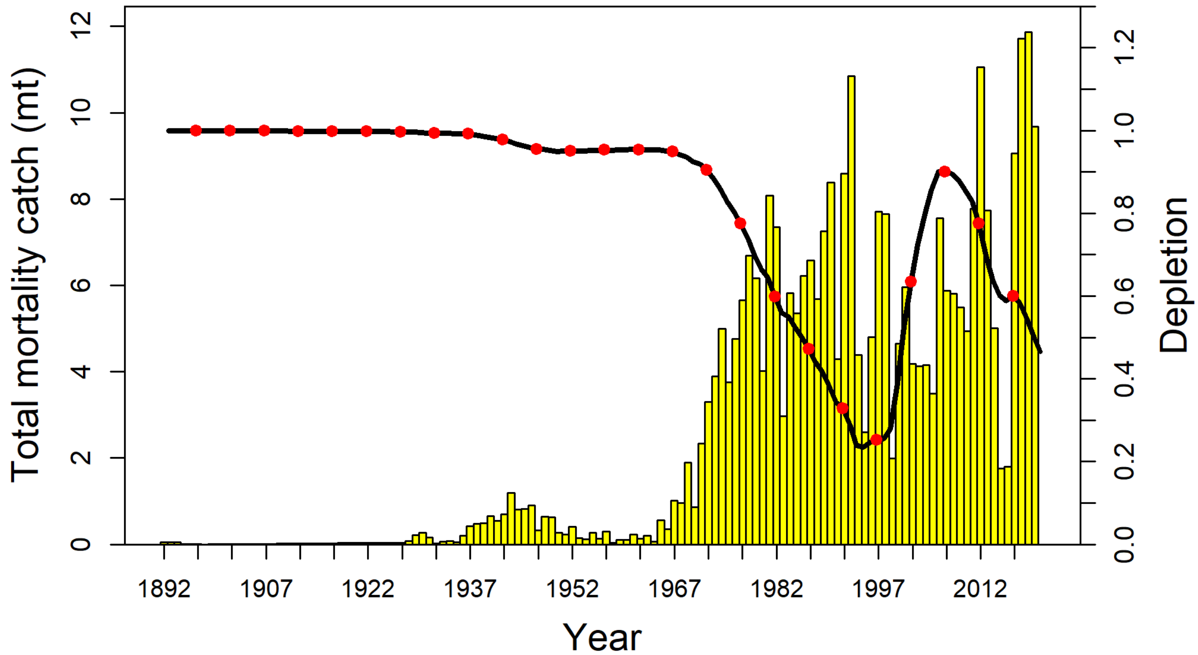


Figure 19. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of quillback rockfish off Oregon for years 1892 - 2020.

For more information, please contact Brian Langseth at brian.langseth@noaa.gov

f) Status of quillback rockfish (*Sebastes maliger*) in U.S. waters off the coast of California in 2021 using catch and length data

Investigators: B.J. Langseth, C.R. Wetzel, J.M. Cope, and J.E. Budrick

This assessment reports the status of quillback rockfish (*Sebastes maliger*) off the California coast using data through 2020. Quillback rockfish are a medium- to large-sized nearshore rockfish found from southern California to the Gulf of Alaska. Off the U.S. West Coast quillback rockfish are primarily located north of central California, with few observations south of Point Conception. The stock off the California coast was assessed as a separate stock from other populations off the U.S. West Coast because of the fairly sedentary nature of quillback rockfish, and different exploitation history and magnitude of removals off the California coast. Populations off Oregon and Washington are assessed in separate stock assessments. This is the first stock assessment of quillback rockfish using catch and length composition data. Quillback rockfish was last assessed in 2010, coastwide, using Depletion-Based Stock Reduction Analysis.

Quillback rockfish off the coast of California are caught in both the recreational and commercial fisheries (Figure 20 – bars). Recreational removals are the largest source of fishing mortality and represent approximately 70 percent of the total removals of quillback rockfish across all years. Recreational removals peaked in the late 1970s and early 1980s, with two years of exceptionally large catches in 1984 and 1993. Removals declined sharply in 1994, but increased to levels similar to the late 1970s and early 1980s in the mid-2000s and again in recent years. The majority of the commercial landings for quillback rockfish occurred between 1990 and 2008, and outside these years, apart from 1945-1946, 1984, and the last four years, commercial landings for quillback rockfish have been less than 2 mt per year.

Relative spawning output declined steadily from the first modeled year until 1999, with the exception of a slight increase around 1990, and then increased due to several above average recruitment events that occurred in the mid- to late-1990s. Relative spawning output increased until 2007 and remained level until 2016, after which it declined through 2020. The 2021 relative spawning output was 14%, and below the threshold of 25 percent of unfished spawning output.

The primary uncertainty for the California quillback rockfish model was in estimates of growth, particularly whether growth differed from Oregon and Washington populations, which had growth data available. The ability to estimate additional process and biological parameters for quillback rockfish was limited by data as few California fish were aged. Future assessments would benefit from collecting more length and otolith samples from the recreational and commercial fleets, particularly otolith samples from very small and very large individuals, to best inform growth parameters.

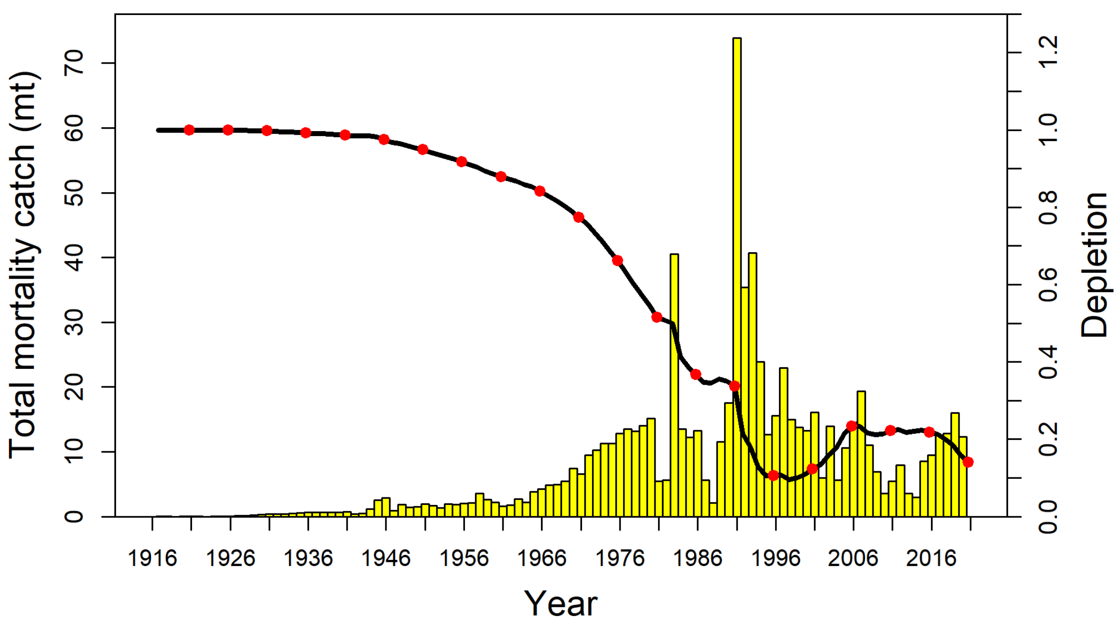


Figure 20. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of quillback rockfish off California for years 1916 - 2020.

For more information, please contact Brian Langseth at brian.langseth@noaa.gov

3. Management

I. Thornyheads

J. Sablefish

1. Research

a) Limitations and applications of macroscopic maturity analyses: A comparison of histological and visual maturity staging in multiple west coast groundfish species

Investigators: Markus A. Min, Melissa A. Head, Jason M. Cope, Jim D. Hastie and S. Flores

Accurate maturity schedules are critical to ensure that stock assessment models can track changes in spawning stock biomass. To generate updated maturity estimates, the Northwest Fisheries Science Center's Fishery Resource Analysis and Monitoring Division instituted a reproductive biology program in 2009. This program uses histological analysis of ovaries to determine maturity, a technique that is more reliable than the traditional macroscopic method but is also time-consuming and expensive. As macroscopic maturity data are still being collected by multiple agencies on the US west coast, most prominently the Oregon Department of Fish and Wildlife (ODFW), we evaluated the usefulness of these macroscopic maturity recordings by verifying their accuracy using histological methods. Two species in this study, arrowtooth flounder (*Atheresthes stomias*) and canary rockfish (*Sebastes pinniger*), representative of west coast flatfishes and rockfishes (*Sebastes* spp.), had high correspondence between length at 50% biological (physiological) maturity (L50) evaluated histologically and macroscopically. Estimates of L50 for sablefish (*Anoplopoma fimbria*), a representative west coast roundfish, varied significantly between macroscopic and histological methods. Functional maturity (potential spawners in a given year) determined via histology did not correlate with macroscopic maturity for any studied species. In its current form, macroscopic maturity collections are insufficient for assessments of species with significant reproductive complexities but have limited application in assessing changes in maturity schedules over time. However, a lack of standardization among different state departments of fish and wildlife severely hinders any attempt at using macroscopic maturity data to analyze spatial trends in maturity.

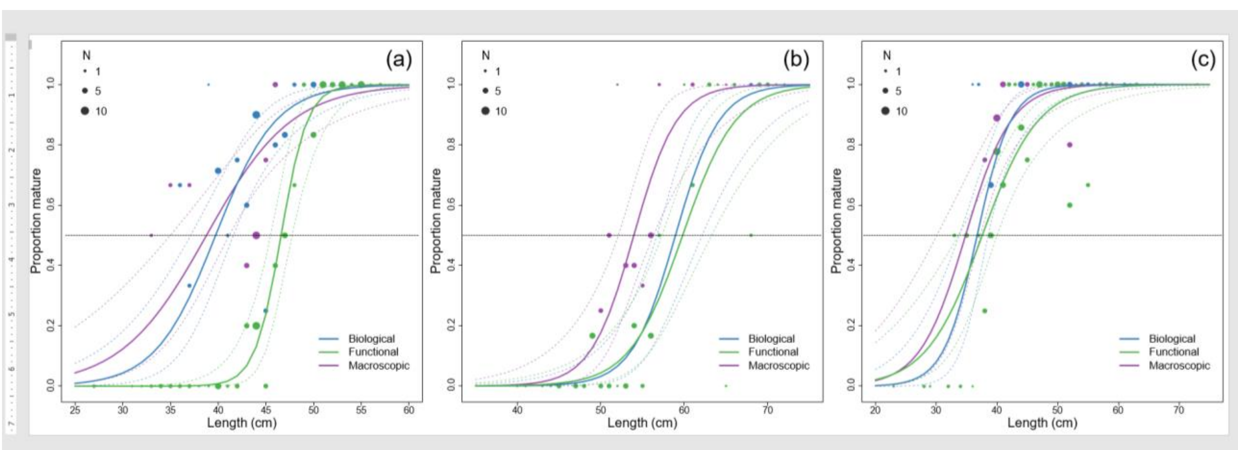


Figure 21. Comparison of maturity ogives fit to maturity data for the three different types of maturity data (biological, functional, and macroscopic) for (**a)** canary rockfish (*Sebastes pinniger*), (**b)** sablefish (*Anoplopoma fimbria*), and (**c)** arrowtooth flounder (*Atheresthes stomias*). Confidence intervals are for the proportion mature at each length

Min, M., Head, M.A., Cope, J., Hastie, J. and Flores, S. 2021. Limitations and applications of macroscopic maturity analyses: A comparison of histological and visual maturity staging in multiple west coast groundfish species. Environmental Biology of Fishes. 105. 10.1007/s10641-021-01208-2.

For more information, please contact Melissa Head at Melissa.Head@noaa.gov.

b) The shadow model: how and why small choices in spatially explicit species distribution models affect predictions

Investigators: Commander C.J.C., Barnett L.A.K., Ward E.J., Anderson S.C., Essington T.E.

The use of species distribution models (SDMs) has rapidly increased over the last decade, driven largely by increasing observational evidence of distributional shifts of terrestrial and aquatic populations. These models permit, for example, the quantification of range shifts, the estimation of species co-occurrence, and the association of habitat to species distribution and abundance. The increasing complexity of contemporary SDMs presents new challenges—as the choices among modeling options increase, it is essential to understand how these choices affect model outcomes. Using a combination of original analysis and literature review, we synthesize the effects of three common model choices in semi-parametric predictive process species distribution modeling: model structure, spatial extent of the data, and spatial scale of predictions. To illustrate the effects of these choices, we develop a case study centered around sablefish (*Anoplopoma fimbria*) distribution on the west coast of the USA. The three modeling choices represent decisions necessary in virtually all ecological applications of these methods, and are important because the consequences of these choices impact derived quantities of interest (*e.g*., estimates of population size and their management implications). Truncating the spatial extent of data near the observed range edge, or using a model that is misspecified in terms of covariates and spatial and spatiotemporal fields, led to bias in population biomass trends and mean distribution compared to estimates from models using the full dataset and appropriate model structure. In some cases, these suboptimal modeling decisions may be unavoidable, but understanding the tradeoffs of these choices and impacts on predictions is critical. We illustrate how seemingly small model choices, often made out of necessity or simplicity, can affect scientific advice informing management decisions—potentially leading to erroneous conclusions about changes in abundance or distribution and the precision of such estimates. For example, we show how incorrect decisions could cause overestimation of abundance, which could result in management advice resulting in overfishing. Based on these findings and literature gaps, we outline important frontiers in SDM development**.**

Commander CJC, Barnett LAK, Ward EJ, Anderson SC, Essington TE. 2022. The shadow model: how and why small choices in spatially explicit species distribution models affect predictions. PeerJ 10:e12783 https://doi.org/10.7717/peerj.12783

For more information, contact Eric Ward at Eric.Ward@noaa.gov

c) PSTAT Oceanographic features delineate growth zonation in Northeast Pacific sablefish

Investigators: Haltuch, M.A., Connors, B., Kapur, M., Rogers, L., Berger, A., Echave, K., Williams, B., Lundsford, C., Marshall, K., Punt A.E.

The Pacific Sablefish Transboundary Assessment Team (PSTAT), in collaboration with the NWFSC, AFSC, DFO, ADF&G, PFMC, and NPFMC, held a public workshop to solicit feedback on the ongoing range-wide sablefish Management Strategy Evaluation (MSE) during spring 2021. The MSE explores the consequences of spatial stock structure and movement for regional management. The workshop engaged fishery stakeholders, Alaska Natives and Tribal governments, First Nations, scientists, managers, and Non-governmental organization staff from each region on discussions about sablefish science and management. The workshop introduced the basic premise, goals, and utility of a MSE and participants' roles in the process. The successful sablefish MSE experience from British Columbia was introduced, along with the range of time horizons for incorporating stakeholder input into this NE Pacific MSE. Then the Operating Model (OM) structure and justification for focusing on the NE Pacific, rather than the traditional regional approach to scientific analyses was discussed. Breakout groups focused on identifying fishery objectives, performance metrics, and proposed near term MSE management procedures to evaluate.

Since the spring 2021 workshop, the Operating Model (OM) development has been completed and is currently being tuned to observed data. The study reanalyzing all available sablefish tagging data used to specify movement in the OM is in preparation for publication. The team anticipates initial results during 2023.

For more information, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

2. Assessment

a) 2021 Update Sablefish Stock Assessment: Status of Sablefish (*Anoplopoma fimbria*) along the US West coast in 2021.

Investigators: Kapur, M. S., Lee, Q., Correa, G. M., Haltuch, M., Gertseva, V., and Hamel, O. S. 2021

This update assessment reports the status of sablefish (Anoplopoma fimbria) off the US West coast using data through 2020. The resource is modeled as a single stock; however, sablefish disperse to and from offshore seamounts, along the coastal waters of the US West Coast, Canada, and Alaska, and across the Aleutian Islands to the western Pacific. Their movement is not explicitly accounted for in this analysis.

During the first half of the 20th century, it is estimated that sablefish were exploited at relatively modest levels. Modest catches continued until the 1960s, along with a higher frequency of above average, but uncertain, estimates of recruitment through the 1970s. The spawning biomass increased during the 1940s to 1970s. Subsequently, biomass is estimated to have declined between the mid-1970s and the early 2010s, with the largest peaks in harvests during the 1970s followed by harvests that were, on average, higher than pre-1970s harvest through the 2000s. At the same time, there were a higher frequency of generally lower than average recruitments from the 1980s forward. Despite estimates of harvest rates that were largely below overfishing rates from the 1990s forward and a few high recruitments from the 1980s forward, the spawning biomass has only recently begun to increase. This stock assessment suggests spawner per recruitment rates higher than the target during some years from the 1990s forward for two reasons. First, there have been many years with lower than expected recruitment. Second, stock assessment estimates of unfished spawning biomass have generally been declining in each subsequent assessment since 2007. Estimates of unfished biomass scale catch advice.

The estimates of uncertainty around the point estimate of unfished biomass are large across the range of models explored within this assessment, suggesting that the unfished spawning biomass could range from about 100,000 mt to over 200,000 mt. This uncertainty is largely due to the confounding of natural mortality, absolute stock size, and productivity. The point estimate of 2021 spawning biomass from the base model is 97,802 mt, however, the 95% interval ranges broadly from 40,802-154,801 mt. The point estimate of 2021 spawning biomass relative to an unfished state (i.e., depletion) from the base model is 57.9% of unexploited levels (95% interval: 38.4%-77.5%).

Sablefish recruitment is estimated to be quite variable with large amounts of uncertainty in individual recruitment events. A period with generally higher frequencies of strong recruitments spans from the early 1950s through the 1970s, followed by a lower frequency of large recruitments during 1980 forward, contributing to stock declines. The period with a higher frequency of high recruitments contributed to a large increase in stock biomass that has subsequently declined throughout much of the 1970s forward. Less frequent large recruitments during the mid-1980s through 1990 slowed the rate of stock decline, with another series of large recruitments during 1999 and 2000 leading to a leveling off in the stock decline. The above-average cohorts from 2008, 2010, 2013, and 2016 are contributing to a slightly increasing spawning stock size.

Unfished spawning biomass was estimated to be 168,875 mt (107,749-230,001 ~95% interval). The abundance of sablefish was estimated to have declined to near the target during the period 1980-2000. The estimate of the target spawning biomass was 67,550 (43,099-92,001, ~95% interval). The stock was estimated to be above the target stock size in the beginning of 2021 at 97,802 mt (40,801-154,802, ~95% interval). The stock was estimated to be above the depletion level that would lead to maximum yield (0.4) (Figure 22). The estimate of the stock's current 2021 level of depletion was 0.579.

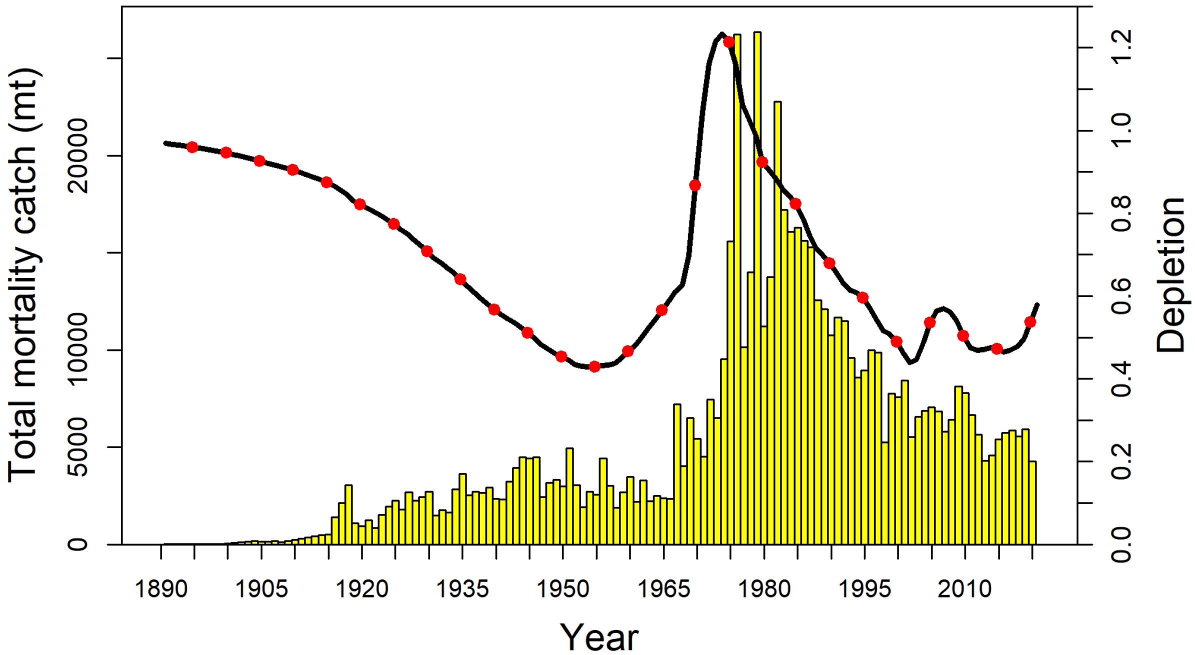


Figure 22. Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for sablefish.

1. Research

2. Assessment

3. Management

K. Lingcod

1. Research

a) Geographic variability in lingcod (*Ophiodon elongatus*) life-history and demography along the U.S. West Coast

Investigators: Lam L.S., Basnett, B.L., Haltuch, M.A., Cope J., Andrews K., Nichols K.M,Longo G.C., Samhouri, J.F., Hamilton S.L.

Understanding the spatial patterns as well as environmental and anthropogenic drivers of life-history variation for exploited fish populations is important when making management decisions and designating stock boundaries. These considerations are especially germane for stocks that are overfished or recently rebuilt, such as lingcod (*Ophiodon elongatus*), a commercially and recreationally valuable species of groundfish along the West Coast of North America. Between 2015 and 2017, 2,189 lingcod were collected from 24 port locations, spanning 28° of latitude from southeast Alaska (60°N) to southern California (32°N), to investigate latitudinal patterns in size and age structure, growth, timing of maturity, condition, and mortality, as well as to identify biologically relevant population breakpoints along the coast. The authors found strong latitudinal patterns in these life history and demographic traits consistent with Bergmann's Rule: lingcod from colder, northern waters were larger at age, lived longer, matured at larger sizes, and had lower natural mortality rates than lingcod from lower latitudes. Female lingcod were larger at age, lived longer, and matured at larger sizes compared to males within each examined region. In addition, authors found evidence for strong associations between lingcod life-history traits and oceanographic variables. Cluster analysis using life history traits indicated that central Oregon is a biologically-relevant breakpoint for lingcod along the U.S. West Coast. This newfound breakpoint, in conjunction with a recently identified genetics breakpoint in central California discovered by Longo et al. (2020), highlights the need for future lingcod stock assessments to consider population dynamics and genetic connectivity when managing complex, trans-boundary stocks.

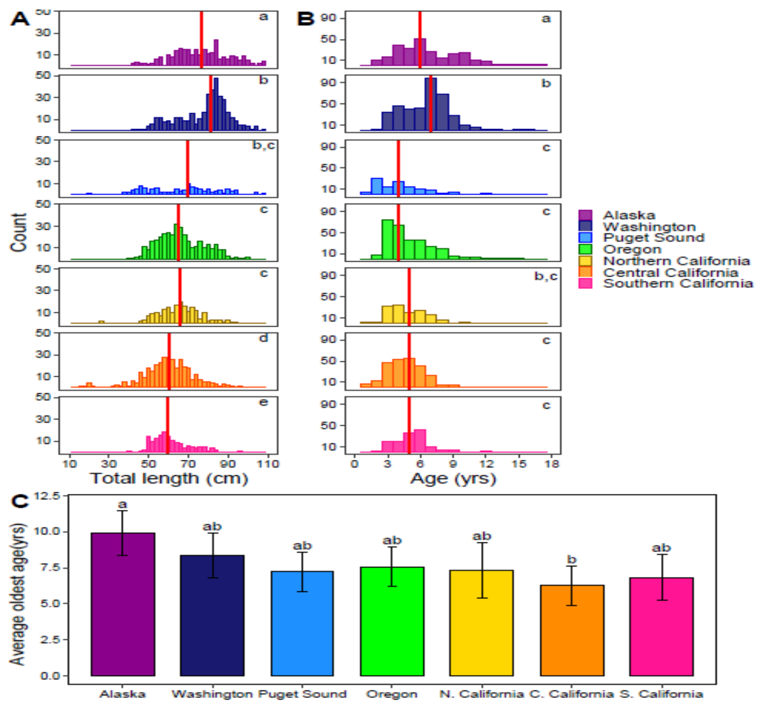


Figure 23. A) Size- and B) age-frequency of lingcod by region (sexes pooled) in order of decreasing latitude. The red vertical line indicates median size and age per region, respectively. Regions were compared using the nonparametric Kruskal-Wallis test; nonparametric pairwise comparisons were conducted using Steel-Dwass All Pairs where non-overlapping letters indicate significant difference (α=0.05). Note that nonparametric analysis was performed on extracted residuals from the linear regression between length and depth. C) average oldest age (yrs) was calculated using the mean of the upper quartile of ages. Error bars were calculated using ±2 SE. Statistical significance is noted by the lack of overlapping letters above error bars.

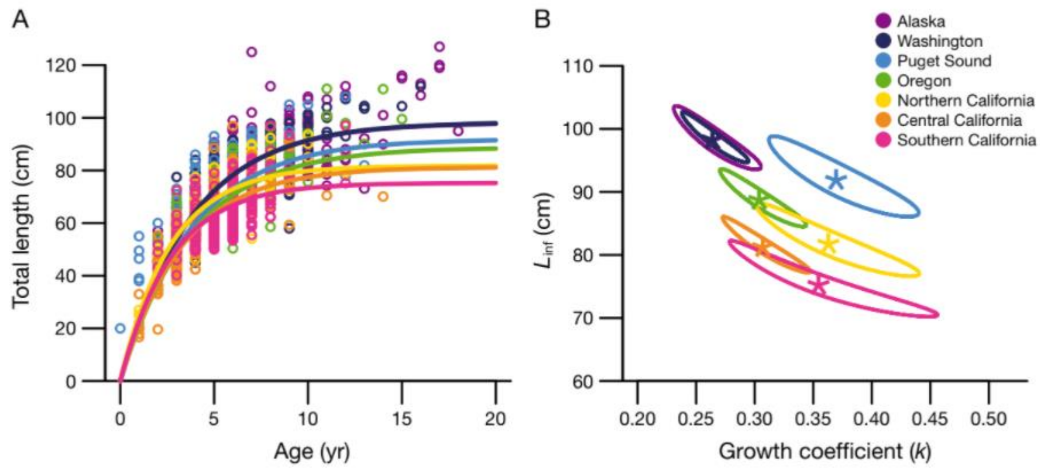


Fig. 24. A) Spatial variation in lingcod von Bertalanffy growth curves across 7 sampled regions; B) 95% confidence intervals for predicted maximum asymptotic length (L_∞) and growth coefficients (k) for each region. Overlapping intervals indicate no differences in growth. Note growth curves for lingcod from Alaska and Washington overlap

Lam L.S., Basnett, B.L., Haltuch, M.A., Cope J., Andrews K., Nichols K.M, Longo G.C., Samhouri, J.F., Hamilton S.L. 2021. Geographic variability in lingcod (*Ophiodon elongatus*) life-history and demography along the U.S. West Coast: Oceanographic drivers and management implications. Mar. Ecol. Prog. Ser. 670:263-222

For more information, contact Laurel Lam at laurel.lam@noaa.gov

b) Male lingcod (*Ophiodon elongatus*) with blue color polymorphism

Investigators: Wood, C.L., Leslie, K.L., Greene, A., Lam, L.S., Basnett, B., Hamilton, S.L., Samhouri, J. F.

The unusual blue color polymorphism of lingcod (*Ophiodon elongatus*) is the subject of much speculation but little empirical research; ~20% of lingcod individuals exhibit this striking blue color morph, which is discrete from and found within the same populations as the more common brown morph. In other species, color polymorphisms are intimately linked with host–parasite interactions, which led us to ask whether blue coloration in lingcod might be associated with parasitism, either as cause or effect. To test how color and parasitism are related in this host species, we performed parasitological dissection of 89 lingcod individuals collected across more than 26 degrees of latitude from Alaska, Washington, and California, USA. We found that male lingcod carried 1.89 times more parasites if they were blue than if they were brown, whereas there was no difference in parasite burden between blue and brown female lingcod. Blue individuals of both sexes had lower hepatosomatic index (i.e., relative liver weight) values than did brown individuals, indicating that blueness is associated with poor body condition. The immune systems of male vertebrates are typically less effective than those of females, due to the immunocompromising properties of male sex hormones; this might explain why blueness is associated with elevated parasite burdens in males but not in females. What remains to be determined is whether parasites induce physiological damage that produces blueness or if both blue coloration and parasite burden are driven by some unmeasured variable, such as starvation. Although our study cannot discriminate between these possibilities, our data suggest that the immune system could be involved in the blue color polymorphism–an exciting jumping-off point for future research to definitively identify the cause of lingcod blueness and a hint that immunocompetence and parasitism may play a role in lingcod population dynamics.

Figure 25. (a) Lingcod (*Ophiodon elongatus*) of two color morphs: blue (topmost and fourth-from-top) and brown (second-from-top, third-from-top and bottommost. (b) Blue coloration affects both external and internal tissues (photo: Laurel Lam).

Wood, C. L., Leslie, K. L., Greene, A., Lam, L. S., Basnett, B., Hamilton, S. L., Samhouri, J. F. 2021. The weaker sex: Male lingcod (*Ophiodon elongatus*) with blue color polymorphism are more burdened by parasites than are other sex–color combinations. PloS one, 16(12), e0261202.

For more information, contact Laurel Lam at laurel.lam@noaa.gov

c) Why so blue? Assessing prevalence and correlates of blue-colored flesh in lingcod (*Ophiodon elongatus*) across their geographic range.

Investigators: Galloway, A.W., Beaudreau, A.H., Thomas, M.D., Basnett B.L., Lam L.S., Hamilton S.L., Andrews K.S., Schram J.B., Watson J.,

Abstract Intraspecific variation in external and internal pigmentation is common among fishes and explained by a variety of biological and ecological factors. Blue-colored flesh in fishes is relatively rare but has been documented in some species of the sculpin, greenling, and perch families. Diet, starvation, photoprotection, and camouflage have all been suggested as proximate mechanisms driving blue flesh, but causal factors are poorly understood. We evaluated the

relative importance of biological and spatial factors that could explain variation in blue coloration in 2021 lingcod (*Ophiodon elongatus*) captured across their range in the northeastern Pacific, from southeast Alaska to southern California. The probability of having blue flesh was highest for fish that were female, caught in shallower water, and smaller in body size. The incidence of blueness varied by region (4–25% of all fish) but was also confounded by differences in sex ratios of fish caught among regions. We analyzed the multivariate fatty acid composition of a subset of 175 fish from across the sampling range to test for differences in trophic biomarkers in blue lingcod. Lingcod fatty acid composition differed between regions and flesh colors but not between sexes. Blue-fleshed fish had lower concentrations of total fatty acids, 18:1ω-9, 16:1ω-7, 18:1ω-7, and ω-6 fatty acids, suggesting differences in energetics and energy storage in blue fish. While our data indicate potential links between diet and blue flesh in lingcod, important questions remain about the physiological mechanisms governing blueness and its biological consequences.

Figure 26.

Fig. 1 Examples of blue-fleshed fish and serum. **a** Blue-fleshed rock greenling (*Hexagrammos lagocephalus*; Aleutian Islands, AK; Photo by Scott Gabara). **b**, **c** Blue flesh and mouth tissues of a lingcod (Port Orford, OR; Photos by Aaron Galloway); **d** Blue serum from lingcod (San Juan Islands, WA; Photo by Aaron Dufault); **e** Representative range of color variants—from the left, individuals 1, 3, and 4 were designated 'brown' and individuals 2 and 5 were designated 'blue' (Photo by Laurel Lam)

Galloway A.W., Beaudreau A.H., Thomas M.D., Basnett B.L., Lam L.S., Hamilton S.L., Andrews K.S., Schram J.B., Watson J., Samhouri J.F. 2021. Assessing prevalence and correlates of blue-colored flesh in lingcod (*Ophiodon elongatus*) across their geographic range. *Marine Biology*, *168*(9), 1-15.

For more information, contact Laurel Lam at laurel.lam@noaa.gov

2. Assessment

a) Status of lingcod (*Ophiodon elongatus*) along the northern U.S. west coast in 2021

Investigators: Ian G. Taylor, Kelli F. Johnson, Brian J. Langseth, Andi Stephens, Laurel S. Lam, Melissa H. Monk, Alison D. Whitman, Melissa A. Haltuch

This assessment reports the status of lingcod (*Ophiodon elongatus*) north of 40°10'N along the U.S. west coast using data through 2020. Lingcod were modeled as two stocks split at 40°10'N. This choice is informed by a consideration of genetic differences (Longo et al. 2020) as well as differences in growth and management. Models for lingcod do not include catches or dynamics from the Alaskan, Canadian, or Mexican populations.

Data included information on landings for each commercial and recreational fleet; commercial discards, available from the West Coast Groundfish Observer Program; relative abundance as informed by the Triennial Survey, West Coast Groundfish Bottom Trawl Survey, commercial trawl fishery, and each recreational fishery; and length and age compositions, available from the previous sources as well as research by L. Lam.

The stock biomass is currently trending downwards, though the rate of the decline is highly uncertain (Figure 27). Although the biomass is currently estimated to be declining, no estimate is below the minimum stock size threshold and all estimates since the late 1990s are above the management target (Figure 27).

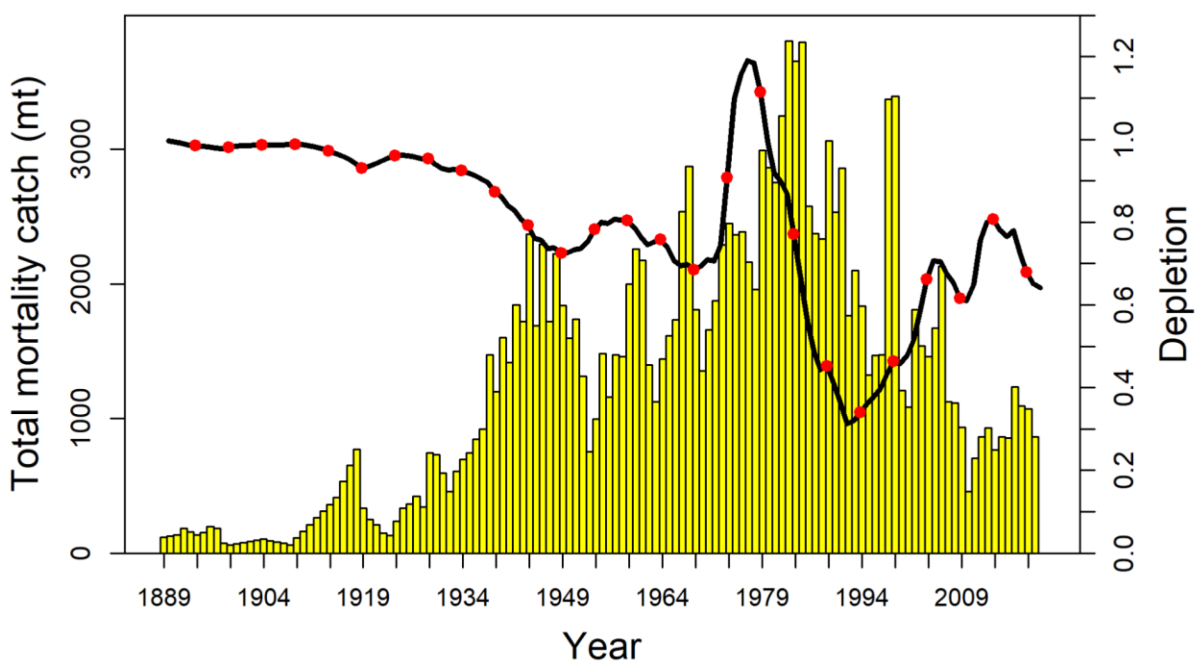


Figure 27. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of lingcod north of 40°10'.

For more information, please contact Ian Taylor at Ian.Taylor@noaa.gov

b) Status of lingcod (*Ophiodon elongatus*) along the southern U.S. west coast in 2021

Investigators: Kelli F. Johnson, Ian G. Taylor, Brian J. Langseth, Andi Stephens, Laurel S. Lam, Melissa H. Monk, John E. Budrick, Melissa A. Haltuch

This assessment reports the status of lingcod (*Ophiodon elongatus*) south of 40°10'N along the U.S. west coast using data through 2020. Lingcod were modeled as two stocks split at 40°10'N. This choice is informed by a consideration of genetic differences (Longo et al. 2020) as well as differences in growth and management. Models for lingcod do not include catches or dynamics from the Alaskan, Canadian, or Mexican populations.

Data included information on landings for each commercial and recreational fleet; commercial discards, available from the West Coast Groundfish Observer Program; relative abundance as informed by the Triennial Survey, West Coast Groundfish Bottom Trawl Survey, commercial trawl fishery, and each recreational fishery; and length and age compositions, available from the previous sources as well as research by L. Lam. Information on relative abundance, length, and age was also available from the NWFSC Hook and Line Survey (Hook and Line Survey). The final model included ages from only the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS) because of conflicts between age- and length-composition data.

Over the last decade, the spawning biomass has been trending upward due to a period of above-average recruitment which ended in 2013, though the rate of the increase is highly uncertain (Figure 28). Uncertainty in the initial stock size is vast and this uncertainty is carried forward until approximately the early 1980s when more informative data are available. The current estimated biomass is below, but close to, the management target with the uncertainty in this estimate spanning well above and below the management target and the minimum stock size threshold (Figure 28).

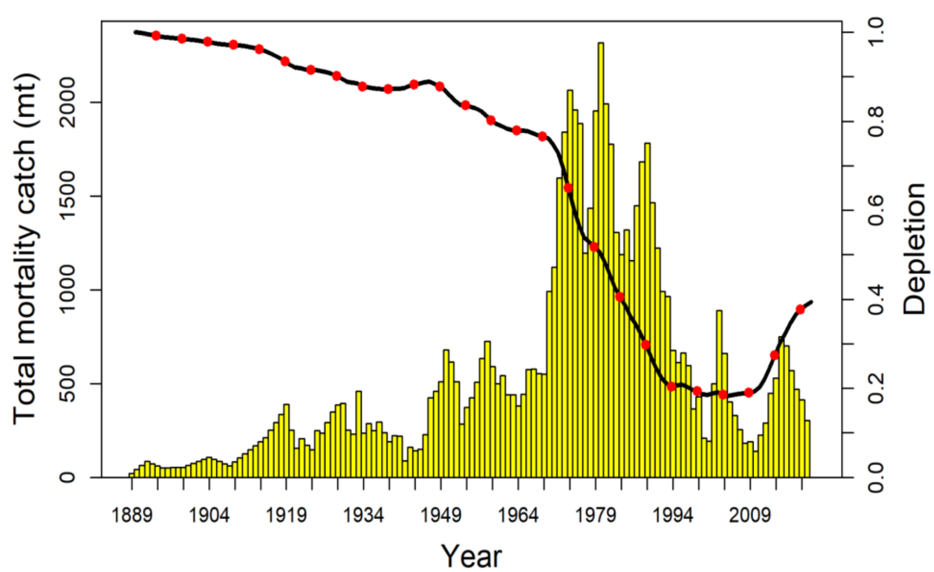


Figure 28. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of lingcod south of 40°10'.

For more information, please contact Kelli Johnson at Kelli.Johnson@noaa.gov

L. Atka Mackerel

M. Flatfish

1. Research

a) Food habit variability of arrowtooth flounder (*Atheresthes stomias*) in the northeast Pacific Ocean

Investigator: Douglas Draper

A diet study of arrowtooth flounder (*Atheresthes stomias*) was undertaken to provide current information on their food habits and predator-prey relationships in the California Current Ecosystem. Arrowtooth flounder stomachs (n = 573) were collected between 2013 and 2018 from 397 trawls during the Northwest Fisheries Science Center's West Coast Groundfish Bottom Trawl Survey. A total of 357 stomachs (62.3%) contained prey, which revealed a highly piscivorous diet across all lengths examined (14 – 77 cm) and described a regionalized and opportunistic feeding behavior. Increased predator length correlated both with an increase in percentage of fish prey consumed and an increase in depth of capture. Smaller (< 43 cm) and shallower (≤ 183 m) arrowtooth flounder consumed a relatively high percentage of euphausiids and shrimp, while larger arrowtooth flounder (≥ 43 cm) captured at greater depths (> 183 m) consumed more fish and fewer shrimp and euphausiids. Arrowtooth flounder diet varied by geographic area, likely resulting from regional differences in prey availability. North of the mean latitude of capture (44.45◦N), Pacific hake (*Merluccius productus*) and Pacific herring (*Clupea pallasii*) were the predominant fish in arrowtooth flounder diets, while arrowtooth flounder caught south of the mean latitude consumed mostly Pacific hake and rockfishes (Scorpaenidae). Unidentified teleost fish contributed much to the diet across all size, depth, and latitude ranges.

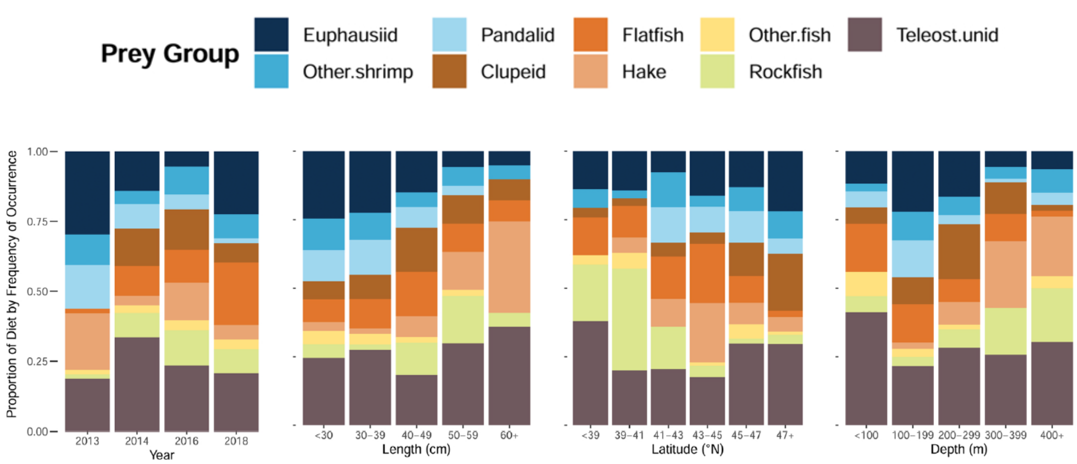


Figure 29. Stacked barplots of diet proportions by frequency of arrowtooth flounder prey groups for year, length, latitude, and depth bins.

2. Assessement

a) Stock Assessment of the Dover sole (*Microstomus pacificus*) along the U.S. West Coast in 2021

Investigators: C.R. Wetzel and A.M. Berger

This is an assessment of the Dover sole population off the U.S. west coast, including coastal waters of California, Oregon, and Washington from the U.S./Mexico border to the U.S./Canadian border. It does not include Canadian or Alaskan populations and assumes that these northern populations do not contribute to the stock being assessed here.

The longest time series of fishery-independent information off the U.S. west coast arises from the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS) that has been conducted annually from 2003 - 2019. The length and age data from this survey were highly influential on the model estimates of stock size and status. Additionally, these data were used to externally estimate starting parameter values by sex for length-at-age and the fixed values by sex for length-weight relationship. Dover sole off the U.S. west coast appear to have complex movement patterns, moving across depths, likely driven by season, spawning, and by size. Additionally, observations indicate possible sex-specific aggregations where a higher proportion of female fish are found in shallower (less than 300 m) and deeper waters (greater than 900 m), with higher proportion of males observed at intermediate depths (300 - 700 m).

The estimated spawning biomass at the beginning of 2021 was 232,065 mt (~95 percent asymptotic intervals: 154,153 to 309,977 mt), which when compared to unfished spawning biomass (294,070 mt) equates to a relative stock status level of 79 percent (~95 percent asymptotic intervals: 71 to 87 percent). The estimated scale of the stock ($SB0$) from this assessment, 294,070 mt, is lower than the value estimated in the 2011 assessment of 469,866 mt but well within the 2011 ~95 percent asymptotic interval (182,741 - 756,991 mt). Fishing intensity (1 - SPR) over the past decade has been well below the target SPR30%, ranging between 0.11 and 0.2. The estimated target spawning biomass based on the 25 percent management target is 73,518. Sustainable total yield, landings plus discards, using SPR30% is estimated at 22,891 mt.

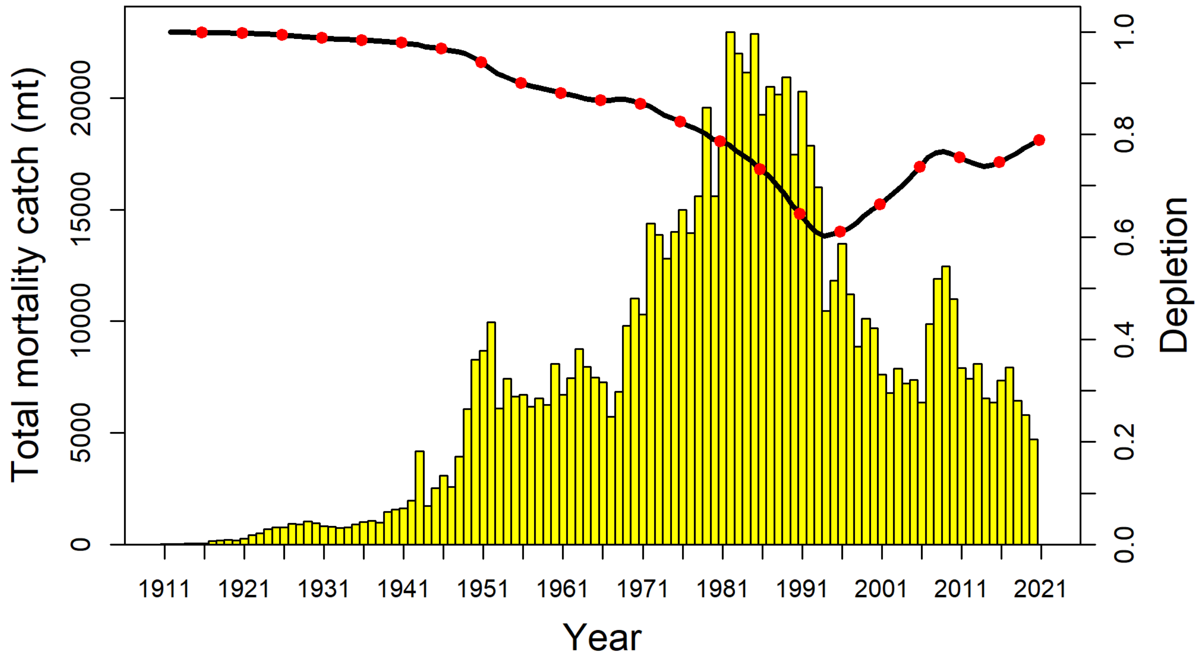


Figure 30. Total catch (bars) and depletion (line: relative to average unexploited equilibrium spawning output) of Dover sole for years modeled.

For more information, please contact Chantel Wetzel at chantel.wetzel@noaa.gov

1. Research

N. Halibut

O. Other Groundfish

1. Research

a) U.S. California Current Climate Change Vulnerability Assessment

Investigators: Michelle McClure, Melissa Haltuch and others

In 2015 NOAA Fisheries released its Climate Science Strategy to address a growing need for information about how climate change may affect living marine resources, their habitats and the people who depend on them. The Climate Science Strategy identified seven key objectives and called for each region to develop a Regional Action Plan to cover them, including an assessment of the risk climate change poses to protected species and fisheries. Researchers from the NOAA Fisheries' Northwest and Southwest Fisheries Science Centers have developed a Climate Vulnerability Assessment (CVA) that examines the risk of anticipated climate change to species managed under the Magnuson-Stevens Act and ESA-listed salmon and steelhead in California, Oregon, Washington and Idaho. The general CVA publication that compasses groundfish, coastal pelagic species, highly migratory species, and protected species is in review.

For more information, please contact Michelle McClure at Michelle.McClure@noaa.gov or Melissa Haltuch at Melissa.Haltuch@noaa.gov

b) Bomb radiocarbon age validation for California Current (CC) rockfish

Investigators: Melissa Haltuch, Andi Stevens, Owen Hamel, Patrick McDonald, John Field

Otolith-derived ages provide an informative piece of data in fisheries stock assessment in regards to estimating recruitments, growth, and exploitation rates. The research and data needs sections of NWFSC stock assessments routinely identify the need for age-determination and age-validation studies. Historical otolith collections that include fish caught by commercial vessels fishing out of northern California ports during the 1960's until present are available at the SWFSC. These historical samples are ideal for the application of bomb radiocarbon age validation methods that require fish with birth years during the late 1950s through the 1970s. Rockfish are the focus of the bomb radiocarbon analyses due to longevity, and thus the likelihood of large ageing bias and variability at older ages. Ongoing radiocarbon age validation work is focusing on black and canary rockfish with the aim of producing more reliable ageing error matrices that will improve stock assessment's ability to model age imprecision and bias, reducing assessment uncertainty.

For more information, please contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

c) Feeding ecology of select groundfish species captured in the Northwest Fisheries Science Center's west coast bottom trawl survey, using gut contents and stable isotopes

Investigators: Keith Bosley, J. Buchanan, A. Chappell, D. Draper, and K.M. Bosley

We are examining the diets of multiple groundfish species as an ongoing component of the NMFS West Coast Bottom Trawl Survey. Stomachs and tissue samples were collected at sea and preserved for gut content and stable-isotope analyses. We focused on several species of *Sebastes*, sablefish, and some flatfishes, and now have stomach content and stable-isotope data covering multiple years. Yellowtail, darkblotched, canary, sharpchin and stripetail rockfishes prey largely on zooplankton, with euphausiids composing a majority of their diet. Shrimp also contribute significantly to the diets of darkblotched and canary rockfishes, whereas bocaccio, yelloweye and chilipepper rockfishes all share a highly piscivorous diet. Greenstriped and rosethorn rockfishes show a strong preference for benthic prey, greenstriped preferring various shrimp species, and rosethorn preferring a mix of shrimp and galatheid crabs. Finally, widow rockfish and Pacific ocean perch exhibit a more omnivorous feeding strategy, eating a variety of zooplankton, including euphausiids, amphipods, shrimp and gelatinous organisms. Stable isotope values averaged by year indicate that bocaccio and yelloweye rockfish feed approximately one trophic level above Pacific ocean perch and above darkblotched, greenstriped, sharpchin, stripetail and widow rockfishes. All other species in this study feed at mixed trophic levels. Multivariate analyses of diet data show significant differences in diet among species but strong overlap among benthic and bentho-pelagic species. Stable-isotope data also show significant differences among species and years. These results demonstrate the groundfishes in this study are significant consumers in both benthic and pelagic habitats, feeding across multiple trophic levels.

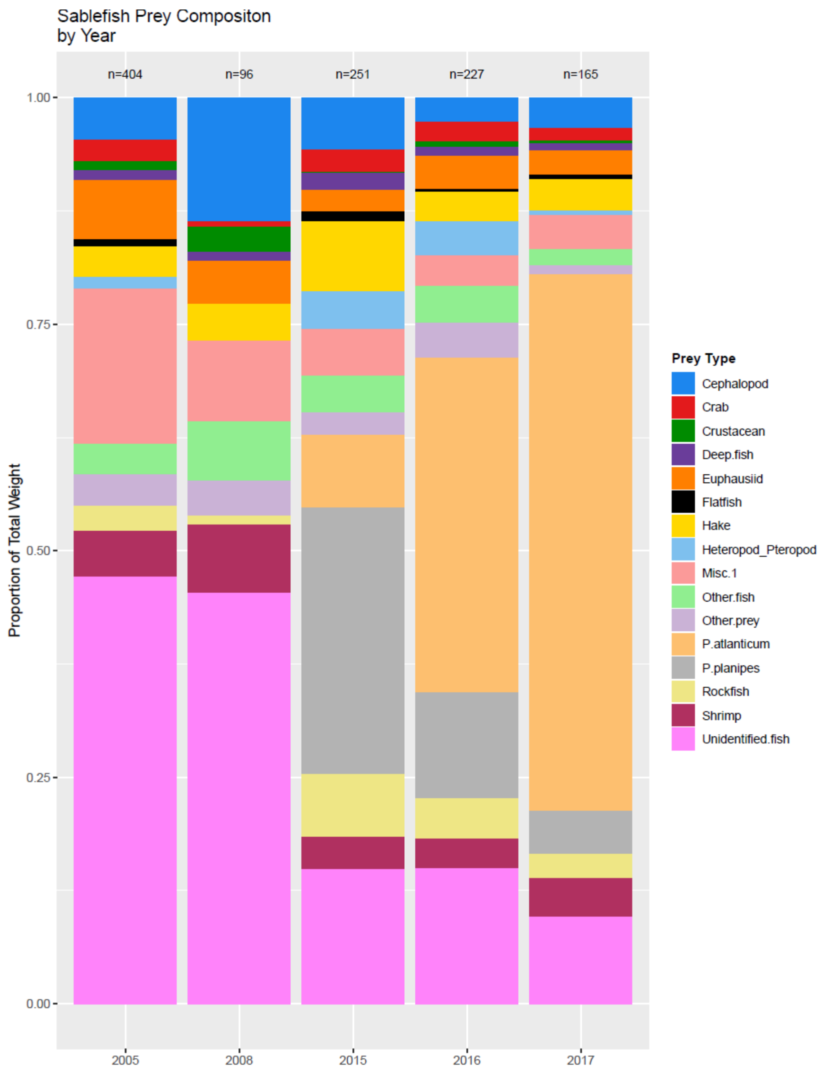


Figure 31. Stacked barplot of diet proportions by weight of sablefish prey groups for 2005, 2008, 2015-2017.

For more information, please contact Keith Bosley at Keith.Bosley@noaa.gov and Doug.Draper@noaa.gov

d) Climate shock effects and mediation in fisheries

Investigators: Fisher, M.C., S.K. Moore, S. Jardine, J. Watson, J.F. Samhouri

Climate shocks can reorganize the social-ecological linkages in food-producing communities, leading to a sudden loss of key products in food systems. The extent and persistence of this reorganization are difficult to observe and summarize, but are critical aspects of predicting and rapidly assessing community vulnerability to extreme events. We apply network analysis to evaluate the impact of a climate shock-an unprecedented marine heatwave-on patterns of resource use in California fishing communities, which were severely affected through closures of the Dungeness crab fishery. The climate shock significantly modified flows of users between fishery resources during the closures. These modifications were predicted by pre-shock patterns of resource use and were associated with three strategies used by fishing community member vessels to respond to the closures: temporary exit from the food system, spillover of effort from the Dungeness crab fishery into other fisheries, and spatial shifts in where crab were landed. Regional differences in resource use patterns and vessel-level responses highlighted the Dungeness crab fishery as a seasonal "gilded trap" for northern California fishing communities. We also detected disparities in climate shock response based on vessel size, with larger vessels more likely to display spatial mobility. Our study demonstrates the importance of highly connected and decentralized networks of resource use in reducing the vulnerability of human communities to climate shocks.

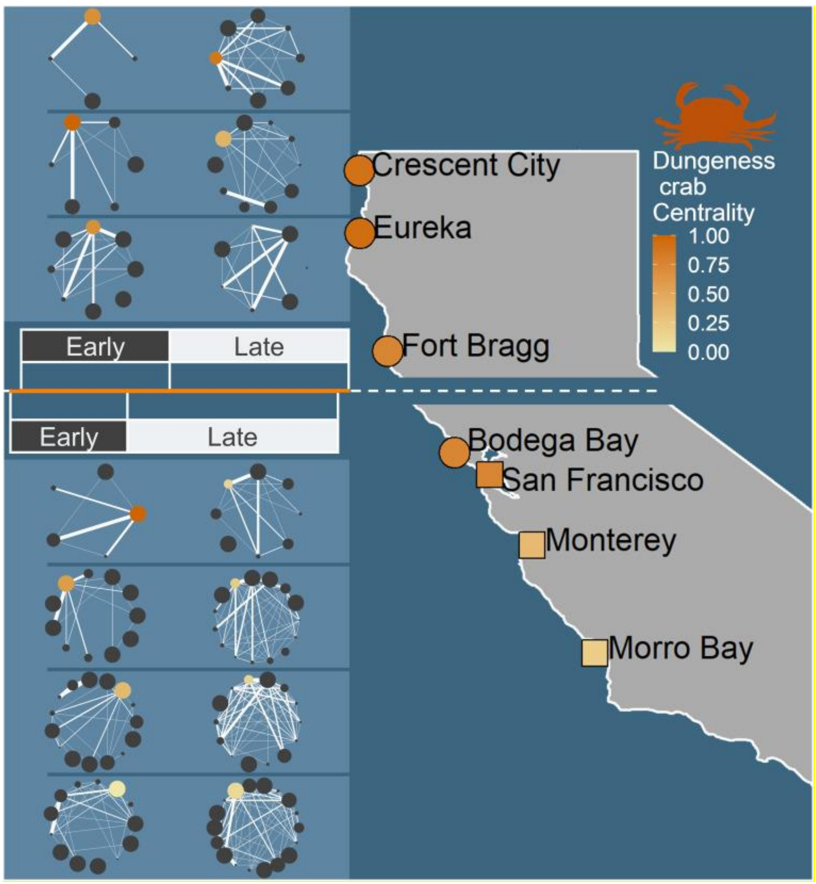


Figure 32. The seven California fishing communities included in this study and their pre-shock fisheries participation networks. Pre-shock early (*Left*) and late (*Right*) networks represent a 3-y average (crab years 2013 to 2015) of participation prior to the 2016 fishery closures. The Dungeness crab fishery node is shaded orange in each network according to its betweenness centrality, a measure of importance (note that nodes are not consistently positioned across networks). The timeline shows the relative duration of the early and late seasons for fishing communities in the two California management districts (above/below timeline). Point color on the map indicates average Dungeness crab betweenness centrality across the early and late seasons, and point shape indicates whether the fishing community was considered part of the northern region (circle) or the central region (square) for this study.

Fisher, M.C., S.K. Moore, S. Jardine, J. Watson, J.F. Samhouri. 2021. Climate shock effects and mediation in fisheries. Proceedings of the National Academy of Sciences USA 118 (2) e2014379117. https://doi.org/10.1073/pnas.2014379117

For more information, please contact Jameal Samhouri at jameal.samhouri@noaa.gov

e) Footprints of fixed gear fisheries in relation to rising whale entanglements on the U.S. West Coast

Investigators: Feist, B.E., J.F. Samhouri, K.A. Forney, L.A. Saez.

On the U.S. West Coast, reports of whales entangled in fishing gear increased dramatically in 2014. In this study, a time series of fishing activity maps was developed from 2009 to 2016 for the four fixed-gear fisheries most commonly implicated in entanglements. Maps were generated using vessel monitoring system (VMS) data linked to port-level landings databases, which were related to entangled whale reports over the same time period and with modelled distributions of humpback whales *Megaptera novaeangliae* Borowski. Over the full study period, neither marked increases in fishing activity nor changes in fisheries footprints within regions with high whale densities were detected. By contrast, a delayed fishery opening in California due to a harmful algal bloom in spring of 2016 led to ~5–7 times average levels of Dungeness crab *Metacarcinus magister* (Dana) fishing activity, which was consistent with a high rate of entanglement in that year. These results are consistent with current hypotheses that habitat compression caused by a marine heatwave increased the overlap of whales with fishing activity, despite minimal changes in the fisheries themselves. This study adds to literature on bycatch of protected species in otherwise sustainable fisheries, highlighting the value of using VMS data for reducing human–wildlife conflict in the ocean.

Feist, B.E., J.F. Samhouri, K.A. Forney, L.A. Saez. 2021. Footprints of fixed gear fisheries in relation to rising whale entanglements on the U.S. West Coast. Fisheries Management and Ecology 28(3): 283-294. DOI: 10.1111/fme.12478

For more information, please contact Blake Feist at blake.feist@noaa.gov

2. Assessments

3. Management

a) Incoherent dimensionality in fisheries management

Investigator: A.M Berger

Fisheries policy inherently relies on an explicit definition of management boundaries that delineate the spatial extent over which stocks are assessed and regulations are implemented. However, management boundaries tend to be static and determined by politically negotiated or historically identified population (or multi-species) units, which creates a potential disconnect

with underlying, dynamic population structure. The consequences of incoherent management and population or stock boundaries were explored through the application of a two-area spatial simulation-estimation framework. Results highlight the importance of aligning management assessment areas with underlying population structure and processes, especially when fishing mortality is disproportionate to vulnerable biomass among management areas, demographic parameters (e.g., growth and maturity) are not homogenous within management areas, and connectivity (via recruitment or movement) unknowingly exists among management areas. Bias and risk was greater for assessments that incorrectly span multiple population segments compared to assessments that cover a subset of a population segment, and these results were exacerbated when there was connectivity between population segments. Directed studies and due consideration of critical population segments, spatially-explicit models, and dynamic management options that help align management and population boundaries would likely reduce estimation biases and management risk, as would closely coordinated management that functions across population boundaries. *Oregon Chapter American Fisheries Society.*
For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

b) Incoherent dimensionality in fisheries management: consequences of misaligned stock assessment and ecological boundaries

Investigators: A.M Berger, J.J. Deroba, K.M. Bosley, D.R. Goethel, B.J. Langseth, A.M. Schueller, D.H. Hanselman

Fisheries policy inherently relies on an explicit definition of management boundaries that delineate the spatial extent over which regulations are implemented. However, management boundaries tend to be static and determined by politically negotiated or historically identified population units, which creates a potential disconnect with underlying, dynamic population structure. Additionally, understanding spatial population structure and aligning the management boundaries with the population areas may improve management advice. We use a two-area (single stock-recruit relationship but differing demographic or fishery characteristics) spatial simulation-estimation framework to evaluate the consequences associated with misalignment among management and population boundaries (i.e., boundary incoherence). Results highlight the importance of aligning management areas with underlying population structure and processes, especially when fishing mortality is disproportionate to vulnerable biomass among management areas, demographic data (e.g., growth and maturity) is not homogenous within management areas, or connectivity (via recruitment or movement) exists among management areas. Spatially incoherent population and management unit boundaries created bias in population estimates, averaging a 12.2% median relative error (MRE; at 10% boundary incoherence) to 79.9% MRE (at 50% boundary incoherence) in terminal year spawning stock biomass. Bias was largest (>200% MRE) when spatial patterns in fishery selectivity, growth, and maturity were supplemented with disproportionate recruitment and directional movement. The risk of drastically misinformed management (arising from population estimates > 2 standard deviations from spatially coherent models) increased with the degree of boundary incoherence. *World Fisheries Congress.*

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

c) Space jam: evaluating assumptions and methods for conducting spatial stock assessments

Investigators: C. Barceló, A.M Berger, A. Dunn, D.R. Goethel, S. Hoyle, P. Lynch, J. McKenzie

Abstract: Climate change is affecting the distribution of target species, fisheries, and fish communities in ways that influence the productivity and population structure of harvested species. Stock assessments must therefore be able to include ecosystem information at a spatiotemporal scale relevant to the population. Nevertheless, there is no clear guidance on how best to integrate ecosystem information or spatial population structure into stock assessment models. Currently, there are several modeling platforms that can incorporate spatial structure (either explicitly or implicitly), each with unique features of methodology, modelling approach, or underlying assumptions. In this presentation, we review: 1) the current state of applying spatial structure in stock assessments used for management, 2) the spatial capabilities of contemporary spatial stock assessment modeling platforms, and 3) and a computer simulation-based participatory research experiment to elicit current successes, existing limitations, and future research needs. Based on a questionnaire surveying international platform developers (14 developer responses and 10 platforms/models), results highlight differences in the parametrization of movement, incorporation of tagging data, integration of fleets and surveys, modeling of productivity and population structure, and other key spatial or ecosystem-linkage features. Initial results from the participatory simulation experiment will also be discussed to identify the commonalities and key differences in the decisions made to build a spatial stock assessment and the related modeling assumptions. The results from this study will serve to inform best practices for applying spatial stock assessments and will help guide the development of 'next generation' stock assessment platforms. *American Fisheries Society.*

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

d) Strength and consistency of density dependence in marine fish productivity

Investigators: A. Rindorf, M. van Deurs, D. Howell, E. Andonegi, A. Berger, B. Bogstad, N. Cadigan, B. Elvarsson, N. Hintzen, M. Roland, M. Taylor, V. Trijoulet, T. van Kooten, F. Zhang, J. Collie

The correct prediction of the shape and strength of density dependence in productivity is key to predicting future stock development and providing the best possible long-term fisheries management advice. Here, we identify unbiased estimators of the relationship between somatic growth, recruitment and density, and apply these to 80 stocks in the Northeast Atlantic. The analyses revealed density-dependent recruitment in 68% of the stocks. Excluding pelagic stocks exhibiting significant trends in spawning stock biomass, the probability of significant density dependence was even higher at 78%. The relationships demonstrated that at the commonly used biomass limit of 0.2 times maximum spawning stock size, only 32% of the stocks attained three quarters of their maximum recruitment. This leaves 68% of the stocks with less than three quarters of their maximum recruitment at this biomass limit. Significantly lower recruitment at high stock size than at intermediate stock size was seen in 38% of the stocks. Density dependence in late growth occurred in 54% of the stocks, whereas early growth was generally density-independent. Pelagic stocks were less likely to exhibit density dependence in recruitment than demersal and benthic stocks. We recommend that both the degree to which productivity is related to density and the degree to which the relationship changes over time should be investigated. Both of these aspects should be considered in evaluations of whether sustainability and yield can be improved by including density dependence in forecasts of the effects of different management actions. *Fish and Fisheries*.

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

e) Finding the perfect mismatch: evaluating misspecification of population structure within spatially explicit integrated population models

Investigators: K.M. Bosley, A.M. Schueller, D.R. Goethel, D.H. Hanselman, K.H. Fenske, A.M. Berger, J.J. Deroba, and B.J. Langseth

Spatially stratified integrated population models (IPMs) can account for fine-scale demographic processes and support spatial management for complex, heterogeneous populations. Although spatial IPMs may provide a more realistic representation of true population dynamics, few studies have evaluated the consequences associated with incorrect assumptions regarding population structure and connectivity. We utilized a simulation-estimation framework to explore how mismatches between the true population structure (i.e. uniform, single population with spatial heterogeneity or metapopulation) and various parametrizations of an IPM (i.e. panmictic, fleets-as-areas or a spatially explicit, tag-integrated model) impacted resultant fish population estimates. When population structure was incorrectly specified in the IPM, parameter estimates were generally unbiased at the system level, but were often biased for sub-areas. Correctly specifying population structure in spatial IPMs led to strong performance, whereas incorrectly specified spatial IPMs performed adequately (and better than spatially aggregated counterparts). Allowing for flexible parametrization of movement rates (e.g. estimating age-varying values) was more important than correctly identifying the population structure, and incorporation of tag-recapture data helped movement estimation. Our results elucidate how incorrect population structure assumptions can influence the estimation of key parameters of spatial IPMs, while indicating that, even if incorrectly specified, spatial IPMs can adequately support spatial management decisions. *Fish and Fisheries*.

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

V. Ecosystem Studies

A. Socioeconomics

a) Understanding climate impacts on groundfish fisheries and fishing communities along the US West Coast

Investigators: Jameal Samhouri, Chris Harvey, Isaac Kaplan, Karma Norman, Owen Liu, and collaborators at NOAA NWFSC and SWFSC, universities, and beyond.

A group of collaborators at NOAA NWFSC, SWFSC, NMFS Western Regional Office, and multiple universities are working together to (a) improve understanding of how climate variability and change influence availability of groundfish to fisheries and fishing communities along the US West Coast, and (b) determine how existing fisheries management approaches perform under climate change and in an uncertain future. This group's work is divided into three major components: a Species Distribution Modeling (SDM) Module, an Atlantis Ecosystem Model Module, and a Communities Module. The SDM Module is focused on determining environmental affinities of groundfish based on ocean observations and regional ocean models, and using that information to project expected groundfish distribution shifts in relation to west coast communities. This Module leverages the recent development of the R package sdmTMB, a joint product of DFO and NOAA scientists and others. The Atlantis Module builds on the SDM Module by considering how future changes in local availability of individual groundfish stocks are affected by coast-wide threshold harvest control rules and spatial closures. The Communities Module serves as a foundation for both the SDM and Atlantis Modules by exploring definitions of fishing communities, assessing changes in the footprints of the groundfish trawl fishery over time in relation to environmental change and other factors, and evaluating the potential for indicators of ecosystem change to inform National Standard 8 under the Magnuson Stevens Act. Together, this work is intended to generate new products and insights to support the US Pacific Fisheries Management Council process, including but not limited to harvest policy and spatial allocation decisions; the Climate and Communities Initiative; and marine planning activities enriched by deep, community-level analyses.

For more information, please contact Jameal Samhouri (jameal.samhouri@noaa.gov)

B. Assessment Science

1. Research

a) Integrated Ecosystem Assessment of the California Current

Investigators: C.J. Harvey, N. Garfield, G.D. Williams, and N. Tolimieri, eds.; numerous contributors from the NWFSC, SWFSC and partner institutions

An integrated ecosystem assessment (IEA) is a science support element for ecosystem-based management (EBM); the IEA process involves synthesizing and analyzing information through steps that include scoping, indicator development, risk analysis, and evaluating management strategies. The primary goal of the California Current IEA is to inform the implementation of EBM by melding diverse ecosystem components into a single, dynamic fabric that allows for coordinated evaluations of the status of the California Current ecosystem. We also aim to involve and inform a wide variety of stakeholders and agencies that rely on science support for EBM, and to integrate information collected by NOAA and other federal agencies, states, non-governmental organizations, and academic institutions. The essence of IEAs is to inform the management of diverse, potentially conflicting ocean-use sectors. As such, a successful California Current IEA must encompass a variety of management objectives, consider a wide-range of natural drivers and human activities, and forecast the delivery of ecosystem goods and services under a multiplicity of scenarios. This massive undertaking will evolve over time.

The California Current IEA team develops an ecosystem status report (ESR) of the California Current each year, which describes the status and trends of many ecosystem indicators, including some related to groundfish. The ESR is presented to the Pacific Fishery Management Council and developed into an annual tech memo. ESRs and tech memos can be found at https://www.integratedecosystemassessment.noaa.gov/regions/california-current-region/index.html. Also, the California Current IEA team is conducting in-depth quantitative analysis of ecosystem indicators; assessing the risk posed by natural and anthropogenic stressors to key ecosystem resources and human wellbeing; and evaluating potential management strategies to determine which strategies are most effective in moving the ecosystem toward management goals and objectives, and to identify potential management tradeoffs. Many of these efforts also involve analyses related to groundfish.

For more information please contact Dr. Chris Harvey at NOAA's Northwest Fisheries Science Center, Chris.Harvey@noaa.gov.

2. Cooperative Ageing Unit

The Cooperative Ageing Project (CAP) operates under a grant from the Northwest Fisheries Science Center to Pacific States Marine Fisheries Commission and provides direct support for U.S. West Coast groundfish stock assessments by providing fish ages derived primarily from otoliths. In 2021, CAP production aged 27,740 age structures and production double read 5,551 age structures. Production ages supported the 2021 stock assessments on sablefish, Dover sole, vermilion/sunset rockfish complex, copper rockfish, quillback rockfish, lingcod and the 2022 Pacific hake. Resources were also allocated to produce age estimates on anticipated assessments for 2023. CAP continued the practice of recording otolith weights prior to breaking and burning most specimens when possible. Over 20,000 otolith weights were collected in 2021 to support research into alternative methods of age determination. For our participation in the NOAA Strategic Initiative investigating the use of Fourier Transform Near-Infrared Spectrometry for rapid age assessment, CAP sent to Seattle (AFSC) 2 years of sablefish and canary rockfish surveys to be scanned by our infrared spectrometer.

For more information, please contact Jim Hastie at Jim.Hastie@noaa.gov

3. Modeling

a) The effect of survey frequency and intensity on U.S. west coast stock assessment estimates

Investigators: Owen S. Hamel, Ian G. Taylor, Jason M. Cope, Vladlena Gertseva, Melissa A. Haltuch, Aimee Keller, Andi Stephens, James T. Thorson, John R. Wallace, Chantel R. Wetzel

Fisheries management systems rely on stock assessments to inform management. Stock assessments, in turn, rely on well-designed and comprehensive surveys to provide data necessary to estimate scale and trends in fish populations. Given limited budgets and the financial demands of conducting surveys and the concomitant laboratory and analytical requirements, it is important to consider tradeoffs in designing surveys and evaluate alternative ways to reduce survey effort if required. We conducted a retrospective analysis of the impact of reducing the intensity or frequency of the U.S. West Coast Groundfish Bottom Trawl survey across eleven recently assessed species. Survey effort was reduced by approximately half through either an every-other year survey or reducing the number of vessels from four to two in each year. The influence of the survey reductions on assessment outputs and catch limits depend upon species life history, frequency of occurrence in the current survey, and the data-richness of each assessment. All approaches to reducing survey sampling led to increased uncertainty in stock assessment results, while variability in assessment results among survey configurations was greater for species that are less commonly encountered in the survey, species with less information from other sources, species that have not been heavily exploited, and for data-moderate assessments, which rely more heavily on survey indices.

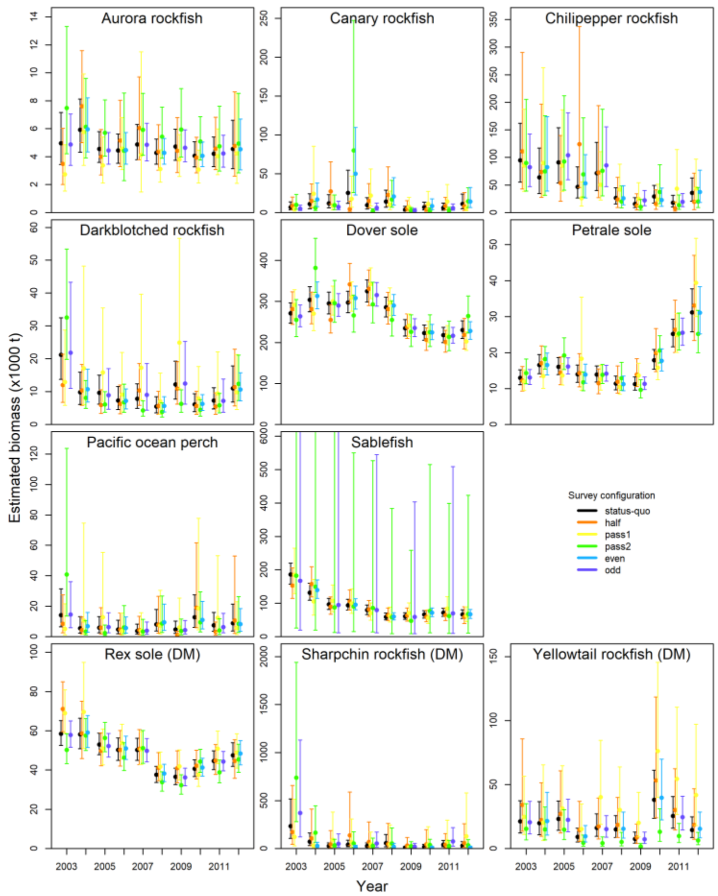


Figure 33. GLMM-derived indices of abundance and 75% lognormal confidence intervals for each survey configuration for each species. “DM” indicates species with Data Moderate stock assessments. The upper limit of the confidence intervals for sablefish that extend beyond the range of the figure are 1,451,000 t and 777,000 t for “odd” in 2003 and 2005, and 1,314,000 t, 1,131,000 t, and 616,000 t for “pass2” in 2003-2005.

For more information, please contact Owen Hamel at Owen.Hamel@noaa.gov

b) Spatio-temporal trends in west coast groundfish reproduction: A case study of ecologically important species with varying life history strategies

Investigators: Melissa A. Head, Jason M. Cope, Aimee Keller

Ecosystem-based fisheries management (EBFM) aims to support strong fisheries and communities by considering variables that affect a species' health and productivity, i.e. spatio-temporal trends, environmental changes, and fishing pressure. Fisheries managers use life history data to inform stock assessment models. A critical component to this is estimating spawning stock biomass. Reproduction is a fundamental process of population dynamics and changes in its success contribute to a large portion of variability in marine populations. Understanding the timing of maturity, and factors that influence spawning capability are important to measure reproductive potential. Stock assessments conducted at the Northwest Fisheries Science Center (NWFSC) aim to implement EBFM practices by incorporating spatio-temporal varying life history parameters. To accomplish this, the NWFSC implemented a reproductive program in 2011 2011 to ensure US west coast groundfish stock assessments could incorporate latitudinal variability in spawning capacity (Figure 34). This data set now spans multiple years across a large geographical range, and has provided a unique opportunity to explore EBFM concepts, i.e. spatio-temporal changes in maturity, timing of spawning, and reproductive development. We have collected size and age at maturity estimates of over 40 groundfish species along the entire west coast. This extensive data set allows for evaluation of spatio-temporal trends in reproduction, and for understanding more about the drivers of observed variability for multiple groundfish species that span the entire U.S. west coast. We found differences in maturity and skip spawning between important biogeographical regions of the coast (Cape Mendocino and Pt. Conception, CA) for several of the species. In addition to the spatial trends, we found temporaldifferences in the reproductive cycle.

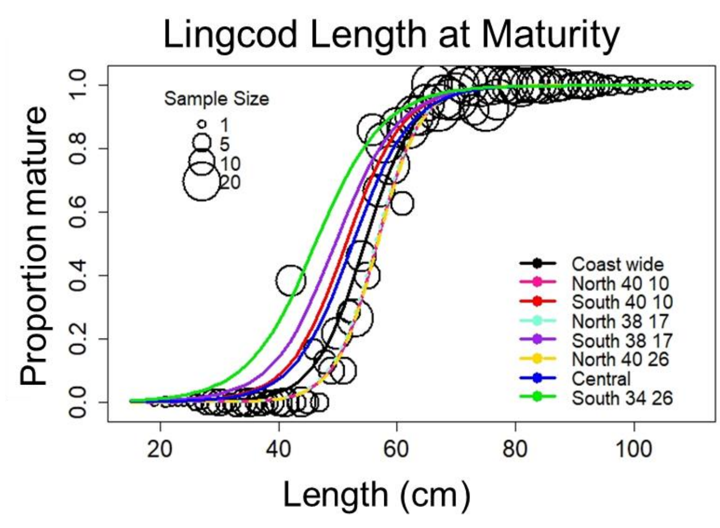


Figure 34. Latitudinal variability in spawning capacity for a representative groundfish species: lingcod.

For more information, please contact Melissa Head at Melissa.Head@noaa.gov**b) Evaluating**

C. Survey Science

1. Research

a) Three-dimensional ontogenetic shifts of groundfish in the northeast Pacific

Investigators: Lingbo Li, Anne Hollowed, Edward Cokelet, Michelle McClure, Aimee Keller, Wayne Palsson, Steve Barbeaux

Although climate-induced shifts in fish distribution have been widely reported at the population level, studies that account for ontogenetic shifts and sub-regional differences when assessing responses are rare. In this study, groundfish distributional changes were assessed at different size classes by species within nine sub-regions using indicators of shifts in depth, latitude, and longitude. We examined large, quality-controlled datasets of depth-stratified, random bottom trawl surveys conducted during summer in three large regions – the Gulf of Alaska and the west coast of Canada and the U.S. – over the period 1996-2015, a time period punctuated by a marine "heat wave". Temporal biases in bottom temperature were minimized by subdividing each region into three sub-regions, each with short-duration surveys. Near-bottom temperatures, weighted by stratum area, were unsynchronized across sub-regions and exhibited varying sub-regional interannual variability. The weighted-mean bottom depths in the sub-regions also vary largely among sub-regions. The centroids (centers of gravity) of groundfish distribution were weighted with catch per unit effort (CPUE) and stratum area for ten commercially important groundfish species by size class and sub-region. Our multivariate analyses showed that there were significant differences in aggregate fish movements of temperature responses across sub-regions but not among species or sizes. Groundfish demonstrated poleward responses to warming temperatures only in a few sub-regions and moved shallower or deeper to seek colder waters depending on the sub-region. They likely form geographically distinct thermal ecoregions, instead of continuously moving northward along northeast Pacific shelf under global warming. Shallow-depth species exhibited greatly different distributional responses to temperature changes across sub-regions while deep-depth species of different sub-regions tend to have relatively similar temperature responses. Future climate studies would benefit by considering fish distributions on small sub-regional scales.

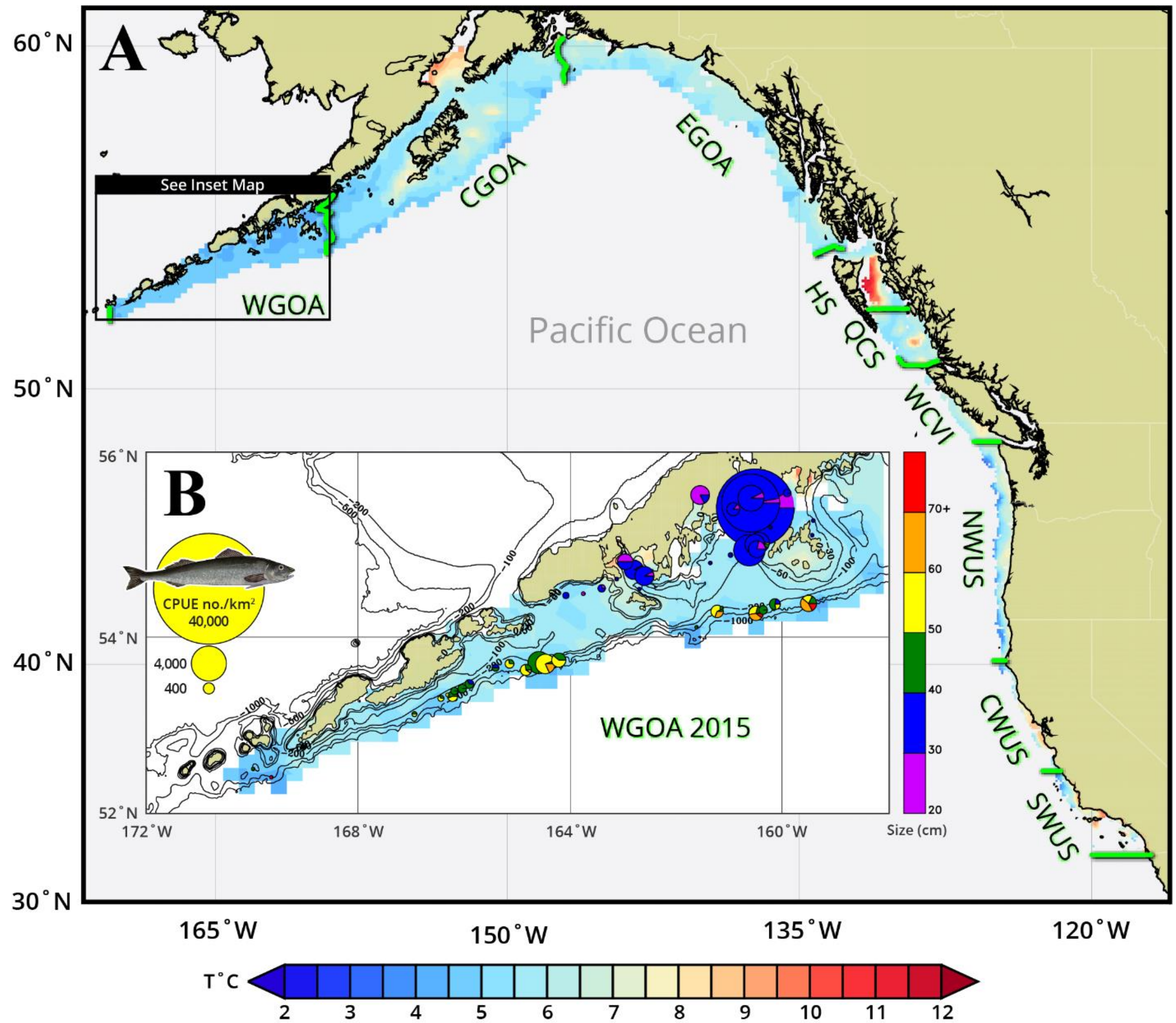


Figure 35. Mean bottom temperature map and western Gulf of Alaska (WGOA) sablefish distribution. (A) Bottom temperature was averaged 1996-2015 and interpolated to a 0.1104 X 0.0833 degree longitude-latitude grid (5 x 5 nmi at 41°N, Mercator projection) across the nine subregions in this study: western (WGOA), central (CGOA) and eastern (EGOA) Gulf of Alaska, Hecate Strait (HS), Queen Charlotte Sound (QCS), west coast Vancouver Island (WCVI), and northern (NWUS), central (CWUS) and southern (SWUS) west coast of U.S. (B) catch per unit effort (CPUE; number per km^2) of sablefish by size class (color bar on the right) in individual non-zero catch hauls during the bottom trawl survey over the WGOA in 2015. Bathymetric contours are at 50, 100, 200, 500, and 1,000 m depth.

For more information, please contact Aimee Keller at Aimee.Keller@noaa.gov

D. Observer Program and Science

1. West Coast Observer Program

The FRAM West Coast Groundfish Observer Program (WCGOP) continued collecting fishery-dependent data during 2021 on groundfish fleets along the entire U.S. west coast. The groundfish fishery is broken down into two main categories the catch share fisheries and the non-catch share fisheries. The catch share fishery can be further broken down into the shorebased fleet and the at sea fleet. The at sea fleet includes catcher-processors (CPs) and motherships. The catch share fisheries require 100% observer and shore side monitoring. The non-catch share fisheries require observer coverage upon request and coverage is randomly assigned by fishery and port group.

a) Catch Shares

There are three sectors in the catch share program: shorebased, motherships (includes motherships and mother ship catcher-vessels), and catcher-processors. All vessels participating in the shorebased sector or acting as mother ship catcher-vessels (MSCV's) must carry one observer on all trips. Motherships and catcher-processors carry two observers each trip. The shorebased sector is managed through Individual Fishing Quotas (IFQ's) and includes all vessels that land catch at shore side processors. Catch shares regulations allow the shorebased sector to use trawl, longline, or pots to harvest IFQ species. The mother ship and catcher-processor sectors target Pacific hake using trawl gear and process it entirely at-sea. Motherships and catcher-processors have formed cooperatives to ensure sectors can attain Pacific hake quota without exceeding bycatch caps for overfished species or salmon.

Catch Share observers are deployed in the following catch share fisheries:

- All vessels participating in the Shore-based Individual Fishing Quota (IFQ) program including hake and non-hake groundfish trawl and fixed gear vessels
- All motherships participating in the at-sea hake fishery
- All mother ship catcher-vessels participating in the at-sea hake fishery
- All catcher-processors participating in the at-sea hake fishery

b) Non-catch shares

The observer program collects data in other west coast fisheries that are not part of the catch share program. The program had vessels ranging in size from skiffs to larger fixed gear vessels and depths ranging from less than 20 ft. to more than 300 ft. Due to its unique data collection circumstances in both the catch shares and non-catch shares fisheries, the program continues to stress safety and data quality.

Table 1. The following tables summarize the West Coast Groundfish Observer Program (WCGOP), including catch shares, non-catch shares and at-sea-hake-observer program (A-SHOP), activity in 2020 and 2021 during the global COVID-19 pandemic. Most of the whiting catcher vessels still require 100% monitoring, but are carrying electronic monitoring (EM) not observers. Consequently, the number of vessels, trips, seadays and observers in table for shoreside

IFQ fixed gear, shoreside hake and MSCV are low. These values only represent the vessels still carrying observers, and do not represent the fleet.

DESCRIPTION	2020	2021
Number of catch share observers	63	58
Number of non-catch share observers	38	41
Number of A-SHOP Observers	48	37

DESCRIPTION	Shoreside IFQ Trawl		Shoreside IFQ Fixed Gear		Shoreside Hake		MSCV		A-SHOP	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Number of vessels	39	40	2	2	1	1	2	1	15	14
Number of trips	446	611	13	5	28	30	6	2	47	45
Number of Sea days (with fish ng activity)	1,274	1,736	65	23	73	80	85	59	1600	1440
Number of Observers	57	57	6	3	2	1	3	2	48	37

NonCatch Share - NCS Sea Days		
FISHERY DESCRIPTION	**2020**	**2021**
CA Cucumber Trawl	4	0
CA Emley-Platt SFCFA EFP	8	15
CA Halibut	71	105
CA Nearshore	113	119
CA Pink Shrimp	15	7
CA Real Good Fish Monterey Bay EFP	5	0
CA Ridgeback Prawn	23	6
Electronic Monitoring EFP	31	107
IPHC Directed Commercial Halibut	21	25
Limited Entry Sablefish	301	356
Limited Entry Zero Tier	28	21
OR Blue/Black Rockfish	39	89
OR Blue/Black Rockfish Nearshore	111	122
OR Cook Midwater H&L EFP	5	0
OR Pink Shrimp	169	195
Trawl Gear Modification EFP	365	147
WA Pink Shrimp	91	80
WC Open Access Fixed Gear	43	65

For more information, please contact Jon McVeigh at Jon.McVeigh@noaa.gov

2. Research

a) Comparing predictions of fisheries bycatch using multiple spatiotemporal species distribution model frameworks

b) Bycatch quotas, risk pools, and cooperation in the Pacific whiting fishery (Bycatch Quotas and Risk Pools PGTF)

c) The utility of spatial model-based estimators of unobserved bycatch

d) Fishing to live or living to fish: job satisfaction and identity of west coast fishermen

e) Joint and several liability in fishery cooperatives

f) Catch shares drive fleet consolidation and increased targeting but not spatial effort concentration nor changes in location choice in a multispecies trawl fishery

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E. By-catch Reduction Engineering

1. Research

a) Reducing seafloor and benthic macroinvertebrate impacts using semi-pelagic trawl technology to harvest U.S. West Coast demersal groundfishes

Investigator: Mark Lomelli

This research compared the catch efficiency and trawl-seafloor interactions between a conventional demersal trawl rigged with bottom tending doors and bottom sweeps and a semi-pelagic trawl outfitted with midwater doors and elevated sweeps (Fig. 36). Door spread sensors showed the semi-pelagic trawl had a 42 m greater door spread than the conventional demersal trawl. Further, bottom contact sensors showed the doors of the semi-pelagic trawl fished on average >63.5 cm above the seafloor. In terms of catch efficiency, the semi-pelagic trawl caught significantly more sablefish (*Anoplopoma fimbria*) than the conventional demersal trawl. For other target groundfishes such as lingcod (*Ophiodon elongatus*), Dover sole (*Microstomus pacificus*), and petrale sole (*Eopsetta jordani*), the semi-pelagic trawl on average caught more fish than the conventional demersal trawl, but not at a significant level. A sled outfitted with DIDSON sonar imagery and a video camera was towed across trawl paths of the two trawl designs to observe their interactions with the seafloor. The DIDSON sonar imagery and video footage data is currently being analyzed.

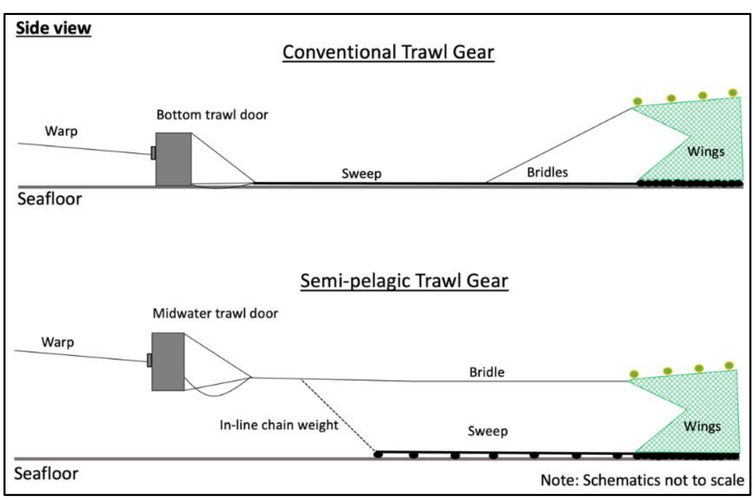

Figure 36. Schematic comparison between a conventional bottom trawl and a semi-pelagic trawl.

For more information, please contact Mark Lomelli at mark.lomelli@noaa.gov

b) Testing a dual sorting grid system to reduce juvenile sablefish catches in the West Coast groundfish bottom trawl fishery

Investigator: Mark Lomelli

This study tested a dual sorting grid system (Fig. 37) to reduce juvenile sablefish (*Anoplopoma fimbria*) catches (e.g., fish smaller than ~45 cm in total length) in the West Coast groundfish bottom trawl fishery. The unique characteristic of the dual grid system is that it consists of a double grid system to provide smaller-sized fished increased escapement opportunities In this research, we tested three different grid sizes: 6.9 x 6.9, 8.3 x 8.3, & 9.5 x 9.5 cm. Of the three grid sizes examined, the 8.3 x 8.3 cm grid size performed best at reducing catches of smaller-sized sablefish (a mean catch reduction of 45.8% for sablefish <45 cm in length was noted) while maintaining catches of preferred marketable-sized sablefish. While our study achieved positive results, fishers' input, our catch data and in situ video observations indicate that gear modifications could be made that could further enhance the performance of the grid system, and affect fishers voluntary use of the gear.

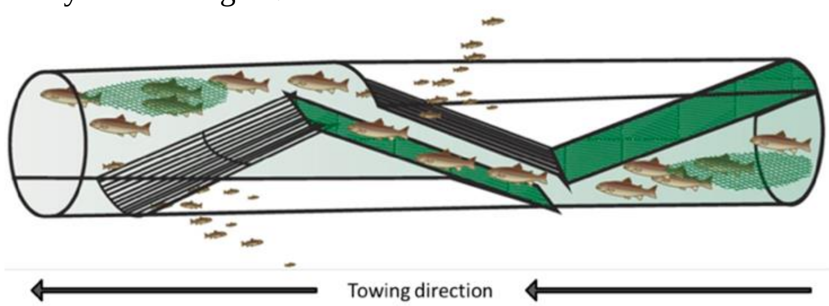

Figure 37. Schematic example of a dual grid system (From: Sistiaga et al., 2016; Fish. Res.)
For more information, please contact Mark Lomelli at mark.lomelli@noaa.gov

c) Disentangling the web of factors influencing whale bycatch in fixed gear fisheries on the U.S. west coast

Investigators: B. Feist, J. Samhouri, and in collaboration with the SWFSC and WCRO

Protection of endangered and threatened cetaceans has resulted in population recoveries and the delisting of species across the globe. While this increase in population size is desirable from a conservation perspective, it can have unintended consequences for human activities such as shipping and fishing that operate in the same ocean waters. Anomalous ocean conditions can increase the probability of whale entanglement with fishing gear by altering spatio-temporal distributions of both fisheries and cetaceans in such a way that co-occurrence increases. Entangled whale reports on the U.S. west coast increased dramatically from historical norms, ca. 2014, especially among humpback whales. Gear type can only be determined in about half of the reports, which is predominantly fixed-gear (pot- and trap-based), the majority of which originating from the highly profitable Dungeness crab fisheries. In this paper we address the question of whether changes in the spatio-temporal distributions of these fixed-gear fleets occurred coincident with the increase in entanglement sightings, and if these changes placed the fisheries in closer proximity to cetaceans. We also examine two alternate and non-mutually exclusive scenarios, including (i) changes in the spatio-temporal distribution of whales that may have resulted in overlap with fisheries activities, and (ii) increases in human observation of whale activity. We find that fishing vessel activity for the dominant pot-based fishery, Dungeness crab, was somewhat declining from 2009 to mid-2016, rather than increasing, despite increases in whale entanglement reporting that began ca. mid-2014. However, unprecedented fishing activity in the months of May and June in California (but not Washington or Oregon) were evident during the domoic acid closures of the 2015-16 Dungeness crab season, which likely led to cooccurrence of humpbacks with Dungeness fishing activities. This result is consistent with the hypothesis that increased entanglement of humpback whales that began ca. 2014 was likely a result of changes in whale spatial distributions, exacerbated by a delay in fishing effort during the 2015-16 season. Future efforts to incorporate forecasts of cetacean and fishing distributions, and oceanographic conditions, will provide information to anticipate the potential for conflicts rather than after they have already occurred.

For more information, please contact Dr. Blake Feist at NOAA's Northwest Fisheries Science Center, Blake.Feist@noaa.gov.

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NMFS Southwest Fisheries Science Center

Agency Report to the Technical Subcommittee of the Canada-U.S. Groundfish Committee

April 2022

Edited by Melissa Monk

With contributions from John Field, Tom Laidig, Nick Wegner, Sabrina Beyer, Joe Bizzarro and E.J. Dick

A. AGENCY OVERVIEW

The Southwest Fisheries Science Center (SWFSC) conducts fisheries and marine mammal research at three laboratories in California. Activities are primarily in support of the Pacific Fishery Management Council, the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), as well as a number of international fisheries commissions and conventions. The Science and Research Director is Kristen Koch and John Crofts is the Deputy Director. All SWFSC divisions support the essential needs of the NMFS and the Pacific Fishery Management Council (PFMC) for groundfish, including as active members of the PFMC's Scientific and Statistical Committee (SSC), the Groundfish Management Team, and other management teams and advisory bodies.

The Center is headquartered in La Jolla, which hosts three divisions that conduct research on a wide range of Pacific and Antarctic fish, marine mammals, sea turtles, and marine habitats; the Antarctic Ecosystem Research Division (led by Dr. George Watters), the Marine Mammal and Turtle Division (led by Dr. David Weller), and the Fisheries Resources Division (acting director Dr. John Hyde). The Fisheries Resources Division (FRD) conducts research on groundfish, large pelagic fishes (tunas, billfish and sharks), and small coastal pelagic fishes (anchovy, sardine and mackerel), and is the only source of groundfish research at the La Jolla facility. The Fisheries Research Division is also the primary source of federal support for the California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys that have taken place along much of the California coast since 1951. Researchers at FRD have primary responsibility for ichthyoplankton collections, studies of species abundance and distribution (including responses to climate variability), systematics, and the application of early life history information to stock assessments.

The Fisheries Ecology Division (FED) in Santa Cruz is directed by Dr. Steve Lindley, and three of the four research branches conduct studies focused on groundfish. The FED recently underwent a reorganization due to supervisor retirements and new hires. Dr. Steve Lindley is currently the acting supervisor of the Fisheries Economics team. The Molecular Ecology team (led by Dr. Carlos Garza) studies the molecular ecology and phylogeny salmonids and groundfish. Dr. John Field now oversees a larger Fisheries Assessment Group with three teams, Fisheries and Ecosystem Oceanography (led by Dr. John Field), Habitat and Groundfish Ecology (led by Dr. E.J. Dick) and Fisheries Assessment Modeling (led by Dr. Michael O'Farrell).

All of the teams within the Fisheries Assessment Group support the needs of NMFS and the Pacific Fishery Management Council, one of which is groundfish stock assessment. Specific objectives of the FED groundfish programs include: (1) collecting and developing information useful in assessing and managing groundfish stocks; (2) conducting stock assessments and improving upon stock assessment methods to provide a basis for harvest management decisions at the PFMC; (3) characterizing and mapping biotic and abiotic components of groundfish habitats, including structure-forming invertebrates; (4) disseminating information, research findings and advice to the fishery management and scientific communities; and (5) providing professional services (many of which fall into the above categories) at all levels, including inter-agency, state, national and international working groups. Dr. Xi He from FED was the most recent SWFSC representative to the Pacific Council's Groundfish Management Team, however that seat is currently vacant since Dr. He's retirement earlier in 2021. Several scientists from the Fisheries Ecology Division in Santa Cruz currently serve on the Pacific Council's Scientific and Statistical Committee.

There is also much collaboration among the three teams within the Fisheries Assessment Group. The Fisheries Assessment Modeling team primarily conducts stock assessments for both groundfish and salmon, focusing on research to advance fisheries assessment methods. The Habitat and Groundfish Ecology team also conducts groundfish stock assessments, and utilizes a number of survey tools, e.g., visual surveys conducted with remotely operated vehicles (ROV), human-occupied submersibles, autonomous underwater vehicles (AUV), scuba, hook-and-line fishing and captive rearing, to study deep-water demersal communities and groundfish ecology. The Fisheries and Ecosystem Oceanography team within the group is responsible for leading the annual pelagic juvenile rockfish recruitment and ecosystem assessment survey along the West Coast.

The Environmental Research Division (ERD) is led by Dr. Toby Garfield and has researchers located in both Monterey and Santa Cruz. The ERD is a primary source of environmental information to fisheries researchers and managers along the west coast, and provides science-based analyses, products, and information on environmental variability to meet the agency's research and management needs. The objectives of ERD are to: (1) provide appropriate science-based environmental analyses, products, and knowledge to the SWFSC and its fishery scientists and managers; (2) enhance the stewardship of marine populations in the California Current ecosystem, and other relevant marine ecosystems, by understanding and describing environmental variability, the processes driving this variability, and its effects on the production of living marine resources, ecosystem structure, and ecosystem function; and (3) provide science-based environmental data and products for fisheries research and management to a diverse customer base of researchers, decision-makers, and the public. The ERD also contributes oceanographic expertise to the groundfish programs within the SWFSC, including planning surveys and sampling strategies, conducting analyses of oceanographic data, and cooperating in the development and testing of environmental and biological indices that can be useful in preparing stock assessments.

B. MULTISPECIES STUDIES

B1. Research on larval rockfish at the SWFSC

Contact: William Watson (william.watson@noaa.gov)

Larval Rockfish Investigators: Andrew Thompson, William Watson

During the past seven years (2013-2020), the ichthyoplankton and molecular ecology laboratories at the SWFSC, La Jolla, built species-specific larval rockfish time-series by genetically sequencing individual larvae from winter CalCOFI samples between 1998 and 2013. Results of this work are currently published in a master's thesis and two peer-reviewed scientific publications, and time-series from blue rockfish (*Sebastes mystinus*) were used by the Pacific Fisheries Management Council to inform the status of this stock.

In 2020-21 we continued to analyze this data. For example, Jessica Freeman who recently earned a masters degree from SIO utilized nonparametric multivariate and Bayesian analyses to better understand drivers of larval rockfish species richness and community structure dynamics. A manuscript describing this research is now under review in Marine Ecology Progress Series. In addition, Noah Ben-Aderet, who was a postdoctoral researcher with us from 2018-2020 removed otoliths from a subset of eight of the genetically-identified species between 1998 and 2013. Noah measured otolith core width as a proxy for maternal investment and outer band width size as a proxy for growth rate. Noah (who now works for the Ocean Protection Council), two additional postdocs in our lab (Will Fennie and Garfield Kwan) are currently conducting analyses to test whether environmental conditions during parturition affect maternal investment and if maternal investment and/or environmental conditions impact rate of growth. Our initial results show that larvae with higher maternal investment were more likely to be found in offshore than inshore locations and when parents were bathed in cold, oxygen rich Pacific subarctic water. Maternal investment, in turn, significantly and positively correlated with larval growth rates. The ultimate goal of this project is to identify mechanisms that affect rockfish recruitment and determine if larval condition can predict recruitment success. We are currently determining if there is a link between larval condition and rockfish recruitment as quantified by surveys from oil platforms conducted by Milton Love's lab at UCSB between 1999 and 2013.

In 2019-2020, we initiated another genetics project seeking to identify rockfishes in CalCOFI samples. Rather than sequencing individual larvae, we extracted DNA from the ethanol in which CalCOFI samples are stored. We then used metabarcoding techniques similar to those used for environmental DNA analysis to sequence DNA from all fishes in a sample. It turned out that the traditional primers used for fish metabarcoding (MiFish 12S) discriminated poorly among rockfish species. Hence, we designed rockfish-specific metabarcode primers within the cytochrome *b* gene. We metbarcoded DNA from four stations per year between 1998 and 2019 and used recently-developed bioinformatics pipelines to quantify the number of DNA reads for each species in a sample. Initial results demonstrate that we are able to identify most rockfish species from ethanol preservative. To translate sequence reads to larval abundances, however, we need to evaluate the species-specific rates of DNA amplification. When the lab reopens post-covid, we plan to quantify larval abundances from the plankton samples that were metabarcoded. The metabarcoding work is led by Zachary Gold, a postdoc at the NWFSC.

We are currently conducting a study to evaluate the implications of larval rockfish diet on larval condition. We obtained NSF-Rapid funds (this project was led by SIO researcher Rasmus Swalethorp) to collect plankton samples in conjunction with CalCOFI cruises in fall 2020 and winter and spring 2021. Quantifying gut contents from larvae can be problematic because fish tend to excavate stomachs when fixed in preservative. To mitigate gut excavation, plankton were cooled in a freezer prior to preservation. In addition, to assess larval prey field, water was pumped directly from the ocean in the locations where plankton samples were collected. SIO masters student Kamran Walsh is currently dissecting rockfish guts, delineating ingested zooplankton species and measuring the condition of each larva.

We began in 2019-2020 a collaboration with the NWFSC to explore larval rockfish dynamics before, during, and after the 2014-2016 Marine Heatwave. We obtained from Toby Auth rockfish larvae collected annually off the Newport Hydrological Line from 2013-2019. Prior to the cessation of non-mission essential work at the SWFSC due to the coronavirus pandemic, we completed tissue extractions from all larvae (approximately 1800) and sequenced and identified approximately 1000. We were on track to complete identification by the end of April 2020, but had to postpone lab work due the restricted access to the Center. Once the SWFSC more fully reopens, we should be able to complete the identifications in about a month if we can work at our pre-shutdown pace.

Finally, our project to update larval fish identifications from historic CalCOFI surveys to current taxonomic standards has been on hiatus since March 2020 due to the very limited lab access available. Processing of samples from more recent surveys has substantially slowed as well. We currently have completed all surveys from July 1961 through December 2015, and samples collected during the primary rockfish reproductive seasons, winter and spring, of 2016-2021. This provides a 60-year time series of larval abundances of the rockfish species visually identifiable as larvae (*Sebastes aurora*, *S. diploproa*, *S. goodei*, *S. jordani*, *S. levis*, *S. macdonaldi*, *S. paucispinis*).

B.2 Research on Juvenile Rockfish at the SWFSC

Contact: John Field (john.field@noaa.gov)

Since 1983 the SWFSC has conducted a Rockfish Recruitment and Ecosystem Assessment Survey in late Spring surveys for pelagic young-of-the-year (YOY) rockfish using a modified Cobb midwater trawlThe survey supports the development of recruitment indices for stock assessments of many winter-spawning rockfish (e.g., chilipepper, bocaccio, canary, blue/deacon, black, shortbelly and widow rockfishes), and a suite of fisheries and ecosystem oceanography studies (reviewed in Santora et al. 2021a). From 1983 through 2003 the survey was limited spatially to a "core" area of central California (the southern end of Monterey Bay to just north of Point Reyes, CA). However, the spatial coverage was expanded in 2004 to include all of California waters, due to concerns over the application of recruitment indices from a limited spatial scale in coastwide stock assessments. The 2022 survey will represent the 40th year of continuous effort for this survey, following a very sparse 2020 survey on a chartered fishing vessel which was limited to the core area and associated with an extensive evaluation of the associated uncertainty (Santora et al. 2021b). A "more typical" coastwide survey was completed in 2021 (Sakuma 2021).

The results of the 2021 survey indicate that catches of young-of-the-year (YOY) rockfish, sanddabs and Pacific hake increased from the very low levels observed in 2019 and 2020, although they remained well below the peak abundance levels that occurred during and shortly after the 2015-2016 large marine heatwave. The relative abundance of northern anchovy remained at very high levels observed in recent years, however no adult Pacific sardine were encountered in the core area in either 2020 or 2021, consistent with the observed decline in their abundance seen in other surveys. Results from the 2021 survey also suggest that the relative abundance of krill in this region also increased, but remained slightly below long-term average levels, and a similar trend was observed for myctophids (lanternfishes). The abundance of market squid increased quite substantially between 2020 and 2021, but interestingly, pelagic octopus catches, which often covary strongly with YOY groundfish and market squid (Sakuma et al. 2016), remained low in 2021. The interpretation of these results (reported to the California Current Integrated Ecosystem Assessment and the CalCOFI "State of the California Current" report, e.g., Weber et al. 2021) are that recent ocean conditions have not been highly conducive to high rockfish and groundfish recruitment, although the abundance of alternative forage (anchovy, krill and cephalopods) would indicate that the forage base for California Current predators remains robust. Survey results also indicated that catches of pyrosomes and other pelagic thalacians remained at high levels in 2021, extending to a ten year period of (generally) high to very high abundance in southern California Current waters (Miller et al. 2019).

The RREAS survey data have been pooled with data from NWFSC pelagic juvenile cruises, including the PWCC/NWFSC survey from 2001-2009 and the NWFSC Pre-recruit survey from 2011 through 2019. A recent analysis of the pooled data from these surveys described the variability in the temporal and spatial abundance and distribution patterns of YOY rockfishes along the U.S. West Coast (Field et al. 2021). This analysis used dynamic factor analysis (DFA) to evaluate spatial coherence patterns in pelagic juvenile rockfish catch rates over the scale of the California Current. The results indicate that while there is considerable, there are many years in which abundance patterns are very heterogeneous, particularly to the north and south of major promontories such as Cape Mendocino and Point Conception (see Figure 1). Results also confirm that the high abundance levels of YOY rockfish observed during the 2014-2016 large marine heatwave were largely coastwide events. Species association patterns of pelagic YOY for over 20 rockfish taxa in space and time, using non-metric multi-dimensional scaling (NMDS), are also described. The results of this work will help to inform survey design and consideration of the most appropriate means to develop indicators of recruitment strength used to inform stock assessment models.

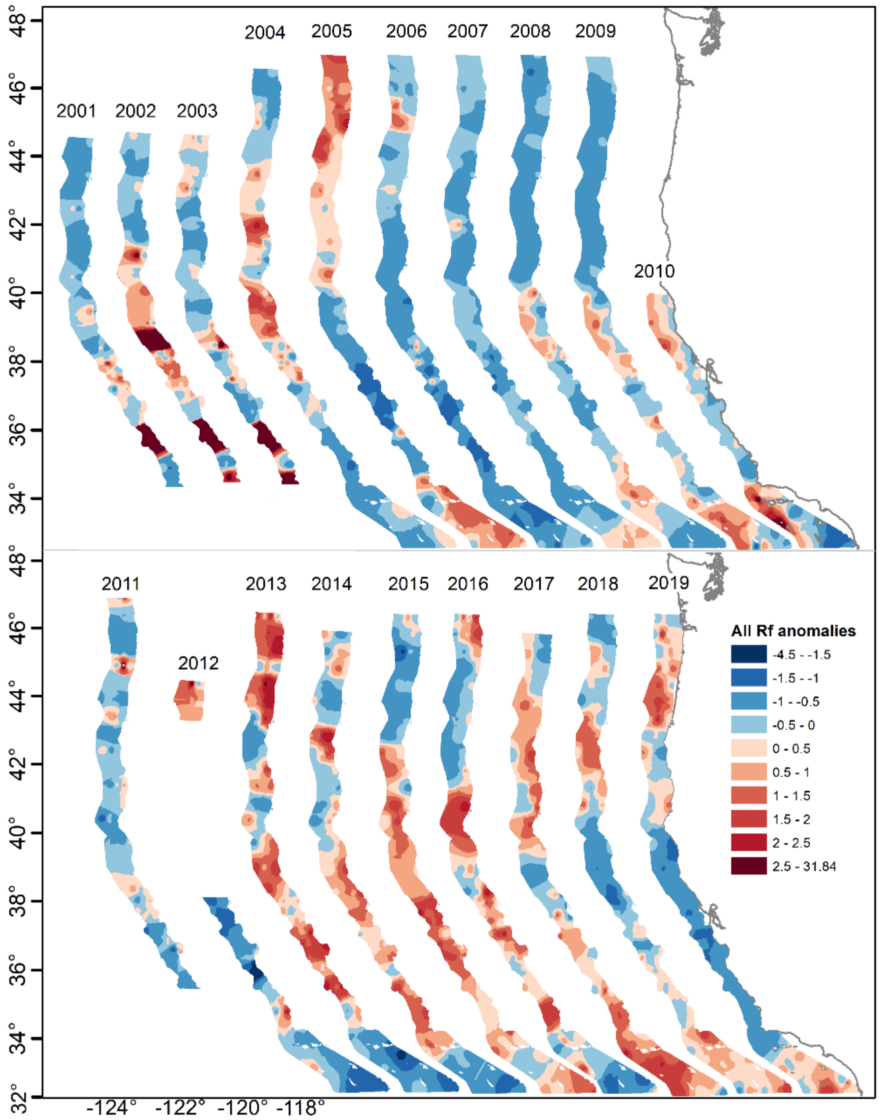

Figure 1: Interannual variability in relative pelagic young-of-year rockfish abundance, based on z-scores from a spatial climatology of years with complete coastwide coverage.

C. BY SPECIES, BY AGENCY

C1. Nearshore rockfish stock assessments

C2. Shelf Rockfish

In late 2021, Drs. Melissa Monk and E.J. Dick completed stock assessments for the vermillion/sunset rockfish complex in southern and central/northern California to support PFMC management efforts (Dick et al. 2021, Monk et al. 2021). The stock assessment review panel endorsed two models for California waters, north and south of Point Conception, which were subsequently adopted for management by the Pacific Council. These assessments included the first large-scale effort to age vermilion rockfish, and several aging laboratories were involved in an official CARE (Center for Age Reading Experts) exchange, with each lab providing 60 fish that are subsequently aged by each lab involved in the age determination effort. The results will provide robust information on ageing error among the aging labs.

C2.a. Rockfish barotrauma and release device research at SWFSC La Jolla Lab
Contact: Nick Wegner (nick.wegner@noaa.gov)

The Genetics, Physiology, and Aquaculture program at the SWFSC in La Jolla continues to evaluate the effects of capture and barotrauma on rockfishes (*Sebastes* spp.) following release in recreational fisheries. This work focuses in three major areas: 1. Acoustic telemetry tagging studies to document the survival rates and sublethal effects of catch and release and barotrauma on important management species such Cowcod (*S. levis*) and Bocaccio (*S. paucispinis*) (Figure 2). Laboratory studies examining the sensitivity of rockfishes to hypoxia both before and immediately following laboratory induced barotrauma using hyperbaric chambers, and 3. Working with the recreational fishing community in California to measure the effectiveness and angler preference for different types of commercially available descending devices used to release rockfishes suffering from barotrauma.

Analysis of acoustic tagging work to date has shown species-specific long-term survival rates of 50.0% for Cowcod (n=46, CI= 35.7-70.5%) and 89.5% for Bocaccio (n=41, CI 80.2-99.8%). For Cowcod (which showed much lower survival rates), fish length, sea surface temperature, and dissolved oxygen levels at depth all significantly affected survival. For fish that survived, general additive models (GAMs) of post-release behavior showed that capture and barotrauma affected Cowcod and Bocaccio for at least 30 days post release. Dissolved oxygen also significantly affected post-release behavior. The modeled impact of dissolved oxygen on both survival rate and post-release behavior have led to on-going laboratory-based studies to examine the effects of hypoxia on Cowcod and Bocaccio behavior and physiology. Specifically this work is examining behavioral avoidance to low oxygen using a custom-built shuttle-box system, and determining the effects of hypoxia on metabolism through respirometry trials. Better understanding how low levels of dissolved oxygen contribute to mortality and rockfish behavior will allow for refinement of the catch-and-release process and the implementation of release guidelines that maximize survival. In addition, such work can provide insight into limits on rockfish suitable habitat. This work was recently published in *ICES Journal of Marine Science* (Wegner et al. 2001).

Research testing the effectiveness of descending devices released 2,275 rockfish from 32 species. While there were some significant differences between device types, all devices were effective for releasing rockfishes back to depth. Initial post-release mortality (defined as all mortality events observable from the vessel while fishing) across all devices was relatively low (7.5%) in capture depths less than 100 m. These results suggest that rockfishes should be released at least half-way to the bottom (preferably directly to the bottom) for the device to be effective in minimizing post-release mortality. Although all descending devices work, at-sea conditions, vessel type, and fish size tend to influence effectiveness and user preference of different device types. This work was recently published in *Fisheries Research* (Bellquist et al. 2019)

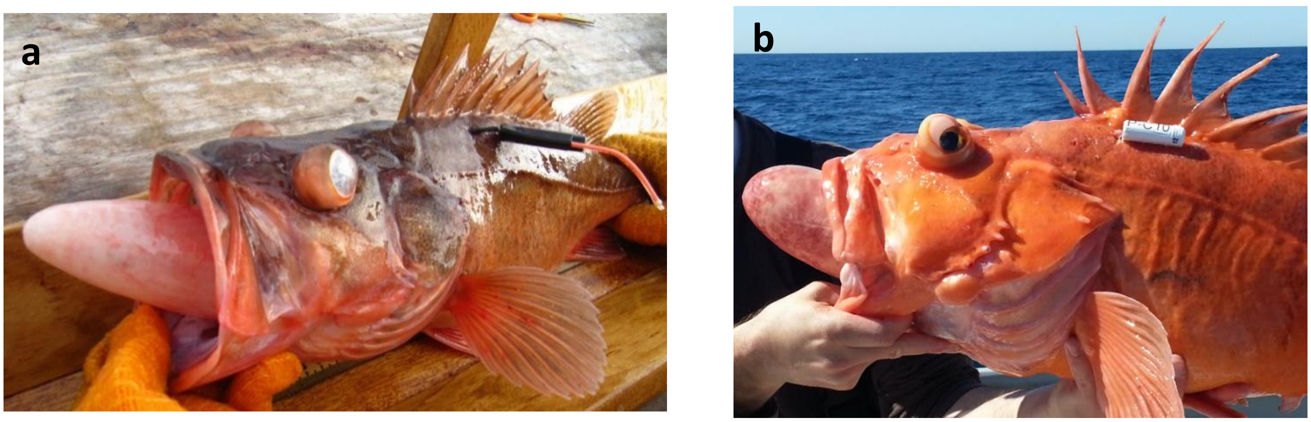

Figure 2: Acoustic transmitter attachment and external barotrauma indicators for a) 47.5 cm FL Bocaccio tagged with a V9 single-anchored transmitter displaying a bloated body, everted esophagus, exophthalmia, and ocular emphysema. b) 64.0 cm Cowcod tagged with a double anchored V13 transmitter showing a bloated body, everted esophagus, exophthalmia, and the first onset of ocular emphysema (anterior-dorsal portion of eye).

D. OTHER RELATED STUDIES

D1. SWFSC FED Habitat and Groundfish Ecology Team 2019-20 Research on California Demersal Communities

Contact: E.J. Dick (edward.dick@noaa.gov) FED HAGE Investigators: Joe Bizzarro, Tom Laidig, Melissa Monk, Diana Watters

The SWFSC/FED Habitat and Groundfish Ecology Team (HAGE) completes stock assessments on groundfish species and conducts research focused on deep-water California demersal communities. The goal for the deep-water component is to provide sound scientific information to ensure the sustainability of marine fisheries and the effective management of marine ecosystems, with objectives to: (1) improve stock assessments, especially of groundfish species in untrawlable habitats; (2) characterize fish and habitat associations to improve EFH identification and conservation; (3) contribute to MPA design & monitoring; and (4) understand the significance of deep-sea coral (DSC) as groundfish habitat. The HAGE uses a variety of underwater vehicles to survey demersal fishes, macro-invertebrates (including members of DSC communities), and associated seafloor habitats off northern, central, and southern California. These surveys have resulted in habitat-specific assemblage analyses on multiple spatial scales; fishery-independent stock assessments; baseline monitoring of MPAs; documentation of marine debris on the seafloor; and predictive models of the distribution and abundance of groundfishes and deep sea corals. The following are a few examples of recent projects conducted by the HAGE and collaborators.

D2. Expanding Pacific Research and Exploration of Submerged Systems Campaign
Contact: Tom Laidig (tom.laidig@noaa.gov)
In 2018, a team of federal and non-federal partners initiated a new phase of collaborative ocean science off the western United States. The EXpanding Pacific Research and Exploration of Submerged Systems (EXPRESS) campaign targets deepwater areas off California, Oregon, and Washington. The core focus of campaign activities is the collection of spatially explicit deepwater habitat information including multibeam, backscatter, and visual data on continental shelf, shelf edge, and slope habitats. This goal will be attained through partnerships between NOAA (NOS and NMFS), BOEM, USGS, and MBARI. From initial successes, this nascent interagency effort quickly evolved into a major field program engaging and exciting scientists and marine resource managers spanning numerous disciplines and organizations. EXPRESS members were involved in two research expeditions in 2021. Three EXPRESS expeditions are currently planned for 2022 including a joint NWFSC/SWFSC cruise off Oregon and Northern California surveying benthic habitats to examine deep-sea coral communities in and around the newly proposed wind energy areas off Southern Oregon and Northern California.

D3. The importance of corals and sponges as groundfish habitat off Central and Southern California
Contact: Tom Laidig (tom.laidig@noaa.gov)
FED HAGE Investigators: Joseph J. Bizzarro, Rebecca Miller, Tom Laidig, Diana Watters
The overall goal of this project is to investigate the utilization of corals and sponges as habitat for groundfishes by analyzing extensive, long-term video data sets collected in central and southern California. Fish densities, sizes, diversity, and assemblage structure will be compared among similar seafloor habitat types with varying amounts and types of corals and sponges. Comparisons will be made within and between central and southern California study sites to assess the amount of spatial variability in fish-coral associations. Successful completion of this project will result in quantitative estimates of the relative importance of corals as habitat for a variety of commercially and ecologically significant groundfishes and the spatial consistency of these associations.
The project was initiated during early 2020, with the first two years devoted to database standardization, video review, data editing, and new data collection. Using digital seafloor video data collected during human occupied submersible dives, we completed video review and data collection for 106 dive-transects among 85 dives from Central California at depths of 35–303, and 97 dive-transects among 72 dives from Southern California at depths of 22–360. Preliminary results indicate that rockfishes were the dominant fish taxa associated with deep-sea corals and sponges (DSCS) in both study regions and scales of < 1 body length (BL) and < 3 m. At a scale of < 1 BL, relatively abundant (> 50 documented individuals) fishes off central

California had generally stronger DSCS associations; however, differences between regions were not substantial. Sponges were more strongly utilized than corals by the studied groundfish assemblages at the < 1 BL scale in both regions. In contrast to the 1 BL scale, relatively abundant fishes (> 50 individuals) in southern California exhibited stronger associations with DSCS at < 3 m distance than those off central California. Relative use of sponges and corals was similar at this scale, and more overall associations and associations of both sponges and corals were noted. Analysis is ongoing, with submission of a manuscript for peer-review anticipated by the end of FY22.

D4. Model-based estimation of average fish weights from recreational fisheries
Contact: E.J. Dick (Edward.Dick@noaa.gov)

E.J. Dick (SWFSC, FED), Jason Edwards (PSMFC) and Theresa Tsou (WDFW) developed a method to estimate average fish weights from recreational fisheries using a model-based approach. Their method improves upon existing ad-hoc imputation algorithms in that it identifies sources of variability in average weight through model selection procedures, imputes missing values, and provides estimates of uncertainty for both observed and unobserved strata. WDFW has approved this methodology for use in their catch estimation procedures, and is currently working to obtain further funding for implementation with groundfish stocks.

D5. Rockfish Reproductive Ecology Laboratory and Field Studies

Contact: sabrina.beyer@noaa.gov (Affiliate)/ **sbeyer@ucsc.edu**

Ongoing studies at the SWFSC Fisheries Ecology Division in partnership with the University of California Santa Cruz highlight spatiotemporal variability in reproductive output, including fecundity and the production of multiple annual larval broods in California rockfishes (*Sebastes* spp). Laboratory work continued in 2020 to process egg and larval samples collected in Central California in order to document interannual variability in reproductive effort correlated with oceanographic conditions in a range of economically important rockfishes. Samples of gravid Chilipepper (*S. goodei*), Bocaccio (*S. paucispinis*), Yellowtail (*S. flavidus*) and Widow (*S. entomelas*) rockfishes will be incorporated into a nearly three-decade time-series of fecundity data dating back to the 1980s and 1990s and spanning a range of environmental conditions in the Central region of the California Current to better understand environmental drivers of reproductive plasticity and maternal reproductive effort. The autodiametric method of fecundity analysis was developed, tested and implemented for more rapid processing of unfertilized oocytes in Chilipepper, Yellowtail and Rosy rockfish (*S. rosaceus*). The autodiametric method, on average, was five times faster than the traditional gravimetric counting method for unfertilized stages in rockfishes and will increase the efficiency of reproductive data collection.

D6. California Current Trophic Database

Contact: Joe.Bizzarro@noaa.gov (Affiliate)

In the California Current Large Marine Ecosystem (CCLME), recent population crises, including seabird and sea lion unusual mortality events, a salmon population collapse, and increasing whale entanglements, have raised the level of interest in the causes and consequences of climate driven shifts in trophic interactions. Quantitative information that details trophic relationships is fundamental to address these types of complex ecological issues. A comprehensive database to help address such questions, the California Current Trophic Database (CCTD), was conceived and developed at Southwest Fisheries Science Center (SWFSC) in collaboration with researchers from all of the Pacific coast science centers as well as several academic institutions. So far, 24 data sets have been contributed, representing 105,562 individuals among 143 predator taxa collected throughout the CCLME from 1967–2019. These taxa consist of squids (n=5), elasmobranchs (n=13), bony fishes (n=118), and marine mammals (n=7). The vast majority of the bony fish and elasmobranch samples are groundfish. The CCTD is a first step towards a comprehensive database for the CCLME, results will be shared among collaborators and made available online as the project progresses.

E. GROUNDFISH PUBLICATIONS OF THE SWFSC, 2020– PRESENT

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STATE OF ALASKA
GROUNDFISH FISHERIES

ASSOCIATED INVESTIGATIONS IN 2021

Prepared for the Sixty-second Annual Meeting of the Technical Subcommittee of the Canada-United States Groundfish Committee

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April 2022

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION of COMMERCIAL FISHERIES & DIVISION of SPORT FISH
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STATE OF ALASKA GROUNDFISH FISHERIES AND ASSOCIATED INVESTIGATIONS IN 2021

I. Agency Overview

A. Description of the State of Alaska commercial groundfish fishery program (Division of Commercial Fisheries)

The Alaska Department of Fish and Game (ADF&G) has jurisdiction over all commercial groundfish fisheries (does not include Pacific halibut) within the internal waters of the state and to three nautical miles offshore along the outer coast. A provision in the federal Gulf of Alaska (GOA) Groundfish Fishery Management Plan (FMP) gives the State of Alaska limited management authority for demersal shelf rockfish (DSR) in federal waters east of 140^{o} W longitude. The North Pacific Fisheries Management Council (Council) acted in 1997 to remove black and blue (now called deacon) rockfish from the GOA FMP. In 2007, dark rockfish was removed from both the GOA and the Bering Sea and Aleutian Islands (BSAI) FMPs. Thus, in these areas the state manages these species in both state and federal waters. The state also manages the lingcod resource in both state and federal waters of Alaska. The state manages some groundfish fisheries occurring in Alaska waters in parallel with National Oceanic and Atmospheric Administration (NOAA), adopting federal seasons and, in some cases, allowable gear types as specified by NOAA. The information related in this report is from the state-managed groundfish fisheries only.

The State of Alaska is divided into three maritime regions for marine commercial fisheries management. ADF&G personnel are listed in Appendix I by division and region. The Southeast Region extends from the Exclusive Economic Zone (EEZ) equidistant line boundary in Dixon Entrance north and westward to 144^{o} W longitude and includes all of Yakutat Bay (Appendix II). The Central Region includes the Inside and Outside Districts of Prince William Sound (PWS) and Cook Inlet including the North Gulf District off Kenai Peninsula. The Westward Region includes all territorial waters of the Gulf of Alaska south and west of Cape Douglas and includes North Pacific Ocean waters adjacent to Kodiak, and the Aleutian Islands as well as all U.S. territorial waters of the Bering, Beaufort, and Chukchi Seas.

1. Southeast Region

The **Southeast Region** Commercial Fisheries groundfish staff are in Sitka, Juneau, and Petersburg. Sitka staff are comprised of the project leader, two fishery biologists, and one seasonal fishery technician. Staff in Juneau include one full-time fishery biologist and one seasonal fishery biologist, and Petersburg staff include one fishery biologist and one seasonal fishery technician. In addition, the project provides support for port samplers in Ketchikan to sample groundfish landings. The project also receives biometric assistance from ADF&G headquarters in Juneau.

The Southeast Region's groundfish project has responsibility for research and management of all commercial groundfish resources in the territorial waters of the Eastern GOA as well as in federal waters for demersal shelf rockfish (DSR); black, deacon, and dark rockfishes; and lingcod. The project cooperates with the federal government for management of the adjacent EEZ. The Petersburg fishery biologist and project leader attend meetings of the Council’s GOA Groundfish Plan Team and produce the annual stock assessment for DSR for consideration by the Council.

Project activities center around fisheries monitoring, resource assessment, and inseason management of the groundfish resources. Inseason management decisions are based on data collected from the fisheries and resource assessment surveys. Primary tasks include fish ticket collection, editing, and data entry for both state and federally managed fisheries; dockside sampling of sablefish, lingcod, Pacific cod, and rockfish landings; and logbook collection and data entry. Two sablefish longline assessment surveys were conducted in 2021.

2. Central Region

The **Central Region** commercial fisheries groundfish management and research staff are primarily located in Homer. The management staff in Homer consists of an area management biologist, an assistant area management biologist (serves as regional port sampling and age reading project leader), a research analyst (processes fish tickets and manages databases), a fisheries biologist (serves as lead port sampler and age reader), and two seasonal fisheries technicians (samplers stationed in Seward and Homer with travel to Whittier); additional seasonal technicians are utilized in Homer and Cordova as funding allows for sampling, observing, and age reading. The area management biologist serves as a member of the Council's GOA Groundfish Plan Team. The research staff in Homer consists of a Groundfish research project lead, a fishery biologist, and a research analyst. Commercial Fisheries groundfish staff are supported by regional staff in Anchorage.

Commercial fisheries groundfish staff are responsible for the research and management of groundfish species harvested in Central Region, which includes state waters of Cook Inlet and Prince William Sound (PWS) areas, as well as federal waters for lingcod, and black, deacon, and dark rockfishes. Within Central Region, groundfish species of primary interest include sablefish, Pacific cod, walleye pollock, lingcod, rockfishes, skates, sharks, and flatfishes. Management staff collect harvest data through commercial groundfish sampling, fisher interviews, logbooks, and onboard observing. Commercial harvest information (fish tickets) is processed in Homer for state and federal fisheries landings in Central Region ports. For some fisheries, logbooks are required, and data are collected and entered into local databases to provide additional information, including catch composition, catch per unit effort (CPUE), depth, and location data. Historically, Central Region research staff produce relative abundance estimates of groundfishes caught in bottom trawl surveys targeting Tanner crab in Kachemak Bay and in the inside waters of PWS. Bottom trawl surveys in Central Region are conducted by ADF&G research vessels the *R/V Solstice* and the *R/V Pandalus*. The Kachemak Bay and PWS trawl surveys were conducted within a consistent survey grid from 1990 to 2019. Due to a lack of funding, the Kachemak Bay survey has not been conducted since 2019. Due to emerging Tanner crab fisheries, the PWS trawl survey has not been conducted within the historical survey grid since 2019, and thus 2020 and 2021 survey results are not included in this report. The PWS historical survey grid will again be surveyed annually beginning in 2022 through funding from the Exxon Valdez Oil Spill Trustees Council.

3. Westward Region

The **Westward Region** Groundfish management and research staff are in Kodiak and Dutch Harbor. Kodiak staff is comprised of a regional groundfish management biologist, an area groundfish management biologist, an assistant area groundfish management biologist, a groundfish research project leader, an assistant groundfish research project biologist, a groundfish dockside sampling program coordinator, a groundfish dockside sampling program assistant biologist, a lead trawl survey biologist, an assistant trawl survey biologist, a fish ticket processing technician, and several seasonal dockside sampling technicians. An area management biologist, an assistant area groundfish management biologist and a fish ticket processing technician are in the Dutch Harbor office. Seasonal dockside sampling also occurs in Chignik, Sand Point, and King Cove. The *R/V Resolution*, *R/V K-Hi-C*, and *R/V Instar* hail from Kodiak and conduct a variety of groundfish related activities in the waters around Kodiak, the south side of the Alaska Peninsula, and in the eastern Aleutian Islands.

Major groundfish activities include: fish ticket editing and entry for approximately 7,000 tickets from both state and federal fisheries; analysis of data collected on an annual multi-species trawl survey encompassing the waters adjacent to the Kodiak archipelago, Alaska Peninsula, and Eastern Aleutians; management of black rockfish, dark rockfish, state-waters Pacific cod, lingcod, and Aleutian Island state-waters sablefish fisheries; conducting dockside interviews and biological data collections from commercial groundfish landings; and a number of research projects. In addition, the Westward Region has a member on the Council's GOA Groundfish Plan Team.

4. Headquarters

    a. Alaska Fisheries Information Network

The 1996 Magnuson-Stevens Act called for developing regional fishery databases coordinated between state and federal agencies. The Alaska Fisheries Information Network (AKFIN), created in 1997, accomplishes this objective. The AKFIN program provides the essential fishery catch data needed to manage Alaska's groundfish and crab resources within the legislative requirements of the Act in Section 303(a)5. Alaska has diverse data collection needs that are like other states. But the extensive geographic area and complexity of fisheries management tools used in Alaska have resulted in AKFIN becoming a cooperative structure that is responsive to the needs to improve data collection. The Pacific States Marine Fisheries Commission (PSMFC) manages the AKFIN grant with the funding shared by ADF&G statewide, AKFIN contract, and the PSMFC sponsored AKFIN Support Center (AKFIN-SC) in Portland, Oregon. ADF&G has primary responsibility for the collection, editing, maintenance, analysis, and dissemination of these data and performs this responsibility in a comprehensive program.

The overall goal of ADF&G's AKFIN program is to provide accurate and timely fishery data that are essential to management, pursuant to the biological conservation, economic and social, and research and management objectives of the FMPs for groundfish and crab. The specific objectives related to the groundfish fisheries are to collect groundfish fishery landing information, including catch and biological data, from Alaskan marine waters extending from Dixon Entrance to the BSAI;

1) to determine ages for groundfish samples using age structures (as otoliths, vertebrae, and spines) arising from statewide commercial catch and resource survey sampling conducted by ADF&G;
2) to provide the support mechanisms needed to collect, store, and report commercial groundfish harvest and production data in Alaska;
3) to integrate existing fishery research data into secure and well-maintained databases with consistent structures and definitions;

4) to increase the quality and accuracy of fisheries data analysis and reporting to better meet the needs of ADF&G personnel, AKFIN partner agencies, and the public, and to make more of this information available via web-access while maintaining the department's confidentiality standards;
5) to provide GIS services for AKFIN fishery information mapping to ADF&G Division of Commercial Fisheries personnel and participate in GIS and fishery data analyses and collaboration with other AKFIN partner agencies; and
6) to provide internal oversight of the AKFIN contract between the ADF&G and the PSMFC.

Groundfish species include walleye pollock, Pacific cod, sablefish, skates, various flatfish, various rockfish, Atka mackerel, lingcod, sharks, and miscellaneous species.

The foundation of the state's AKFIN project is an extensive port sampling system for collection and editing of fish ticket data from virtually all the major ports of landing from Ketchikan to Adak and the Pribilof Islands, with major emphasis on Sitka, Homer, Kodiak, and Dutch Harbor. The port sampling program includes collection of harvest data, such as catch and effort, and the collection of biological data on the species landed. Age determination is based on samples of age structures collected from landed catches. A dockside sampling program provides for collection of accurate biological data (e.g., size, weight, sex, maturity, and age) and verifies self-reported harvest information submitted on fish tickets from shoreside deliveries of groundfish throughout coastal Alaska. In addition, the GOA Groundfish FMP and the BSAI Groundfish FMP require the collection of groundfish harvest data (fish tickets) in the North Pacific. The AKFIN program is necessary for management and for the analytical and reporting requirements of the FMPs.

The state's AKFIN program is supported by a strong commitment to development and maintenance of a computer database system designed for efficient storage and retrieval of the catch and production data on a wide area network and the internet. It supports the enhancement of the fish ticket information collection effort including regional fishery monitoring and data management; GIS database development and fishery data analysis; catch and production database development and access; the Age Determination Unit laboratory; database management and administration; fisheries data collection and reporting; and fisheries information services.

Local ADF&G personnel maintain close contact with fishers, processors, and enforcement to maintain a high quality of accuracy in the submitted fish ticket records. Groundfish landings are submitted electronically from the interagency electronic reporting system, eLandings, to the eLandings repository database. Signed copies of the fish tickets are submitted to the local offices of ADF&G within seven days of landing. Data are reviewed, compared to other observations, edited, and verified. Once data are processed by local staff members, the fish ticket data are pulled into the ADF&G database of record; the statewide groundfish fish ticket database. Fish ticket data are immediately available to inseason management via the analysis and reporting tool, OceanAK. Verified fish ticket data are also available immediately after processing from this tool, as well.

Within the confines of confidentiality agreements, raw data are distributed to the National Marine Fishery Service (NMFS, NOAA Fisheries, both the Alaska Regional office and the Alaska Fishery Science Center), the Council, the Commercial Fisheries Entry Commission (CFEC), and the AKFIN Support Center on a regularly scheduled basis. Summary groundfish catch information is also provided to the Pacific States Fisheries Information Network (PACFIN), the State of Alaska Board of Fisheries (BOF), NOAA Fisheries, Council and the AKFIN Support Center.

The fishery information collected by the AKFIN program is not only essential for managers and scientists who must set harvest levels and conserve the fisheries resources, but it is also valuable for the fishermen and processors directly involved in the fisheries, as well as the public. To meet those needs, the department has designed, implemented, and continues to improve database systems to store and retrieve fishery data, and continues to develop improvements to fishery information systems to provide data to other agencies and to the public.

Groundfish fishery milestones for this ongoing ADF&G AKFIN program are primarily the annual production of catch records and biological samples. In calendar year 2021, ADF&G AKFIN personnel processed 12,127 groundfish fish tickets, collected 27,868 groundfish biological samples and measured 15,048 age structures (see tables below for regional breakdown). These basic measures of ongoing production in support of groundfish marine fisheries management by AKFIN funded ADF&G personnel are representative of the level of annual productivity by the AKFIN program since its inception in 1997 (Contact Lee Hulbert).

Groundfish Fish Tickets Processed - Calendar Year 2021

ADF&G Region	Total fish tickets
1 - Southeast	3,465
2 - Central	1,753
4 - Westward; Kodiak, Chignik, AK Pen.	5,697
4 - Westward; BSAI	1,212
Total	12,127

Groundfish Biological Data Collection - Calendar Year 2021

ADF&G Region	AWL samples collected	Age estimates produced by regional personnel	Age estimates produced by the ADU lab
1 - Southeast	7,405	n/a	8,180
2 - Central	12,121	1,753	1,855
4 - Westward	8,342	3,260	n/a
Total	27,868	5,013	10,035

b. Interagency Electronic Reporting System - eLandings (Contact Carole Triem)

ADF&G maintains a commercial harvest database, based on landing report receipts – fish tickets. These data are comprehensive for commercial salmon, herring, shellfish, and groundfish from 1969 to present. Data are stored in an Oracle relational database and available to statewide staff via the OceanAK reporting tool. Data are transferred annually to CFEC, where additional license and value information is merged with all fish ticket records. Once completed, the data are provided to the AKFIN support center, then summarized and made available to PACFIN.

Beginning in 2001, the agencies tasked with commercial fisheries management in Alaska (ADF&G, NOAA Fisheries, IPHC) began development of consolidated landing, production, and IFQ reporting from a sole source – the Interagency Electronic Reporting System (IERS). The goal is to move all fisheries dependent data to electronic reporting systems (Figure 1). The web-based reporting component of this system is eLandings (Figure 2**).** The application for the at-sea catcher processor fleet is seaLandings. Vessels using the seaLandings application upload landing and production reports to the centralized database. tLandings was developed to address electronic reporting on-board groundfish and salmon tender vessels. The application and the landings reports are stored on a portable thumb drive and are delivered to the shoreside processor for upload to the eLandings repository database. Fisheries management agencies use a separate application, the IERS Agency Interface, to view and edit landing reports. The IERS management/development team have implemented an electronic logbook application, eLogbook, currently used by groundfish catcher processors and longline catcher vessels. The IERS has been successfully operated in Alaska's commercial fisheries since August 2005. To date, approximately 1.7 million landing reports have been submitted to the eLandings repository database. More than 99% of all groundfish landings are submitted electronically.

Our approach, throughout this project, has been staged implementation which allows a small staff to successfully manage this ambitious project. Salmon fisheries are more diverse and seasonal than groundfish and crab fisheries. ADF&G will always support conventional, paper-based reporting for smaller buyers and processors. In November 2015, ADF&G adopted a regulation to require larger seafood processors to use the tLandings application for all tendered salmon. All tendered groundfish must be reported using the tLandings application, as well. During the 2021 salmon season, 96% percent of all salmon landings were submitted electronically.

Functionality for Southeast crab processors was added to eLandings in 2021, making forward progress on the goal to implement electronic reporting for all fisheries. Aside from ongoing maintenance, most development resources are aimed at completing the Processor HTML5 application. The new Processor HTML5 site will be available for beta testing by select processor users soon.

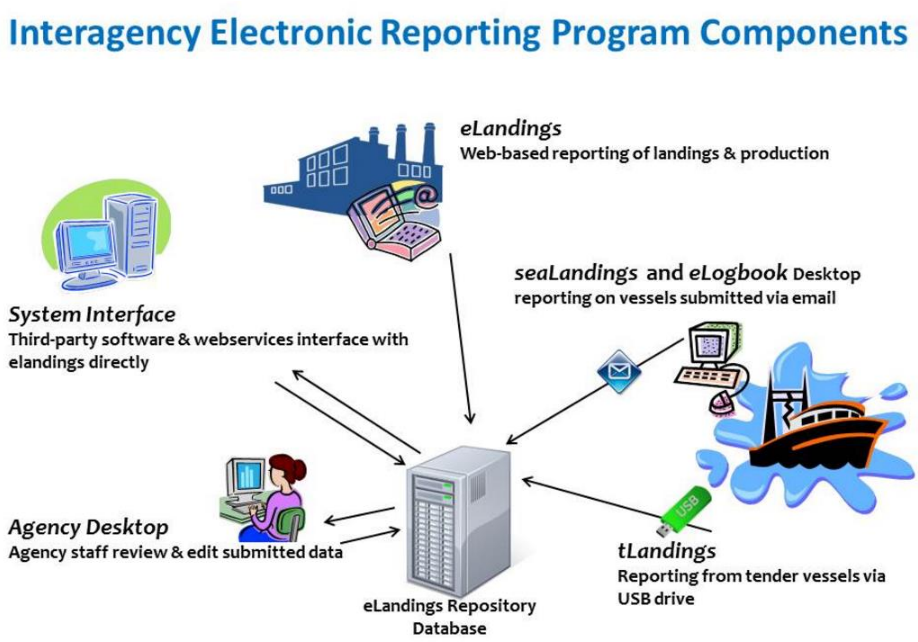

Figure 1.–Data are reported by the seafood industry using eLandings web, seaLandings and tLandings. Agency staff review, edit and verify landing and production reports within the eLandings agency desktop tool. Industry can pull harvest data for their company from the database using the eLandings system interface tools.

The IERS features include electronic landing and production reports, real time quota monitoring, immediate data validation, and printable (.pdf) fish ticket reports. The IERS provides processors with web-based electronic catch and production data extraction using an XML output. ADF&G personnel, funded by AKFIN, Rationalized Crab Cost Recovery funds, and IFQ Halibut/Sablefish Cost Recovery funds, participate in the IERS project on the development, implementation, and maintenance levels. During 2021, the IERS recorded 171,086 landing reports in crab, groundfish, and salmon fisheries. The IERS is extensively documented on a public and secure wiki at:

https://elandings.alaska.gov/confluence/.

Local ADF&G personnel in six locations throughout the state of Alaska (Petersburg, Sitka, Juneau, Homer, Kodiak, and Dutch Harbor) maintain close contact with groundfish fishers, processors, and state/federal enforcement to maintain a high quality of accuracy in the submitted fish ticket records. The Interagency Electronic Reporting System – eLandings, seaLandings, tLandings, and eLogbook applications, with immediate data validation and business rules, has improved data quality and allows personnel to function at a higher level. User support is provided by ADFG and NMFS staff, who monitor the eLandings Help Desk email address. IFQ reporting support is provided by the NOAA Fisheries Data Technicians.

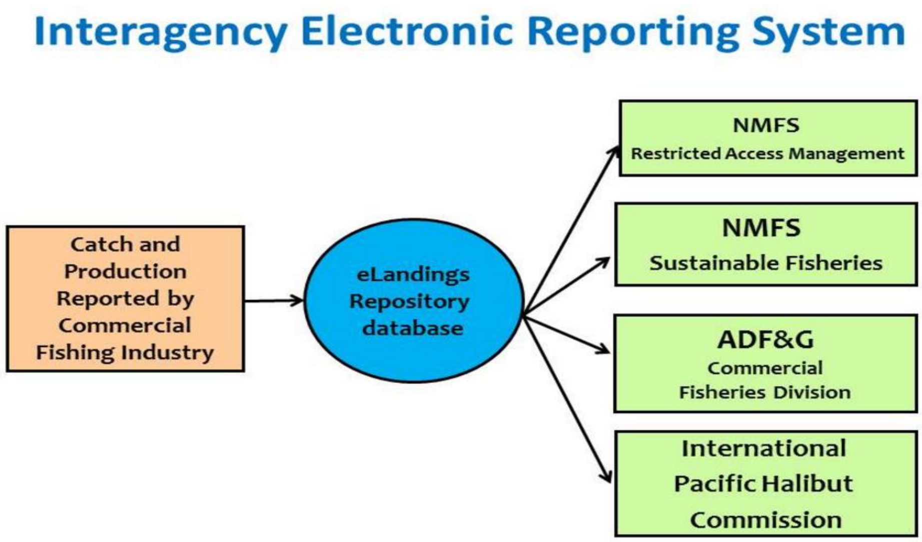

Figure 2.–Interagency staff have established methods to pull data from the repository database into their databases of record. The ADF&G fish ticket records are pulled into the commercial fisheries fish ticket database once data verification has occurred.

Landing and production data are submitted to a central database, validated and reviewed, and pulled to the individual agency databases. Landing data are available to agency personnel within seconds of submission of the report. Printable documentation of the landing report and the Individual Fishery Quota debit are created within the applications. Signed fish tickets continue to be submitted to local offices of ADF&G for additional review and comparison to other data collection documents. These documents include vessel/fisher logbooks, agency observer datasets, and dockside interviews with vessel operators.

Detailed data are distributed to the State of Alaska CFEC annually. As outlined in State of Alaska statue, 16.05.815, detailed groundfish data are available to the NOAA Fisheries-Alaska regional office from the eLandings repository database. The AKFIN Support Center receives groundfish data on a monthly schedule, which is summarized and provided to PACFIN. The CFEC merges the ADF&G fish ticket data with fisher permit and vessel permit data. This dataset is then provided to the AKFIN Support Center, which distributes the data to the professional staff of the Council, NOAA Alaska Science Center staff, and summarized data to PACFIN. Summary groundfish catch information is also posted on the ADF&G Commercial Fisheries website: http://www.cf.adfg.state.ak.us/geninfo/finfish/grndfish/grndhome.php. Summarized data are provided to the BOF, the Council, and to the State of Alaska legislature as requested.

5. Gene Conservation Laboratory

The ADF&G Gene Conservation Laboratory (GCL) is a statewide program located in Anchorage. The mission of the GCL is to protect genetic resources and provide genetic information and advice to department staff, policy makers, and the public to support management of resources.

In the past, the GCL collected genetic information on black, yelloweye, light and dark dusky rockfish, and pollock. The GCL used traditional genetic markers, such as allozymes, mitochondria DNA, and microsatellites, to identify larval and juvenile rockfish (Seeb and Kendall 1991), to study population structure of black rockfish in the Gulf of Alaska (Seeb 2004), and to investigate spatial and temporal genetic diversity in walleye pollock from Gulf of Alaska, eastern Bering Sea, and eastern Kamchatka (Olsen et al. 2002).

In 2019, the GCL developed an operational plan with Division of Sport Fish to sample and analyze yelloweye and black rockfish from inside and outside waters of Prince William Sound, North Gulf of Alaska, and Southeast Alaska (Howard et al. 2019a-c). The GCL used Restriction site Associated DNA Sequencing (RAD-Seq) to develop a new set of Single Nucleotide Polymorphism (SNP) genetic markers and presented this work at the 2020 Alaska Marine Science Symposium. The GCL has genotyped black and yelloweye rockfish from inside and outside waters from southern and northern Southeast Alaska, Prince William Sound, and Kodiak Island to investigate genetic population structure. The GCL staff are working on a final set of samples from the Northern Gulf of Alaska (NGA) and anticipate completing a final report in summer 2022.

6. Age Determination Unit

The Mark, Tag, and Age (MTA) Laboratory's Age Determination Unit (ADU) is the statewide groundfish and invertebrate age reading program based out of Juneau, AK. The ADU is responsible for providing age data support to regional commercial fisheries programs to monitor population health, assess stock size and growth, and research species life history. The ADU also is responsible for monitoring and improving the quality of age data through precision testing of production data and continual training of age readers. During 2021, the ADU received 10,865 otolith sets from central and southeast Alaska commercial and survey sampling (representing fifteen groundfish species). The ADU produced 11,459 ages and distributed 10,310 ages to region managers, including data from samples received in previous years but processed in 2021. Age data quality is assessed through precision monitoring using additional, independent estimates. A random 30% of specimens and reads with outlying fish and otolith size-at-age are selected for precision testing (data are compared to estimated ranges from growth models; otolith measurements are described below). Discrepancies between precision tests and original ages are resolved through development of independent age estimates by the disputing readers. During 2021, quality control procedures resulted in an additional 6,240 age estimates. Personnel learn to interpret seasonal banding patterns through training with experienced age readers and independent reading of preprocessed age structures. Trained personnel also continue to calibrate on preprocessed structures to insure consistency of age estimates. Training and calibration procedures resulted in an additional 2,349 age estimates. Given production, quality control, and training procedures, the ADU recorded 20,048 groundfish ages.

Correlations have been found between fish length, otolith morphometrics, and age. The ADU collects otolith measurements and uses them to identify and resolve age estimation, specimen sequence, data entry, and species identification errors. During processing, otolith length, height, and weight are recorded from a minimum of one age structure per fish (10,682 otoliths in 2021, representing 17 groundfish species). To identify possible age estimation errors, the ADU compares fish length, otolith weight, and age to estimated fish and otolith size-at-age ranges for lingcod, yelloweye rockfish, rougheye rockfish, shortraker rockfish, shortspine thornyhead, and sablefish. Estimated size-at-age values were developed from Ludwig von Bertalanffy and exponential growth models, and reasonable error ranges per size were entered into a database table.

To ensure consistency of age criteria across programs, the ADU exchanges specimens and data, attends workshops, and presents research through the Committee of Age Reading Experts (CARE; Working Group of the TSC). In 2021, ADU personnel participated in age structure exchanges to address agency and TSC concerns, prepared CARE documents for the TSC meeting, and participated in virtual meetings. The ADU concluded a sablefish exchange with the Alaska Fisheries Science Center in Seattle, WA (AFSC), Newport Research Station, Northwest Fisheries Science Center in Newport, OR (NWFSC), and Fisheries and Oceans Canada (DFO); and continued work on a rougheye exchange with AFSC; a lingcod otolith exchange with ADF&G Homer-Sport; and a yelloweye rockfish exchange with ADF&G Homer.

The ADU groundfish age estimation is funded by the State of Alaska, AKFIN, and special project support. In fiscal year 2021, approximately 57% of funding was provided by the State of Alaska, 36% by AKFIN, and 7% from research grants. During 2021, the ADU employed 11 people (approximately 51-man months) to age, process samples, enter data, maintain sample archives, measure samples, and complete other support tasks.

B. Description of the State of Alaska sport groundfish program (Division of Sport Fish)

ADF&G manages all sport groundfish fisheries within the internal waters of the state, in coastal waters out to three miles offshore, and throughout the EEZ, except for the sport halibut fishery which is managed by the IPHC and NMFS. The Alaska BOF extended existing state regulations governing the sport fishery for all marine species into the waters of the EEZ off Alaska in 1998. This was done under provisions of the Magnuson-Stevens Fishery Conservation and Management Act that stipulate that states may regulate fisheries that are not regulated under a federal FMP or other applicable federal regulations. No sport fisheries are included in the GOA FMP.

Most management and research efforts are directed at halibut, rockfish, lingcod, and sablefish; the primary bottomfish species targeted by the sport fishery. Statewide data collection programs include an annual mail survey (Alaska Sport Fishing Survey, also known as the Statewide Harvest Survey, SWHS) that estimates overall catch and harvest (in number of fish) of halibut, rockfishes (all species combined), lingcod, Pacific cod, sablefish, and sharks (all species combined), and a mandatory logbook to assess harvest and release of selected species including halibut, rockfish (pelagic, yelloweye, or other nonpelagic), lingcod, sablefish, and salmon shark in the charter boat fishery.

The lack of stock assessment information for state-managed species has prevented development of abundance-based fishery objectives. As a result, management is based on building a conservative regulatory framework specifying bag and possession limits, seasons, and methods and means. Stock status is evaluated by examining time series data on age, size, and sex composition. The lack of stock assessments, coupled with increasing effort and harvest in several groundfish sport fisheries, accentuate the need for developing comprehensive management plans and harvest strategies that include the sport and commercial sectors.

Regional programs with varying objectives address estimation of sport fishery statistics including harvest and release magnitude and biological characteristics such as species, age, size, and sex composition. Research is funded through sport fishing license sales, state general funds, and the Federal Aid in Sport Fish Restoration Act ("Dingell-Johnson Act"). There are essentially two maritime regions for marine sport fishery management in Alaska.

1. Southeast Region

The **Southeast Region** extends from the EEZ boundary in Dixon Entrance north and westward to Cape Suckling, at approximately 144° W longitude. Regional staff in Juneau coordinate a data collection program for halibut and groundfish in conjunction with a regionwide salmon harvest studies project. The regional research coordinator, project leader, and the project research analyst are based in Juneau. The project biometrician is stationed in Anchorage. Since 2014, the area management biologists in Yakutat, Juneau, Sitka, Petersburg/Wrangell, Ketchikan, and Craig have been responsible for the onsite daily supervision of the field technicians throughout the region. A total of 25-30 technicians work at the major ports in the Southeast region, where they interview anglers and charter operators and collect data from sport harvests of halibut and groundfish while also collecting data on sport harvests of salmon. In 2020, an Action Plan was developed which guided the collection of data during onsite surveys to minimize impacts of COVID to staff and sport anglers. Low sport fishing license sales due to travel restrictions in 2020, in combination with COVID-related extraction plans resulted in elimination of staffing the port of Elfin Cove in the Southeast region harvest assessment project during 2020 and 2021.

Biological data collected included lengths of halibut, rockfish, lingcod, and sablefish, sex of lingcod, sex and age of black rockfish at Sitka, and genetic information of black rockfish; technicians also collect other basic data including the sport fishery sector (charter or unguided) and the statistical areas fished. Otoliths were collected from black rockfish landed at Sitka for estimation of age composition in 2016–2021. Genetic information was collected from black rockfish in 2021. Data summaries were provided to the Alaska BOF, other ADF&G staff (especially through the Statewide Rockfish Initiative), the public, and a variety of other agencies such as the Council, IPHC, and NOAA Fisheries.

The Regional Management Coordinator and Area Management Biologists in Yakutat, Haines/Skagway, Sitka, Juneau, Petersburg/Wrangell, Craig, and Ketchikan are responsible for groundfish management in those local areas. The demersal shelf rockfish and lingcod sport fisheries are managed under the direction of the Demersal Shelf Rockfish Delegation of Authority and Provisions for Management (5 AAC 47.065) and the Lingcod Delegation of Authority and Provisions for Management (5 AAC 47.060) for allocations set by the Alaska BOF.

2. Southcentral Region

The **Southcentral Region** includes state and federal waters from Cape Suckling to Cape Newenham, including PWS, Cook Inlet, Kodiak, the Alaska Peninsula, the Aleutian Islands, and Bristol Bay. The Southcentral Region groundfish staff consists of two regional management biologists as well as area management biologists and assistants for the following areas: (1) PWS and the North Gulf areas, (2) Lower Cook Inlet, and (3) Kodiak, Alaska Peninsula, and the Aleutian Islands. In addition, a region-wide harvest assessment project is based in the Homer office, consisting of a project leader, project assistant, and six technicians. Seasonal technicians collected data from the sport harvest at six major ports in the region. Low sport fishing license sales in 2020 due to travel restrictions resulted in funding cuts to the Southcentral region harvest assessment project. One technician position was not filled, but the data collected by this technician were collected by other project personnel.

Ongoing assessment of sport harvest and fishery characteristics at major ports throughout the region includes interviews of anglers and charter boat operators and sampling of the sport harvest. Data collected included length, age, and sex of halibut, rockfishes, lingcod, and sharks; sablefish, Pacific cod, and other infrequently harvested sport bottomfish species may also be sampled opportunistically. All non-halibut age reading was done in Homer, and the staff members are active participants in CARE. Halibut otoliths were forwarded to the IPHC for age reading.

Southcentral Region staff are responsible for management of groundfish fisheries, except halibut, in state and federal waters. In addition, staff provide sport halibut harvest statistics to the IPHC and the Council, assist in development and analysis of the statewide charter logbook program and SWHS, provide information to the BOF, advisory committees, and local fishing groups, draft and review proposals for sport groundfish regulations, and disseminate information to the public.

II. Surveys

Fishery surveys, where applicable, are addressed in research sections by species.

III. Marine Reserves

Nothing to report for 2021.

IV. Groundfish Research, Assessment, and Management

A. Hagfish

1. Research

In 2016, the **Southeast Region** began an opportunistic survey for hagfish *Eptatretus stoutii* and *E. deani* during the annual shrimp pot surveys to gather information on distribution and life history information including: size at maturity, fecundity, sex ratio, length, and weight frequencies. Survey sampling continued in 2017 and stations were expanded to Clarence Strait based on bycatch occurrence of hagfish during the sablefish longline survey. Samples were collected in Ernest Sound and Behm Canal using longlined 20-L bucket traps dispersed 5.5 m apart with each trap consisting of 9.5 mm escape holes, 1 kg weight, and a 102 mm entry funnel and destruct device. Each set was sampled for count-by-weight (number of hagfish and weight per trap) and a sub-sample of 5 hagfish per trap or 125 per set were frozen and sampled for biological information in the lab. A total of 828 hagfish were sampled with the largest length recordings for *E. deani* at 790 mm for females and 620 mm for males. A total of 547 sampled hagfish were identifiable as males or females and were used to calculate size at 50% maturity (L50; Figure 3). An additional 1,200 black hagfish were sampled for length and weight only from 2021 commercial landings (Contact Rhea Ehresmann).

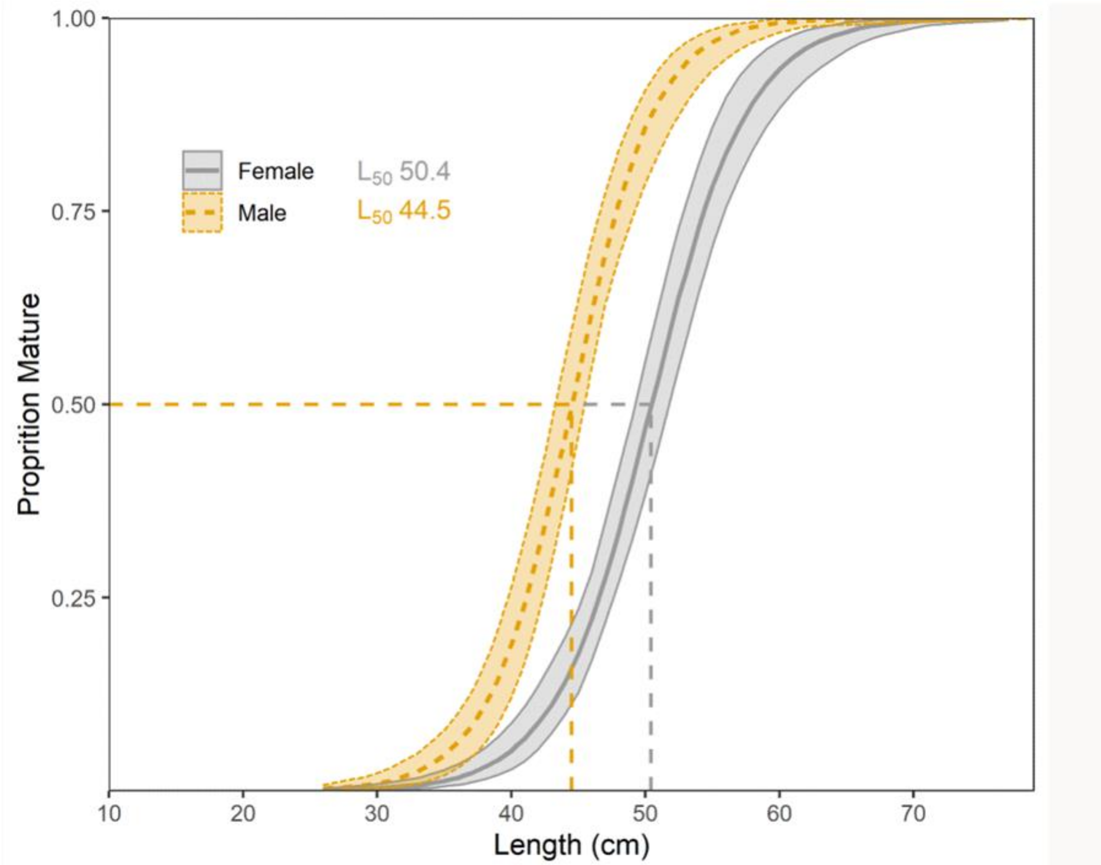

Figure 3.–.Preliminary size at 50% maturity with 95% confidence intervals for male (44.4 cm, n=218) and female (51.6 cm, n=329) *E. deani* in southern Southeast Alaska.

2. Assessment

There are no stock assessments for hagfish.

3. Management

A commissioner's permit is required before a directed fishery may be prosecuted for hagfish. This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes. Gear is restricted to 3,000 gallons in volume using any combination of gear types included Korean style traps, buckets, and barrels per vessel. In 2018, six hagfish management areas were created within the Southeast Region. In 2021, one commissioner's permit was issued for directed fishing of hagfish in the **Southeast Region**.

4. Fisheries

The directed fishery for hagfish in the Southeast region has a total guideline harvest level (GHL) of 77.1 mt for 2021. In 2021 a total of 17.8 mt of hagfish were harvested in the directed fishery. The primary species caught is *E. deani* and a market has been developing for Alaskan hagfish where they are sold for food. Currently in the **Westward**, **Central**, and **Southeast Regions** hagfish are allowed up to 20% as bycatch in aggregate with other groundfish during directed fisheries for groundfish.

B. Dogfish and other sharks

1. Research

The **Division of Sport Fish—Southcentral Region** collected harvest and fishery information on sharks through the groundfish harvest assessment program although no specific research objectives were identified. Interviews were conducted representing 850 boat-trips and 9,543 angler-days of effort targeting or harvesting groundfish species in 2021. Interviewed anglers caught five salmon sharks and kept two , caught sleeper shark, which was retained, and caught 637 spiny dogfish and kept 59. No sharks were sampled for biological data (Contact Martin Schuster).

2. Assessment

There are no stock assessments for dogfish or sharks.

3. Management

Directed fisheries for spiny dogfish in the Central and Southeast Regions are allowed under terms of a commissioner's permit. The commercial bycatch allowance in the **Southeast Region** is 35% round weight of the target species in longline and power or hand troll fisheries. Full retention of dogfish bycatch is permitted in the salmon set net fishery in Yakutat. In the **Central Region**, bycatch had historically been set at 20% of the round weight of the target species on board a vessel, the maximum allowable retention amount in regulation; however, from 2014 through 2021, allowable bycatch levels of all shark species in aggregate (includes spiny dogfish) were set at 15% by emergency order (EO).

The practice of "finning" is prohibited; all sharks retained must be sold or utilized and have fins, head, and tail attached at the time of landing. "Utilize" means use of the flesh of the shark for human consumption, for reduction to meal for production of food for animals or fish, for bait or for scientific, display, or educational purposes.

Sport fishing for sharks is allowed under the statewide Sport Shark Fishery Management Plan adopted by the BOF in 1998. The plan recognizes the lack of stock assessment information, the potential for rapid growth of the fishery, and the potential for overharvest, and sets a statewide daily bag limit of one shark and a season limit of two sharks of any species except spiny dogfish which have a daily bag limit of five. Sport demand for sharks continued to be low in 2021.

4. Fisheries

No applications for commissioner's permits were received in 2021, and no permits have been issued in **Central Region** since 2006. During 2021, there was no commercial harvest of spiny dogfish as bycatch in Cook Inlet Area with 1.3 mt harvested in PWS.

Estimates of the 2021 sport harvest of sharks are not yet available, but harvest in 2020 was estimated at 80 sharks of all species in Southeast Alaska and 180 sharks in Southcentral Alaska. The precision of these estimates was relatively low; the Southeast estimate had a CV of 83% and the Southcentral estimate had a CV of 83%. The statewide charter logbook program also required reporting of the number of salmon sharks kept in the charter fishery. In 2020, 7 salmon sharks were harvested by charter anglers in Southeast, 8 were harvested in Southcentral. Charter anglers are believed to account for most of the sport salmon shark harvest.

C. Skates

1. Research

The **Central Region** conducted bottom trawl surveys targeting Tanner crab in Cook Inlet and PWS within a consistent survey grid from 1990 to 2019. The survey captures many groundfish species and population indices are generated for commercially important groundfishes including longnose, big, and Bering skate. The time series for these species begins when full accounting first occurred which was in 1999 for big and longnose skates and in 2001 for Bering skate. The 2020 and 2021 PWS surveys were conducted in new survey areas and were not part of the historical index survey grid and therefore results are not included in this report. No Cook Inlet surveys have been conducted since 2019 when ADF&G funding was eliminated and it is uncertain when that survey will resume (Contact Mike Byerly).

2. Assessment

There are no stock assessments for skates in state waters but the PWS trawl survey biomass time series as well as biomass time series from other Central Region trawl surveys in Kachemak and Kamishak Bays in Cook Inlet have recently been included in the federal stock assessment of the skate stock complex in the GOA (Ormseth 2019).

3. Management

A commissioner's permit is required before a directed commercial fishery may be prosecuted for skates. This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes.

4. Fisheries

Currently in the **Central Region**, skates are harvested commercially as bycatch up to 5% of target species; this allowable bycatch level is set by EO to align with the NMFS maximum retainable allowance (MRA) for skates in the GOA.

A directed fishery in PWS for big and longnose skates was prosecuted under the authority of a commissioner's permit in 2009 and 2010. However, the fishery was deemed unsustainable, and no permits were issued thereafter. The permit stipulated seasons, district, gear, and included a logbook requirement.

In the Cook Inlet Area, skate harvest was 6.0 mt in 2021. In PWS, skate harvest was 17.3 mt in 2021, an increase from 7.9 mt in 2020. Federal Pacific cod fisheries were closed in 2020 with state-managed Pacific cod fisheries opened with reduced guideline harvest levels. Due to bycatch limits set as a percentage of the targeted species, harvest levels of the target species may affect the amount of bycatch harvested. In 2021, federal and state Pacific cod fisheries were open which increased the amount of bycatch harvested compared to 2020, particularly with longline gear.

Over the last ten years, in **Southeast Region**, skate landings in internal waters of Northern Southeast Inside (NSEI) and Southern Southeast Inside (SSEI) fluctuated with a low harvest in 2011 of 1.5 mt and a high in 2014 of 18.7 mt. In 2021, a total of 5.1 mt of skates were landed. Skate harvest fluctuates with current market value.

D. Pacific cod

1. Research

Commercial landings in the **Southeast Region**, **Central Region**, and the **Westward Region** are sampled for length, weight, age, sex, and stage of maturity. Harvest rate and biological information are gathered from fish ticket records, port sampling programs, a tagging program, and during stock assessment surveys for other species. A mandatory logbook program was initiated in 1997 for the state waters of Southeast Alaska.

Age Determination Unit personnel in the **Southeast Region** are collaborating with NOAA Alaska Fishery Science Center and Little Port Walter staff to perform a long-term Pacific cod and walleye pollock rearing study. Juvenile fish are being raised under constant monitoring to investigate techniques to study life history and condition. Methods include studying daily marks and otolith growth through fluorescent stains and near infrared spectroscopy as well as testing blood, tissue, and bone samples across ontogeny to study changes in chemistry and hormones across life stages.

Pacific cod are captured in **Central Region** Tanner crab bottom trawl surveys. A population biomass index from the PWS and Cook Inlet bottom trawl surveys is generated each year of those surveys (see Skate – Research section above for more information on these surveys). PWS trawl surveys were not conducted in 2020–2021 in the historical survey area, and therefore, results are not included in this report. No Cook Inlet surveys have been conducted since 2019 and it is uncertain when that survey will resume (Wyatt Rhea-Fournier).

In the **Central Region**, skipper interviews and biological sampling of commercial Pacific cod deliveries from Cook Inlet and PWS areas during 2021 occurred in Homer, Seward, Whittier, and Cordova. Sample data collected included date and location of harvest, species, length, weight, sex, and gonad condition (maturity stage). Otoliths were collected from approximately 20% of sampled fish. Data are provided to NMFS for use in stock assessment (Contact Elisa Russ).

The **Division of Sport Fish—Southcentral Region** creel sampling program also collects data on Pacific cod catch by stat area (on a vessel-trip basis) through dockside interviews, and lengths of sport-caught Pacific cod, though this is a secondary objective and there are no sample size targets. Interviewed anglers caught 3,015 Pacific cod in 2021, of which 2,192 were retained. Biological data were collected from 395 Pacific cod in Southcentral Region. No information is collected in the Southeast Region creel survey program on the Pacific cod sport fishery.

2. Assessment

No stock assessment programs were active for Pacific cod during 2021.

3. Management

In 2020 federal/parallel fisheries in the Gulf of Alaska (GOA) were closed and state-waters season opening dates were coordinated with the federal closure to allow for orderly and manageable fisheries. In Central and Westward Regions, the state-waters guideline harvest levels (GHLs) were based on a 35% reduction from the maximum prescribed harvest limits in regulation. This GHL reduction provided the opportunity for limited fisheries in state waters while recognizing the need for conservative fishery management at 2020 Pacific cod stock levels. Federal Pacific cod fisheries in GOA reopened in 2021 and regulatory allocation levels from federal allowable biological catches (ABCs) resumed to set state GHLs.

The internal waters of the **Southeast Region** are comprised of two areas, NSEI and SSEI Subdistricts. The GHR was based on average historic harvest levels rather than on a biomass-based acceptable biological catch (ABC) estimate. The Pacific cod GHR is managed on the calendar year cycle and applies directed fishery harvest as well as incidental bycatch. Management of the directed Pacific cod fishery uses a July 1 to June 30 timeline to coincide with seasonal fishery activity that primarily targets spawning aggregation from October to April. This fishery has the most participation in the winter months, and inseason management actions such as small area closures are implemented to spread out the fleet and reduce the risk of localized depletion. Pacific cod in state waters along the outer coast are managed in conjunction with the Total Allowable Catch (TAC) levels set by the federal government for the adjacent EEZ waters.

In the GOA, Pacific cod Management Plans are established for fisheries in five groundfish areas: **Prince William Sound**, **Cook Inlet**, **Kodiak**, **Chignik,** and **South Alaska Peninsula**. Included within the plans are season, gear, and harvest specifications. Initially the state-waters fisheries were restricted to pot or jig gear to minimize halibut bycatch and avoid the need to require onboard observers in the fishery. However, in PWS the use of longline gear has been permitted since 2009 in response to the very low levels of effort and harvest by pot and jig gear and high level of interest from the longline gear group. Guideline harvest levels are further allocated by gear type.

Annual GHLs are based on the estimate of ABC of Pacific cod as established by the Council. Current GHLs are set at 25% of the Central Gulf of Alaska (CGOA) ABC, apportioned between the Kodiak, Chignik, and Cook Inlet Areas, 25% of the Eastern Gulf ABC for the PWS Area, and 30% of the Western Gulf Pacific cod ABC for the South Alaska Peninsula Area. Most CGOA state-waters fisheries open after the respective gear sector closure in the federal Pacific cod A season, generally late winter through early spring. A 58-foot overall length (OAL) vessel size limit is in place for the Chignik and South Alaska Peninsula Areas. The Cook Inlet and Kodiak Areas have a harvest cap for vessels larger than 58-ft OAL that limits harvest to a maximum of 25% of the overall GHL. If the GHL is not fully harvested, the fishery management plans allow removal of area exclusivity, vessel size restrictions, and gear limits later in the season to increase harvest to promote achievement of GHLs.

In the **Bering Sea/Aleutian Islands area**, a Pacific cod Management Plan for an exclusive Aleutian Islands Subdistrict, west of 170° W longitude, state-waters fishery has been adopted. Included within the plan are season, gear, and harvest specifications. The fishery GHL is set by regulation at 39% of the Aleutian Islands ABC for Pacific cod and may not exceed 15 million lbs.

Currently, on January 1, the Aleutian Islands state-waters Pacific cod season opens in the Adak Section, between 175° W long and 178° W long, to vessels 60 feet OAL or less using trawl, pot, and jig gear, and vessels 58 feet OAL or less using longline gear. The state waters of the Aleutian Islands Subdistrict, west of 170° W long, open 4 days after the closure of the federal Bering Sea-Aleutian Islands for vessels catcher-vessel greater than or equal to 60 feet in OAL pot gear fishery closes. When waters west of 170° W long are open, trawl vessels may not be greater than 60 feet OAL, pot vessels may not be greater than 100 feet OAL, jig vessel may not be more than 60 feet OAL and longline vessels may not be greater than 58 feet OAL. All state waters west of 170° W long open for trawl vessels 100 feet or less OAL and pot vessels 125 feet or less OAL on March 15 at 12:00 noon Alaska time. If the GHL is not fully harvested, the fishery management plan allows removal of area exclusivity later in the season to increase harvest to promote achievement of the GHL.

A state-waters Pacific cod fishery management plan has also been adopted in waters of the Bering Sea near Dutch Harbor. The **Dutch Harbor Subdistrict** Pacific cod season is open to vessels 58 feet or less OAL using pot gear, with a limit of 60 pots. The fishery GHL is set at 10% of the Bering Sea ABC for Pacific cod in 2021. The season opens seven days after the federal Bering Sea–Aleutian Islands pot/longline sector's season closure, and may close and re-open as needed to coordinate with federal fishery openings. Additionally, there is a Pacific cod season open to vessels 58 feet or less OAL using jig gear. The fishery GHL is set at 100,000 pounds which is subtracted from the overall Bering Sea ABC for Pacific cod. The season opens May 1. If the GHLs are not fully harvested, the fishery management plans allow removal of area exclusivity, vessel size restrictions, and gear limits later in the season to increase harvest to promote achievement of GHL.

There is no bag, possession, or size limit for Pacific cod in the sport fisheries in Alaska, and the season is open year-round. Sport harvest of Pacific cod is estimated through the SWHS.

4. Fisheries

Most of the Pacific cod harvested in the **Southeast Region** are taken by longline gear in the NSEI Subdistrict during the winter months. Prior to 1993 much of the cod taken in Southeast Alaska commercial fisheries was utilized as bait in fisheries for other species. In recent years, the Pacific cod harvest has been largely sold for human consumption. A total of 137 mt of Pacific cod were harvested in Southeast state-managed (internal waters) fisheries during 2021 with 120 mt harvested from the directed fishery (Figure 4).

For **Central Region** state-waters Pacific cod fisheries, the dominant gear type has been pot gear in **Cook Inlet** Area and longline gear in **PWS** fisheries with each gear type allocated 85% of GHLs in respective areas. In Cook Inlet Area 25% of the GHL is allocated to jig gear and in PWS 25% is allocated to pot and jig gear combined.

Gear type allocations vary by management area in the **Westward Region** state-waters Pacific cod fisheries. In the **Kodiak**, **Chignik**, and **South Alaska Peninsula** state-waters Pacific cod fisheries, pot gear and jig gear are legal gear types. Pot gear is the dominant gear type in the Chignik and South Alaska Peninsula Areas as pot gear is allocated 90% and 85% of the area GHL, respectively. In the Kodiak Area, pot and jig vessels are each allocated 50% of the GHL; however, pot gear vessels often harvest a larger percentage if GHLs are not on track to be met and gear and restrictions are lifted. In the **Dutch Harbor Subdistrict** state-waters Pacific cod fishery, pot and jig gear are legal gear types however each gear has a separate allocation. In the **Aleutian Islands Subdistrict** state-waters fishery, trawl, jig, longline, and pot are all legal gear types. Pot and trawl vessels participated in 2021; however, harvest by gear type is confidential due to the number of processors and vessels.

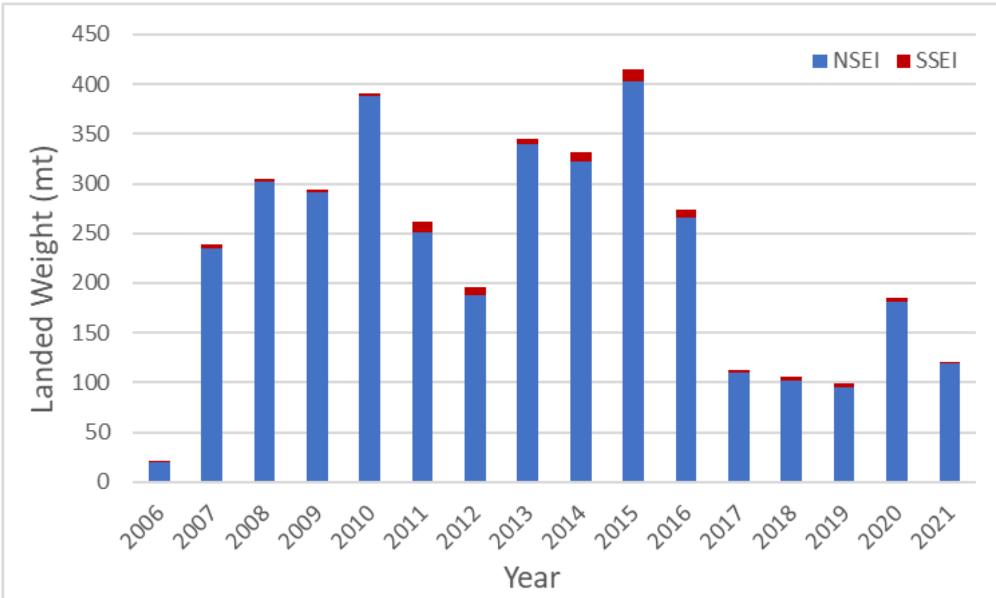

Figure 4.–Annual harvest of Pacific cod for the directed and bycatch fisheries in the Northern Southeast Inside (NSEI) Subdistrict, shown in blue, and the Southern Southeast Inside (SSEI) Subdistrict, shown in red, 2006–2021.

In the **Central Region**, the Cook Inlet Area state-waters fishery GHL is 3.75% of the federal CGOA Pacific cod ABC and the PWS GHL is 25% of the EGOA ABC. The 2021 GHLs for the state-waters Pacific cod seasons in the Cook Inlet and PWS areas of the Central Region were 512 mt and 496 mt, respectively. The Cook Inlet Area and PWS GHLs increased 150% from 2020 to 2021. This follows a sharp decrease in the GHL resulting from a steep decline in abundance observed in the NMFS survey and a subsequent decline from 2018 to 2019 in both areas, resulting in federal Pacific cod GOA closures in 2020.

Pacific cod harvest during 2021 state-waters seasons was 428 mt from Cook Inlet Area and 421 mt from PWS. In Cook Inlet Area, the GHL is allocated 85% to pot gear and 15% to jig gear; pot vessels harvested 84% of their allocation and there was no effort or harvest from jig vessels. For PWS, the GHL is allocated 85% to longline gear and 15% to jig and pot gear combined; longline achieved 94% their allocation; pot vessels harvested 31% of the pot/jig allocation and, as in Cook Inlet Area, there was also no effort or harvest by jig vessels in 2021.

In the **Westward Region**, the Kodiak Area state-waters Pacific cod GHL is based on 12.5% of the annual CGOA Pacific cod ABC, the Chignik Area GHL is based on 8.75% of the annual CGOA ABC, and the South Alaska Peninsula Area GHL is based on 30% of the WGOA Pacific cod ABC. The 2021 Pacific cod GHLs were 1,707 mt in the Kodiak Area, 1,195 mt in the Chignik Area and 2,396 mt in the South Alaska Peninsula Area. Total state-waters Pacific cod catch in the Kodiak, Chignik, and South Alaska Peninsula was 1,655 mt, 1,063 mt, and 2,128 mt, respectively. Pot gear vessels took approximately 78% of the total 2021 catch in these state-waters Pacific cod fisheries. In the Aleutian Islands Subdistrict state-waters Pacific cod 2021 GHL 6,804 mt. Legal gear is limited to nonpelagic trawl, pots, longline and jig gear during state-waters the Pacific cod fishery.

The 2021 total state-waters Pacific cod catch for the Aleutian Islands Subdistrict was 6,762 mt. The **Dutch Harbor Subdistrict** state-waters Pacific cod 2021 GHL for pot gear is based on 10% of the annual Bering Sea Pacific cod ABC. In 2021, the total state-waters catch for the Dutch Harbor Subdistrict pot gear fishery was 12,513 mt. The Dutch Harbor Subdistrict state-waters Pacific cod GHL for jig gear is 45 mt, which is subtracted from the annual Bering Sea Pacific cod ABC. The 2021 harvest for this fishery is confidential due to limited participation.

Estimates of the 2021 sport harvest of Pacific cod are not yet available from the SWHS, but the 2020 estimates were 9,253 fish in the **Southeast Region** and 14,038 fish in the **Southcentral Region**. The estimated annual harvests for the recent five-year period (2016-2020) averaged 9,891 fish in Southeast Alaska and 15,542 fish in Southcentral Alaska. Statewide Pacific cod harvest peaked at over 60,000 fish in 2014 and in 2018 was at the lowest level since 2003.

E. Walleye Pollock

1. Research

Age Determination Unit personnel in the **Southeast Region** are collaborating with NOAA Alaska Fishery Science Center and Little Port Walter staff to perform a long-term Pacific cod and walleye pollock rearing study. Juvenile fish are being raised under constant monitoring to investigate techniques to study life history and condition. Methods include studying daily marks and otolith growth through fluorescent stains and near infrared spectroscopy as well as testing blood, tissue, and bone samples across ontogeny to study changes in chemistry and hormones across life stages.

In the **Central Region** skipper interviews and biological sampling of PWS commercial trawl pollock deliveries during 2021 occurred in Kodiak. Sample data collected included date and location of harvest, species, length, weight, sex, and gonad condition. Otoliths were collected from approximately half of sampled fish and aged by Homer staff (Contact Elisa Russ).

Pollock are captured in **Central Region** Tanner crab bottom trawl surveys. A population biomass index from the PWS and Cook Inlet bottom trawl surveys is generated each year of those surveys (see Skate – Research section above for more information on these surveys). PWS trawl surveys were not conducted in 2020–2021 in the historical survey area, and therefore, results are not included in this report. The historical survey area will again be surveyed annually beginning in 2022. No Cook Inlet surveys have been conducted since 2019, and it is uncertain when that survey will resume (Mike Byerly or Wyatt Rhea-Fournier).

Beginning in 1998, spatial patterns of genetic variation were investigated in six populations of walleye pollock from three regions: North America – Gulf of Alaska (GOA); North America – Bering Sea; and Asia – East Kamchatka. The annual stability of the genetic signal was measured in replicate samples from three of the North American populations. Allozyme and mtDNA markers provided concordant estimates of spatial and temporal genetic variation. These data show significant genetic variation between North American and Asian pollock as well as evidence that spawning aggregations in GOA, such as PWS, are genetically distinct and may merit consideration as distinct stocks. These data also provide evidence of inter-annual genetic variation in two of three North American populations. Gene diversity values show this inter-annual variation is of similar magnitude to the spatial variation among North American populations, suggesting the rate and direction of gene flow among some spawning aggregations is highly variable. This study was published in 2002 in the Fishery Bulletin (Olsen et al. 2002; Contact Bill Templin).

2. Assessment

No stock assessment work was conducted by ADF&G on pollock in 2021.

3. Management

Prince William Sound Area pollock pelagic trawl fishery regulations include a January 13 registration deadline, logbooks, catch reporting, check-in and check-out provisions, and accommodation of an ADF&G observer upon request. The PWS Inside District is divided into three sections for pollock management: Port Bainbridge, Knight Island, and Hinchinbrook, with the harvest from any section limited to a maximum of 60% of the GHL. Additionally, the fishery is managed under a 5% maximum bycatch allowance that is further divided into five species or species groups. In addition, the PWS Rockfish Management Plan allows only 0.5% rockfish bycatch during this pollock fishery. In 2013, new management measures were implemented to set the PWS pollock GHL at 2.5% of the federal Gulf of Alaska ABC. For **Cook Inlet Area,** directed fishing for pollock is managed under a "Miscellaneous Groundfish" commissioner's permit. Initiated in December 2014, a commissioner's permit fishery for pollock using seine gear was prosecuted through 2016. In **Central Region**, pollock is also retained as bycatch to other directed groundfish fisheries, primarily Pacific cod (Contact Jan Rumble).

There are no bag, possession, or size limits for pollock in the sport fisheries in Alaska. Harvest of pollock is not explicitly estimated by the SWHS and no pollock harvest information is collected in charter logbooks or creel surveys in Southcentral or Southeast Alaska.

4. Fisheries

The 2021 PWS pollock pelagic trawl fishery opened January 20 and closed February 15. There were 22 landings made by 11 vessels with a total harvest of 2,544 mt, 96% of the 2,643 mt GHL, which included harvest from the test fishery. Rockfish bycatch during the fishery totaled 3.7 mt, below the 11.5 mt allowed as bycatch to the pollock harvested. The harvest bycatch cap for salmon was exceeded by 11.6%, with a harvest of 1.0 mt and a limit of 0.9 mt. In the Cook Inlet Area, no seine pollock commissioner's permits were issued in 2021. Pollock was harvested in **Central Region** as bycatch to other groundfish fisheries at low levels; in 2021, 0.6 mt was harvested in Cook Inlet Area and 0.1 mt in PWS (Contact Jan Rumble).

F. Pacific Whiting (hake)

1. Research

There was no research conducted on Pacific whiting (hake) in 2021.

2. Assessment

There are no stock assessments for Pacific whiting (hake).

3. Management

A commissioner's permit is required in **Central Region** and **Southeast Region** before a directed fishery may be prosecuted for Pacific Whiting (hake). This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes.

4. Fisheries

There was no directed fishery for Pacific whiting (hake) in 2021. Currently in **Central Region** and **Southeast Region** Pacific whiting (hake) are grouped with the "other groundfish" assemblage and are allowed up to 20% as bycatch in aggregate during directed fisheries for groundfish.

G. Grenadiers

1. Research

There was no research conducted on grenadiers in 2021.

2. Assessment

There are no stock assessments for grenadiers.

3. Management

A commissioner's permit is required in **Central Region** and **Southeast Region** before a directed fishery may be prosecuted for grenadiers. This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes.

4. Fisheries

There was no directed fishery for grenadiers in 2021. Currently in the **Central Region** and **Southeast Region** grenadiers are considered part of the "other groundfish" assemblage and are allowed up to 20% as bycatch in aggregate during directed fisheries for groundfish.

H. Rockfishes

Commercial rockfish fisheries are managed under three assemblages: DSR, pelagic shelf rockfish (PSR), and slope rockfish. DSR include the following species: yelloweye, quillback, China, copper, rosethorn, canary, and tiger. PSR include black, deacon, dusky, dark, yellowtail, and widow. Slope rockfish contain all other *Sebastes* species. Thornyhead, *Sebastolobus* species, are defined separately; in Central Region, thornyhead rockfish harvest is combined with slope rockfish for reporting.

1. Research

In the **Southeast Region**, biological samples of rockfish are collected from the directed commercial DSR fishery; however, sampling effort was expanded in 2008 to include the sampling of DSR caught as bycatch in the IFQ halibut fishery. The sampling of the halibut fishery was started in part to obtain more samples in years that the directed fishery was not opened. Fishery data are also collected from the logbook program, which is mandatory for most groundfish fisheries. The logbook program is designed to obtain detailed information regarding specific harvest location. In 2021, length, weight and age structures were collected from 759 yelloweye rockfish caught in the halibut commercial longline fisheries. There were no yelloweye rockfish sampled from the directed fishery due to ongoing directed fishery closures in 2021. In 2021, length, weight, and age data were collected from 176 black rockfish caught in the directed commercial black rockfish fishery. In collaboration with the ADF&G Statewide Rockfish Initiative (SRI) group, in 2021 a maturity project began in Southeast Alaska to gain more information on life history parameter estimates for both yelloweye and black rockfish.

Skipper interviews and port sampling of commercial rockfish deliveries in **Central Region** during 2021 occurred in Homer, Seward, Whittier, and Cordova. Efforts throughout the year were directed at the sampling of rockfish delivered as bycatch to other groundfish and halibut fisheries, primarily DSR and slope species. The directed jig fishery in the Cook Inlet Area that targets PSR opens July 1 and historically has been the focus of rockfish sampling during the last half of the year. Sample data collected includes date and location of harvest, species, length, weight, sex, gonad condition, and otoliths. Homer staff determine ages of PSR and DSR otoliths; otoliths from slope and thornyhead rockfish species are sent to the ADF&G Age Determination Unit in Juneau. In 2018, a new project was initiated to study genetic variation between outside waters of North Gulf, outside waters of PWS, and inside waters of PWS for both yelloweye and black rockfish; tissue samples were collected in 2018 and 2019 with genetic analysis currently being completed. Additionally, ovaries were collected from both species of rockfish in 2019 and 2020 for maturity and fecundity studies; histological processing of yelloweye is complete and processing is currently being completed on Cook Inlet Area black rockfish ovaries. An age structure exchange was also conducted on yelloweye rockfish between commercial and sport age reading staff in Homer. The genetics and gonad collections, and age structure exchange, were conducted as collaborative interdivisional research as part of the SRI initiated in 2017 (Contact Elisa Russ).

Funding for **Central Region** DSR ROV surveys ended in 2016 and ROV surveys have not been conducted since then. Rockfishes are captured in **Central Region** bottom trawl surveys for Tanner crab. All rockfish are sampled for length, weight, sex, and age structures. Rougheye/blackspotted rockfish composed >90% of the rockfish catch by weight in all years. A population biomass index from the PWS and Cook Inlet bottom trawl surveys is estimated for rougheye/blackspotted rockfish each year of those surveys (see Skate – Research section above for more information on these surveys). PWS trawl surveys were not conducted in 2020–2021 in the historical survey area, and therefore, results are not included in this report. The historical survey area will again be surveyed annually beginning in 2022. No Cook Inlet surveys have been conducted since 2019 and it is uncertain when that survey will resume (Mike Byerly or Wyatt Rhea-Fournier).

In 2019 and in 2021 a hydroacoustic survey was conducted in the North Gulf District for black rockfish following Westward Region's survey methodology. This survey was conducted aboard the Westward Region research vessel *R/V K-Hi-C* with Westward Region staff in the Chiswell Islands (high sport fishery harvest) and around the Nuka bank (high commercial fishery harvest).

As part of the ADF&G Statewide Rockfish Initiative, Central Region is developing a black rockfish assessment model for the Cook Inlet Area and a yelloweye rockfish assessment model for Inside District of the PWS Area. Data for both models include commercial and sport fishery removals along with length and age compositions from each fishery. As part of this effort, commercial and sport harvest reconstructions are being conducted for those years where either known harvest is not available for commercial landing from fish tickets or is presently difficult to estimate for sport fishery landings. These data-moderate assessments are utilizing an integrated stock assessment framework implemented in the Stock Synthesis Data Limited Tool (SS-DL) developed by Jason Cope (https://github.com/shcaba/SS-DL-tool) (Contact Mike Byerly or Wyatt Rhea-Fournier).

The **Westward Region** continued port sampling of several commercial rockfish species in 2021. Rockfish sampling concentrated on black and dark rockfish with opportunistic sampling of other miscellaneous *Sebastes* species. Skippers were interviewed for information on effort, location, and bycatch. Length, weight, gonadal maturity, and otolith samples were collected (Contact Sonya El Mejjati). Staff from the Kodiak office are in the process of aging black rockfish otoliths through the 2021 season. The Westward Region also continued to conduct hydroacoustic surveys of black and dark rockfish in the Northeast, Afognak, Eastside, and Southeast districts of the Kodiak Management Area in 2021 to generate biomass estimates for both black and dark rockfish. Surveys of Northeast, Afognak, Eastside, and Southeast districts in the Kodiak Management Area will continue in 2022. As one of ADF&G's SRI research priorities, a black rockfish maturity study was initiated in 2019 and collections continued through 2021 with the goal of updating the maturity parameters for black rockfish in the Kodiak Area (Contact Carrie Worton).

The **Division of Sport Fish—Southeast Region** continued to collect catch and harvest data from rockfish as part of a marine harvest onsite survey program with rockfish harvests tabulated back to 1978 in some ports. Rockfish objectives included estimation of 1) species composition, 2) length composition and average weight, as derived from a length-weight regression relationship, 3) age and sex composition of black rockfish at Sitka, 4) genetic composition of black rockfish from inside and outside ports, and 5) biomass of total sport removals (harvest and release mortality). Primary species harvested in Southeast Alaska included those from the pelagic assemblage (primarily black and dusky rockfish), and lesser amounts of slope species such as silvergray, shortraker, and redbanded rockfish. A total sample size of 4,535 rockfish was obtained from the sport harvests at the ports of Ketchikan, Craig, Wrangell, Petersburg, Juneau, Sitka, Gustavus, and Yakutat in 2021 (Contact Mike Jaenicke).

The **Division of Sport Fish—Southcentral Region** continued collection of harvest and fishery information on rockfish as part of the harvest assessment program. Rockfish objectives included estimation of 1) species composition, 2) age, sex, and length composition of primary species, and 3) the spatial distribution of rockfish harvest and groundfish effort by port. The 2021 total sample size from the sport harvests at Seward, Valdez, Whittier, Kodiak, Central Cook Inlet, and Homer was 461 rockfish (Contact Martin Schuster). The Division of Sport Fish conducted research in PWS on the ability of six species of rockfish to resubmerge unassisted when released at the surface. This study is ongoing and will be completed during the summer of 2022. Results will be published as an ADF&G Fishery Data Series report or journal publication in 2023 (Contact Brittany Blain-Roth or Jay Baumer). In addition, a University of Alaska, Fairbanks Graduate Student/ADF&G Biologist collected life history information on yelloweye rockfish to improve estimates of maturity, fecundity and skip-spawning between Prince William Sound and Northern Gulf of Alaska (Contact Brittany Blain-Roth or Donald Arthur). Similar data continue to be collected from black rockfish in the same area. Mr. Arthur completed his master's thesis work in 2020, and it is published as "The Reproductive Biology of Yelloweye Rockfish (*Sebastes ruberrimus*) in Prince William Sound and the Northern Gulf of Alaska." The chapters are 1) Maturity, Ovarian Cycle, and Skip Spawning of Yelloweye Rockfish *Sebastes ruberrimus* in Prince William Sound and the Northern Gulf of Alaska and 2) Fecundity of Yelloweye Rockfish *Sebastes ruberrimus* in the Northern Gulf of Alaska. In addition, a journal publication in the North American Journal of Fisheries Management will be available in April 2022 titled "Alaskan Yelloweye Rockfish *Sebastes ruberrimus* fecundity revealed through an automated egg count and digital imagery method."

The **Age Determination Unit** continued the North Pacific Research Board funded project 1803: Reconstructing reproductive histories of yelloweye rockfish through opercular hormone profiles.

ADF&G personnel sampled opercula and otoliths from female yelloweye rockfish along with black rockfish and other representative species. Ages were estimated using otoliths and corresponding bands were identified on opercula. Sampled opercula material was sent to Baylor University to analyze progesterone, cortisol, and estradiol concentrations (Figure 9). Lifetime reproductive and stress hormone profiles were constructed for 22 female yelloweye rockfish and individual profiles were used to estimate age of sexual maturity and annual spawning frequency. Results suggest that the age of physiological sexual maturity was 10.5 ± 0.8 years (SE), functional age of maturity was 17.4 ± 1.7 years, and spawning frequency was 45.1 ± 5.1 %. Stress data suggest females are potentially resilient or not exposed to chronic periods of stress.. Yelloweye and black rockfish operculum samples paired with blood and ovary samples are being processed to validate results (Contact Dion Oxman).

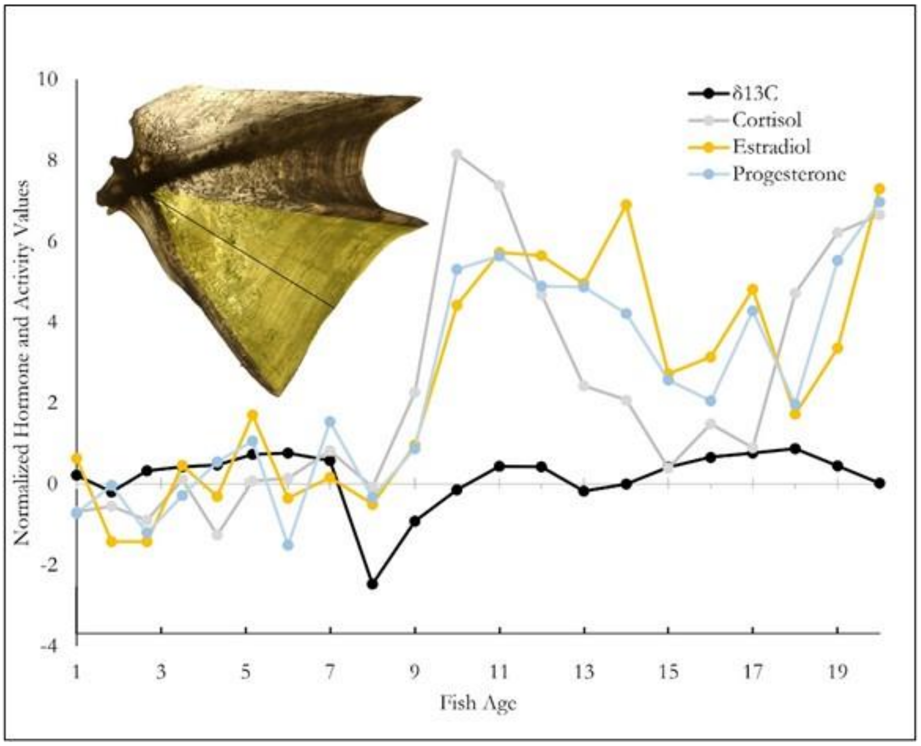

Figure 5.–Carbon Isotope (black), cortisol (grey), estradiol (orange) and progesterone (blue) estimated from annual growth increments within the operculum of a 20-year-old female yelloweye rockfish caught in 2018. The sampled region of the operculum is highlighted in yellow. Isotope activity and hormone concentrations were normalized based on concentrations prior to the first peak, assuming this represented non-reproductive levels.

ADU and Kodiak Otolith Lab staff are working to establish a black rockfish species misidentification evaluation using fish length and otolith weight at age and otolith morphology criteria to detect errors in contemporary and historical data. Standard growth and logarithmic models were used to estimate prediction intervals for region specific data and model results were evaluated using otolith morphology indicative of black rockfish. Both models were able to identify potential errors, but the otolith weight at age model was better able to identify species errors. Further evaluation of model results and validation using genetic samples are being investigated (Contact Kevin McNeel and Carrie Worton).

2. Assessment

The **Southeast Region** performs multi-year stock assessments for DSR in the Southeast District. Biomass is estimated by management area as the product of yelloweye rockfish density determined from line transect surveys, the area of rocky habitat within the 100-fathom contour no deeper than 180 m, and the average weight of yelloweye rockfish. Yelloweye rockfish density for the stock assessment is based on the most recent estimate by management area. Yelloweye rockfish densities for each area are multiplied by the current year's average commercial fishery weight of yelloweye rockfish specific to that management area. Allowable biological catch for SEO is set by multiplying the lower bound of the 90% confidence interval of total biomass for yelloweye rockfish by the natural mortality rate (M = 0.02). In the past, the yelloweye biomass estimate was expanded to the entire DSR assemblage by multiplying the proportion of other DSR species in the commercial catch (2.0 to 4.0%). However, starting in 2015, the non-yelloweye DSR biomass estimate has been calculated from catch data from 2010–2014 recreational, commercial, and subsistence fisheries and added to the yelloweye ABC to obtain a total for the entire DSR assemblage. There is no stock assessment information available for DSR in NSEI and SSEI management areas, and surveys for non-DSR species (e.g., black rockfish) have not been conducted since 2002.

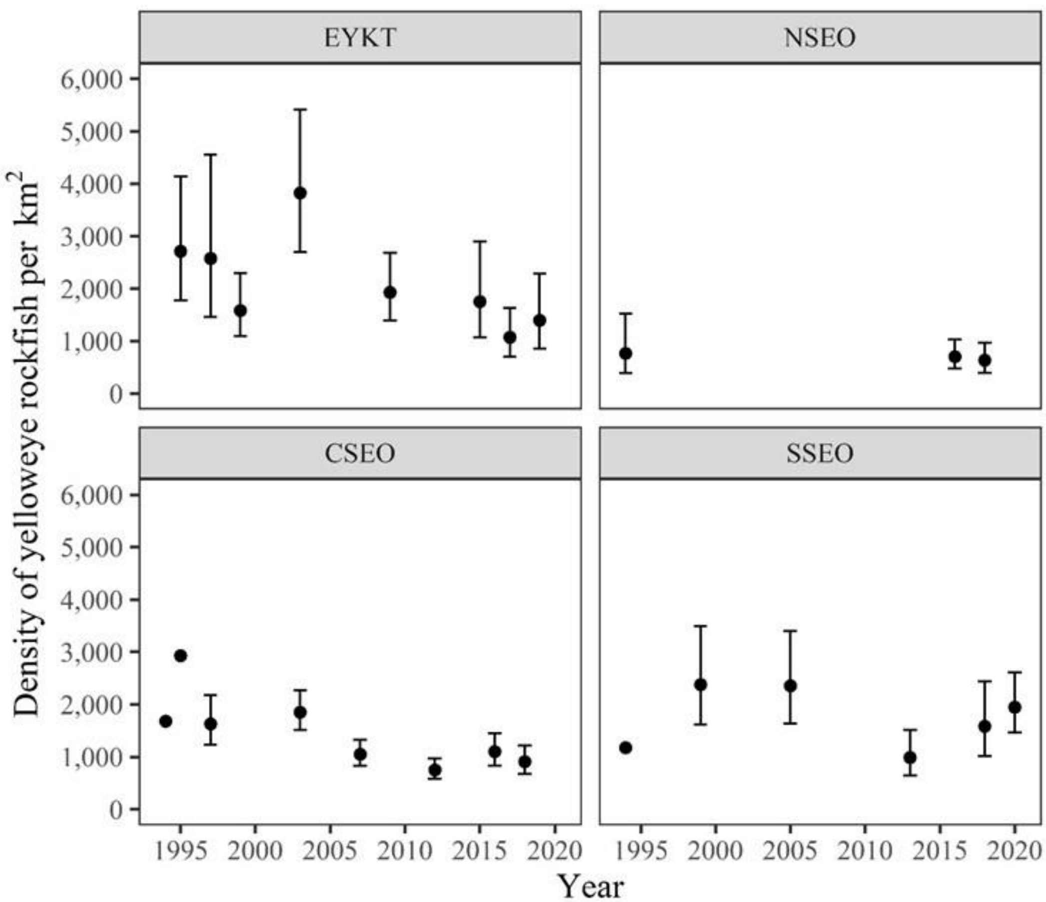

Figure 6.–Density estimates of yelloweye rockfish with 90% confidence intervals in the Eastern Gulf of Alaska management areas.

Prior to 2012, line transect surveys were conducted using a manned submersible. Since 2012, visual surveys have been conducted using a remotely operated vehicle (ROV). The last ROV surveys were conducted in 2020 in the Southern Southeast Outside (SSEO) section, 2019 in the Eastern Yakutat (EYKT) section, and 2018 in the SSEO, Central Southeast Outside (CSEO) and Northern Southeast Outside (NSEO) sections. Density estimates were derived from each of these surveys except for the SSEO management area where the data analyzation is in progress (Figure 10). Density estimates by area for the most recent submersible surveys ranged from 553–1,562 yelloweye rockfish per km^2 with CV estimates of 14–25%. The most recent density estimates for EYKT in 2019 was 1,397 yelloweye rockfish per km^2 (CV = 27%), SSEO in 2020 was 1,949 yelloweye rockfish per km^2 (CV = 15%), CSEO in 2018 was 910 yelloweye rockfish per km^2 (CV = 14%), and NSEO in 2018 was 637 yelloweye rockfish per km^2 (CV = 59%). In addition, fish lengths for yelloweye rockfish, lingcod, black rockfish, and halibut are measured from ROV video data using stereo camera imaging software (SeaGIS, Ltd; Contact Rhea Ehresmann).

Central Region conducts ROV surveys along the northern Gulf of Alaska coast from the Kenai Peninsula to PWS to monitor the local abundance of DSR in selected index sites; however, assessment surveys have not been conducted in recent years (Contact Mike Byerly or Wyatt Rhea-Fournier).

In the **Westward Region** rockfish surveys using hydroacoustic equipment were deployed to assess black and dark rockfish stocks in the Kodiak Management Area. Surveyed areas included the Northeast, Afognak, Eastside, and Southeast districts of the Kodiak Management Area (Contact Carrie Worton).

3. Management

Management of DSR in the **Southeast Region** is based upon a combination of total allowable catch (TAC), guideline harvest range (GHR), seasons, gear restrictions, and trip and bycatch limits. Directed commercial harvest of DSR is restricted to hook-and-line gear. Directed fishing quotas are set for Southeast Outside management areas (NSEO, CSEO, SSEO, and EYKT) based on the stock assessment. Directed fishery quotas for the two internal water management areas (NSEI and SSEI) are set at 25 mt annually. Regulations adopted in 1994 included logbook requirements and 5-day trip limits of 6,000 pounds sold per vessel in all areas except EYKT where the trip limit was 12,000 pounds. New regulations adopted in 2018 further restricted trip limit rules by prohibiting additional fish to taken or allowed on board a vessel until the trip limit period expired. The EYKT trip limit amount was also reduced to 8,000 pounds.

The directed DSR fishery season in SEO occurs in the winter, prior to the start of the commercial halibut IFQ season. The SEO TAC for DSR is set after decrementing estimated subsistence harvest, the remainder is allocated 84% to the commercial sector and 16% to the sport sector. The 2021 ABC for DSR was 268 mt, which resulted in a TAC of 261 mt with allocations of 219 mt to commercial fisheries and 42 mt to sport fisheries. Estimated subsistence harvest for 2021 was 7 mt. A significant portion of the total commercial harvest is taken as bycatch during the halibut fishery. Each year DSR bycatch is estimated and decremented from the commercial TAC prior to the determining whether an area has enough quota remaining to prosecute a directed fishery.

Management of the commercial black rockfish fishery in the Southeast Region is based upon a combination of GHLs and gear restrictions. Directed fishery GHLs are set by management area and range from 11 mt in EYKT and IBS to 57 mt in SSEOC with a total GHL of 147 mt for the

Eastern Gulf of Alaska Area. A series of open and closed areas was also created for managers to better understand the effects of directed fishing on black rockfish stocks. Halibut and groundfish fishermen are required to retain and report all black rockfish caught (Contact Rhea Ehresmann).

In the **Central Region**, commercial rockfish fisheries in Cook Inlet and PWS areas are managed under their respective regulatory Rockfish Management Plans. Plan elements include a fishery GHL of 68 mt for each area and 5-day trip limits of approximately 0.5 mt in the Cook Inlet District, 1.8 mt in the North Gulf District, and 1.4 mt in PWS. Rockfish regulations underwent significant change beginning in 1996 when the BOF formalized the GHL into a harvest cap for all rockfish species in Cook Inlet and PWS areas and adopted a 5% rockfish bycatch limit for jig gear during the state-waters Pacific cod season. In 1998, the BOF adopted a directed rockfish season opening of July 1 for the Cook Inlet Area and restricted legal gear to jigs to target PSR species. At the spring 2000 BOF meeting, the BOF closed directed rockfish fishing in PWS and established a bycatch-only fishery with mandatory full retention of all incidentally harvested rockfish. In November 2004, the BOF also adopted a full retention requirement for rockfish in the Cook Inlet Area and restricted the directed harvest to PSR. Rockfish bycatch levels were also set at 20% during the sablefish fishery, 5% during the state-waters Pacific cod season, and 10% during other directed fisheries. In 2010, the BOF adjusted rockfish bycatch levels for Cook Inlet to 10% during halibut and directed groundfish, other than rockfish, and 20% nonpelagic rockfish during the directed PSR fishery. In addition, logbooks are required during the Cook Inlet Area directed jig fishery. In 2014, the BOF adopted regulations to adjust rockfish bycatch levels during the parallel Pacific cod season in PWS to 5%, for consistency with the PWS state-waters season; in addition, a 0.05% rockfish bycatch limit was established for the PWS pollock pelagic trawl fishery. Proceeds from rockfish landed in excess of allowable bycatch and harvest levels are surrendered to the State of Alaska (Contact Jan Rumble).

The **Westward Region** has conservatively managed black rockfish since 1997, when management control was transferred to the State. Area GHLs were set at 75% of the average production from 1978–1995 and sections were created to further distribute effort and thereby lessen the potential for localized depletion. Since 1997, section GHLs have been reduced in some areas that have received large amounts of effort.

In the Kodiak Area, vessels may not possess or land more than 2.3 mt of black rockfish in a 5-day period. Additionally, vessel operators are required to register for a single groundfish district fishery at a time. Registration requirements also exist for the Chignik and South Alaska Peninsula Areas. In the Kodiak Area, fishers may retain up to 20% of black rockfish by weight caught incidentally during other fisheries, and in the Chignik and South Alaska Peninsula Area black rockfish may be retained up to 5% by weight. In the Aleutian Islands District of the Bering-Sea Aleutian Islands Area, fishers may retain up to 20% of black rockfish and 20% for dark rockfish caught in the Bering Sea–Aleutian Islands area incidentally during other fisheries. A voluntary logbook program was initiated in 2000 in the hope of obtaining CPUE estimates as well as more detailed harvest locations; the logbook program was made mandatory in 2005 (Contact Nathaniel Nichols).

In 2021, the Kodiak Area black rockfish GHL was 55 mt, allocated across five districts. GHLs were attained in two districts of the Kodiak Area for a total harvest of 40 mt. The Chignik and South Alaska Peninsula area GHLs were 45 mt and 34 mt, respectively. In the Chignik Area, the 2021 black rockfish harvest was confidential due to low participation and harvest, and no black rockfish harvest occurred in the South Alaska Peninsula Area. The Aleutian Islands GHL for black rockfish was 41 mt allocated across three sections. No vessels made directed black rockfish landings in the Aleutian Islands Area; all harvest was incidental retention. In 2021, less than 1 mt of black and 6.8 mt of dark rockfish were harvested incidental to other groundfish species.

Sport fisheries are managed primarily under two assemblages: pelagic, defined the same as for commercial fisheries, and nonpelagic, which includes all other species of the genus *Sebastes*.

Beginning in 2020, a functioning deepwater release mechanism was required on all vessels sport fishing in Alaskan saltwater, and all rockfish not harvested were required to be released at depth of capture or at a depth of 100 feet.

For the 2021 season, the **Southeast Region's** sport bag and possession limit for pelagic rockfish was five fish per day, 10 in possession. The sport fishery in Southeast outside waters is allocated a portion of the TAC (16%) for demersal shelf rockfish. All Southeast Alaskan waters were closed to retention of demersal shelf rockfish during 2021. There was a bag and possession limit of one slope rockfish in all waters of Southeast Alaska during 2021 Anglers could retain five pelagic rockfish per day.

As in Southeast Alaska, sport rockfish regulations in the **Southcentral Region** largely rely on bag limits for regulating effort and are more restrictive for nonpelagic species to account for their lower natural mortality rates. The open season for rockfish was year-round in all areas. In 2021, the bag limit in Cook Inlet was five rockfish daily, only one of which could be a nonpelagic species; the possession limit was two bag limits. The bag limit in PWS was four rockfish per day, with a possession limit of eight rockfish; only one per day and one in possession could be a nonpelagic species. The bag limit in the North Gulf Coast area was four rockfish per day, only one of which could be a nonpelagic species; the possession limit was two bag limits. The bag limit for Chiniak and Marmot Bay areas off Kodiak was three rockfish, six in possession, no more than two per day, four in possession of which could be nonpelagic and one per day, two in possession of which could be a yelloweye. The bag limit in the remainder of Kodiak was five rockfish per day, 10 in possession, no more than two per day, four in possession of which could be nonpelagic species, and no more than one per day, two in possession of the nonpelagic species could be a yelloweye. The bag limit in the Alaska Peninsula and Aleutian Islands was 10 rockfish per day. For all areas off Kodiak, the Alaska Peninsula, and the Aleutian Islands, the possession limit was two bag limits.

In 2017 the department began the SRI, an interdivisional process to develop comprehensive harvest strategies for groundfish, beginning with black and yelloweye rockfish using information from all fisheries. Commercial and sport fisheries are currently managed separately, and several areas of the state lack annual harvest targets for the sport fishery. There was agreement on the need to develop harvest strategies that applied to all removals and an integrated approach to management, to set harvest guidelines and control rules. The department is committed to developing abundance-based goals where assessment is possible and simpler strategies where information is lacking. The initial focus on black and yelloweye rockfish is to address immediate management needs and serve as models for other groundfish species.

4. Fisheries

Directed fisheries for only black rockfish occurred in the **Southeast Region** in 2021. The directed fisheries for DSR in SEO and inside waters were closed again in 2021 due to stock health concerns. DSR was taken as bycatch with 111.1 mt harvested in SEO and 26.8 mt in internal waters. Harvest in the directed black rockfish fishery in Southeast Outside District (SEO) was 4.8 mt and black rockfish bycatch harvest in all groundfish, halibut, and salmon troll fisheries in SEO was 2.8 mt. Slope, PSR, and thornyhead rockfish were also taken as bycatch in internal waters with 51.9 mt harvested in 2021.

For **Central Region** commercial rockfish fisheries, both the Cook Inlet and PWS areas have a rockfish GHL of 68 mt, which includes both directed and bycatch harvest. In the Cook Inlet Area in 2021, the total rockfish harvest was 23.6 mt, an increase from 17.9 mt in 2020, primarily as a result of the GOA Pacific cod fisheries reopening in 2021 after the 2020 closure. In Cook Inlet Area, the PSR harvest was 8.4 mt primarily from the directed PSR fishery by jig gear, the only allowable gear type in that fishery (7.4 mt), with the remainder harvested by longline gear during other directed groundfish and halibut fisheries. Harvest of other rockfish (DSR and slope species) was 15.2 mt with the majority from longline gear (13.6 mt) and the remainder from jig gear during other directed groundfish and halibut fisheries. In PWS, rockfish are only harvested as bycatch, there is no directed fishery. The PWS harvest of 64.5 mt in 2021 was an increase from 37.3 mt, an increase of approximately 73% from 2020, although still below the GHL.

Sport harvest (guided and unguided) is estimated primarily through the SWHS (all species combined). Charter vessel logbooks provide reported harvest for the guided sector in three categories - pelagic, yelloweye, other nonpelagic. Additionally, species-specific data are available only from creel surveys.

Harvest reporting areas for these programs are different than commercial reporting areas, making direct comparisons difficult. Methods were recently developed to estimate sport harvest in numbers of fish for black and yelloweye rockfish in the same geographic reporting areas as used in commercial fisheries. Additional methods are being developed to estimate sport removals by weight and for other rockfish species (contact Sarah Webster).

Sport rockfish harvest is typically estimated in numbers of fish. Estimates of the 2021 harvest are not yet available from the SWHS, but the 2020 estimates for all species combined were 83,269 fish in Southeast and 112,303 fish in Southcentral Alaska. The average annual harvest estimates for the recent five-year period (2016–2020) were 145,447 rockfish in Southeast Alaska and 146,800 fish in Southcentral Alaska. Rockfish harvest in the sport fishery has increased substantially in recent years, likely in response to more restrictive limits for other sport caught fish.

I. Thornyhead rockfish

1. Research

There was no research conducted on thornyhead rockfish in 2021.

2. Assessment

There are no stock assessments for thornyhead rockfish.

3. Management

There is no directed fishery for thornyhead rockfish, and they may only be harvested as bycatch in halibut and other groundfish fisheries.

4. Fisheries

In **Central Region** thornyhead rockfish are retained as bycatch up to 10% in aggregate with other rockfish during a halibut or directed groundfish fishery, with exceptions occurring in PWS for the bycatch allowance in the directed sablefish fishery (20%), Pacific cod (5%), and directed pollock trawl fishery (0.05%). For directed drift or set gillnet fisheries for salmon or herring up to 10% of thornyhead rockfish combined with other rockfish in aggregate may be retained. Proceeds from bycatch overages are forfeited to ADF&G.

In **Southeast Region**, thornyhead were retained as bycatch, based on the round weight of the target species, of up to 15% in aggregate with other rockfish. For pot gear only, 5% thornyhead bycatch was permitted in the sablefish and Pacific cod fisheries. Any bycatch overages that occurred in state waters were forfeited to ADF&G.

J. Sablefish

1. Research

In 2021, sablefish longline surveys were conducted for both the NSEI and SSEI areas in the **Southeast Region**. These surveys are designed to measure trends in relative abundance and biological characteristics of the sablefish population. Biological data collected in these surveys include length, weight, sex, and maturity stage. Otoliths are collected and sent to the ADU in Juneau. The cost of these surveys is offset by the sale of the fish landed; however, in 2021 two permit holders participated in the surveys and sold their Personal Quota Share (PQS), thus reducing the impact on the quota for fish harvested and sold by the state. The department plans to allow permit holders to harvest their PQS aboard future NSEI longline surveys.

In addition to longline surveys, a mark-recapture survey is conducted using longlined pots in most years since 2000. This survey has used the state research vessel *Medeia* since 2012. A survey was not completed in 2021 due to budgetary constraints, but the survey will occur in May 2022. The mark-recapture results serve as a component of the NSEI stock assessment (Contact Rhea Ehresmann).

In **Central Region**, ADF&G conducted longline surveys for sablefish from 1996 through 2006 in PWS. Longline survey effort was extended into the North Gulf District in 1999, 2000 and 2002. All longline surveys were discontinued due to lack of funding, and with the goal of transitioning to a pot longline survey, particularly in PWS. Between 1999 and 2005, sablefish were opportunistically tagged in PWS on ADF&G trawl surveys. Sablefish tagging surveys were conducted in PWS in 2011, 2013, and 2015 using pot longline gear. There were 1,203 fish, 318 fish, and 26 fish tagged in 2011, 2013, and 2015, respectively. CPUE was very low in 2013 with an average of 0.11 fish per pot. To date, 349 fish have been recaptured from the 2011 survey and 63 were captured from the 2013 survey and 10 from the 2015 survey. Of all tagged releases, 52% have been recaptured within PWS and 43% outside in the GOA with the remainder of unknown location. There have been no PWS sablefish tagging surveys since 2015.

Sablefish are captured in **Central Region** Tanner crab bottom trawl surveys. A population biomass index from the PWS and Cook Inlet bottom trawl surveys is generated each year of those surveys with the catch composed of predominantly 1 and 4-yr old fish (see Skate – Research section above for more information on these surveys). PWS trawl surveys were not conducted in 2020–2021 in the historical survey area, and therefore, results are not included in this report. The historical survey area will again be surveyed annually beginning in 2022. No Cook Inlet surveys have been conducted since 2019 and it is uncertain when that survey will resume (Mike Byerly or Wyatt Rhea-Fournier).

In **Central Region**, skipper interviews and biological sampling in 2021 occurred in Whittier, Seward, and Cordova. Data collected included date and location of harvest, length, weight, sex, gonad condition, and otoliths. Otoliths were sent to the Age Determination Unit. Logbooks are required in both fisheries to provide catch and effort data by date and location (Contact Elisa Russ).

The Division of Sport Fish—Southeast Region collects catch, harvest, and biological data from sablefish as part of a marine harvest survey program. Ports sampled in 2021 included Juneau, Sitka, Craig, Petersburg/Wrangell, Gustavus, Yakutat, and Ketchikan. Length data were collected from 469 sablefish in 2021, primarily from the ports of Sitka, Ketchikan, and Juneau (Contact Mike Jaenicke). Port sampling of sablefish is opportunistic in **Southcentral Region** and is not a primary objective of the program; port samplers in Southcentral Alaska measured only four sablefish from the sport harvest in 2021, reflecting the relatively low harvests. Interviewed anglers in Southcentral Region retained 56 of 72 sablefish caught in 2021).

The **Age Determination Unit** worked with the AFSC, Auke Bay Laboratories to investigate the use of age-0 lapillar and sagittal otoliths to infer daily growth in juvenile sablefish in the Gulf of Alaska. Otoliths from rhinoceros auklet bill-load samples from 1978 to present, survey samples, and samples from laboratory reared juvenile sablefish were removed and prepared. The external and internal structure of otoliths collected from bill-load samples were significantly damaged due to storage and were not useful for modeling size nor daily growth. Focus was shifted to samples included in growth trials conducted at Auke Bay Laboratories. Otolith size and daily increment width was measured using image analysis. The relationships between lapillar and sagittal otolith increment width, comparison of total increment count on both structures, otolith size to fish size, temperature and feeding ration were modeled. Evaluations of survey and laboratory reared juvenile sablefish found close agreement in daily age between otoliths, strong linear relationships between otolith size and fish size, and peak otolith increment width in both structures between 14°C and 18°C and at maximum feed rations. These findings support current and previous studies, and investigators plan to publish methods and findings (Contact Kevin McNeel).

2. Assessment

In the **Southeast Region**, the department uses mark-recapture methods with external tags and fin clips to estimate abundance and exploitation rates for sablefish in the NSEI Subdistrict. Sablefish are captured with pot gear in May or June, marked with a tag and a fin clip then released. Tags are recovered from the fishery and fish are counted at the processing plants and observed for fin clips. In addition to the mark-recapture work, an annual longline survey is conducted in NSEI to provide biological data as well as relative abundance information. In the NSEI Subdistrict, the 2021 recommended ABC was 569.3 mt, a 3.1% increase from the 2020 ABC. The ABC was generated using a statistical catch-at-age (SCAA) model, which reduces reliance on the annual mark-recapture project by integrating multiple indices of abundance and biological data (catch, mark-recapture abundance estimates, survey and fishery CPUE, and survey length and age composition data). In the SSEI Subdistrict, the 2021 annual harvest objective (AHO) was set at 272.7 mt, a 5% increase from 2020. For SSEI, an annual longline survey is conducted to provide biological data as well as relative abundance information. Unlike NSEI, the department does not currently estimate the absolute abundance of SSEI sablefish. There appears to be substantial movement of sablefish in and out of the SSEI area, which violates the assumption of a closed population; consequently, Peterson mark-recapture estimates of abundance or exploitation rates are not possible for this fishery. Instead, the SSEI sablefish population is managed based on relative abundance trends from survey and fishery CPUE data, as well as with survey and fishery biological data that are used to describe the age and size structure of the population and detect recruitment events (Contact Rhea Ehresmann).

3. Management

There are three separate internal water areas in Alaska which have state-managed limited-entry commercial sablefish fisheries. The NSEI and SSEI (**Southeast Region**) and the PWS Inside District (**Central Region**) each have separate seasons and GHLs. In the Cook Inlet Area, there is a state-managed open access sablefish fishery with a separate GHL.

In the **Southeast Region** both the SSEI and NSEI sablefish fisheries have been managed under a license limitation program since 1984. In 1994 the BOF adopted regulations implementing an equal share quota system where the annual GHL was divided equally between permit holders and the season was extended to allow for a more orderly fishery. In 1997 the BOF adopted this equal share system as a permanent management measure for both the NSEI and SSEI sablefish fisheries. During the February 2009 BOF meeting, the BOF made no changes affecting the regulation of commercial sablefish fisheries; however, bag and possession limits were established for the sablefish sport fishery. At the 2012 BOF meeting, a regulation was passed to require personal use and subsistence sablefish household fishing permits. Bag (50 fish per permit), vessel (200 fish per vessel) and hook (350 per permit) limits were adopted for personal use sablefish fishing at the 2015 BOF meeting. In 2017, the CFEC approved a public petition for SSEI longline permit holders to fish pot gear due to whale depredation and rockfish bycatch issues, thus making the permit a longline/pot permit. The NSEI fishery is restricted to longline gear only. In 2018, the BOF amended SSEI sablefish longline and pot seasons to a concurrent season occurring from June 1 to November 15, adopted new regulations to require commercial sablefish pots to have two 4-inch circular escape rings and allowed for the possession of live sablefish for delivery as a live product. In 2018, the BOF also approved the use of pots in the personal use sablefish fishery with a limit of two pots per person, 8 pots per vessel.

There is no open-access sablefish fishery in the Southeast Outside District as there are limited areas that are deep enough to support sablefish populations inside state waters. In some areas of the Gulf, the state opens the fishery concurrent with the EEZ opening. These fisheries, which occur in Cook Inlet Area's North Gulf District and the Aleutian Island District, are open access in state waters, as the state cannot legally implement IFQ management at this time. The fishery GHLs are based on historic catch averages and closed once these have been reached.

In **Central Region**, the Cook Inlet Area sablefish GHL is set using a historic baseline harvest level adjusted annually by the relative change to the ABC in the federal CGOA. In 2004, the BOF adopted a sablefish fishery-specific registration, logbook requirement, and 48-hour trip limit of 1.8 mt in the Cook Inlet Area. For PWS, a limited-entry program that included gear restrictions and established vessel size classes was adopted in 1996. Between 1996 and 2014, the PWS fishery GHL was set at 110 mt, which is the midpoint of the harvest range set by a habitat-based estimate. Tagging studies conducted by NMFS and ADF&G indicate that sablefish populations throughout GOA including PWS are likely mixed. Therefore, the GHL was adjusted by applying the relative change each year in the NMFS GOA sablefish ABC, which is derived from NMFS stock assessment surveys. The GHL was adjusted beginning in 2015 by applying the relative change in the GOA-wide ABC for sablefish back to 1994; this adjustment continued in 2021. PWS fishery management developed through access limitation and in 2003 into a shared quota system wherein permit holders are allocated shares of the GHL. Shares are equal within each of four vessel size classes but differ between size classes. In 2009, the BOF adopted regulations which included a registration deadline, logbooks, and catch reporting requirements; new season dates of April 15–August 31 were also adopted. The new season opening date, one month later than in previous years, was adopted to reduce the opportunity for whale depredation on hooked sablefish which predominately occurred prior to May 1.

The sole **Westward Region** sablefish fishery occurs in the Aleutian Islands. The GHL for the Aleutian Islands is set at 5% of the combined Bering Sea Aleutian Islands TAC. The state GHL can be adjusted according to recent state-waters harvest history when necessary. From 1995 to 2000 the fishery opened concurrently with the EEZ IFQ sablefish fishery. In 2001 the BOF changed the opening date of the state-waters fishery to May 15 to provide small vessel operators an opportunity to take advantage of potentially better weather conditions. From 1995 to 2000 all legal groundfish gear types were permissible during the fishery. Effective in 2001, longline, pot, jig and hand troll became the only legal gear types. Vessels participating in the fishery are required to register and fill out logbooks provided by ADF&G. In 2013, the BOF changed the season opening and closing dates reverting them back to coincide with the federal IFQ season.

The **Southeast Region sport fishery** for sablefish was regulated for the first time in 2009. Sport limits in 2021 were four fish of any size per day, four in possession, with an annual limit of eight fish applied to nonresidents. The sablefish sport fishery in the remainder of Alaska has no limits.

4. Fisheries

In the **Southeast Region**, the 2021 NSEI quota was set at 516.1 mt of sablefish. The fishery is managed by equal quota share with each permit holder allowed 7.1 mt. The 2021 NSEI sablefish fishery opened August 15 and closed November 15 by regulation. The 73 permit holders landed a total of 491 mt. The SSEI quota was set at 272.7 mt with an equal quota share of 12.4 mt for each of the 19 permit holders for longline/pot gear and three permit holders for pot gear. The 2021 SSEI sablefish fishery season allowed longline/pot gear permits to fish from June 1–November 15. The 22 permit holders landed a total of 196.5 mt of sablefish (Contact Rhea Ehresmann).

In the **Central Region,** the 2021 Cook Inlet Area sablefish fishery opened at noon July 15 with a GHL of 34.9 mt and closed by regulation on December 31; 3 vessels made 14 landings for a harvest of 5.5 mt of sablefish, an increase from 2020 when there was no effort or harvest. The 2021 PWS sablefish fishery opened April 15 with a GHL of 94.3 mt. For the second season in a row, some of the fleet requested, and were granted, an extension of the season to December 31 because of COVID-19 complications (from the regulatory closure of August 31). PWS sablefish harvest totaled 63.5 mt, an increase of 47% from 2020; harvest has been steadily increasing since the 7.7 mt historical low in 2015, although still not achieving the GHL. There has been an increase in the use of pot gear in the fishery in recent years in response to excessive orca whale depredation on sablefish in PWS, however, longline gear still dominated in 2021 harvesting 60%, with 40% harvested with pot gear (Contact Jan Rumble).

Within the **Westward Region**, only the Aleutian Islands have sufficient habitat to support mature sablefish populations of enough magnitude to permit commercial fishing. All other sections within the region are closed by regulation to avoid the potential for localized depletion from the small amounts of habitat within the jurisdiction of the state. Bycatch from the areas closed to directed fishing is limited to 1%. The 2021 Aleutian Island fishery opened concurrent with the IFQ season, on March 6 with pot, longline, jig and hand troll gear allowed. The GHL was set at 405.6 mt for the state-waters fishery. The harvest from the 2021 Aleutian Islands sablefish fishery was 55.1 mt. The season remained open until the December 7 closure date (Contact Asia Beder).

The most recent sablefish sport harvest estimates from the SWHS are for 2020. The estimated harvest was 6,414 fish in Southeast Alaska and 3,824 fish in Southcentral Alaska. SWHS estimates are suspected to be biased due to misidentification and misreporting. Sablefish are not commonly taken by anglers in most areas of the state, and relatively high catches were reported from some areas where sablefish are rarely or never observed by creel survey crews. Charter logbooks indicated guided harvests of 14,020 sablefish in Southeast Alaska and 5,928 sablefish in Southcentral Alaska in 2019 (Contact Jeff Nichols, Jason Dye).

K. Lingcod

1. Research

In the **Southeast Region**, dockside sampling of lingcod caught in the commercial fishery continued in 2021 in Sitka with 885 fish sampled for biological data. Otoliths were sent to the ADU in Juneau for age determination (Contact Rhea Ehresmann).

In the **Central Region**, skipper interviews and port sampling were conducted in Cordova, Seward, and Homer. Data obtained included date and location of harvest, length, weight, sex, and age structures. Otoliths were sent to the ADU in Juneau. Gonad condition (stage of maturity) was generally not determined as nearly all fish were delivered gutted; however, evidence of sex (vent/papilla) was required by EO to remain intact on lingcod by having fishers cut one inch forward of the vent when gutting fish (Contact Elisa Russ). Funding for Central Region lingcod ROV surveys ended in 2016 and no surveys have been conducted in recent years (Contact Mike Byerly).

The Division of Sport Fish—Southeast Region continued to collect catch, harvest, and biological data from lingcod as part of a marine harvest survey program with lingcod harvests tabulated back to 1987 in some ports. Data collected in the program include statistics on effort, catch, and harvest of lingcod taken by Southeast Alaska sport anglers. Ports sampled in 2021 included Juneau, Sitka, Craig, Petersburg/Wrangell, Gustavus, Yakutat, and Ketchikan. Length and sex data were collected from 1,631 lingcod in 2021, primarily from the ports of Sitka, Ketchikan, Craig, and Yakutat (Contact Mike Jaenicke).

The **Division of Sport Fish—Southcentral Region** continued collection of harvest and fishery information on lingcod through the groundfish harvest assessment program. Lingcod objectives include estimation of 1) the age, sex, and length composition of lingcod harvests by ports and 2) the geographic distribution of harvest by each fleet. The program sampled 482 lingcod from the sport harvest at Seward, Valdez, Whittier, Kodiak, and Homer in 2021. These ports account for most of the sport lingcod harvest in Southcentral Alaska (Contact Martin Schuster).

The **Age Determination Unit (ADU)**, in collaboration with the Gulf of Alaska Bottomfish program (GOAB) and member agencies of the Committee of Age Reading Experts (CARE), initiated a comparison between lingcod otolith and fin spine age estimation methods and potential validation of both methods. To date, the ADU and GOAB performed direct comparisons between methods using paired structures collected in Southcentral and Southeast Alaska by GOAB and the

Southeast Alaska Region port sampling program. Initial comparisons between methods showed an average difference between methods of -0.72 years and average percent error/ average coefficient of variation were 6.23/ 8.81%, respectively. Member agencies of CARE have continued efforts to collect paired structures for further investigations (Contact Kevin McNeel or Chris Hinds).

2. Assessment

There is no stock assessment for lingcod in the **Southeast Region**.

Central Region conducts ROV surveys along the northern Gulf of Alaska coast from the Kenai Peninsula to PWS for to estimate local abundance and biomass of lingcod concurrently with DSR. No surveys were conducted in 2021 (Contact Mike Byerly or Wyatt Rhea-Fournier).

3. Management

Management of commercial lingcod fisheries in the **Southeast Region** is based upon a combination of GHRs, season, and gear restrictions. Regulations include a winter closure for all users, except longliners, between December 1 and May 15 to protect nest-guarding males. GHLs were reduced in 2000 in all areas and allocations were made between directed commercial fishery, sport fishery, longline fisheries, and salmon troll fisheries. The 27-inch minimum commercial size limit remains in effect and fishermen are requested to keep a portion of their lingcod with the head on and proof of gender to facilitate biological sampling of the commercial catch. Vessel registration is required, and trip limits are utilized by ADF&G staff when needed for the fleet to stay within their allocations. The directed fishery is limited to jig or dinglebar troll gear. In 2003 the BOF established a super-exclusive directed fishery registration for lingcod permit holders fishing in the IBS area.

The **Central Region** has directed commercial fisheries for lingcod in Cook Inlet and PWS areas. Regulations for the commercial lingcod fishery include open season dates of July 1 to December 31 and a minimum size requirement of 35 inches (89 cm) overall or 28 inches (71 cm) from the front of the dorsal fin to the tip of the tail. The directed lingcod fishery in the Cook Inlet Area is limited to jig gear only. Guideline harvest levels are 24 mt for Cook Inlet Area and 3.3 mt in the PWS Inside District and 11.5 mt for the PWS Outside District. Resurrection Bay, near Seward, is closed to commercial harvest of lingcod. In 2009, a new BOF regulation permitted retention of lingcod at a 20% bycatch level in PWS waters following closure of the directed season. Cook Inlet Area also allows 20% bycatch levels for lingcod; however, no bycatch may be retained after the GHL is achieved.

In the **Southeast Region**, sport harvests of lingcod are incorporated into a regionwide lingcod management plan. This plan reduced GHLs for all fisheries (combined) in seven management areas and allocated a portion of the GHL for each area to the sport fishery. Since 2000, harvest limit reductions, size limits, and mid-season closures have been implemented by emergency order in various management areas to ensure sport harvests do not exceed allocations. The sport fishery lingcod season for 2021 was May 16–November 30. Charter vessel operators and crew members were prohibited from retaining lingcod while guiding clients. For resident anglers, the limits regionwide were one fish per day and two in possession, with no size limits or annual limits. Additional restrictions were put into place for nonresidents to keep harvest from exceeding allocations specified by the Alaska BOF:

1) In the Northern Southeast Inside area, nonresidents were allowed one fish daily and in possession, the fish must be 30–35 inches in length or at least 55 inches or greater in length, and the annual limit was two fish, of which one must be 30–35 inches in length and one must be at least 55 inches in length;
2) In the Northern Southeast Outside area, nonresidents were allowed one fish daily and in possession, the fish must be 30–40 inches in length or at least 55 inches or greater in length, and the annual limit was two fish, of which one must be 30–40 inches in length and one must be at least 55 inches in length;
3) In the Southern Southeast area, nonresidents were allowed one fish daily and in possession, the fish must be 30–45 inches in length or at least 55 inches or greater in length, and the annual limit was two fish, of which one must be 30–45 inches in length and one must be at least 55 inches in length.
4) In the Yakutat area, nonresidents were allowed one fish daily and in possession, no size limits, and the annual limit was two fish.

In addition, the Pinnacles area near Sitka has been closed to sport fishing year-round for all groundfish since 1997 (Contact Jeff Nichols).

A suite of regulations was established in 1993 for sport lingcod fisheries in **Southcentral Alaska** considering the lack of quantitative stock assessment information. Resurrection Bay remained closed to lingcod fishing year-round to rebuild and protect the population, although there is no formal rebuilding plan. The season was closed region-wide from January 1 through June 30 to protect spawning and nest guarding lingcod. Daily bag and possession limits in 2021 were two fish in Cook Inlet and Kachemak Bay, and one fish in North Gulf Coast and Prince William Sound areas. All areas except Kodiak had a minimum size limit of 35 inches (with head attached or 28 inches from tip of tail to front of dorsal fin with head removed) to protect spawning females (Contact Jason Dye or Matt Miller). The bag limit in Kodiak, the Alaska Peninsula, and the Aleutian Islands was two lingcod with a possession limit of four fish, and a season closure from January 1 to June 30. There were no size limits in these areas.

K. Fisheries

Lingcod are the target of a “dinglebar” troll fishery in the **Southeast Region**. Dinglebar troll gear is power troll gear modified to fish for groundfish. Additionally, lingcod are landed as significant bycatch in the DSR longline, halibut longline, and salmon troll fisheries. The directed fishery landed 134 mt of lingcod in 2021. An additional 48 mt was landed as bycatch in halibut and other groundfish fisheries and 19 mt in the salmon troll fishery.

Central Region commercial lingcod harvests have primarily occurred in the North Gulf District of the Cook Inlet Area and PWS. In 2021, in both areas, the fisheries closed by regulation on December 31. The 2021 lingcod GHL was 23.8 mt in Cook Inlet. Approximately 58% of the lingcod harvest from Cook Inlet Area was taken in the directed lingcod jig fishery and the remainder was harvested as bycatch primarily with longline gear. In PWS, lingcod harvest in 2021 was 10.1 mt, a small decrease from 11.7 mt harvested in 2020, below the GHL of 14.8 mt for the PWS Inside and Outside Districts combined. PWS lingcod harvest was dominated by longline gear (99%) with a small amount harvested with pots and trawl, as bycatch. (Contact Jan Rumble).

In the **Westward Region**, no directed lingcod effort occurred during 2021. All lingcod were harvested incidental to other federal and state managed groundfish fisheries. The 2021 harvest totaled 17 mt in the Kodiak Area, 1.8 mt in the Chignik Area, and <1 mt in the South Alaska Peninsula and Aleutian Islands – Bering Sea Areas combined.

Sport lingcod harvest estimates from the SWHS for 2020 (the most recent year available) were 10,069 lingcod in Southeast Alaska and 12,783 lingcod in Southcentral Alaska. The average estimated annual harvest for the recent five-year period (2016-2020) was 12,538 fish in Southeast Alaska and 13,011 fish in Southcentral Alaska.

L. Atka Mackerel

1. Research

There was no research on Atka mackerel during 2021.

2. Assessment

There are no state stock assessments for Atka mackerel.

3. Management

A commissioner's permit is required in **Central Region** and **Southeast Region** before a directed fishery may be prosecuted for Atka mackerel. This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes.

4. Fisheries

There was no directed fishery for Atka mackerel in 2021. Currently in the **Central Region** and **Southeast Region** Atka mackerel are considered part of the "other groundfish" assemblage and are allowed up to 20% as bycatch in aggregate in directed fisheries for groundfish.

M. Flatfish

1. Research

There was no research on flatfish during 2021.

2. Assessment

There are no stock assessments for flatfish.

3. Management

Trawl fisheries for flatfish are allowed in four small areas in the internal waters of the **Southeast Region** under a special permit issued by the department. The permits are generally issued for no more than a month at a time and specify the area fished and other requirements. Trawl gear is limited to beam trawls, and mandatory logbooks are required, observers can be required, and there is a 20,000-pound weekly trip limit.

In **Central Region** flatfish may be harvested in a targeted fishery only under the authority of an ADF&G commissioner's permit. The permit may stipulate fishing depth, seasons, areas, allowable sizes of harvested fish, gear, logbooks, and other conditions determined to be necessary for conservation or management purposes.

There are no bag, possession, or size limits for flatfish (excluding Pacific halibut) in the sport fisheries in Alaska. Harvest of flatfish besides Pacific halibut are not explicitly estimated by the

SWHS and no information is collected in the creel surveys and port sampling of the sport fisheries in Southcentral or Southeast Alaska. Flatfish are occasionally taken incidentally to other species and in small shore fisheries, but the sport harvest is believed to be negligible.

4. Fisheries

No effort has occurred in the **Southeast Region** fishery in recent years. Since 2000, only one vessel has applied for a commissioner's permit to participate in this fishery; this vessel made a single flatfish landing in 2014. Due to limited participation, harvest information is confidential for this landing. The Southeast flatfish trawl areas are also the sites of a shrimp beam trawl fishery. In the past, most of the Southeast harvest was starry flounder.

In **Central Region** during 2021, one commissioner's permit to catch flatfish was issued in the Cook Inlet Area and none in PWS. The purpose of the Cook Inlet Area permit was to test the viability of pot gear; however, there was limited success.

In state waters of the **Westward Region**, the State of Alaska adopts most NOAA Fisheries regulations, and the flatfish fishery is managed under a parallel management structure.

N. Pacific Halibut and IPHC Activities

The sport halibut fishery is monitored by the **Division of Sport Fish**. Data on sport fishery effort and harvest are collected through port sampling in Southeast and Southcentral Alaska, the SWHS, and charter vessel logbooks. Estimates of harvest and related information are provided annually to the IPHC for use in the annual stock assessment, and to the North Pacific Fishery Management Council (Council). The Council's Scientific and Statistical Committee has periodically reviewed the state's estimation and projection methods. ADF&G provides an analysis each year that is used by the Council to recommend regulatory changes for the charter fishery to keep its harvest within allocations specified in the Catch Sharing Plan for Guided Sport and Commercial Fisheries in Alaska. The Council's recommendations are incorporated by the IPHC as annual management measures for the charter fishery. Estimates of sport harvest and associated analyses are posted on the North Pacific Fishery Management Council's web page at http://www.npfmc.org (Contact Brianna King).

O. Other groundfish species

In 1997 the BOF approved a new policy that would strictly limit the development of fisheries for other groundfish species in the **Southeast Region**. Fishermen are required to apply for a permit for miscellaneous groundfish if they wish to participate in a directed fishery for species that do not already have regulations in place. Permits do not have to be issued if there are management and conservation concerns. The state also has a regulation that requires that the bycatch rate of groundfish be set annually for each fishery by emergency order unless otherwise specified in regulation.

V. Ecosystem Studies

N/A

VI. Other Related Studies

Staff in the **Central Region** currently house all survey data in an MS Access database format. Queries are complete for calculating CPUE, abundance, and biomass estimates from most surveys. All data are additionally captured in GIS for spatial analysis.

ADF&G manages state groundfish fisheries under regulations set triennially by the BOF.

ADF&G announces the open and closed fishing periods consistent with the established regulations and has authority to close fisheries at any time for justifiable conservation reasons. The department also cooperates with NOAA Fisheries in regulating fisheries in offshore waters.

A. User Pay/Test Fish Programs

The department receives receipt authority from the state legislature that allows us to conduct stock assessment surveys by recovering costs through sale of fish taken during the surveys. Receipt authority varies by region. In the **Southeast Region,** several projects are funded through test fish funds, notably the sablefish longline assessments and mark-recapture work, the herring fishery, and some salmon assessments.

VII. Publications

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Whiteside, C., and K. Bevaart. 2021. Fishery management plan for the Chignik Area state-waters Pacific cod season, 2022. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 4K21-16, Kodiak.

Whiteside, C., and K. Bevaart. 2021. Fishery management plan for the Chignik District commercial Tanner crab fishery, 2022. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 4K21-10, Kodiak.

Whiteside, C., and K. Bevaart. 2021. Fishery management plan for the Kodiak Area state-waters Pacific cod season, 2022. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K21-15, Kodiak.

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A. Websites

ADF&G home page: http://www.adfg.alaska.gov

Commercial fisheries: http://www.adfg.alaska.gov/index.cfm?adfg=fishingCommercial.main

Sport fisheries: http://www.adfg.alaska.gov/index.cfm?adfg=fishingSport.main

Advisory announcements: http://www.adfg.alaska.gov/index.cfm?adfg=newsreleases.main

Groundfish and shellfish statistical area charts: http://www.adfg.alaska.gov/index.cfm?adfg=CommercialByFisheryGroundfish.groundfishmaps

Age Determination Unit: http://mtalab.adfg.alaska.gov/ADU/

Gene Conservation Laboratory Home Page:

http://www.adfg.alaska.gov/index.cfm?adfg=fishinggeneconservationlab.main

Rockfish conservation:
http://www.adfg.alaska.gov/index.cfm?adfg=fishingSportFishingInfo.rockfishconservation

ADF&G Groundfish Overview Page:
http://www.adfg.alaska.gov/index.cfm?adfg=CommercialByFisheryGroundfish.main

Region I, Southeast Region, Groundfish Home Page:
http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareasoutheast.groundfish

Region II, Central Region, Groundfish Pages:
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Westward Region, Groundfish Pages:
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Commercial Fisheries Entry Commission: http://www.cfec.state.ak.us/

State of Alaska home page: http://www.alaska.gov

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APPENDICES

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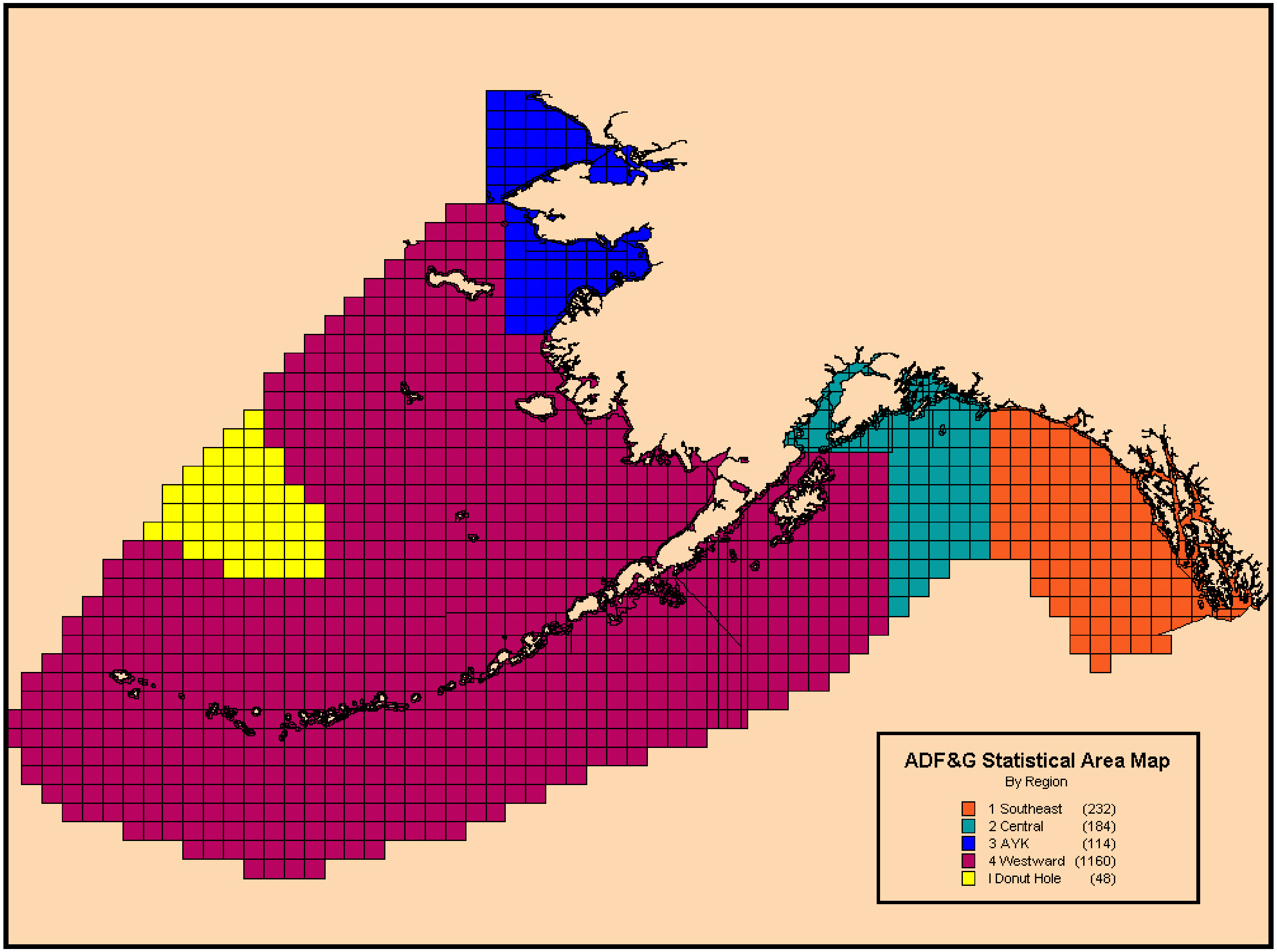
Appendix II. Map depicting State of Alaska commercial fishery management regions.



California Department of Fish and Wildlife
Agency Report
to the
Technical Subcommittee
of the
Canada-United States Groundfish Committee

April 2022

Prepared by

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I. Agency Overview

Within the California Department of Fish and Wildlife (CDFW), the Marine Region is responsible for protecting and managing California's marine resources under the authority of laws and regulations created by the State Legislature, the California Fish and Game Commission (CFGC) and the Pacific Fishery Management Council (PFMC). The Marine Region is unique in the CDFW because of its dual responsibility for both policy and operational issues within the State's marine jurisdiction (0 – 3 miles; 0-4.8 km). It was created to improve marine resources management by incorporating fisheries and habitat programs, environmental review and water quality monitoring into a single organizational unit. In addition, it was specifically designed to be more effective, inclusive, comprehensive and collaborative in marine management activities.

The Marine Region has adopted a management approach that takes a broad perspective relative to resource issues and problems. This ecosystem approach considers the values of entire biological communities and habitats, as well as the needs of the public, while ensuring a healthy marine environment. The Marine Region employs approximately 140 permanent and 100 seasonal staff that provide technical expertise and policy recommendations to the CDFW, CFGC, PFMC, and other agencies or entities involved with the management, protection, and utilization of finfish, shellfish, invertebrates, and plants in California's ocean waters.

Groundfish project staff are tasked with managing groundfish and providing policy recommendations to the CDFW, CFGC, and PFMC. Other staff work indirectly on groundfish, such as our California Recreational Fisheries Survey (CRFS) staff that sample our recreational fisheries and our Marine Protected Areas (MPA) Project and their remotely operated vehicle (ROV) work that benefits groundfish. Additionally, Pacific States Marine Fisheries Commission (PSMFC) staff sample the state's commercial groundfish fishery. The Marine Region's annual Year in Review provides a summary of all its programs, including groundfish. The Marine Region's annual By the Numbers Report provides another view of the breadth of work conducted by CDFW's Marine Region.

Contributed by Traci Larinto (Traci.Larinto@wildlife.ca.gov)

II. Surveys

ROV Visual Survey and Analysis for MPA and Fishery Data Needs

Scientists from CDFW's Groundfish and MPA Management Projects continued analysis of ROV survey data collected from 2014 to 2016 to develop methods for estimating fish density and total expanded biomass for select species using design and model-based approaches. CDFW will develop models with the 2014-2016 statewide survey data and the most recent coverage from 2019-2021 to inform upcoming stock assessments of Copper (*Sebastes caurinus*) and Quillback (*S. maliger*) rockfish in 2023. A workshop will be held in November of 2022 to review advancements since the 2020 methodology review by the PFMC's Scientific and Statistical Committee (SSC) and evaluate best practices for incorporating estimates of absolute abundance and length composition data into the Stock Synthesis assessment platform regularly used in PFMC groundfish stock assessments. In addition, density by depth and length frequency by depth are being considered relative to depth restrictions to provide empirical estimates of changes in selectivity with depth restrictions.

The estimates of density and biomass from these models may also be used to measure MPA performance. Preliminary results indicate differences in length compositions and density inside and outside MPAs as a result of site selection or accumulation of biomass in long established locations with protections. Two area models reflecting these differences may provide more representative estimates of status and scale if incorporated in assessments currently only reflecting data from openly fished areas. Future surveys may provide a time series to examine long-term trends in abundance to inform fishery and MPA management.

Contributed by John Budrick (John.Budrick@wildlife.ca.gov) and Michael Prall (michael.prall@wildlife.ca.gov)

III. Reserves

Marine Protected Areas Research and Monitoring

Marine Protected Area Monitoring Program research teams have completed seven long-term projects to gain a better understanding of MPAs. Teams collected and synthesized past research and utilized a variety of novel scientific approaches for their final reports. These reports will inform the evaluation of California's MPA network and contribute to the upcoming 2022 decadal management review of the network.

Since 2019, the Ocean Protection Council (OPC) has funded projects totaling $14.8 million through the Marine Protected Area Monitoring Program. These projects were administered by California Sea Grant in partnership with OPC and the CDFW. The collaborative projects supported research in California's network of MPAs and involved researchers from 24 universities, agencies, and institutions across the state. These projects build on more than a decade of monitoring, and include data from the MPA Baseline Monitoring Program, which ran from 2007-2018.

Results showcase the complexities of studying, understanding, and making recommendations for MPAs, while taking into account factors such as the kelp crisis and conducting research during the COVID-19 pandemic. Despite challenges, teams made progress answering MPA network questions spanning diverse topics from ecological, physical, chemical, human use, and climate change impacts, to enforcement metrics used to evaluate the effectiveness of California's MPAs.

The results and recommendations gleaned from the completed MPA long-term monitoring projects are one part of the information gathering needed to understand the effectiveness of California's MPA network. California's 124 MPAs span the state's 1,100-mile (1,770 km) coastline and protect 852 square miles (2,207 km^2; 16 percent) of state waters. Individual MPAs have varying levels of protection, including reserves that encompass 9 percent of state waters and prohibit all "take" within their boundaries. California's MPA network is the largest of its kind in North America and one of the largest ecologically connected networks in the world. These results, combined with research dating back to the creation of the MPA network in 2012, will help to inform the future of California's MPAs.

The California marine protected area long term monitoring program final reports 2019-2021 are available online. The links below contain project result summaries and the final report PDFs.

All California marine protected area long term monitoring program final reports 2019-2021:

- Establishing a statewide baseline and long-term MPA monitoring program for commercial and CPFV fisheries in the state of California
- Monitoring and evaluation of kelp forest ecosystems in the MLPA marine protected area network
- Evaluating the performance of California's MPA network through the lens of sandy beach and surf zone ecosystems
- California Collaborative Fisheries Research Program – monitoring and evaluation of California marine protected areas
- Assessment of rocky intertidal habitats for the California marine protected area monitoring program
- Integrated ocean observing systems for assessing marine protected areas across California
- Monitoring and evaluation of mid-depth rocky reef ecosystems in the MLPA marine protected area

In fall 2021, the CDFW, in partnership with the OPC, hosted a series of four public Community Meetings. The meetings were held both to inform California's ocean community about the upcoming MPA Decadal Management Review, and to receive public input on the process.

Nearly 400 participants shared diverse perspectives at the meetings and provided valuable feedback to help CDFW prepare for the review, including:

- Interest in engaging with MPA management, science, and the monitoring process
- A desire for increased collaboration and participation across agencies and groups/organizations interested in management of MPAs
- Requests for increased and diversified communications and outreach from the State and partners about California's MPA Network

Feedback received during these meetings has been captured in a Key Themes Summary document. In addition, recordings of the meetings will soon be posted to CDFW's Decadal Management Review web page.

For any inquiries or comments about the review or MPAs in general, please email the MPA Decadal Management Review Team.

IV. Review of Agency Groundfish Research, Assessment and Management

A. Groundfish, all species combined

1. Research off California

Scientific Collecting Permits are issued by CDFW to take, collect, capture, mark, or salvage, for scientific, educational, and non-commercial propagation purposes. Permits are generally issued for three years, except that student permits are for one year. While a complete report of groundfish-related research activities isn't available for this report, the permits fall into four broad categories: 1) public display in aquariums and interpretive centers; 2) environmental monitoring; 3) life history studies that include age and growth, hormone assays and genetics for population structure; and, 4) studies related to changing environmental conditions such as ocean acidification and hypoxia.

Contributed by Melanie Parker (Melanie.Parker@wildlife.ca.gov)

2. CDFW Research

Cowcod

In 2020, CDFW applied for and was granted a federal Exempted Fishing Permit that would allow select Commercial Passenger Fishing Vessels (CPFV) that are part of the EFP to retain incidentally-caught Cowcod rockfish (*Sebastes levis*). The purpose of the EFP is to collect biological data on Cowcod that are taken in current fishing activities that can be used in future stock assessments. Cowcod was declared overfished in 2000 while the stock has since rebuilt, take has not been allowed, this is, due in part, to assessment uncertainty. This EFP will allow participating CPFVs to retain Cowcod legally when incidentally caught during normal fishing activities and turn those fish over to CDFW to collect needed biological data. To date, four Cowcod have been taken under this EFP.

Contributed by Andrew Klein (Andrew.Klein@wildlife.ca.gov)

Quillback Rockfish

In 2021, CDFW began an ad hoc private vessel recreational sampling program focusing on a few key species, one of which is Quillback Rockfish. CDFW staff have collected 33 fish from various port from San Francisco to Crescent City and plan to continue this sampling program. The goal of this program is to be able to update California-specific age and growth curves.

Contributed by Andrew Klein (Andrew.Klein@wildlife.ca.gov)

Yelloweye Rockfish

In 2021, CDFW continued its ongoing research on Yelloweye Rockfish (*Sebastes ruberrimus*). The population off the West Coast was designated as an overfished stock in the early 2000s. Commercial and recreational regulations were implemented to minimize gear interactions in combination with a prohibition on retention (or limited retention in designated fishing sectors) and area closures. As a result, there has been limited opportunity to collect biological information for studying age and growth parameters that are crucial components of stock assessment modeling.

In coordination with CRFS staff, CDFW collected 42 Yelloweye Rockfish from the recreational fishing sector in 2021. Since 2016, CDFW has collected almost 300 Yelloweye Rockfish from the recreational fishery. Data from these fish will be used to inform future stock assessments on Yelloweye Rockfish.

Contributed by Andrew Klein (Andrew.Klein@wildlife.ca.gov)

Yellowtail Rockfish
Starting in 2013, the PFMC recommended issuance of an Exempted Fishing Permit (EFP) to commercial fishermen to study a method of commercial jig fishing to determine whether it is possible to target Yellowtail Rockfish (*Sebastes flavidus*) inside the Rockfish Conservation Areas (RCA; depth-based fishing closures) while avoiding overfished rockfish species (e.g. Canary (*S. pinniger*), Yelloweye, and Bocaccio Rockfish (*S. paucispinis*)) from the Oregon/California border to Point San Pedro. The goal of this study has been to determine if targeting species in the midwater column can provide additional fishing opportunities for the commercial fishery in the RCAs while avoiding overfished stocks that are more likely to reside on the bottom. Data from trips taken between 2013 and 2020 indicate that the gear is successfully targeting healthy stocks such as Yellowtail and Widow (*S. entomelas*) Rockfish, and now Canary Rockfish, while avoiding overfished species. Canary Rockfish and Bocaccio have since been rebuilt (in 2016 and 2019, respectively), and are currently allowed to be retained and sold under this EFP. The PFMC is currently considering authorizing the use of the EFP gear in the RCAs for fishers targeting these midwater rockfishes as part of the regulation development for 2023-2024. At it's April 2022 meeting, the PFMC included this in the preliminary preferred alternative, action will be taken in June.

Contributed by Melissa Mandrup (Melissa.Mandrup@wildlife.ca.gov)

3. Assessment
CDFW groundfish staff contributed to the 2021 stock assessments by providing length and age data for Lingcod, Copper and Quillback Rockfish, reviewing historic landings, as well as during the review process. Staff were co-authors on some stock assessments (Lingcod [*Ophiodon elongatus*], Copper, Quillback and Squarespot [*Sebastes hopkinsi*] Rockfishes). Multiple staff also participated as Stock Assessment Review panel members. CDFW staff provided additional length and age data for inclusion in the Copper and Quillback Rockfish stock assessments as well as the Lingcod stock assessment.

Contributed by John Budrick (John.Budrick@wildlife.ca.gov)

4. Management
Groundfish management is a complex issue and is conducted by the PFMC with input by CDFW as well as the states of Oregon and Washington and the

treaty tribes, and guided by the federal Pacific Coast Groundfish Fishery Management Plan. With the exception of some nearshore species, harvest guidelines, fishery sector allocations, commercial trip limits and recreational management measures (e.g., bag limits, season limits, RCAs) are recommended by the PFMC and implemented by NMFS.

Proposed Coral and Sea Sponge Closure Areas

In November 2021, CDFW proposed repealing the Cowcod Conservation Areas (CCAs) and continue to manage fishery impacts using the Rockfish Conservation Areas depth-based closures. The CCAs were established to protect areas where Cowcod were concentrated in the early 2000s after Cowcod was declared overfished. Now that Cowcod have recovered, there is no need for the CCAs. However, there is need to protect coral, sea sponge and sea pen habitat as pointed out by the Council's Habitat Committee in their September 2021 report to the PFMC.

The CDFW gathered a group of stakeholders including fishery representatives and environmental groups with the stated goal of repealing the CCAs to increase fixed gear and recreational opportunity while establishing new protections for coral, sponges and other living habitat.

Over the course of several meetings and using NOAA's Deep Sea Coral Data Portal the workgroup was able to identify discrete areas within the CCAs suitable for protection. The workgroup identified eight proposed protection areas that were generally agreeable to all. The proposed areas encompass approximately 44 and 35 percent, respectively, of the observed corals and sponges inside the CCAs. The proposed closures would encompass roughly 12 percent of the total 4,300 square-mile areas currently off limits to groundfish fishing in the CCAs.

CDFW presented the a report about the proposed closed areas for corals and sea sponges at the April 2022 PFMC meeting. This proposal will be included in the range of alternatives for the non-trawl sector area management measures that is being considered by the PFMC. It is hoped that these management measures will be adopted in 2023 and implemented for 2024.

Contributed by Andrew Klein (Andrew.Klein@wildlife.ca.gov)

5. Commercial Fishery Monitoring

Statistical and biological data from landings are continually collected and routinely analyzed by CDFW staff to provide current information on groundfish fisheries and the status of the stocks. California's primary commercial landings database is housed in CDFW's Marine Landings Database System. Outside funding also enables California fishery data to be routinely incorporated into regional databases such as Pacific Coast Fisheries Information Network.

Commercial sampling is conducted by PSMFC staff and occurs at local fish markets where samplers determine species composition of the different market categories, measure and weigh fish, and take otoliths for future ageing. Market categories listed on the landing receipt may be single species (e.g., Bocaccio), or species groups (e.g., group shelf rockfish). Samplers need to determine the species composition so that landings of market categories can be split into individual species for management purposes. Biological data are collected for use in stock assessments and for data analyses to inform management decisions. In 2021, the commercial fishery was sampled in the same manner and at similar rates to pre-COVID-19 pandemic levels.

Inseason monitoring of California commercial species landings is conducted by CDFW biologists. This work is done in conjunction with inseason monitoring, management and regulatory tasks conducted by the PFMC's Groundfish Management Team.

Contributed by Andre Klein (Andrew.Klein@wildlife.ca.gov) and Traci Larinto (Traci.Larinto@wildlife.ca.gov)

6. Recreational Fishery Monitoring
In the beginning of 2021, CRFS continued to operate under modified sampling guidelines to ensure compliance with all department, county and state COVID-19 health advisories and best practices. As guidelines relaxed in the spring, CRFS transitioned away from the modified sampling protocols. This transition allowed for direct sampler observations of catch and species identification, reducing the reliance on angler reported catch for rockfish species. Fish length data, which can be used to estimate weight, was also collected from the northern California Pacific Halibut fishery to help track the pounds landed. In July 2021, normal sampling resumed. Despite these challenges, CRFS staff interviewed California's marine recreational anglers at more than 400 sampling sites coastwide and conducted more than 7,000 field intercept surveys.

The beaches and banks survey was re-established in November 2020 and 2021 marked the first year CRFS had full beaches and banks coverage since 2017. In addition to sampling beaches and banks, CRFS resumed the Angler License Directory Telephone Survey to collect recreational fisheries information. This technique allowed data to be collected from nighttime fishing, as well as fishing originating from private marinas or slips which may otherwise be excluded from regular field intercept surveys.

For more information about CRFS, visit the Department website at https://wildlife.ca.gov/Conservation/Marine/CRFS.

Recreational Inseason Monitoring

Catch and effort information generated by CRFS is uploaded to RecFIN and used to track inseason recreational catch, however there is a five-to-eight week lag time between when data are collected and CRFS catch estimates are available. Preliminary CRFS reports of fish observed or reported are converted into an Anticipated Catch Value (ACV) in metric tons using catch and effort data from previous years and used to track catch inseason. Once the monthly CRFS catch estimate is available, the ACV value is replaced with the CRFS catch estimate for that month. ACVs have been an effective and reliable tool to closely monitor recreational inseason mortality on a weekly basis, and CDFW has used this tool since 2008 for a variety of rockfish species and Pacific Halibut. A recent CDFW report to the PFMC describes how CDFW conducts inseason monitoring and how ACVs are developed.

Contributed by Melanie Parker (Melanie.Parker@wildlife.ca.gov)

C. Pacific Halibut & International Pacific Halibut Commission activities

1. Research and Assessment
   Research and assessment activities for Pacific Halibut (*Hippoglossus stenolepis*) off the coast of California are conducted by the International Pacific Halibut Commission (IPHC).

2. Management
   The CDFW collaboratively manages the Pacific Halibut resource off the coast of California with the IPHC, NMFS, PFMC, other west coast states, and the CFGC. Pacific Halibut management activities occur on an annual timeline, with most changes to management occurring through the PFMC's Catch Sharing Plan and federal regulations published by NMFS. Changes to the Catch Sharing Plan for the following year are approved in November by the PFMC.

   Once the federal regulations are adopted, the state can then take action to conform state regulations to federal regulations for the recreational fishery by notifying constituents within 10 days of publication of the regulations in the Federal Register. Notification is done via press release and the CFGC is notified of the action at their next scheduled meeting.

3. Commercial Fishery Monitoring
   The directed commercial fishery for Pacific Halibut is managed under a coastwide (Washington, Oregon and California) quota and operates as a derby fishery. The fishery was structured based on 56-hour openers that are spaced two weeks apart, beginning the last Tuesday in June. The fishery operates on this schedule until the coastwide quota has been met. California effort in this fishery continued in 2021 with nine different California vessels landing 1,592 dressed kg (3,509 dressed lb) over the three fishery openers.

4. Recreational Fishery Monitoring
   The 2021 recreational Pacific Halibut fishery in California was scheduled to be open May 1- November 15. However, based on the preliminary catch projections available in late June, it was determined the recreational quota of 39,260 net lb (17,808 net kg) would likely be exceeded unless the fishery was closed. CDFW in consultation with the IPHC, NMFS and the PFMC closed the recreational fishery on June 30, 2021.

   In response to high catches in 2020 CDFW increased the frequency of inseason tracking in 2021 from weekly to daily. High catch events began the week of June 7 and continued throughout the month. CRFS recorded 286 Pacific Halibut kept by anglers in June, which is the highest number of sampled fish for a single month on record. Preliminary catch projections from May 1 through June 30 were 33,896 net lb (15,375 net kg) or 86.3 percent of the quota. Typically, quota attainment at the end of June is about 25 percent of the quota.

In June 2021, CRFS samplers measured lengths for 192 Pacific Halibut and the resulting weights were calculated using the IPHC length/weight conversion factor. This robust sample size resulted in the average weight used to calculate June CRFS estimates changing from 10-12 kg (22-26 kg) used in past years to 5.02 kg (11.07 lb) per fish in 2021. The drop in average weight by approximately half resulted in a June CRFS estimate which was dramatically lower than the preliminary catch projection used to make the inseason closure decision with NMFS, PFMC staff and IPHC. As a result, the recreational Pacific Halibut fishery was reopened on September 3, 2021 and remained open until November 15, 2021. The total 2021 catch estimate is 24,800 net lb (11,250 net kg), or 63 percent of the quota.

Contributed by Melanie Parker (Melanie.Parker@wildlife.ca.gov)

April 2022

OREGON'S GROUNDFISH INVESTIGATIONS IN 2021

Marine Resources Program
Oregon Department of Fish and Wildlife

2040 SE Marine Science Drive
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April 2022

OREGON'S GROUNDFISH INVESTIGATIONS IN 2021

OREGON DEPARTMENT OF FISH AND WILDLIFE
2021 TSC AGENCY REPORT

Edited by: Alison Whitman

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Agency Overview

MRP Program Manager: *Dr. Caren Braby*
Resource Management and Assessment: *Dave Fox*
Fishery Management: *Maggie Sommer*
Technical and Data Services: *Justin Ainsworth*

The Oregon Department of Fish and Wildlife's Marine Resources Program (MRP) is responsible for assessing, monitoring, and managing Oregon's marine habitat, biological resources, and fisheries. The MRP's main office is located at the Hatfield Marine Science Center in Newport, OR and includes two additional offices in Newport. There are also field stations in Astoria, Charleston, Brookings, and Corvallis. The MRP has primary jurisdiction over fisheries in state waters (from shore to three miles seaward) and participates in regional and international fishery management bodies including the Pacific Fishery Management Council, the International Pacific Halibut Commission, and the North Pacific Fishery Management Council. Management strategies developed at all levels affect Oregon fish and shellfish stocks, fisheries, resource users, and coastal communities. Staffing consists of approximately 60 permanent and more than 60 seasonal or temporary positions. The current annual program budget is approximately $9 million, with about 76% coming from state funds including sport license fees, commercial fish license and landing fees, and a small amount of state general fund. Grants from federal agencies and non-profit organizations account for approximately 24% of the annual program budget. Funding levels have been relatively stable over recent years.

ODFW staff place rockfish with barotrauma in a recompression cage during an at-sea survey.

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Surveys

Recreational Fisheries Monitoring and Sampling

Sampling of the ocean boat sport fishery by MRP's Ocean Recreational Boat Survey (ORBS) continued in 2021, with limited issues relating to the ongoing global COVID-19 pandemic. A combination of ongoing hiring and employment issues related to the pandemic and the lack of affordable housing on the coast lead to several ports being staffed for shorter time periods than in previous years. Starting in November 2005, major ports were sampled year-round and minor ports for peak summer-fall season. We continue to estimate catch during un-sampled time periods in minor ports based on the relationship of effort and catch relative to major ports observed during summer-fall periods when all ports are sampled. Lingcod (*Ophiodon elongatus*), multiple rockfish species (*Sebastes* spp.), Cabezon (*Scorpaenichthys marmoratus*) and Kelp Greenling (*Hexagrammos decagrammus*) are the most commonly landed species.

The ORBS program continued collecting information on species composition of landed groundfish species at Oregon coastal ports during 2021. Fish lengths and weights were collected again in 2021; however, sampling was slightly limited as there were times for safety reasons (COVID-19) that samplers had the ability to opt out of collecting samples. Since 2003, as part of a related marine fish ageing research project, lingcod fin rays and otoliths from several species of nearshore groundfish, including rockfish species, Kelp Greenling and Cabezon, were gathered, with some modifications in 2021 due to COVID safety protocols. Starting in 2001, a portion of sport charter vessels were sampled using ride-along observers for species composition, discard rates and sizes, location, depth and catch per angler; however, that sampling was suspended in 2020 and 2021 due to COVID safety protocols. This sampling program is anticipated to restart in spring 2022. Beginning in 2003, the recreational harvest of multiple groundfish species is monitored inseason for catch limit tracking purposes.

Other ODFW management activities in 2021 include participation in the U.S. West Coast Recreational Fish International Network (RecFIN) process, data analysis, public outreach and education, and public input processes to discuss changes to the management of groundfish and Pacific Halibut fisheries for 2022.

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Commercial Fisheries Monitoring and Sampling

Commercial fisheries monitoring data from commercial groundfish landings are collected throughout the year and analyzed by ODFW to provide current information on groundfish fisheries and the status of the stocks off Oregon's coast. This information contributes to fisheries management decisions, stock assessments, in-season adjustments to nearshore fisheries, and economic analyses.

Commercial fishery data, including logbooks, fish tickets, and biological data, are uploaded to the Pacific Fisheries Information Network (PacFIN) on a regular basis and are used for inseason monitoring and as a primary commercial data source for federal stock assessment. In 2021, preparations continued to add fixed gear fishery logbooks to the PacFIN clearinghouse. Species composition sampling of rockfish and biological sampling of commercially landed groundfish continued in 2021 for commercial trawl, fixed gear, and hook and line landings. The majority of the landings were monitored at the ports of Astoria, Newport, Charleston, Port Orford and Brookings, with additional sampling occurring routinely at Garibaldi, Pacific City, Depoe Bay, Bandon, and Gold Beach. Biological data including length, weight, age (from collected age structures: otoliths, vertebrae, and fin rays), sex, and maturational status continued to be collected from landings of major commercial groundfish species. All sampling in 2021 was conducted following ODFW-prescribed COVID-19 safety protocols. While the commercial groundfish sampling rate decreased in 2021 because of the need to avoid fish plants with active COVID-19 outbreaks, adequate sampling of all sectors was accomplished.

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Marine Reserves

The ODFW Marine Reserves Program is responsible for overseeing the management and scientific monitoring of Oregon's five marine reserve sites. These sites, from north to south, include: Cape Falcon, Cascade Head, Otter Rock, Cape Perpetua and Redfish Rocks. Reserves are a combination of marine reserves (no fishing) and marine protected areas (some types of fishing activities allowed), as determined by public process. Each reserve has distinct habitat and biological characteristics, and as such, requires site-specific monitoring and research planning. This section presents an update on management and ecological monitoring and research activities from 2021. More information is available on the Oregon Marine Reserves website at http://oregonmarinereserves.com/

Management

Marine Reserves Program Synthesis Report: 2009 - 2021

The ODFW Marine Reserves Program recently completed the *Marine Reserves Program Synthesis Report: 2009-2021* providing a comprehensive overview of the first 10 years of marine reserves implementation in Oregon.

Never Before in Oregon

Implementation of Oregon's marine reserve system is the first long-term nearshore ocean conservation and monitoring program executed by the state. It is the only ecosystem-focused, fisheries-independent monitoring program designed to track and understand ocean changes occurring in Oregon's state waters. It also is the first comprehensive human dimensions research program focused on examining economic, social, and cultural dynamics of the

Oregon coast and coastal communities in relation to marine resources. Beyond Oregon, it is one of the most comprehensive human dimensions research programs ever focused on Marine Protected Areas (MPAs).

An Important Check-in

This report serves as an important check-in on the development and execution of this relatively new nearshore conservation and monitoring program. It gives Oregonians a chance to reflect on the accomplishments, challenges, lessons learned, and contributions since the program's inception. This information can be used to inform adaptive management of the program and serves as a valuable case study for use by other MPA and long-term monitoring programs.

In the report you'll find:

- How our program has implemented the marine reserve legislative mandates including: ecological monitoring, human dimensions research, outreach, community engagement, management plans, and enforcement.
- Results and takeaways from ecological and human dimensions monitoring and research conducted by ODFW and our collaborators.
- The costs of marine reserve implementation, including what state staff and funding resources have been available and how ODFW has spent state resources.
- Challenges, lessons learned, and contributions made by the program.

Monitoring

Ecological monitoring includes sampling with core tools (ODFW-led) and through collaborative activities. Sampling was conducted both in the reserves and in comparison areas outside of the reserves still open to fishing. Despite the challenges of COVID-19, the marine reserve ecological monitoring team successfully conducted oceanographic and intertidal monitoring in 2021 at the following reserves:

- Cape Falcon Marine Reserve: Subtidal temperature, oxygen and salinity data were gathered in the reserve and its comparison area at Cape Meares.
- Cascade Head Marine Reserve: Intertidal monitoring for sea stars and community musselbed surveys were successfully conducted following modified COVID-19 fieldwork protocols. Subtidal temperature, oxygen and salinity data were gathered from this reserve.
- Otter Rock Marine Reserve: Intertidal monitoring for sea stars and community musselbed surveys were successfully conducted following modified COVID-19 fieldwork protocols. Our collaborators at Oregon State University resumed sampling for juvenile fish recruitment surveys; subtidal temperature, oxygen and salinity data were gathered from this reserve.
- Cape Perpetua Marine Reserve: Collaborators with the Partnership for Interdisciplinary Study of Coastal Oceans (PISCO) successfully collected data on intertidal sea stars and musselbeds, and subtidal data on temperature, salinity, oxygen, and pH from the

marine reserve.

- Redfish Rocks Marine Reserve: Subtidal temperature, oxygen and salinity data were gathered from this reserve.

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Research

Nothing new to report in 2021.

REVIEW OF AGENCY GROUNDFISH RESEARCH, ASSESSMENT AND MANAGEMENT

Hagfish

Management

The commercial hagfish fishery operates year-round. Two types of trap gear are typically used by the hagfish fleet, a 55-gallon drum and five-gallon bucket. Each of these contains escape holes to increase the size selectivity of the commercial fishery. Commercial hagfish landings in 2021 were down to 785,977 pounds, or 49% of state harvest guideline of 1.6 million pounds, continuing the decline in landings observed in 2020. Lower landings are largely attributable to reduced effort, as the number of trips declined to 53% of the 2019 level while pounds landed per trip has remained stable. No major hagfish management actions were taken by ODFW in 2021.

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Dogfish and Other Sharks

Assessment

ODFW staff participated in the federal spiny dogfish assessment in 2021 by providing data to the assessment and advice on modeling decisions to the stock assessment team (STAT).

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Skates

Nothing to report in 2021.

Pacific Cod

Nothing to report in 2021.

Walleye Pollock

Nothing to report in 2021.

Pacific Whiting

Management

The US (and Canadian) whiting total allowable catch (TAC) and catch continues to be near record high levels. The new assessment does continue the trend of decreased abundance as the very strong 2010, 2014 and 2016 cohorts begin to leave the population. In March 2021, the Pacific Fishery Management Council (PFMC) recommended and National Marine Fisheries Service implemented an emergency rule to allow an at-sea Pacific whiting processing platform to operate as both a mothership and a catcher-processor within the same calendar year. This action was taken to allow for continued mitigation of risk associated with the COVID-19 pandemic and impacts associated with current processing limitations in these two sectors (i.e., to better ensure a processor would be available to take fish from catcher vessels in the mothership sector, given the continued instances of COVID-19 outbreaks that disrupt processing operations). Increasing the whiting utilization package was finalized in March 2022. Council adopted the whiting utilization final preferred alternatives which will be in effect in 2023.

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Grenadiers

Nothing to report in 2021.

Rockfish

Research

Cross-Shelf Variability of Deacon Rockfish (*Sebastes diaconus)* Age, Growth, and Maturity in Oregon Waters and Their Effect on Stock Status. Published.

The goals of this study were to understand how age, growth and maturity parameters vary with sex and depth in the Deacon Rockfish. As efforts were made to sample a variety of size classes, from both the nearshore and offshore, we also assessed how age composition differed between the two areas and determined what the implications of these differences would be on the reproductive output of the population. Finally, we incorporated the results of this study into the most recent Deacon Rockfish stock assessment and evaluated how altering life history parameters influenced the stock status.

Deacon rockfish were collected nearly monthly at offshore and nearshore sites during favorable weather periods out of Newport, Oregon. Samples were collected periodically from December 2016 to November 2017. The offshore study area was Stonewall Bank and the surrounding area out to 146 m of water depth. The nearshore study areas included Seal Rock and Siletz reefs. Recreational hook and line gear was used for all collections. Terminal gear included a variety of plastic baits, small to medium sized flies and Sabiki rigs (herring jigs).

Prior efforts to collect small Deacon and Blue Rockfish in nearshore waters off Oregon have shown that Sabiki rigs are capable of capturing Deacon Rockfish from adult sizes down to as small as ~8 cm, helping to offset gear-related bias in size-selectivity of typical hook and line fishing gear. Approximately 50 Deacon Rockfish were collected per reef area per sampling day. Fish were measured (cm, fork length) and sexed and otoliths collected for age determination. Ovaries and testes were be examined and assigned a maturity stage. For females, a small section of ovary from fish in stages 1, 2, 3, 6 and 7 were collected and placed in cassettes for histological preparation and microscopic evaluation of maturity. Ovary samples were preserved in 10% buffered formalin and later transferred to 70% ethanol for storage. Ages were determined using the break and burn technique applied to sagittal otoliths) or a variation of the technique in which sagittal otoliths are broken and “baked” for several minutes prior to age determination. For all fish 21 cm or shorter, a caudal fin snip was taken and stored in 100% ethanol (molecular grade) for DNA analysis to confirm species identification.

Our primary goal was to better understand how age, growth and maturity parameters differed between Deacon Rockfish that resided in nearshore and offshore waters off central Oregon. Our study suggests that age and growth parameters do differ by both area and sex but, not surprisingly, sex was a more influential factor than area. We were unable to compare nearshore and offshore age and length at 50% maturity due to the small number of immature females collected offshore. We did find that age and length at 50% maturity values were similar between the nearshore and when nearshore and offshore samples were combined. However, based on larger lengths of offshore females, our work suggests that a significant component of the total reproductive output in Oregon may come from offshore. It is worth noting that this is based on the assumption that the number of females in the nearshore and offshore are equal.

Although our best fit von Bertalanffy model included both sex and area, the effect of area on the parameter estimates was relatively minimal. Primarily, growth rate (k) differed with males in the nearshore growing faster than males in the offshore whereas females in the offshore grew faster than females in the nearshore. Regardless of area, male growth rate was faster than for females. The larger offshore individuals (both male and female) had a more diverse distribution of ages than individuals of the same size class in the nearshore. The offshore individuals we sampled stopped experiencing fishing pressure in 2007 due to the establishment of the Stonewall Yelloweye Rockfish Conservation Area. In the 10 years since its closure, the offshore fish have experienced essentially no fishing pressure allowing larger individuals to obtain older ages than normally occurs for populations experiencing fishing pressure. However, the greater than 10 year age difference suggests that while the complexity of offshore age structure has increased due to the lack of fishing pressure, there were, prior to closure, likely more older fish offshore. It is worth noting when the offshore re-opens to fishing, these larger older individuals are likely to be removed from the population. Although most of the offshore individuals were large mature females, we did capture young-of-the-year individuals. This finding is important because regional knowledge suggests Deacon Rockfish only settle in the nearshore and exhibit an onotogenetic migration from the nearshore to the offshore. Our findings may indicate that there is less movement of individuals between the nearshore and offshore than previously hypothesized.

Re-running the most recent stock assessment and forcing it to use some of the different growth and maturity parameters influences the spawning stock biomass trajectory and estimates of stock status, but all of the estimates were within the range of uncertainty estimated with the base Oregon Blue/Deacon stock assessment model. Although all of these runs were within the range of uncertainty, the stock trends were effectively the same regardless of where the parameter estimates were obtained from, except for the estimates from California, which caused dramatic differences in the stock trend. Incorporating spatiotemporal variability of growth data into stock assessments is increasingly being shown to have profound impacts of stock trajectory and status. As such, for nearshore stocks that are relatively data poor and rely on each individual state to collect their own data, it is important that growth function parameters be estimated (at a minimum) for each state (using locally obtained data) and the relative effect of spatial dynamics are considered. Further, although spatial variation on growth function parameter estimates are often shown to vary with latitude, few studies consider the effects of cross-shelf variability in growth functions. We argue that cross-shelf variability is important to consider as circulation changes dramatically as you move across the shelf and ultimately these differences may affect both growth rates of adults and the dispersal of their larvae.

Contact: Leif Rasmuson (leif.k.rasmuson@odfw.oregon.gov)

Habitat use and activity patterns of Deacon Rockfish (*Sebastes diaconus*) at seasonal scales and in response to episodic hypoxia. Published.

Knowledge of fish movements and residency are key to design and interpretation of results from bioacoustic sonar and visual survey methods, which are being developed as tools for use in nearshore rocky reef surveys to estimate biomass and species composition. Fishers in Oregon report that an important component of the nearshore catch, Deacon Rockfish (*Sebastes diaconus*), become unavailable to harvest seasonally, and suggest periodic migration away from nearshore reef areas. Seasonal and spatial variation in landings data potentially support this theory. We used a high-resolution acoustic telemetry array and a combination of presence/absence receiver arrays, to study the daily and seasonal movements and the activity patterns of 11 acoustically tagged Deacon Rockfish on a nearshore rocky reef off Seal Rock, Oregon. Over the 11-month study period, most fish (n=6) exhibited high site fidelity. For the duration of the high-resolution array (5 mo), these fish had small home ranges (mean 95% kernel density estimation=4,907 m^2) and consistent activity patterns, except during seasonal hypoxia (defined as dissolved oxygen concentration [DO] < 2 mg l^{-1}). During the summer months, resident fish were strongly diurnal with high levels of daytime activity above the bottom in relatively rugose habitat, followed by nighttime rest periods in deeper water in habitat of relatively less rugosity. During hypoxia, fish exhibited moderate activity levels with no rest periods and moved well away from their core activity areas on long, erratic forays. Wintertime activity levels were moderate with less defined daily patterns, but fish continued to remain within the array area.

Overall, resident Deacon Rockfish displayed high site fidelity and coherence in both seasonal and daily movement patterns, but those consistent patterns were completely altered during extended hypoxia. High long-term survival and consistently high detection of resident fish over 11 months indicates that at least some Deacon Rockfish do not exhibit a seasonal migration away from nearshore reefs. Food items ingested by sampled Deacon Rockfish during this study included gelatinous zooplankton and small planktonic crustaceans: the colonial tunicate *Pyrosoma atlanticum*, hydrozoan *Velella vellela*, ctenophore *Pleurobrachia bachei*, brachyuran zoeae/megalopae, and pelagic amphipods. We suggest Deacon Rockfish may be resistant to standard fishing techniques due to these strong prey preferences, hook size, and potentially eye and visual abilities which allow both Blue and Deacon Rockfish to see and feed upon very small and/or transparent prey items such as gelatinous zooplankton.

Although our sample size was necessarily small, detection and position data for tagged fish was excellent, a trade-off due to using a high density of receivers and co-located sync tags. Mid-water schooling behavior of this species benefits detection rates, which can be problematic for more benthic rockfish in high relief habitat. The high-resolution inner VPS array, combined with the perimeter fence, and accelerometer/depth sensors in the tags, provided additional certainty about the fate of fish that remained inside or left the array. A larger study in southern Oregon, using similar methods but tagging both Deacon and Blue Rockfish inhabiting the same area, could shed light on differences in the two species' movements in various habitats including offshore reefs, which may act as refuges for older, more fecund fish in Oregon, in unfished rockfish conservation areas.

Contact: Leif Rasmuson (leif.k.rasmuson@odfw.oregon.gov)

Operationalizing a survey of Oregon's nearshore semi-pelagic rockfish. Published

A primary challenge for an acoustic-based rocky reef survey is identifying the species composition and size distribution of schools, as species identification of acoustic targets is currently not possible for mixed schools of morphologically-similar rockfish species. Identifying an efficient strategy for quantifying these variables using a suspended pelagic stereo drop-camera was the goal of this proposed work. Acquiring drop-camera footage from as many different schools as possible, containing a diversity of species compositions and size distributions, informed us about the range of school structures and allowed us to evaluate the level of sampling effort needed for future broad-scale surveys.

In the fall of 2017 we established 50 transects off of Newport at Seal Rock reef. These transects were evenly spaced in areas 2 and 3 of the ODFW black rockfish pit tagging project. These transects were established as a test location for conducting a "mock" hydroacoustic survey for nearshore semi-pelagic rockfish. This location presented an ideal test location due to 1) its nearness to the ODFW offices and 2) the presence of robust population estimates for the reef's black rockfish (*Sebastes melanops*) population. Over the course of four days, using a contracted local charter passenger fishing vessel, we collected hydroacoustic data using a biosonics 200kHz split beam transducer. For each transect we deployed our suspended stereo camera system 3 times on locations with either large schools of rockfish or rocky reef habitat. For each video drop we collected a minimum of 2 minutes of on-bottom time (based on preliminary examination of existing data). A total of 70 miles of acoustics data were collected and 140 video drops were conducted.

We determined that the best way to process our video data was to use a mean MaxN approach rather than the common MaxN approach. We also demonstrated that there was no effect on the size of the fish observed with each method. Finally, regardless of the method used, the distribution of fish size classes from the fishing fleet was similar to that observed with the camera. The only notable difference is the camera saw larger and smaller fish than those observed in the hook and line data. Our system also has downward facing camera that allows us to compare the fish counts in the acoustic deadzone to the counts from the forward camera system. Our work suggests that there was no statistical difference in the number of fish in the down camera for black rockfish and that there were significantly more Blue/Deacon rockfish in the forward camera than the down camera. These data provide an initial suggestion that that the acoustic deadzone will be a manageable concern in relation to our data.

To establish how the deployment and retrieval of the BASS camera affects the behavior of semi-demersal rockfish, we spent multiple days this summer deploying the camera system directly below the transducer that was ensonifying a school of fish. We then remained over the camera system while we ensonified the school and as we retrieved the camera system. Our analyses suggest that the deployment of the camera system on the schools of fish does not result in the attraction or repulsion of fish to the school. Finally, using the data we collected in September of 2017, we were able to generate population estimates for Black and Blue/Deacon rockfish at Seal Rock reef. Our work found similar orders of magnitude population sizes of Blacks as those estimated by the pit tagging project.

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Influence of near bottom habitat use on the efficacy of a combined hydroacoustic video survey for nearshore semi-pelagic rockfish. In Review.

In the present study, our goal was to estimate the influence of the dead zone on the joint acoustic-visual survey designed to provide a population estimate for three semi-pelagic species – Black, Blue (*Sebastes mystinus*), and Deacon Rockfish *(Sebastes diaconus*). We investigated whether demersal rockfish affected the acoustic data and, if so, whether population estimates for semi-pelagic species needed to account for the presence of demersals when apportioning backscattering data. To answer these questions, we compared acoustic swath data and point estimates from our suspended camera with collocated benthic-oriented video data from remotely operated vehicle (ROV) belt transects that were conducted immediately following the acoustic sampling. The resulting data was used to address five questions: 1) Did the different tools (ROV versus suspended camera) provide similar size distribution estimates; 2) Was our sequential sampling approach successful in detecting spatially consistent concentrations of fish across the reef, 3) Within the acoustic dead zone directly below schools, did the ROV and suspended camera estimate similar species composition and abundance; 4) In areas away from schools, what was the background density of near bottom fish; and 5) How do population estimates for each species differ when estimated from the ROV versus the combined video-hydroacoustic tool?

In this study we set out to determine if the dead zone made an acoustic survey for Oregon's nearshore semi-pelagic rockfish infeasible. To address the question, we paired hydroacoustic and underwater video sampling with ROV video sampling to determine the relative contribution of the dead zone. We first had to assess whether the observations from each tool were similar to one another. In general, we found that there was good spatial coherence in the observations between our two tools, and the densities of observed fish, viewed at the sub-transect scale, were well correlated for the schooling semi-pelagic fish species that were the primary study targets. Further, the length distributions of our target species/species groups differ minimally between the tools and there was little evidence of size selectivity between tools (Kotwicki *et al.*, 2017). Based on these findings, we conclude that by combining these two survey methods we were able to accurately assess the relative importance of fish in the dead zone to an acoustic-based abundance estimate for nearshore semi-pelagic rockfish and support the utility of a combined video-hydroacoustic survey.

While these methods are specifically designed for nearshore species, they can easily be adapted to work with semi-pelagic, shelf rockfish stocks. Our work demonstrates that the dead zone does not negatively affect the ability of the tool to sample our target species/species groups. Our 1 m near bottom exclusion zone enhances the utility of the tool by reducing the number of species we observe. Ultimately this ensures the acoustic density estimate is primarily for target semi-pelagic rockfish and not contaminated by demersal rockfish. Furthermore, targeting fish schools with an easily deployable stereo video system provides an accurate estimate of species composition and length data. In an area where the visibility is characteristically bad, the ability to first identify large schools with hydroacoustic equipment, then deploy cameras directly into these schools, greatly increases the chance of collecting data. In short, we find that the combination of acoustics and suspended cameras are an effective survey tool for semi-pelagic rockfish.

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Statewide Semi-Pelagic Rockfish Survey. Ongoing.

The survey began on August 1, 2021 at the mouth of the Columbia river and progressed southwards. Transects were sampled systematically towards the California border until Cape Blanco at which point transects were sampled in a somewhat random order. This was to allow the vessel to continue to operate in inclement conditions. The survey was completed on October 9, 2021. Small boat operations were conducted in the nearshore on September 11 and October 7-9.

During the survey, from the Columbia River to approximately Heceta Head, low oxygen conditions were observed and appeared to affect fish behavior. In response, additional funds were added to the contract and the section of the survey from Three Arch Rocks to Waldport was resampled from October 17 through November 29, 2021. Hereafter we call this Pass 2 and the data collected from August 1-October 9, Pass 1. During Pass 2, winter conditions were present so survey days were more infrequent than during Pass 1. Further, the Dungeness crab season began on December 1, 2021.

For every full transect, CTD casts were conducted at water depth of 80, 60, 40, and 20 m. A final station was conducted at the shallowest end of the transect. Additional CTD casts were conducted haphazardly throughout the survey to inform speed of sound calculations.

Thirty-seven full transects and 287 rock transects were conducted on pass 1 using the Pacific Surveyor accounting for a total of 3570 km of data collected. 27 transect were conducted on pass 1 using the Arima accounting. Five hundred seven video drops were conducted on Pass 1 and 71 were conducted on Pass 2. Due to the paucity of fish schools on Pass 1, only 48 fishing stations were conducted on pass 1 and 7 on Pass 2. Eight hundred and seven fish were caught during these fishing stations.

These data are in the process of being analyzed and will be presented for a methodology review to the PFMC Scientific and Statistical Committee in the fall of 2022.

Contact: Leif Rasmuson (leif.k.rasmuson@odfw.oregon.gov)

Where are old female Black Rockfish? Ongoing.

During the last stock assessment, scientists showed that the proportion of female black rockfish observed in fisheries catch data starts declining as fish reach ~10 years in age (17 in.). By age 20, the catch is almost entirely males. This begs the following questions. Do large older females die before they reach older ages, and therefore we don't catch them? Alternatively, if older female black rockfish exist, are we not catching them because we use the wrong gear or are we looking in the wrong spot? Knowing if the number of old female black rockfish is truly just a low number or if the catch data is not representing the population is very important. We use these data to determine reproductive output of the population.

We sent out a written survey to the recreational and commercial fleets to determine if they have any hypotheses where these individuals may be. Questions included:

1) Do you think the older female black rockfish are dead or we just don't catch them (Circle one)?
2) If they aren't dead, do you think common current gear can catch old female black rockfish (Circle one)?
3) What is the best gear that could be used?
4) Do the recreational power boat and commercial nearshore fisheries not commonly

operate where old female black rockfish live (Circle one)?
5) If your goal is to fish for old female black rockfish, where would you fish?
6) Do you have any other idea why we don't see them in our catch data?

These data are in the process of being analyzed and next steps will be determined based on the results.

Contact: Leif Rasmuson (leif.k.rasmuson@odfw.oregon.gov)

Inter-Reef Movement of Yelloweye Rockfish. Ongoing.

Yelloweye Rockfish (*Sebastes ruberrimus)*, continue to constrain catch of multiple healthy shelf stocks. One tool that has been used to manage the take of Yelloweye Rockfish is spatial area management through the establishment of places like Yelloweye Rockfish Conservation Areas. A key aspect of effective spatial fisheries management is an understanding of population connectivity. Highly migratory species ultimately may not receive as much protection from spatial closures if they migrate out of closed areas into fished areas. While many rockfish species characteristically have small home ranges making them effective candidates for spatial fisheries management, more data are needed for Yelloweye Rockfish. To answer this question, the ODFW Marine Fisheries Research Project used standard acoustic telemetry techniques, tagged Yelloweye Rockfish in 2005, 2012 and 2013 to understand home range size (Rankin 2019). In all of these studies, the researchers found that some Yelloweye remained in the acoustic array at Stonewall Bank and had a small home range while others left only to return 6+ months later. They also found that some individuals moved up into the water column for a few hours each day before descending back to the bottom. The goal of the proposed project is to understand 1) where do these other Yelloweye Rockfish travel 2) to ascertain if only certain sexes or sizes of fish make these perceived large-scale movements and 3) understand the daily movement dynamics of the species.

While standard acoustic telemetry methods often work well for species with small home ranges, they are not effective for species that make large movements. Further, standard passive tags aren't effective when a species is not actively targeted in fisheries. Pop-up satellite tags are an effective tool for this kind of study and have been proven to be effective at monitoring the movement of rockfish (Rodgveller et al. 2017). We propose to use a chartered fishing boat (paid for with dedicated research funds) to collect Yelloweye Rockfish at Stonewall Bank using hook and line gear. A small fin clip will be collected from the fish to provide both population genetics and sex data. These fish will then be recompressed in barrels for 24 hours on the seafloor. Doing so minimizes the effects of barotrauma on the fish during subsequent tagging. After 24 hours the fish will be recovered, tagged with Desert Star SeaTag-GEO tags and released. Tags will be set to release after 6 months, at which point they broadcast their data to a satellite and back to the office. When tags indicate they have popped off the fish, we will also go out on a boat and attempt to recover the tag using a directional listening device in order to hopefully obtain the much higher resolution data only located on the tag. Regardless which data we use, these data will provide, at minimum, location data where the tag popped off (ideally more) and extensive data on the daily movement dynamics of the fish. These data will provide insight into the inter-reef movement of this important constraining species as well as insight into the daily behavior of the species.

The tags for this project have been purchased. There were delays in tag delivery so work in 2022 will be to deploy these tags. We will also be attaching standard acoustic telemetry tags (VEMCO) to each fish. A few haphazard moorings will be deployed near the release site. We will use these data along with local magnetic field maps to reduce the assumed geomagnetic error of our satellite tags.

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Susceptibility of five species of rockfish to hydroacoustic and bottom trawl survey gears inferred from high resolution behavioral data. Published.

Fisheries independent surveys are an important data input for stock assessments. However, these surveys are expensive to conduct and require precise, well thought out planning to be effective. Although the amount of money allocated to a survey is often dictated by factors beyond the control of the survey development team, surveys must incorporate their understanding of the biology of the focal species or species group into the survey design. Acoustic telemetry data can provide a high-resolution dataset to answer some of these questions. In this study, we reanalyze past acoustic telemetry studies on Black Rockfish (*Sebastes melanops)*, Copper Rockfish (*Sebastes caurinus*), Deacon Rockfish (*Sebastes diaconus*), Quillback Rockfish (*Sebastes maliger*) and Yelloweye Rockfish (*Sebastes ruberrimus*) in order to apply these data to future survey development. We combined the telemetry data with multibeam bathymetry data to 1) understand how the height off bottom of each species changed throughout the day and 2) simply define the habitat utilized by each species. We found, on average, Black, Deacon and Yelloweye Rockfish were all more than 1 m off bottom, whereas Copper and Quillback remained on, or near the bottom throughout the day. Deacon Rockfish were associated with the most rugose bottom, followed by Yelloweye. Black, Copper and Quillback all utilized low relief habitats. In general, we hypothesize that Black and Deacon Rockfish are good candidates for survey by hydroacoustics, whereas, Copper and Quillback appear to be good candidates for survey by bottom trawl. Surprisingly, due to the habitat they reside in, Yelloweye Rockfish were available to hydroacoustics, and likely not available to bottom trawl. However, Yelloweye Rockfish have variable behaviors, as reported by the original work, and as such, we are wary to suggest that hydroacoustics are an appropriate survey tool. We do, however, propose that Yelloweye potentially contribute to backscattering values of acoustic surveys conducted for midwater rockfish, and that bottom trawls are likely not an effective survey tool for Yelloweye Rockfish.

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Assessment

ODFW staff participated on three STATs for Copper, Quillback and Vermilion rockfish federal stock assessments during 2021. Staff provided data, consulted with lead assessors on modeling decisions, and developed and ran models for all three assessments. ODFW assisted with assessment documentation and participation in the Stock Assessment Review (STAR) panels for these species in 2021 as full co-authors on each of these assessments (Wetzel et al. 2021; Langseth et al. 2021; Cope and Whitman 2021).

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Management

Federal Nearshore Management Activities

During the April 2021 meeting, the PFMC began scoping changes to the non-trawl rockfish conservation area (RCA) and other spatial management measures in the non-trawl groundfish sectors on the West Coast. Established in 2003 to mitigate impacts to overfished groundfish species, the non-trawl RCA is a coastwide, contiguous area bounded by coordinates that approximate depth contours. All of the overfished groundfish species except Yelloweye Rockfish have been rebuilt and Yelloweye Rockfish is projected to rebuild by 2029. In November 2021, the PFMC adopted a revised statement of purpose and need for action modifying area management measures and prioritized consideration of allowing non-bottom-contact hook and line gear in the existing non-trawl RCA off Oregon and California to provide access to abundant midwater rockfish stocks. The PFMC is also considering narrowing the non-trawl RCA by adjusting the seaward boundaries, eliminating the RCA, and/or modifying the Cowcod Conservation Area off California. More information on non-trawl area management is available on the PFMC website here.

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Fixed-Gear Nearshore Commercial Fishery

Nearshore rockfish compose the majority of landings in the commercial nearshore fishery. In Oregon, this fishery became a limited-entry permit-based program in 2004, following the rapid development of the open access nearshore fishery in the late 1990's. The commercial nearshore fishery exclusively targets groundfish with separate management groups for Black Rockfish, Blue and Deacon Rockfish, Cabezon, Kelp Greenling, and Oregon's "Other Nearshore Rockfish" complex. The fishery is primarily composed of small vessels (25 ft. average) fishing in waters less than 30 fathoms. Fishing occurs mainly with hook and line jig and bottom longline gear types. The majority of active permit holders are located on the southern Oregon coast, resulting in most of the catch landed in Port Orford, Gold Beach and Brookings. Black Rockfish continue to comprise the majority of landings. The fishery supplies mainly live fish markets, but also provides fresh fish products.

Landings are regulated through bimonthly trip limits, minimum size limits, and annual harvest guidelines (HG). In 2021, landings from commercial nearshore fishing, logbook compliance, economic data, and biological data were published in the 2020 Commercial Nearshore Fishery Data Update (Rodomsky and Matteson 2021). Weekly updates on landings and model projections allow MRP staff to effectively manage the fishery in-season. In 2021, overall effort (number of fishing trips) was close to the historical average until July, after which the fishery slowed, and effort dropped to a new historical minimum by mid-August where it remained through the rest of the year. Black Rockfish landings generally followed the trend in effort, although it remained above the historical minimum. In response, period 5 and period 6 trip limits for Black Rockfish were increased from 1,800 and 1,500 pounds per period respectively to 2,700 pounds per period in both periods to maximize opportunity and HG attainment. Blue and Deacon rockfish landings were above the historical average but did not approach the HG. Blue and Deacon Rockfish trip limits were not adjusted up as they do not limit landings. Other Nearshore Rockfish landings remained near the historical average throughout most of 2021, and trip limits were not adjusted. End of the year attainment of the state HGs was 82% for Black Rockfish, 80% for Other Nearshore Rockfish, and 37% for Blue and Deacon Rockfish. For Cabezon and Greenling management specifics see the Other Groundfish section.

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Federal Non-nearshore Commercial Fishery

Before 2021, during the harvest specifications cycle, trip limits were increased in both the limited entry fixed gear and open access fisheries north of 40 10' N lat. Limited entry fixed gear (LEFG) limits of minor slope rockfish and Darkblotched Rockfish were raised from 4,000 pounds to 8,000 pounds per two months, of which no more than 6,000 pounds may be Blackgill Rockfish. LEFG limits of minor shelf rockfish, Shortbelly and Widow Rockfish were separated and Widow rockfish limits increased to 4,000 pounds per two months, shelf rockfish to 800 pounds per month and 200 pounds of Shortbelly Rockfish per month, from 200 pounds per month combined. The Yellowtail Rockfish limit in the LEFG program was increased from 1,000 to 3,000 pounds per month. The Canary Rockfish LEFG limit was increased from 300 pounds to 3,000 pounds every 2 months.

Open access (OA) trip limits were also increased for many species. Minor slope rockfish and Darkblotched Rockfish increased from 500 pounds to 2,000 lbs per month. OA trip limits increased minor shelf rockfish and separated the Shortbelly, shelf and Widow Rockfish. Window Rockfish increased from 200 pounds to 2,000 pounds per two months, shelf rockfish increased to 800 pounds per month and Shortbelly Rockfish has a limit of 200 pounds per month. Yellowtail and Canary Rockfish also increased, from 500 to 1,500 pounds per month for Yellowtail and an increase to 1,000 lbs from 300 pounds every two months for Canary. These trip limit adjustments do not change the projected impacts compared to impacts evaluated in the PFMC's 2019-2020 groundfish harvest specifications analysis, because that analysis assumed the entire annual catch limit (ACL) would be harvested whereas the projected impacts are still below the ACL, even with the increased trip limits.

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Recreational Fishery

Black rockfish (*Sebastes melanops*) remains the dominant species caught in the recreational ocean boat fishery. The Black Rockfish federal harvest limit remained the same in 2021 as in 2020. With Blue and Deacon Rockfish taken out of the nearshore rockfish complex beginning in 2019, the harvest guideline for that complex was greatly reduced. The retention of Yelloweye Rockfish (*S. ruberrimus*) was prohibited year-round, as it has been since the early 2000s. To remain within the Yelloweye Rockfish impact cap (via discard mortality), the recreational groundfish fishery was restricted pre-season to inside of 40 fathoms from June 1 to August 31. Black rockfish and nearshore rockfish species have become as much of a limiting factor as yelloweye rockfish. The fishery season structure and regulations, such as daily bag limits (with species specific sub-bag limits) and depth restrictions, attempted to balance impacts, as what reduces impacts on one species may increase impacts to the other. Even with those efforts the nearshore rockfish complex harvest guideline was reached in late May, after which time ODFW required anglers to release those species. 2021 was another high effort year, continuing the trend of approximately 100,000 angler trips per year that began in 2015.

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Outreach

ODFW staff did have to reduce in person outreach activities again in 2021 due to COVID restrictions and safety protocols. However, we continued to work with anglers via webinars, conference calls, and online materials.

To reduce bycatch mortality of overfished rockfish species in the sport fisheries, ODFW began an outreach campaign in 2013 with the goal of increasing descending device usage among sport anglers. The effort, branded "No Floaters: Release At-Depth", has distributed over 17,000 descending devices to date, to all charter vessel owners and to the majority of sport boat owners who had previously targeted groundfish or halibut. ODFW staff have also participated in a number of angler education workshops, meetings, and shows to educate anglers and distribute devices. In addition, several thousand stickers and a few hundred hats bearing an emblem of the brand have been distributed with the goal of making rockfish conservation an innate aspect of fishing culture.

This outreach and education campaign continues to be successful. Prior to the campaign, fewer than 40 percent of anglers reported using descending devices. Since the campaign began, the percentage of anglers reporting use increased to greater than 80 percent. To further increase usage, anglers requested that ODFW make descending devices mandatory for any vessel fishing the ocean for bottomfish or halibut. This regulation went into place beginning January 1, 2017, and increased the angler reported usage rates to approximately 95 percent in most ports and months. Additional outreach efforts include: videos online that show fish successfully swimming away after release with a device, rockfish barotrauma flyers, and videos on how to use the various descending devices. This outreach campaign has been the result of collaboration between ODFW, two angler groups (Oregon Coalition for Educating Anglers and Oregon Angler Research Society), Utah's Hogle Zoo, ODFW's Restoration and Enhancement (R & E) program, and the National Marine Fisheries Service Saltwater Recreational Policy. ODFW staff are planning to continue the outreach and education efforts in the future.

Additionally, ODFW has been educating anglers on a relatively new opportunity to use what is termed "longleader gear" to target underutilized midwater rockfish species such as Yellowtail (*S. flavidus*) and Widow (*S. entomales*), while avoiding more benthic species such as Yelloweye rockfish. The longleader gear requires a minimum of 30 feet between the weight and the lowest hook, along with a non-compressible bloat above the hooks, to keep the line vertical in the water column. ODFW has produced informational handouts with the gear specifics, species allowed, and other associated regulations.

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Thornyheads

Nothing to report in 2021.

Sablefish

Management

Sablefish is the most economically valuable species in the West Coast bottom trawl and fixed gear fisheries. Sablefish prices were depressed due to market saturation before COVID-19, and market perturbations caused by the pandemic are leading to even more disruption. In 2021, the PFMC recommended, and NMFS implemented an emergency rule to temporarily allow an extension in the primary sablefish tier fishery from October 31 to December 31, 2021. However, this action did not apply to pot gear until December 10th. The 2021 emergency rule suspended the permit stacking limit and allowed for multiple permit transfers (§86 FR 59873), meaning that pot-endorsed permits could be used by longline vessels to attain up to the limits associated with stacked permits up until December 10th.

The PFMC is continuing to consider changes to the "gear-switching" provision of the trawl individual fishing quota (IFQ) program which allows the use of non-trawl gear to harvest trawl IFQ. In September 2021, the PFMC adopted a range of alternatives that would limit gear switching by several different approaches, and is expected to refine these alternatives and provide guidance for further analysis in June 2022. The gear-switching issue arose during the first 5-year review of the trawl IFQ program and is centered on concerns by trawl fishermen that fixed gear participation has led to higher sablefish quota lease rates and reduced their ability to catch co-occurring stocks. Gear-switching participants are concerned that limits adopted now could undermine significant investments already made to fish in the IFQ fishery with non-trawl gear, under a legal provision of the program. More information on gear-switching is available on the PFMC website here.

The PFMC is also conducting a periodic review of the Limited Entry Fixed Gear Permit Stacking Program. In March 2022, the PFMC recommended including research and data needs recommended by its advisory bodies in the draft review document and seeking public review on the final draft. In addition, the PFMC initiated development of a cost recovery program for this fishery as required by the Magnuson-Stevens Fishery Conservation and Management Act.

An introductory workshop on a Management Strategy Evaluation (MSE) process for sablefish was held April 27-28, 2021 (https://www.pcouncil.org/events/sablefish-management-strategy-evaluation-workshop-to-be-held-online-april-27-28-2021/). The purpose was to engage stakeholders and tribal nations from Alaska, Canada and the West coast to start a dialogue among regions about sablefish science and management.

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Lingcod

Assessment

ODFW staff participated in the STAT for the federal Lingcod (*Ophiodon elongates*) stock assessment and a full co-author on the assessment for the northern lingcod stock (Taylor et al. 2021). Staff provided data, advice on modeling decisions and contributed analyses to the final assessment. Additionally, ODFW staff provided substantial coordination and logistical support to aging efforts for lingcod in both 2020 and 2021. Commercial lingcod samples were aged at WDFW in 2020, and recreational lingcod samples were mounted and sent to NWFSC for aging in late 2020 and 2021. ODFW staff also participated in the STAR panel review for the two lingcod assessments in the summer of 2021.

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Management

Commercial Fishery

Trip limits were increased for Lingcod in both the limited entry fixed gear and open access fisheries North of 40 10′ N latitude. In the limited entry fleet, trip limits were increased from 2,000 to 4,000 pounds every two months. In the open access fleet, trip limits were increased from 900 pounds to 2,000 pounds per month. In 2021, the commercial fleets in Oregon landed 321.8 metric tons of Lingcod, down from 397.1 mt in 2019, likely due to continuing market limits and other factors related to the COVID-19 pandemic.

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Recreational Fishery

Lingcod is a popular target in the Oregon recreational bottomfish fishery. Many anglers especially like to target Lingcod during the months when the fishery is open to all-depths, as larger Lingcod are thought to occur in deeper offshore waters. Lingcod have their own daily bag limit (2 per angler per day), separate from the other bottomfish. There is also a minimum size limit of 22 inches. In 2021, anglers landed just over 48,000 lingcod, totaling 145 mt.

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Atka Mackerel

Nothing to report in 2021.

Pacific Halibut

Management

Oregon's recreational fishery for Pacific Halibut (*Hippoglotus stenolepis*) continues to be a popular, high-profile fishery requiring International Pacific Halibut Commission (IPHC), federal, and state technical and management considerations. In 2021, the IPHC recommended an annual catch limit for Area 2A (Oregon, Washington, and California) of 1.5 million pounds which the IPHC Commissioners indicated would be in place for four years, 2019-2022. The recreational fishery for Pacific Halibut is managed under three subareas with a combination of all-depth and nearshore quotas. In 2021, the Columbia River subarea quota was 18,662 pounds, the Central coast subarea quota was 274,403 pounds, and the Southern coast subarea quota, was 8,000 pounds. Landings in the sport Pacific Halibut fisheries are monitored weekly for tracking landings versus catch limits. The majority of Halibut continue to be landed in the central coast subarea, with the greatest landings in Newport followed by Garibaldi or Pacific City. Total 2021 recreational landings in the Central coast subarea were 123,005 pounds, 45 percent of the quota. Landings in the Southern subarea were 5,699 pounds (71% of the quota) and in the Columbia River subarea, landings were 21,480 pounds (115 %). Fishing in the Central Coast Subarea was restricted by weather for part of May, June, and many anglers switched to coho salmon fishing in July-September, as it was one of the best coho salmon season in many years. The Columbia River Subarea was able to open as scheduled in early May with good catches. The subarea was allowed to exceed its allocation due to there being additional quota available from other Washington subareas. Anglers reported a lot of small fish, in the 26-30 inch size range, many of which were released at sea. The average size of landed fish in 2021 was up by approximately 1/2 pounds net weight from 2020. This low average size was a contributor to the low quota attainment, as there were more fish landed in 2021 than in previous years, just less poundage.

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Other Groundfish

Kelp Greenling

Management – Commercial Fishery

The commercial Kelp Greenling HG for 2021 was 108.0 metric tons. Greenling are targeted by very few commercial fishers despite the relatively high HG and price per pound paid for live fish. The bimonthly trip limit in 2021 was 1,000 pounds per period set after considering public input, markets, and local depletion concerns. Greenling landings ended the year at 9% of the HG attained. Barring changes in targeted effort catch rates and markets, Greenling attainment is likely to continue to remain low.

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Cabezon

Management – Commercial Fishery

The commercial HG for Cabezon increased from 30.2 metric tons in 2020 to 35.0 metric tons in 2021 based on a new stock assessment. Cabezon landings ran close to the historical average through most of the year but were projected to come in well below the HG. To increase opportunity and attainment, ODFW increased the bimonthly trip limit from 1,500 pounds per period to 2,000 pounds for periods 5 and 6, after which landings did increase above average. Final commercial fishery attainment was 79% after in-season adjustments.

Contact: Troy Buell (troy.v.buell@odfw.oregon.gov)

Management – Recreational Fishery

Cabezon (*Scorpaenichthys marmoratus*) is another popular target for some recreational bottomfish anglers. Cabezon have a one-fish sub-bag limit as part of the general marine bag limit, and a 16 inch minimum size, additionally the season does not open until July 1. The Cabezon harvest guideline has remained relatively constant over the last ten years. Even with the average angler catching less than one per day, the quota normally goes very quickly. In each of the previous several years, the quota has been met in six weeks, at which time ODFW prohibited retention. However, in 2021, the season remained open through the end of the year. This was due to a combination of less summer effort on bottomfish due to the good Coho Salmon season and a large year class of Cabezon moving out of the fishery. Fishing is prohibited January through June as that is the time that Cabezon generally spawn and nest guard. Prohibiting fishing during those months, is intended to protect Cabezon during that time.

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Ecosystem Studies

Effectiveness of quantitative stereo landers during day and night. Ongoing.

The need to develop fisheries independent estimates of demersal fishes in Oregon remains an important need for ODFW. Stationary remote underwater vehicles (i.e. video landers) are being used for this purpose in multiple countries throughout the world as well as providing stock assessment data to at least four of the regional fisheries management councils. A key benefit of their use is their simplicity in deployment and retrieval which ultimately makes them an economically strategic tool for monetarily limited agencies. However, there remain ways for us to increase their efficiency. Chartering vessels is inherently costly and time investment to either 1) have a boat not work at night or 2) make runs back and forth to port is not cost effective. Therefore, being able to operate a vessel both during the day and night allows a vessel to be run more efficiently. However, if the species and number of fish detected differ significantly between day and night the results can have dramatic impacts on the development of an index.

Lander drops are being conducted at three regions: nearshore reef sites (Seal Rock or Siletz Reef), mid-shelf reef site (Stonewall Bank), and near-shelf break (Daisy Bank). At each region three grids of 100 drops were established over areas presumed to have a rocky substrate based on available multibeam data. Sample locations were selected that are >400 m apart. Beginning 5 hours before sunset the odd numbered drop locations were sampled until sunset. Following sunset sampling reversed back on the grid only sampling the even numbers. Two stereo lander systems are hop-scotched throughout the study area to increase efficiency. CTD casts equipped with a light meter are made haphazardly throughout the day to characterize the water column. Landers are left on the bottom for 15 minutes to record video. Videos are then scored for both MaxN and mean MaxN. Field work for this project is ongoing.

Contact: Leif Rasmuson (leif.k.rasmuson@odfw.oregon.gov)

Untrawlable habitat survey in partnership with Peter Frey (NWFSC), John Harms (NWFSC) and Kresimir Williams (AFSC). Ongoing.

Survey biologists with NOAA Fisheries in Seattle and Newport are interested in partnering with the commercial and sportfishing industries in the Pacific Northwest to improve stock assessments for Lingcod and shelf rockfish. We are planning to charter one commercial and one sportfishing vessel to conduct a study comparing the effectiveness of four different methods for collecting abundance and biological data for groundfish species found in rocky, high-relief habitats. The four methods are:

- Hook and line gear deployed by rod and reel
- Stereo video imagery from a small, stationary lander
- Stereo still camera imagery from a semi-moored housing
- Environmental DNA (eDNA) collected from water samples near the seafloor

The fieldwork was conducted in 2019 from late October –early November off the Oregon coast between Cascade Head and Heceta Bank in a depth range of 20 –125 fathoms and will target a variety of banks, reefs, and other rocky habitats. Results from this study will help determine the most effective and efficient gear to use in designing a larger, more comprehensive monitoring program for groundfish in the untrawlable habitats of the Pacific Northwest. Video review is ongoing.

ODFW Contact: Leif Rasmuson (leif.k.rasmuson@odfw.oregon.gov)

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Washington Department of Fish and Wildlife Contribution to the 2022 Meeting of the Technical Sub-Committee (TSC) of the Canada-U.S. Groundfish Committee: Reporting for the period from May 2021-April 2022

April 19th-20th, 2022

Edited by:
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April 2022

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I. AGENCY OVERVIEW

The Washington Department of Fish and Wildlife is divided into three major resource management Programs (Fish, Habitat, and Wildlife) and three major administrative support programs (Enforcement, Technology & Financial Management, and Capital & Asset Management). Within the Fish Program, research and management of marine fishes is housed within the Fish Management Division, which also oversees research and management of shellfish, warmwater species, and aquatic invasive species. Two primary work units deal with marine fish research within the Fish Management Division. The Toxics-focused Biological Observation System for the Salish Sea (TBiOS) (formerly Puget Sound Ecosystem Monitoring Program or PSEMP) conducts considerable marine forage fish and groundfish research in Puget Sound but focuses on the accumulation of toxic contaminants in these species. The unit is led by Jim West and also consists of Sandy O'Neill, Dr. Louisa Harding, Mariko Langness, and Rob Fisk. A second and larger work unit within the Fish Management Division is the Marine Fish Science (MFS) Unit, which itself is broadly separated into three groups that deal with distinct geographic regions and/or species assemblages (Puget Sound Groundfish, Marine Forage Fish, and Coastal Marine Fish), though there is some overlap of senior staff. The entire MFS Unit is overseen by Dr. Theresa Tsou, while Lisa Hillier oversees the Unit budget, manages the Washington Conservation Corps (WCC) survey group, and assists with stock assessments both on the coast and in Puget Sound. Kathryn "Kat" Meyer became the lead of the Puget Sound Groundfish Unit in July 2021; Phill Dionne leads statewide marine forage fish research and management; and until December 2021, Lorna Wargo was the lead for the Coastal Unit for groundfish, coastal pelagic species, and shrimp management, fishery monitoring, and research, but this position is now vacant.

Puget Sound Marine Fish Science (PSMFS) Unit ~ Groundfish

PSMFS Unit tasks are primarily supported by supplemental funds from the Washington State Legislature for the recovery of Puget Sound bottomfish populations, and secondarily by a suite of collaborative external grants. The main activities of the unit include the assessment of marine fish populations in Puget Sound, study of marine fish ecology and demography, evaluation of bottomfish in marine reserves and other fishery-restricted areas, and development of conservation plans for key species (and species groups) of interest. Groundfish in Puget Sound are managed under the auspices of the Puget Sound Groundfish Management Plan (Palsson, et al. 1998) and management has become increasingly sensitive to the ESA-listing of Yelloweye Rockfish and Bocaccio in the Puget Sound/Georgia Basin DPS since 2010 (National Marine Fisheries Service 2010)[1].

In addition to Ms. Meyer, staff of the PSMFS Unit during the reporting period included Robert Pacunski, Larry LeClair, Jennifer Blaine, Andrea Hennings, Mark Millard, Ian Craick, and Katie Kennedy. Ms. Meyer also serves as the Washington State representative on the Scientific and Statistical Committee (SSC) of the North Pacific Fishery Management Council (NPFMC), and members of the PSMFS Unit are occasionally called upon to assist with evaluation of documents

[1] Canary Rockfish were also listed in 2010 but were delisted in 2017 based on more recent genetic studies showing no difference between PSGB and coastal populations.

pertinent to fisheries in federal waters off Alaska. In 2018 Lisa Hillier was added to the NPFMC Groundfish Plan Teams for both the Bering Sea and Gulf of Alaska.

Marine Forage Fish (MFF) Unit

Forage fish in Washington are managed under the auspices of the Forage Fish Management Plan (Bargmann 1998) and managed by members of the statewide Marine Forage Fish (MFF) Unit, which works primarily in Puget Sound. Together with Phill Dionne, the MFF Unit is composed of Dr. Todd Sandell, Erin Jaco, Emily Seubert, Patrick Biondo (until February 2022), Adam Lindquist (until August 2021), and Kate Olson. During herring spawning season, the unit receives staff support from members of the Intertidal Shellfish Unit as needed (i.e., the "loan" of four staff at approximately half time for four months).

Primary Contacts – Puget Sound, Forage Fish, and TBiOS:
Groundfish Monitoring, Research, and Assessment

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- *Robert (Bob) Pacunski: 425-379-2314, robert.pacunski@dfw.wa.gov*

Forage Fish Stock Assessment and Research

- *Phill Dionne: 360-902-2641, phillip.dionne@dfw.wa.gov;*
- *Dr. Todd Sandell: 425- 379-2310, todd.sandell@dfw.wa.gov.*

Toxics-focused Biological Observation System for the Salish Sea (TBiOS) (formerly Puget Sound Ecosystem Monitoring Program or PSEMP)

- *Jim West: 360-902-2842, james.west@dfw.wa.gov.*

For complete staff contact information see section IX of this report.

Coastal Marine Fish Science (CMFS) Unit

In addition to Lorna Wargo, three port samplers (Jamie Fuller, Nathan Layman, Timothy Zepplin), and an IT support staff (Eric Mock) all left their positions during the reporting period in the highest staff turnover the Coastal Marine Fish Science (CMFS) Unit has experienced in 20 years. The remaining staff of the CMFS Unit include Rob Davis, Donna Downs, Kristen Hinton, and Michael Sinclair. Two technicians from the PSMFS Unit, Ian Craick and Katie Kennedy, are temporarily assuming some port sampling duties for 2021 while vacant positions are filled. CMFS Unit tasks are supported through a combination of state general and federal funds. Long-standing activities of the unit include the assessment of groundfish populations off the Washington coast, the monitoring of groundfish commercial and recreational landings, coastal rockfish research projects, and the monitoring and management of ocean pink shrimp. In the last two years, the coastal unit has expanded to also include the monitoring and management of coastal pelagic species (CPS), including finfish and squid species, through collaborative research projects with federal and industry partners.

Groundfish and CPS on the Washington coast are subject to state regulatory and policy authority as well as to federal management under the Magnuson-Stevens Fishery Conservation and Management

Act and the PFMC's fishery management plans for groundfish and CPS. The Department's Forage Fish Management Plan also guides management of coastal fishery resources in state waters. The MFS Unit contributes fishery policy and scientific support for federal West Coast groundfish and CPS management via participation on the Coastal Pelagic Species Management Team (CPSMT, Lorna Wargo) and the Scientific and Statistical Committee (SSC, Dr. Theresa Tsou), of the Pacific Fishery Management Council (PFMC). Landings and fishery management descriptions for PFMC are summarized annually in the Stock Assessment and Fishery Evaluation (SAFE) documents.

Additional West Coast fishery management support is provided by the Intergovernmental Ocean Policy Unit, which consists of a currently vacant lead (previously Michele Culver), Corey Niles, Heather Hall, Whitney Roberts, and Victoria Knorr. Whitney also serves on the PFMC's Groundfish Management Team (GMT), as does Erica Crust of the Fish Program's Ocean Sampling Program. Further support is provided to the PFMC by Randi Thurston, who serves on the Habitat Committee.

Primary Contacts – Coastal MFS Unit:

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- *Corey Niles: 360-902-2733, corey.niles@dfw.wa.gov (Coastal Marine Policy Lead).*

Coastal Pelagic Species /Forage Fish Management, Monitoring, Research, and Assessment

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For complete staff contact information see section IX of this report.

II. SURVEYS

A. Puget Sound Bottom Trawl

Brief Survey History, Design, Methodology

Since 1987, the Washington Department of Fish and Wildlife (WDFW) has conducted bottom trawl surveys in Puget Sound – defined as all marine waters of the State of Washington east of the mouth of the Sekiu River in the Strait of Juan de Fuca – that have provided invaluable long-term, fisheries-independent indicators of population abundance for benthic organisms living on low-relief, unconsolidated habitats. These surveys have been conducted at irregular intervals and at different geographic scales since their initiation (Quinnell et al. 1991; Quinnell et al. 1993; Palsson et al. 1998; Palsson et al. 2002; Palsson et al. 2003). Surveys in 1987, 1989, and 1991 were semi-stratified random surveys of the majority of Puget Sound. From 1994-1997 and 2000-2007, surveys were annual, stratified-random surveys focusing on individual sub-basins (WDFW unpublished data; Palsson et al. 1998; Blaine et al. 2020). Starting in 2008, surveys became synoptic again, sampling annually at fixed index sites throughout Puget Sound (Blaine et al., in prep).

The specific objectives of the annual index trawl survey are to estimate the relative abundance, species composition, and biological characteristics of bottomfish species at pre-selected, permanent index stations. Key species of interest include Pacific Cod, Walleye Pollock, Pacific Hake, English Sole, North Pacific Spiny Dogfish, and all species of skates; however, all species of fishes and invertebrates are identified to the lowest taxonomic level practicable, weighed, and recorded. For key species, size distribution data and various biological samples are collected from a subset of individuals from each sampling location. For the index survey, the study area is subdivided into eight regions (eastern Strait of Juan de Fuca, western Strait of Juan de Fuca, San Juan Islands, Georgia Basin, Whidbey Island sub-basin, Central Puget Sound, Hood Canal, and South Puget Sound) and four depth strata ("S"= 5-20 fa, "T"= 21-40 fa, "U"= 41-60 fa, "V"= >60 fa). A total of 51 fixed index stations throughout the study area are sampled each spring (late April-early June) (Figure 1).

Index stations were originally selected from trawl stations sampled during previous survey efforts at randomized locations throughout Puget Sound. Station selection was based on known trawlability and other logistical concerns, and was informed by previously obtained biological data. Stations are named using a four-letter system with the first two letters designating the region, the third letter indicating the sub-region or position within the region (north, south, middle, east, west), and the final letter designating the depth stratum. The index stations have remained relatively consistent since 2008, with a few exceptions: starting in 2009, 5 stations were added to make the current 51-station design; in 2012 and 2013, stations in the shallowest stratum (S) were not surveyed because of concerns from NOAA about impacts to juvenile salmonids; in 2014 and 2015, stations JEWU and CSNV were moved slightly to accommodate concerns raised by fiber-optic cable companies; and in 2020, the survey was unable to be executed due to the COVID-19 pandemic.

The trawling procedure of the survey has remained largely consistent throughout the historical survey period and complete details can be found in Blaine et al. (2016). The 57-foot *F/V Chasina* is the chartered sampling vessel, and it is equipped with an agency-owned 400-mesh Eastern bottom trawl fitted with a 1.25-inch codend liner. The net is towed at each station for a distance of ~0.40 nautical miles at a speed of 1-3 knots, and the tows last approximately 11 minutes. The resulting catch is identified to the lowest taxonomic level possible, weighed, counted, and most of the catch is returned to the sea. The density of fish at each station is determined by dividing the catch numbers or weight by the area sampled with the net, which is based on a mensuration study conducted in 1994 (WDFW unpublished data). A small portion of the catch is retained for biological sampling, either when fresh on deck or after being preserved (freezing, ethyl alcohol, or formalin) for processing in the laboratory. Samples collected may include: fin clips (genetics); scales, spines, and otoliths (ageing); stomachs and intestines (gut contents); and muscle tissue (stable isotopes). When necessary, whole specimens may also be retained for positive identification or special projects being conducted by the WDFW or its collaborators.

From 2008 to 2013, two trawl samples were collected at each station and were spaced several hundred meters apart to be close to each other but not directly overlapping. However, based on the similarity of catches in these paired tows at most stations, and in the interest of minimizing bottomfish mortality associated with the trawl survey, the protocol was altered in 2014. After the first tow is completed, the processed catch is compared to the average catch at that station since 2008. If the species comprising the majority (>75% by weight) of the catch fall within the previous years' average (+/- standard deviation), no second tow is conducted at that station. If it is determined that the species composition was substantially different than expected, a second tow is conducted. This greatly improves the efficiency of the survey, as an average of only 4 stations have required a second tow each year. This newly gained efficiency has allowed institution of a new sampling program, conducting vertical plankton tows, to assess primary prey availability. In 2014 bottom-contact sensors were also added to the footrope to improve understanding of net performance and increase the accuracy of density estimates from the trawl, and a mini-CTD was deployed on the headrope to collect water quality data at each station and provide more accurate depth readings. The first mini-CTD (Valeport) was used until ~2017, but a new model (Star-Oddi) was deployed in 2021. In 2017, a Marport Trawl Explorer was also attached to the headrope to provide a live data feed regarding the net's depth, proximity to the bottom, and opening height.

2021 Survey Results

The WDFW conducted the 13th annual index trawl survey of Puget Sound from April 19 through May 13, 2021. Total vessel time was split between the Marine Fish Science (MFS) Unit (this reporting group) and the Toxics-focused Biological Observation System (TBiOS) group, which conducts their bottom trawl survey biennially and samples separate stations. Due to the ongoing COVID-19 concerns and safety precautions, rather than trade the vessel every few days between the groups per usual, the MFS unit conducted their survey in entirety first, after which TBiOS conducted their survey. During the 16 survey days allocated to the MFS Unit, all 51 index stations were occupied, and a total of 52 index bottom trawls were conducted, as one station required a second tow.

All Fish

An estimated 53,092 individual fish belonging to 80 species or taxa and weighing 8.6 mt were caught during the survey. Overall, the total estimated bottomfish biomass and abundance for Puget Sound was 89,852 mt and 577.9 million individuals, respectively. Compared to the estimates from the 2019 survey (125,670 mt; 550.6 million individuals), the biomass decreased while the abundance increased, which was the opposite pattern observed between 2018-2019 (Figure 2). Among the regions, Central Sound (CS) again supported the highest densities of bottomfish at 305 kg/ha and 1,851 fish/ha, substantially greater than those from any other region (Figure 3); however, these estimates were notably lower than in 2019 (571 kg/ha and 1,984 fish/ha) due to a decrease in Spotted Ratfish and, to a lesser extent, Codfishes (Gadiformes) found in the region. The Western Strait of Juan de Fuca (JW) had the second highest biomass density (166 kg/ha), while Whidbey Island (WI) supported the second highest population density (1,176 fish/ha), which was nearly double the density from 2019 due to increases in Roughback Sculpins, Shiner and Pile Perches, Blackbelly Eelpout, and a variety of flatfishes. The decline in biomass in CS was the largest decrease among regions between 2019 and 2021 at -46%, while abundance estimates in HC, JW, and WI all increased over 50% (57%, 62%, and 72%, respectively). Among the regions, biomass and abundance estimates both increased in only HC and WI.

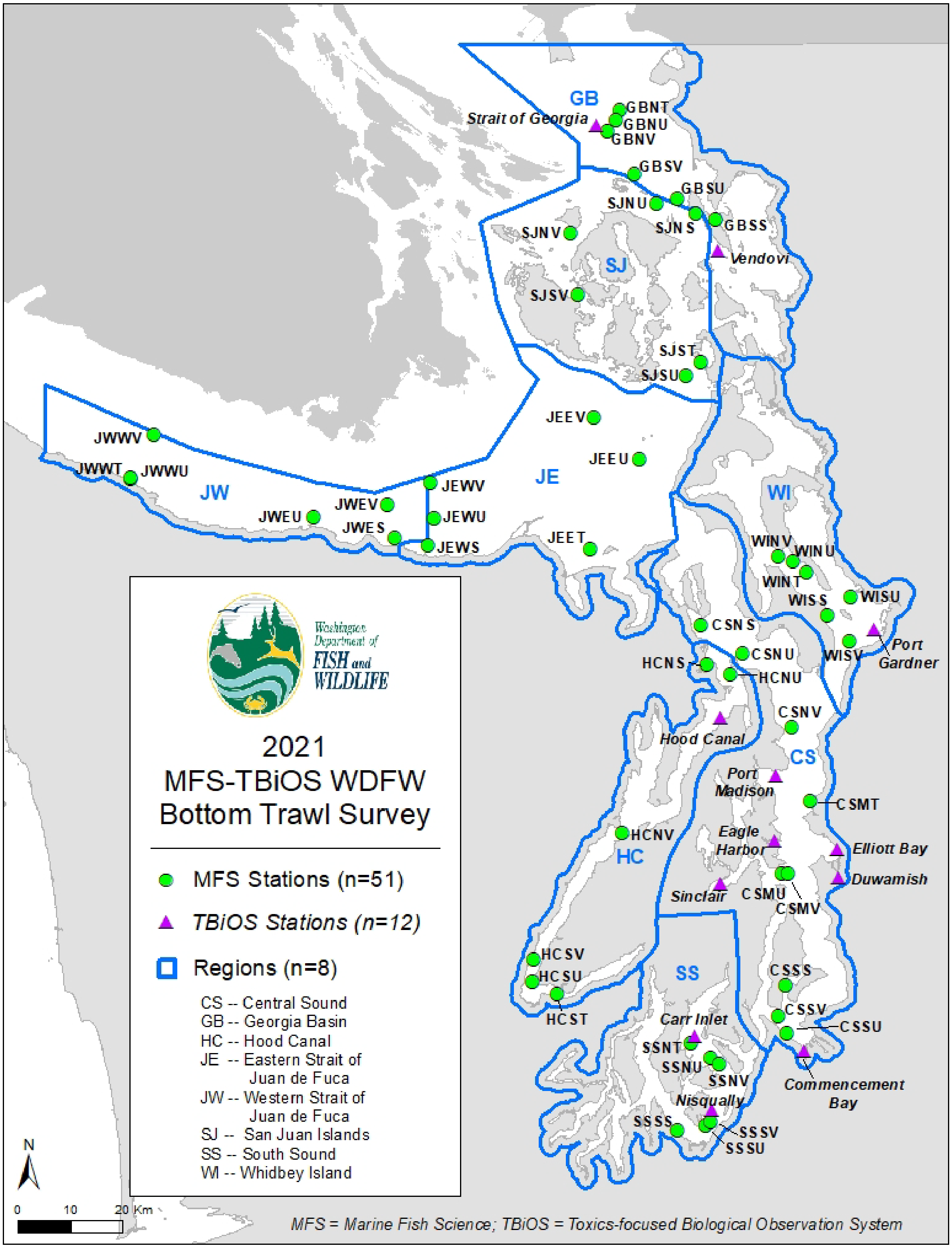

Figure 1: Survey map for the 2021 bottom trawl survey. Green dots indicate MFS Index stations, sampled each year since 2008 (with the exception of 2020). Vessel time in 2021 was split between the Marine Fish Science (MFS) Unit and the Toxics-focused Biological Observation System (TBiOS) team.

Similar to previous years, Spotted Ratfish dominated the catch in terms of biomass, constituting 62% of the total fish catch by weight and 30% of the total number of individual fish, followed by English Sole at 12% and 15%, respectively. These catch rates equate to a biomass estimate of 52,549 mt for Spotted Ratfish (down from 80,798 mt in 2019) and 10,073 mt for English Sole (11,520 mt in 2019), and abundance estimates of 157 million and 80 million individuals, respectively (Figure 4). The remaining fish species contributed 5% or less to the total fish catch weight and 5% or less to the total number of individual fish (aside from Walleye Pollock at 11% and Shiner Perch at 10%) and were categorized into the following species groups for comparisons: Other Flatfishes, Sharks & Skates (Elasmobranchs), Sculpins (Cottoidea), Codfishes (Gadiformes), and Other Fishes (e.g., forage fish, eelpouts). After Ratfish, Codfishes had the second highest abundance estimate at 114 million fish, up from 84 million in 2019 due to increased catches of Pacific Cod and Pacific Tomcod. Other Flatfishes had very similar estimates to English Sole, at 10,323 mt and 78 million individuals. The 'Other Fish' category includes most species that the bottom trawl was not designed to target due to their size and/or behavior (including habitat preference), the most abundant of which were Blackbelly Eelpouts and Shiner Perch.

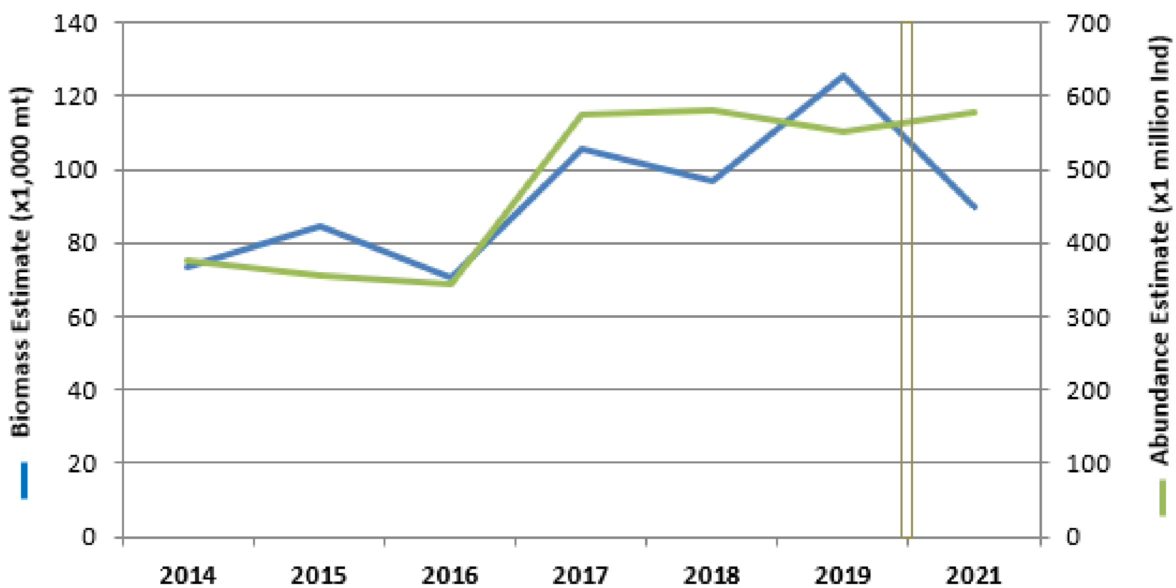

Figure 2: Estimates of bottomfish biomass (x 1,000 mt) and abundance (x 1 million individuals) throughout Puget Sound from the annual bottom trawl surveys since 2014. Parallel lines indicate the missed sampling in 2020.

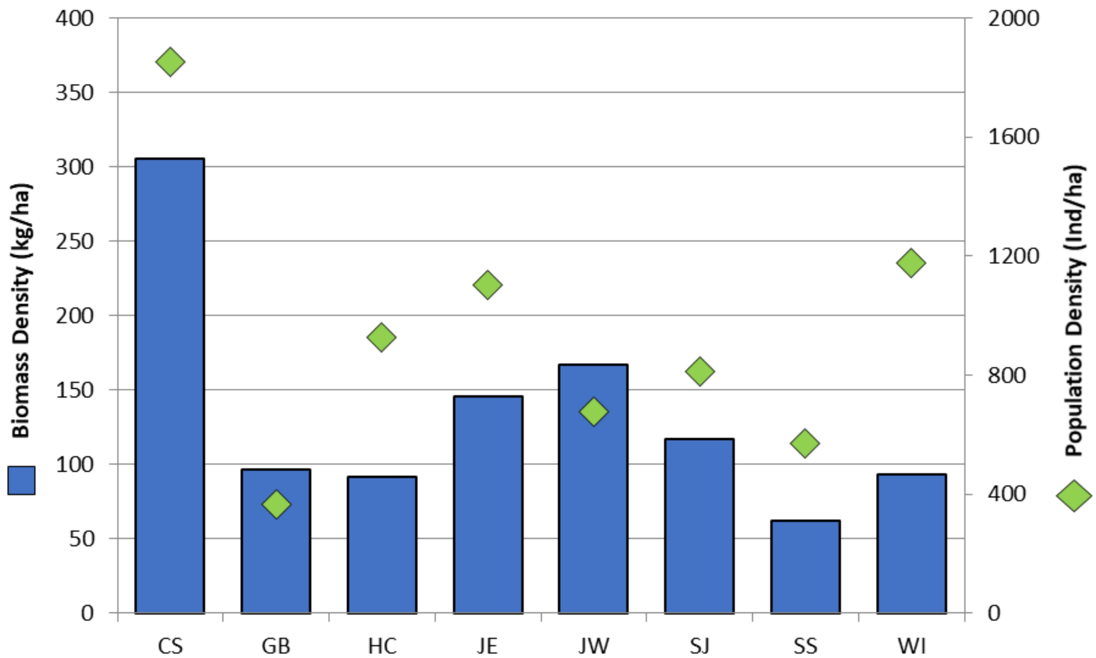

Figure 3: Estimates of bottomfish biomass density (kg/ha) and population density (ind/ha) in each of the eight regions of Puget Sound from the 2021 survey.

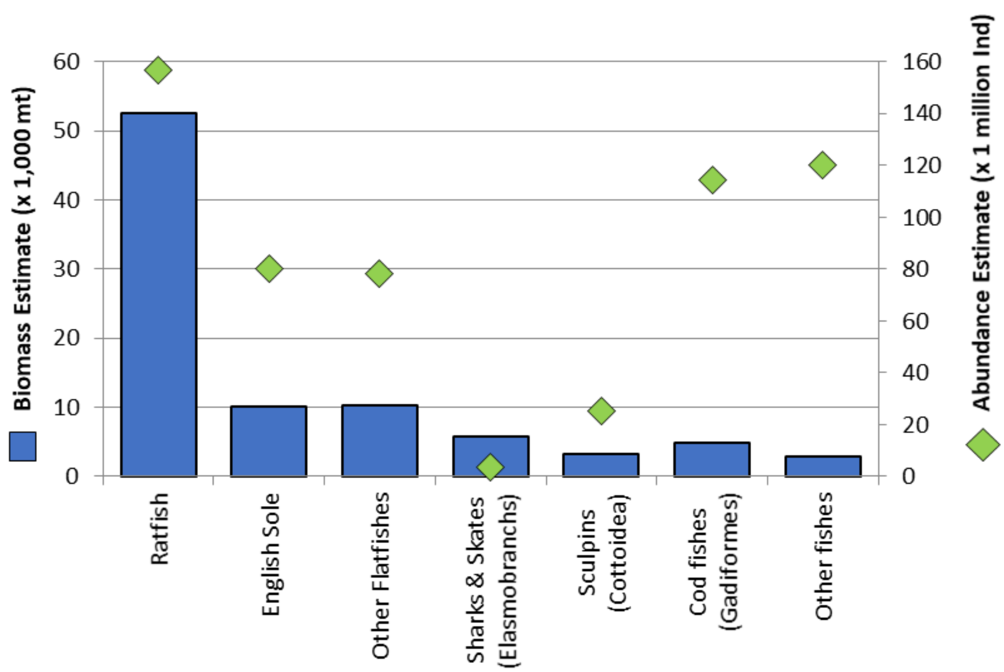

Figure 4: Estimates of bottomfish biomass (x 1,000 metric tons) and abundance (x 1 million individuals). Species were combined into groups by taxa, other than Spotted Ratfish and English Sole, the two most prominent species.

Flatfish

English Sole, as previously mentioned, were the most prevalent species of flatfish, with estimates of 10,073 mt and 80 million individuals (Figure 4), which were 13% and 14%, respectively, lower than those in 2019. Among regions, CS supported the highest densities of English Sole at 40 kg/ha and 253 fish/ha; the smallest population was found in JW at 2.3 kg/ha and 13 fish/ha. In terms of other flatfish species, Rock Sole (2,956 mt & 20.3 million individuals), were the most dominant by both weight and abundance after English Sole. Starry Flounder, Pacific Sanddab, and Dover Sole were the following three species by biomass at 1,994 mt, 1,731 mt, and 1,513 mt, respectively. By abundance, Pacific Sanddab (16.5 million), Dover Sole (9.2 million), and Slender Sole (7 million) followed English Sole and Rock Sole.

While these estimates are for all of Puget Sound, each region supported its own composition of flatfish species, although English Sole dominated the flatfish biomass in 6 of the 8 regions. For the two regions for which other species ranked higher in terms of biomass, Dover Sole dominated the flatfish in JW (52% of regional flatfish biomass estimate), and Starry Flounder did so in SS (48%). Starry Flounder also represented 29% of the flatfish in HC. Rock Sole (31%) closely followed English Sole (32%) in WI and was also a key species in both SJ (22%) and SS (22%). Otherwise, all other flatfish species comprised 19% or less of a region's flatfish biomass. Among the regions, South Sound supported the highest biomass density of non-English Sole flatfish species at 38 kg/ha, while WI supported the highest population density at 275 individuals/ha.

Sharks and Skates (Elasmobranchs)

Compared to 2019, the 2021 North Pacific Spiny Dogfish catch was lower both in terms of individuals, with 68 dogfish caught versus 170 in 2019, and in terms of weight, with 58 kg caught versus 181 kg. Dogfish populations can be migratory, however, and individuals are frequently in the water column rather than on the bottom, so their catchability in the bottom trawl is variable. Nevertheless, dogfish were found in all eight regions, with 44% of the weight and 41% of the individuals being caught in CS.

Neither Brown Catsharks nor Bluntnose Sixgill Sharks were caught in the 2021 survey. These species were both caught in 2019 but have been caught sporadically throughout the history of the survey.

Big Skate biomass and abundance estimates decreased from the 2019 survey from 6,008 mt and 2.5 million individuals, respectively, to 3,637 mt and 1.1 million individuals. Encounter rates of Big Skates were highest in SJ, which accounted for 30% of the abundance and 21% of the biomass, while those in SS accounted for 26% of the abundance and 29% of the biomass. Longnose Skate biomass and abundance estimates also decreased to 1,388 mt and 1.6 million individuals in 2021, compared to 2,222 mt and 2 million individuals in 2019; biomass estimates were highest in JW while abundance estimates were highest in JE. Lastly, 12 Sandpaper Skates were caught in 2021, which is slightly lower than 2019's catch rate of 18. Sandpaper Skates were primarily caught in GB and JE but were also found in JW.

Codfishes (Gadiformes)

Pacific Cod catch was substantially higher than in 2019; 154 fish were caught in this year's survey, weighing a total of 75 kg (compared to 21 fish and 20 kg in 2019), which is the highest catch rate since before the inception of the current survey design in 2014. This catch rate resulted in an estimated population density of 13.3 ind/ha in JW, 5.6 ind/ha in SJ, 3.8 ind/ha in JE, 3.3 ind/ha in GB, and 2.3 ind/ha in CS (
Figure 5). As no trawl survey was conducted in 2020 due to the pandemic, it is unknown whether the significant jumps in population densities for these regions began in 2020 or 2021, but they are promising nonetheless. Pacific Cod caught in the 2021 survey ranged in size from 23 cm to 76 cm, with an average length of 33 cm and a median of 32 cm.

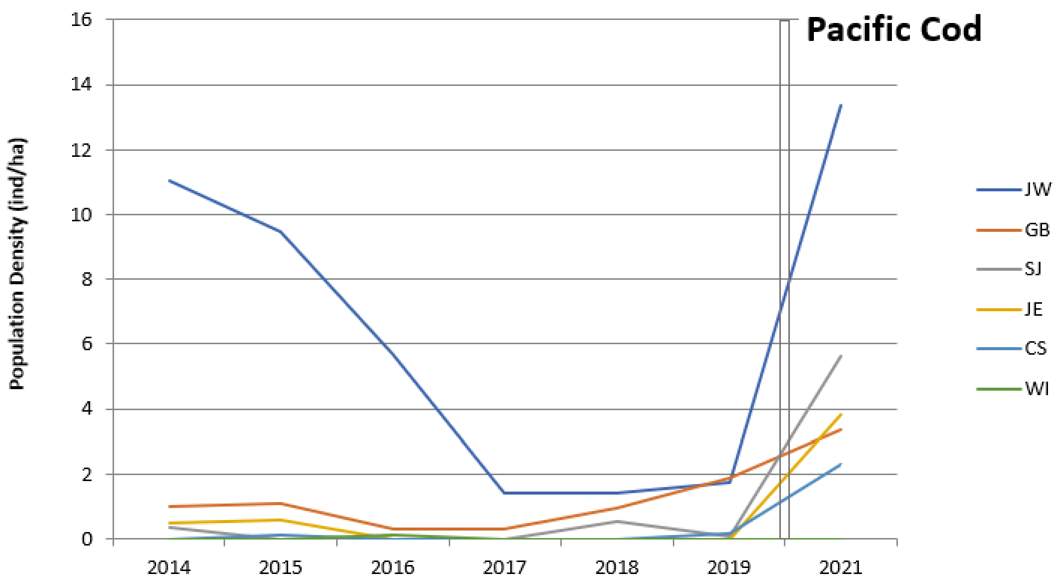

Figure 5: Population density (individuals/hectare) of Pacific Cod caught in the 2014-2021 bottom trawl surveys, by region. Parallel lines indicate the missed sampling year in 2020.

Pacific Hake biomass and abundance estimates both decreased from the 2019 survey to 584 mt and 12.2 million individuals; hake were most abundant in WI and were found in each region except JW. Walleye Pollock were found in all regions but were substantially more abundant in JE, JW, and SJ compared to the other regions. Pollock biomass estimates (2,845 mt) also declined compared to 2019, but abundance estimates (94.8 million) increased by 45%.

ESA-Listed Species

Pacific Eulachon was the only ESA-listed species encountered during the 2021 survey; a record 169 individuals were caught (62 in 2019, 19 in 2018, 29 in 2017) in regions GB, JW, and SJ, with all but 5 being caught in GB. This was the most Eulachon ever caught in the bottom trawl survey, despite sampling design and effort reductions, since 2004; the same was said regarding the encounter rate in

2019. All Eulachon were kept and sent to the WDFW Forage Fish lab for further analysis. No other ESA-listed species were caught.

Other Fishes/Notable Finds

Because rockfish tend to exhibit preferences for rocky, untrawlable habitats, the bottom trawl survey serves as a poor indicator of rockfish populations. With this in mind, however, more rockfish were caught in this survey than in 2019 (Table 1). Ten different species were caught, including Vermilion Rockfish, which was last caught in the trawl survey in 2011. Quillback Rockfish were, as usual, the most abundant species, followed by Brown Rockfish; fewer Quillback were caught than in the previous 3 years, but substantially more Brown Rockfish were caught than in any other year since before 2014. Several more Canary and Copper Rockfishes were also caught in this survey than in 2019. Additionally, there were six juvenile rockfish of an uncommon species that were unable to be identified in the field; they will be identified in the lab at a later date or by UW Fish Collection researchers.

Table 1: Rockfish species counts caught in the bottom trawl survey from 2014-2021.

Species	2014	2015	2016	2017	2018	2019	2021
Black Rockfish	1	-	-	-	-	-	-
Bocaccio	-	-	11	7	3	-	-
Brown Rockfish	2	13	15	16	42	14	91
Canary Rockfish	-	1	-	2	3	3	15
Copper Rockfish	27	7	4	4	123	9	18
Greenstriped Rockfish	2	5	2	8	5	1	-
Puget Sound Rockfish	9	2	-	-	1	-	1
Quillback Rockfish	41	34	117	235	344	207	159
Redbanded Rockfish	-	-	1	-	-	-	-
Redstripe Rockfish	5	4	6	8	4	9	3
Shortspine Thornyhead	-	-	-	-	1	1	-
Splitnose Rockfish	-	-	2	-	3	1	6
Unidentified Rockfish	-	-	-	-	-	-	6
Vermilion Rockfish	-	-	-	-	-	-	1
Yellowtail Rockfish	-	7	-	13	59	5	3
Total	**87**	**73**	**158**	**293**	**588**	**250**	**303**

Like rockfish, Lingcod exhibit a preference for untrawlable habitats, and therefore the bottom trawl is a poor survey method for assessing their populations; however, in the 2021 survey, 52 Lingcod were caught, which is the highest catch rate in the trawl survey since the start of the Index design. Individuals ranged in size from 24 cm to 74 cm, with a median length of 32.5 cm. Almost half (25) of the individuals were caught in JW, with the majority (17) of the other half being caught in SS, and 1-5 in each of CS, GB, HC, and JE. Before the 2021 survey, only two Lingcod had ever been caught in SS – one in 2002 and one in 2008 – in the history of the trawl survey, dating back to 1987.

All but 11 smaller Lingcod, which were retained for WDFW biologists to collect age and genetics samples, were released alive.
Sablefish (aka "Black Cod"), which have been caught in the survey the previous three years, were again found in the survey this year. While 8 Sablefish were caught in the 2019 survey, and all in JW, only 3 were caught in 2021 – one each in JE, JW, and SJ. The lengths were 35 cm, 38 cm, and 73 cm, with the largest being the one caught in JW. Fin clips were taken for genetic analysis, and all individuals were released alive.

A few other less-frequently caught species found in the 2021 survey include a juvenile Dwarf Wrymouth, a, a Pacific Spiny Lumpsucker, and three Brown Irish Lords.

All Invertebrates

An estimated 55,017 individual invertebrates (those species catchable in the bottom trawl) from 82 different species/taxa weighing 2.1 mt were caught in the 2021 survey. Overall, the total estimated invertebrate biomass and abundance for Puget Sound was 24,103 mt and 903 million individuals. While the biomass estimate was almost identical to that from 2019, the population estimate was slightly lower (Figure 6). Among the regions, CS and WI supported the highest biomass densities at 72 kg/ha (Figure 7). SS and JE, however, had the highest population densities at 3,189 ind/ha and 3,169 ind/ha, respectively. Compared to 2019, the largest increase in biomass densities occurred in WI (+43%) while the largest decrease occurred in GB (-44%). Overall invertebrate abundance density estimates in GB, however, more than doubled (+176%) compared to 2019, as did those in SJ (+123%). The abundance increase in both GB and SJ can be attributed mostly to substantially larger catches of several shrimp species.

By weight, the most dominant species were Metridium anemones and Dungeness Crab, comprising a respective 34% and 33% of the total invertebrate catch (Figure 8). By number of individuals, shrimp were by far the predominant species group, comprising 93% of the total number of invertebrates caught; they also contributed 20% of the total invertebrate biomass. Of the 15 species of shrimp identified, Alaskan Pink Shrimp and Dock Shrimp were by far the most abundant species. The remaining invertebrate species contributed 7% or less to the total invertebrate catch by weight or by number.

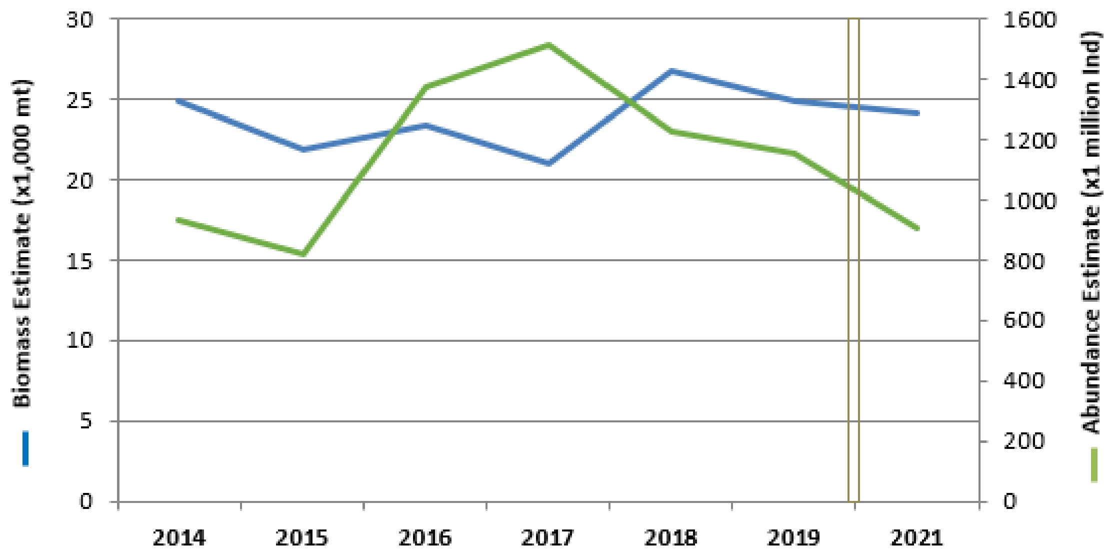

Figure 6: Estimates of invertebrate biomass (x 1,000 mt) and abundance (x 1 million individuals) throughout Puget Sound from the annual bottom trawl surveys since 2014. Parallel lines indicate the missed sampling in 2020.

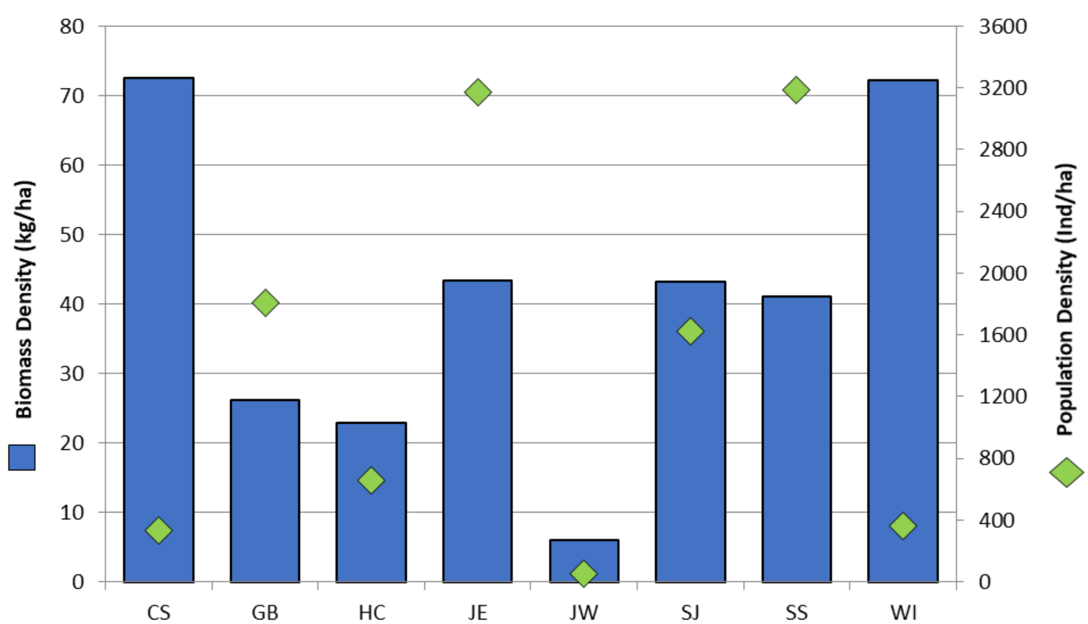

Figure 7: Estimates of invertebrate biomass density (kg/ha) and population density (ind/ha) in each of the eight regions of Puget Sound from the 2021 trawl survey.

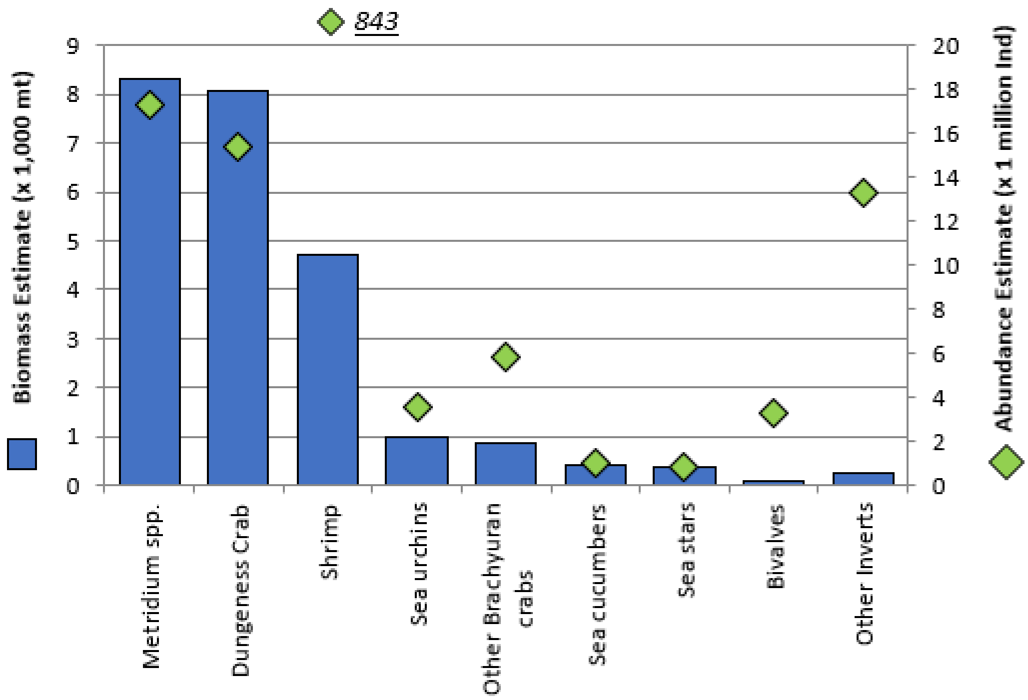

Figure 8: Estimates of invertebrate biomass (x1,000 metric tons) and abundance (x 1 million individuals). Species were combined into groups by taxa, other than Dungeness Crab and Metridium spp, which were the two most prominent species.

Dungeness Crab

Dungeness Crab, a popular commercial and sport fishing target, had 24% lower biomass and abundance estimates in 2021 compared to 2019; total biomass was estimated at 8,063 while abundance was estimated to be 15.3 million individuals. SJ harbored the largest density of Dungeness by biomass while WI harbored the largest density by abundance, and, as per usual, SS supported the smallest densities. Females outnumbered males in all regions except SJ and SS; in JW, 92% of the Dungeness caught were female.

Spot Prawn

Spot Prawn, another popular commercial and sport fishing target, comprised 34% of the total shrimp biomass in 2021, with an estimate of 1,627 mt and 56.8 million individuals. These estimates are lower than those in 2019 of 2,385 mt and 80 million individuals but are more on par with previous years' estimates. On a regional basis, JE supported the largest population by both biomass and population densities, comprising 40% of both totals. This is the first year since 2013 that CS did not support the largest Spot Prawn densities; populations in CS contributed 20% and 16% to the biomass and population densities, respectively.

Sea Stars

Only 59 total sea stars, of 14 species and weighing a total of 21.8 kg, were caught in the 2021 survey compared to 88 sea stars weighing 23.5 kg in 2019; this catch equates to a Sound-wide biomass estimate of 393 mt and an abundance estimate of 844 thousand individuals. Compared to 2019 estimates, the 2021 biomass estimates were 14% higher while the abundance estimates were 25% lower (Figure 9). Stars were also caught in all 8 regions again, with JE supporting both the highest biomass density and the highest population density. Low population levels during 2015 and 2016 are believed to be directly tied to the sea star wasting disease epidemic; the 2017 and 2018 bottom trawl data seemed to indicate the beginning of a recovery, but 2019 and 2021 data show that the population is roughly maintaining levels rather than exhibiting a substantial rebound to pre-epidemic levels. Additionally, 17 Sunflower Stars, which were one of the most affected species in the epidemic, were caught in 2021 compared to 21 in 2019 and 16 in 2018; as in 2019, they were found in all regions except CS and GB.

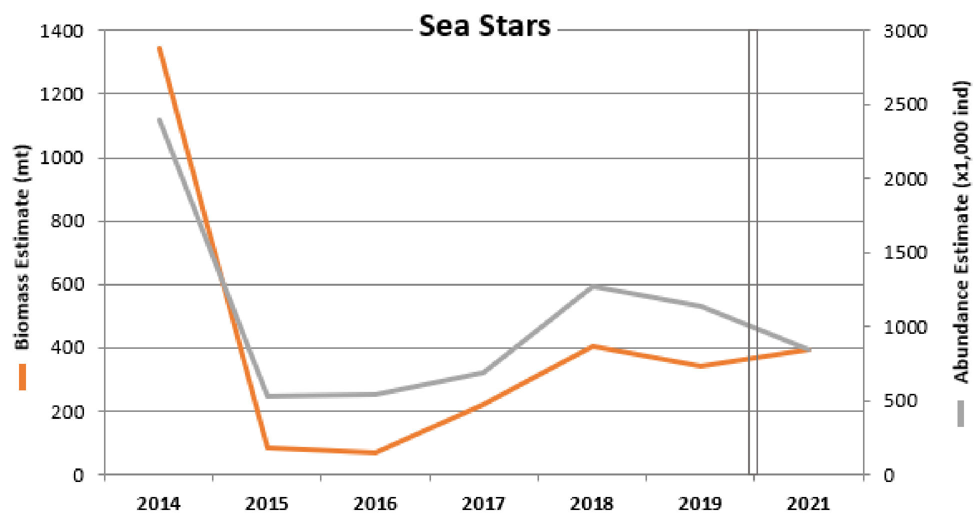

Figure 9: Estimates of sea star biomass (mt) and abundance (x 1,000 individuals) throughout Puget Sound from the annual bottom trawl surveys since 2014. Parallel lines indicate the missed sampling in 2020.

Other Results

While the primary objective of the bottom trawl survey is to gather population data for bottomfish, the regularity and scope of the survey and the vast number of fish handled during it provide a unique opportunity to assist other research. One such "other research" opportunity in recent years has been to conduct vertical plankton tows for monitoring efforts for Puget Sound Partnership and Long Live the Kings; however, due to restraints on time and Covid safety, these were not conducted during the 2021 survey.

We did, however, continue to collect genetic and age samples for a number of species. In total, we collected 261 genetic samples from Pacific Cod, Lingcod, Spiny Dogfish, 10 species of rockfish, and a few less-frequently encountered species, as well as 197 age samples (otoliths) from rockfish and Pacific Cod; all of these samples were sent to the respective labs (Genetics and Aging) at the WDFW for analysis. Additionally, 806 fish were preserved for other researchers. Of these, 455 were Pacific Herring and Eulachon that were collected for the WDFW Forage Fish Unit to study population genetics and reproductive development. The UW/Burke Museum and NOAA received

23 fish specimens needed for their fish collection and genetic bank studies, and some to verify identifications. King County also received 200 English Sole and 6 rockfish to contribute to their biennial trawl survey. In addition to these entities, four other researchers from UW, NOAA, San Francisco State University, and Kwiáht requested and received samples from the trawl survey to assist with ongoing research projects. Lastly, since the end of the 2019 trawl survey, at least 21 data requests from various researchers and other WDFW divisions were fulfilled using bottom trawl survey data.

Assessment and Evaluation

The 2021 WDFW bottom trawl survey had to operate in a different fashion than normal out of consideration for COVID safety. Only 5 WDFW employees, all from the MFSU, were allowed on board at any point during the survey. Instead of WDFW crew and vessel crew sleeping overnight on the boat, the survey was arranged such that the boat returned to a port each night and WDFW crew stayed in hotels and drove separate vehicles. On board, crew had set stations that allowed them to remain 6 feet apart on average from other personnel, and all persons on board wore KN95 masks at all times (expect while drinking or eating). Crew had to monitor themselves for any signs of COVID symptoms and complete daily WDFW attestations. Thanks to the crew's adherence to these safety precautions, no personnel contracted COVID during the survey. Despite the alternative operations resulting in some longer days than usual, all planned stations were sampled to resume the time series of the index design after missing 2020.

WDFW crew continues to use iForms to electronically input most data in the field and utilize barcodes for sample identifiers, which has greatly reduced data entry errors, increased the ability to backup data while in the field, and improved the efficiency with which data are error-checked and finalized in the database. We also continue to use the Marport mensuration gear to obtain live readings of when the net is actually on the bottom; there were a few issues attempting to use the new Marport receiver, so we switched back to the old receiver in order to continue to collect the data. The Hobo footrope accelerometers were also working on every tow, so we will be able to use these recorded readings to improve area swept calculations and, thus, increase the accuracy of population estimates. Between survey seasons we hope to be able to analyze this and recent years' on-bottom data to develop a correction factor that might be applied to previous index survey estimates.

One of the benefits of the annual bottom trawl survey is potentially capturing what might be the beginning of repopulation after years of overfishing or disease. The 2017 survey saw the reappearance of sablefish after a 5-year absence in the survey, so the continued presence of the species in recent surveys is promising. Additionally, the sea star populations following the 2013-15 "Sea Star Wasting Disease" epidemic and mass die-off along the West Coast have remained relatively consistent the past few years, with biomass estimates slightly lower than 2019 and abundance estimates slightly higher. The decline of sea star populations in Puget Sound was captured in this bottom trawl dataset, and the Sunflower Star was exceptionally susceptible to the disease. Sunflower Stars are currently being considered for ESA listing, and the trawl survey dataset is being used as one source of population data to inform this decision.

The WDFW bottom trawl survey is the largest, most geographically expansive, methodologically consistent, and longest-running, fishery-independent survey of benthic organisms in Puget Sound.

As such, this dataset provides an invaluable monitoring opportunity for populations of bottomfish and select benthic invertebrates, particularly given the inter-annual variation of many fish species. Continued collection of these data is important, as they can serve as a baseline for evaluating future population shifts due to fishery management actions, disease outbreaks, catastrophic events, and/or environmental shifts. In 2020, a multi-year survey report covering the 2002-2007 trawl surveys was published as a WDFW technical report (Blaine et al., 2020), which can be found on the WDFW website. The next muti-year survey report covering the index surveys is currently in progress (Blaine et al., in prep).

The data, samples, and estimates from the trawl survey are not only important for the WDFW's marine fish monitoring efforts but are also used by other entities both within and outside the agency. The WDFW's Shellfish Team uses the estimates of Dungeness Crab and Spot Prawns to better inform fishery management decisions; a researcher and her students at SFSU are researching the embryonic development of Spotted Ratfish; NOAA is building a collection of fish genetics; and three University of Washington researchers are furthering their studies on Longnose Skates, Spotted Ratfish, and poachers, all of which are possible thanks to data and samples from the trawl survey. These are just a few examples of how the bottom trawl survey includes such far-reaching applications that influence the knowledge and management of other species and supports other research efforts.

The 2022 bottom trawl survey will occur from 25 April – 27 May 2022. *For more details on the trawl survey, contact Jen Blaine (Jennifer.blaine@dfw.wa.gov).*

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B. Annual Pacific Herring Assessment in Puget Sound

Consistent with previous years, Pacific herring stocks in Puget Sound (southern Salish Sea) were assessed by WDFW staff through spawn deposition field surveys from January through June using the established methods of Stick et al. (2014) and Sandell et al. (2019). WDFW staff based in the Olympia, Mill Creek and Port Townsend offices attempt to conduct spawn deposition surveys of all herring populations in Washington annually (acoustic-trawl surveys were discontinued in 2009 due to budget cuts; as a result, we are no longer able to estimate the age structure, fecundity, etc. of the herring stocks). Stock biomass assessment activities for the 2022 spawning season are in progress.

WDFW recognizes 21 different herring stocks in Puget Sound and two coastal stocks (Willapa Bay and Grays Harbor), based primarily on the timing and location of spawning activity; historically there were three distinct genetic groupings (Cherry Point, Squaxin Pass, and the “all other stocks” complex). However, recent research focusing on SNP sequencing has determined that, at present, only the Cherry Point and Elliott Bay stocks are unique; the remaining stocks now comprise the “Other Stocks” grouping (Petrou et al., 2021). Within this group, research has identified differences in spawn timing that include an “Early Winter” (Jan-Feb), “Late Winter” (Feb-March), and “Spring” (April and later) stock groupings; only five of the stocks have been fully analyzed to date.

The 2021 spawn deposition field season began on December 28th (2020) to account for a trend of earlier spawning at Semiahmoo Bay; all other surveys occurred during the 2021 calendar year. A total of 162 surveys were completed, up from 135 in 2020 due to Covid-19 disruptions. Surveys included the primary spawning areas of 20/21 Puget Sound herring stocks; we were again unable to survey Point Roberts in 2021 due to border closures. After the historically high estimated spawning biomass (ESB) in 2020 (18,559 metric tonnes), the total for 2021(10,255 mt) returned towards the ten-year average (10,500 mt). This was mainly driven by reductions in ESB at Quilcene Bay (Hood Canal; 3,491 mt, down from 7,340 mt in 2020) and Port Orchard-Port Madison (2,472 mt, down from 7,077 mt in 2020). The 2021 total was bolstered by a strong year at Semiahmoo Bay, with 2,395 mt (922 mt in 2020). However, the genetically distinct, late-spawning Cherry Point stock ESB was only 157 mt in 2021, down from 274 mt in 2020, though this may be an underestimate as we were unable to survey Point Roberts (late spawn at Point Roberts is considered part of the Cherry Point total). Three stocks that normally have spawn had no spawn detected in 2021 (Quartermaster Harbor, South Hood Canal, Discovery Bay); five other stocks continued to have no spawn detected (Wollochett, Fidalgo Bay, Kilisut, Interior San Juan Islands, NW San Juan Island).

Coastal surveys of Willapa Bay and Grays Harbor stocks were limited by staff availability and adverse weather. Only one survey was conducted in Grays Harbor on 2/10/21, with no spawn detected, and no surveys were carried out in Willapa Bay. In general, herring spawning biomass for these areas is relatively small compared those of the southern Salish Sea.

The estimated spawning biomass totals are provided in Table 2. Given the fluidity of our genetic stock groupings, we now consider the basin of spawning activity (Figure 10) as the preferred method of biomass reporting; Figure 11 shows the marked shift from a broadly based spawn deposition (heaviest in the North through mid 1990s) towards the dominance of the few stocks mentioned above beginning in 2016. This loss of diversity from the "Herring Portfolio" (Siple and Francis, 2015) undermines the stability of southern Salish Sea herring in the face of environmental instability. The long-term decline in certain regions, particularly South Puget Sound, remain a cause for concern.

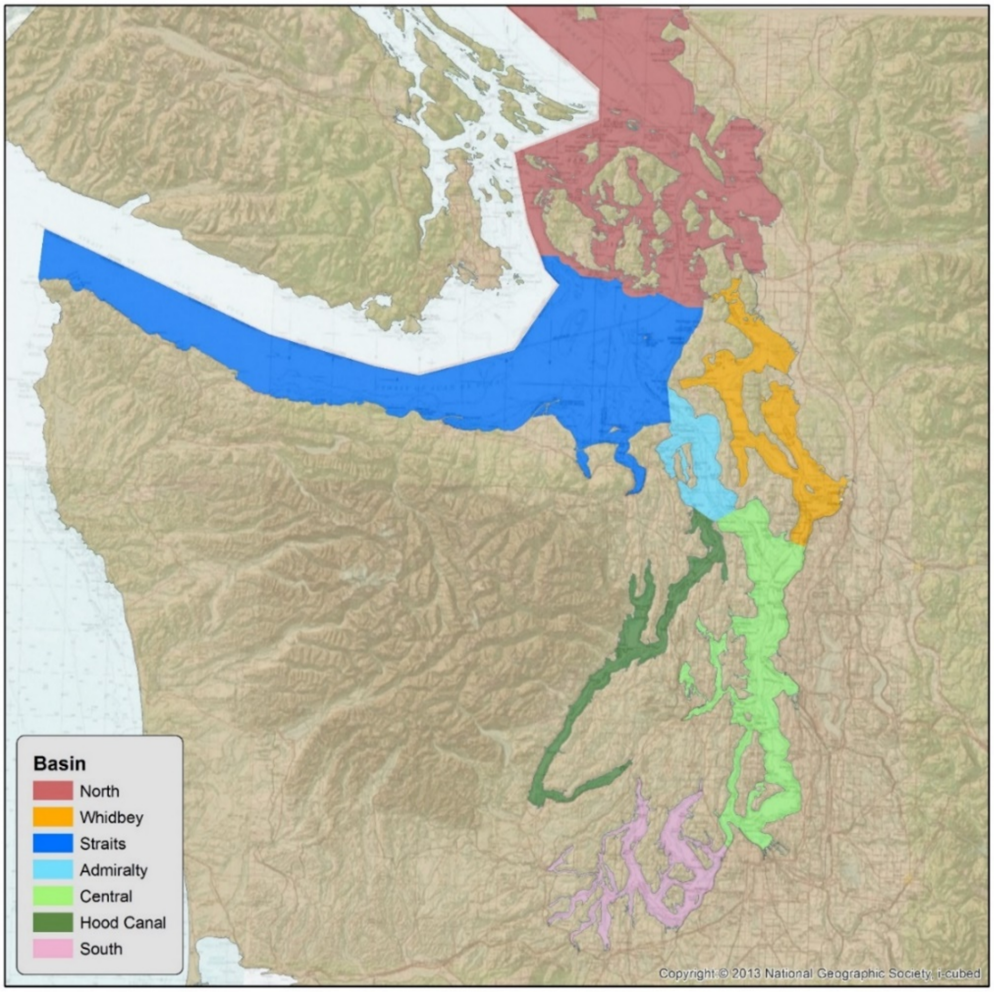

Figure 10: Map of the six basins used as herring regions in the southern Salish Sea.

Table 2: Pacific Herring biomass estimates by stock from spawn deposition surveys, 2012-2021.

Stock and Region (Unique genetic groups in *italic*)	PUGET SOUND HERRING SPAWNING BIOMASS ESTIMATES (Metric Tons), 2012-2021									
South Puget Sound	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Squaxin Pass	534	503	357	294	236	271	381	14	110	75
Purdy	122	236	76	29	0	20	15	110	884	239
Wollochet Bay	28	9	35	0	0	5	0	0	0	0
South Puget Sound Total	685	748	469	323	236	297	396	124	994	314
Central Puget Sound										
Quartermaster Harbor	98	142	40	50	0	0	11	22	0	0
Elliott Bay	263	194	26	122	99	68	199	0	380	23
Port Orchard-Port Madison	197	167	82	83	0	0	12	1,867	7,077	2,472
Central Puget Sound Total	558	503	148	256	99	68	222	1,889	7,457	**2,495**
Hood Canal										
South Hood Canal	239	181	102	256	226	90	58	38	31	0
Quilcene Bay	2,382	1,880	2,810	3,717	6,496	4,482	5,816	2,960	7,118	3,289
Port Gamble	367	248	154	313	163	164	451	207	191	201
Hood Canal Total	2,988	2,308	3,065	4,286	6,884	4,736	6,325	3,205	7,340	**3,491**
Whidbey Basin										
Port Susan	55	26	62	64	55	103	67	64	33	24
Holmes Harbor	615	531	416	414	448	70	341	385	64	724
Skagit Bay	402	412	267	259	44	176	310	208	539	219
Whidbey Basin Total	1,072	969	745	736	547	349	718	657	636	**967**
North Puget Sound										
Fidalgo Bay	81	91	200	73	5	5	0	0	0	0
Samish/Portage Bay	390	629	706	507	929	451	379	204	729	402
Semiahmoo Bay	797	516	2,566	5,309	1,631	2,097	1,603	1,175	922	2,395
Cherry Point	1,016	824	910	475	468	337	249	290	274	157
Interior San Juan Islands	5		5	34		0	61	167		0
NW San Juan Islands	0				0		0	0		0
North Puget Sound Total	2,289	2,059	4,386	6,398	3,033	2,890	2,292	1,836	1,925	**2,954**
Strait of Juan de Fuca										
Discovery Bay	95	0	5	11	221	93	232	102	150	0
Dungeness/Sequim Bay	39	64	65	7	40	153	93	78	57	34
Kilist Harbor	0	0	5	0	0	0	0	0		0
Strait of Juan de Fuca Total	134	64	74	18	261	247	326	180	207	34
Other Stocks Total (excludes Cherry Pt. and Squaxin	6,176	5,325	7,620	11,247	10,356	7,979	9,649	7,587	18,175	**10,023**
Puget Sound Total	7,726	6,651	8,888	12,017	11,060	8,587	10,279	7,891	18,559	**10,255**
Note: For 2020, sampling was affected by Covid-19	Green	Good coverage	Yellow	Intermediate	Rose	Insufficient coverage		Red	No surveys	

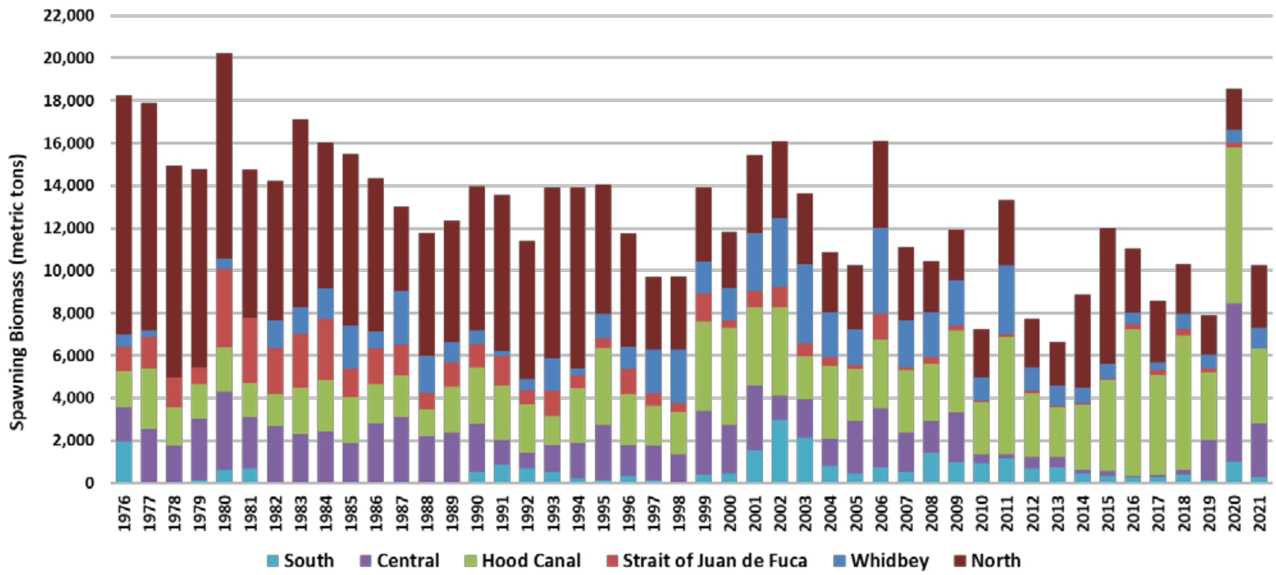

Figure 11: Pacific Herring spawning biomass estimates by basin in the southern Salish Sea, 1976-2021.

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C. *Remotely operated vehicle (ROV) Studies of ESA-listed Rockfish in the greater Puget Sound/Georgia Basin DPS*

The PSMFS Unit completed a two-year survey of the U.S. portion of the Yelloweye Rockfish and Bocaccio DPSs in January 2017 (see previous TSC reports for preliminary results). Survey stations where Yelloweye Rockfish were observed were prioritized to enable a population estimate for the species to be made as soon as possible. No Bocaccio were encountered at any survey station, though four fish were noted during “exploratory” deployments. Video review of these transects is on-going, with most of the remaining videos containing few or no fish of interest.

In March and April of 2018, the WDFW conducted a three-week survey in a portion of the Yelloweye Rockfish and Bocaccio DPSs lying in **Canadian waters of the Gulf Islands** within the southern Strait of Georgia. The goals of this survey were to: 1) estimate the population size of Yelloweye Rockfish (and Bocaccio as possible) within the survey area; and 2) utilize a stereo-camera system to collect accurate length information of Yelloweye Rockfish, which is needed for the length-based spawner-per-recruit (SPR) model that will be used as a basis for tracking recovery of the species per the conditions of the federal Recovery Plan. The survey was designed using the same Maximum Entropy (MaxEnt) modelling approach as the 2015-16 Puget Sound survey. The model was developed by Bob Pacunski with data provided by Dana Haggarty (DFO Canada). Funding for the survey was provided by NOAA (Dan Tonnes). A total of 64 transects were completed over 13 sampling days. Yelloweye rockfish were scarce in the southern portion of the survey area, but encounters increased as sampling moved northward. At least 57 Yelloweye rockfish were identified during video review, but no Bocaccio were observed during the survey. Video review has been completed and the data are undergoing final QA/QC prior to analysis.

In August 2018, the WDFW conducted a three-week survey of the **San Juan Islands**, which lies within the US portion of the DPSs for Bocaccio and Yelloweye Rockfish, with a total of 60 transects completed over 13 sampling days. This survey had the same goals and sampling design as the survey of the Canadian Gulf Islands and was meant to facilitate cross-border comparisons of rockfish prevalence and size distribution. Consistent with previous ROV surveys of the San Juan Islands in 2008 and 2010, Yelloweye Rockfish were seldom encountered, with only 14 fish observed on 9 transects. Canary rockfish were rarely encountered in the 2008 and 2010 surveys, but 33 fish were seen on eight transects in the most recent survey. No Bocaccio were seen in this survey. Video review has been completed and the data are undergoing final QA/QC prior to analysis.

In October 2018, the WDFW partnered with DFO Canada to conduct a 14-day survey of the **Canadian waters of southern and central Strait of Georgia**. This survey utilized the WDFW-owned ROV deployed from the 40-m long Canadian Coast Guard Ship *Vector*. The primary goals of this survey were to 1) evaluate densities of “inshore rockfish,” as defined by DFO, inside and outside established Rockfish Conservation Areas; and 2) use a stereo-camera system to obtain length measurements of Yelloweye Rockfish that will be used in population recovery models. This survey was also designed based on the results of a MaxEnt habitat suitability model. Most stations were randomly assigned to High probability polygons inside and outside of selected RCAs, but in some cases, it was necessary to hand-place stations due to a lack of matching habitat outside of an RCA. A total of 85 transects were completed in 14 survey days. The habitat in this survey was characterized by high densities of sponges, which provided a highly complex and crevice-rich environment utilized by several rockfish species. In contrast to the previous two surveys, Yelloweye Rockfish were commonly encountered, with over 200 fish of all sizes observed during the survey. No Bocaccio were observed. Reviews of the transect videos were completed in early 2020, and those data have been passed off to DFO along with the associated tracking data for analysis.

In August 2019 the WDFW PSMFS unit initiated an ROV survey focused on benthic rockfishes, Lingcod, and Kelp Greenling within the **interior marine waters of Washington** using a two-stage survey design. Within the Yelloweye Rockfish and Bocaccio DPSs, the survey design was based on the results of a MaxEnt habitat suitability model. Due to a lack of reliable bathymetry coverage for the waters of the Strait of Juan de Fuca west of the western DPS boundary, the MaxEnt approach could not be implemented, and the survey design was based on an evaluation of known and suspected habitats identified during previous drop-camera and ROV surveys. After 450 stations were randomly placed within the highest probability (>50%) habitats identified in the model (Figure 13), the survey began on August 6 but was suspended on September 26th due to an equipment failure on the support vessel *R/V Molluscan*. Because the WDFW was already in the process of purchasing a replacement vessel for the *Molluscan*, they opted not to replace the failed equipment in order to apply those funds to the purchase of the new vessel. The new vessel, the *R/V Salish Rover* (Figure 12), was acquired in December 2019, with retrofitting and needed maintenance completed in June 2020. Due to the COVID-19 pandemic, WDFW protocols prevented the survey from restarting until October 2020, but equipment problems with the ROV system and poor weather conditions only allowed for two days of sampling to be conducted in 2020. Twelve days of sampling were conducted from January to March 2021 before the survey was suspended for staff to conduct the WDFW trawl survey. Due to continuing restrictions on field work resulting from the pandemic, it was recognized that the full survey could not be completed within the designated time/budget framework. Therefore, to provide for a comparable dataset to the ROV survey conducted in 2015-16, the 2019-21 survey scope was narrowed to focus on only those stations inside of Admiralty Inlet (Figure 14). The ROV survey resumed in June with six days of sampling conducted between June and September 2021. A total of 184 transects at planned survey stations were completed and the collected video is currently undergoing review.

For more details on the ROV program, contact Bob Pacunski (Robert.pacunski@dfw.wa.gov).

Figure 12: WDFW's new vessel for ROV (and other) operations, the R/V *Salish Rover*. The "*Rover*" is 57 feet long and has a full galley, settee area, head, and 3 staterooms with 2 bunks each.

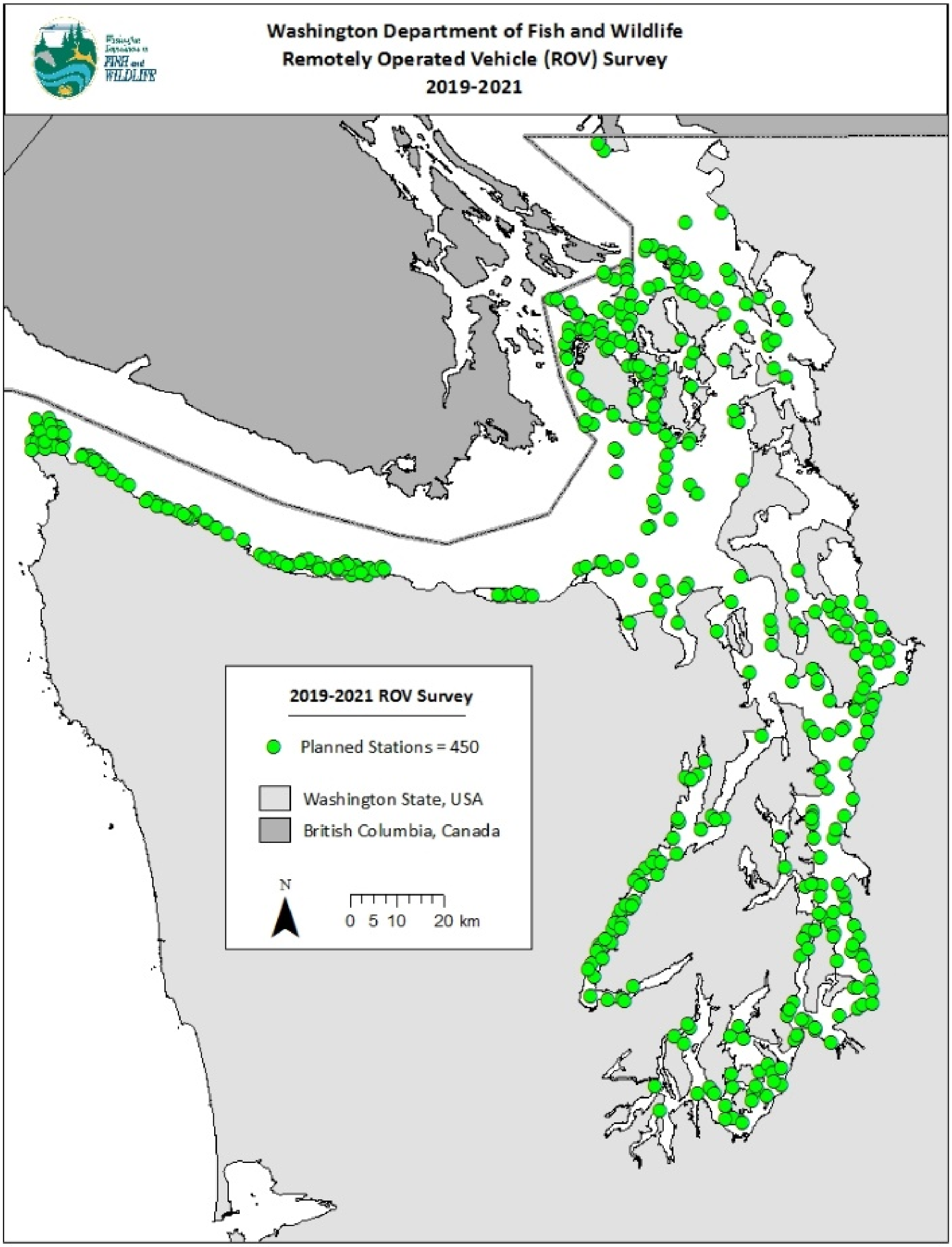

Figure 13: Randomly selected stations (n=450) for the 2019-21 ROV survey. Stations all lie within the highly suitable stratum predicted by the MaxEnt model based on prior ROV survey data.

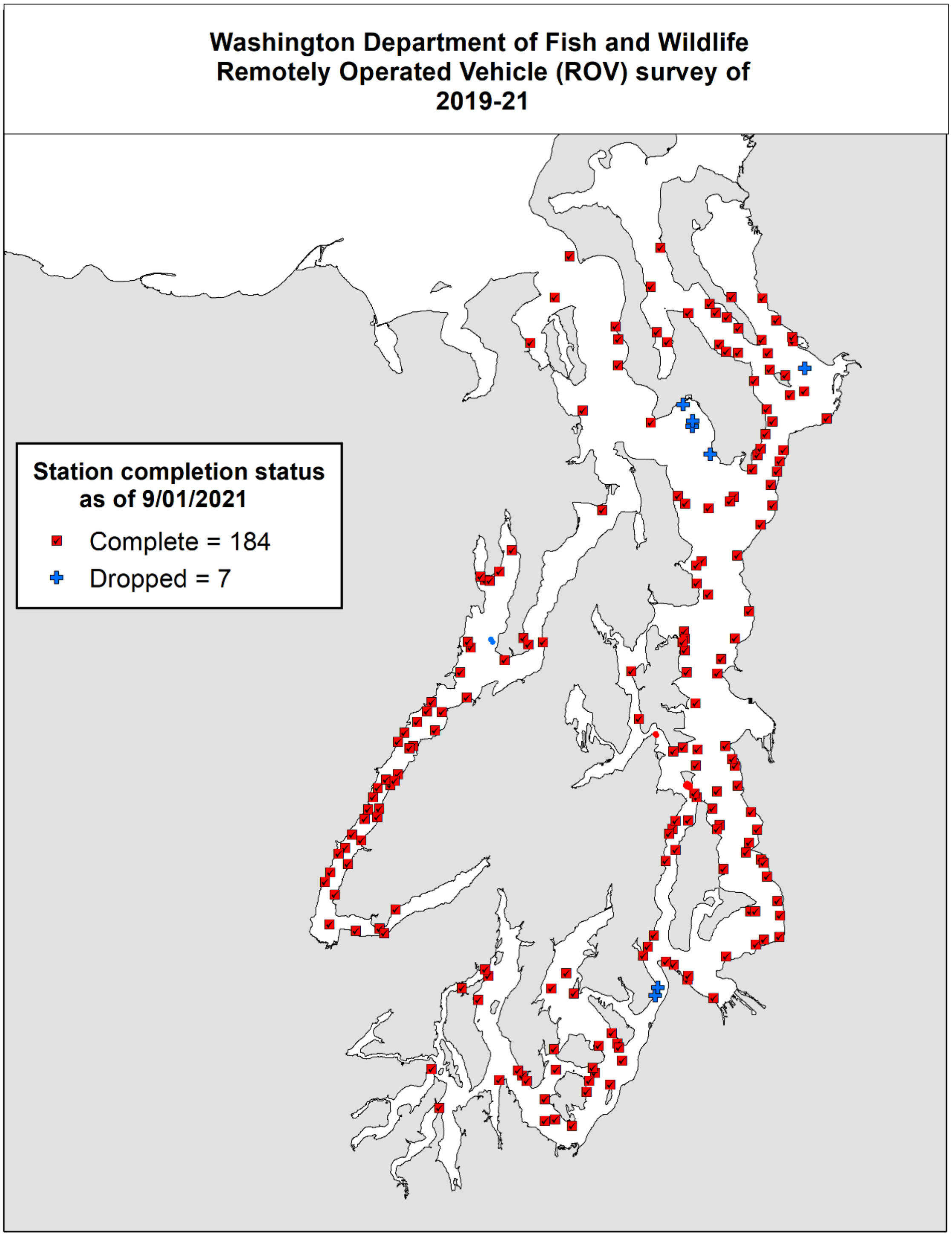

Figure 14: Revised scope of the 2019-2021 ROV survey due to scheduling setbacks from COVID-19 and the new vessel acquisition.

D. Coastal Black Rockfish Relative Abundance Rod-and-Reel Survey

Background

The WDFW has conducted fishery independent rockfish surveys on the Washington coast since the 1980s. Historically, these surveys have primarily focused on Black Rockfish due to the predominance of this species in recreational fishery landings. Concerns over population sizes of other less dominant, but recreationally sought after, nearshore groundfish species has recently motivated survey design changes to address this data need. From 2014 to 2017, the WDFW conducted a series of experimental rod-and-reel studies focused on the development of a catch-per-unit-effort survey that could describe relative changes in abundance over time of all groundfish species found on Washington's nearshore rocky reefs. Results of these studies were considered in the creation of a coastwide survey strategy piloted in 2018. This strategy is composed of two annual legs, or separate surveys: one focused on rockfish that typically school above rock piles in the spring and another targeting demersal groundfish species in the fall. After some significant adjustments to the 2018 survey design, the annual Black Rockfish Survey and the Demersal Groundfish Survey were implemented in the spring and fall of 2019, respectively. The Black Rockfish Survey, focused on all schooling rockfish species of Washington's nearshore waters, including Black, Yellowtail, Blue, Deacon, Canary, and Widow rockfish, has continued with standardized methods through the spring of 2021 and is summarized here.

Methods

The 2021 Black Rockfish survey was scheduled from March to May, remaining consistent with historic WDFW spring survey timing. The study area includes the entire Washington Coast, from the mouth of the Columbia River to the confluence of the Sekiu River with the Strait of Juan de Fuca, and includes all coastal Marine Areas. Location depths are limited to under 40 fathoms, which includes the extent of the typical depth range of Black Rockfish, and all locations where the WDFW rod-and-reel surveys have previously encountered Black Rockfish. Within this study area, 125 specific GPS coordinates located at rocky reefs were chosen as unique index stations in the spring of 2019; the coordinates of seven of these stations were adjusted in the fall of 2019 to avoid hazards and better accomplish both spring and fall survey objectives from a single GPS position. All 125 stations were scheduled to be surveyed in the spring of 2021 at the GPS locations defined in 2019 (Figure 15).

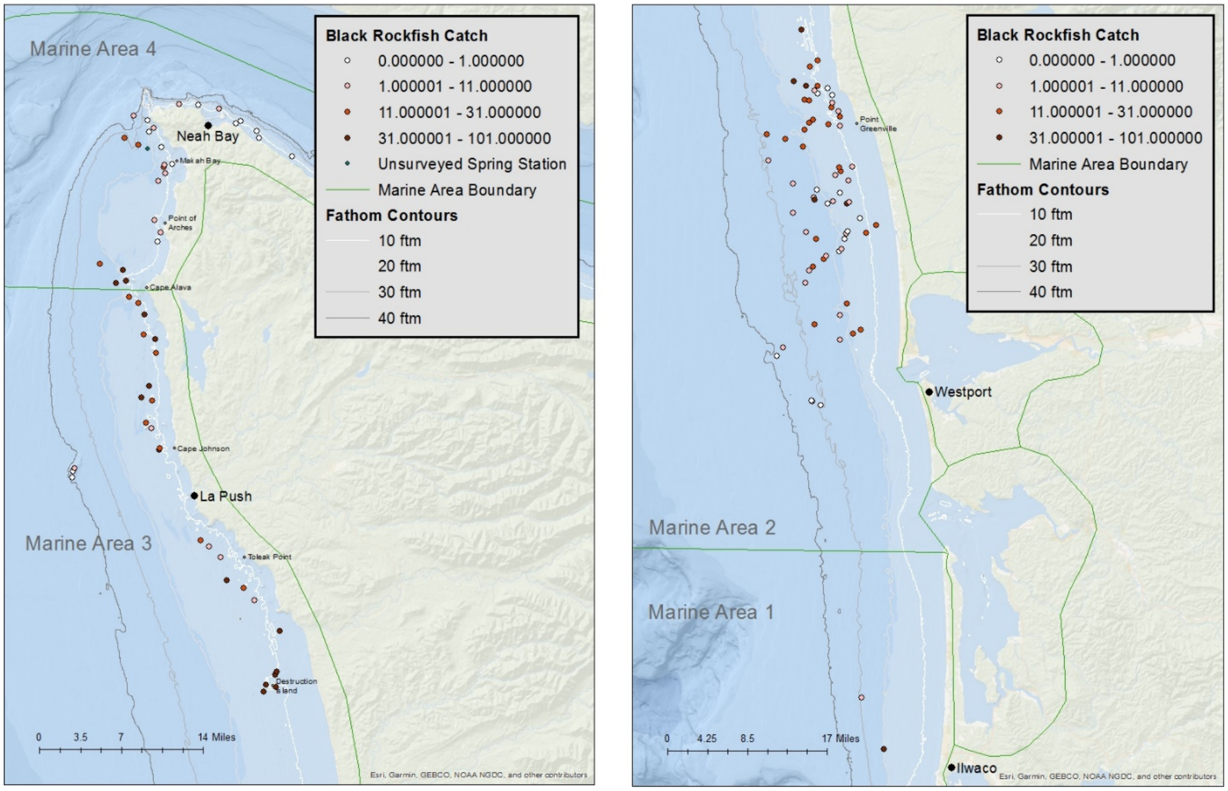

Figure 15: Spring index stations on the northern (left) and southern (right) Washington coast with associated total catch of Black Rockfish in the spring of 2021 by number of individuals.

Once stations were established in 2019, fishing effort remained largely unchanged for the spring Black Rockfish Surveys. Survey operations were conducted on three recreational charter vessels staffed with five hired anglers and three to four WDFW scientific staff. Fishing gear and tackle have been unaltered since 2019 and were kept consistent across all stations surveyed. Terminal tackle consisted of two shrimp flies tied on a leader above a dropper weight, and leaders were pre-tied at specified lengths before the charter day to ensure consistency.

All fishing effort was conducted during daylight hours, and charter days ranged from 8-11 hours. Stations to be visited on any given charter day were chosen before leaving port by the lead biologist after consultation with the vessel's captain and consideration of current ocean conditions. Fishing effort at each station consisted of four, eight-minute fishing drifts that began within 50 yards of the station's GPS position. At each station, captains took time to scout for fish aggregations and hard bottom/high relief areas near the station coordinates before setting up each drift. Vessels drifted unanchored for all fishing effort. A fishing "drift" was defined as any consecutive time span that was spent fishing, beginning when the first angler's hook entered the water and ending when the last angler's hook left the water for any reason. Captains were allowed to slow drifts to maintain an effective and similar fishing speed and direction for all drifts at a single station.

Five anglers fished for the total fishing time at each station surveyed. Each charter day the same five anglers fished all stations. Individual anglers were assigned a position on the vessel to fish for all drifts at a single station. Depending on the captain's preference, these standard angler fishing positions were established on either the starboard or port side of the vessel and were evenly spread out on the chosen side of the vessel from bow to stern. Before fishing began at each station, anglers were randomly assigned to one of the standard fishing positions. Reduced vessel capacity and social distancing requirements introduced in 2021 COVID-19 safety plans necessitated a more dispersed angler placement on the smaller "six-pack" charter vessel used for all stations in Marine Area 3 and stations at Cape Alava in Marine Area 4. Three anglers were evenly spread out on the starboard side of the vessel and two anglers fished on the port side, one toward the bow and another mid-ship. Safety precautions also prevented the randomization of any angler position on this vessel.

For each drift, anglers started and ended fishing at the same time but were allowed to retrieve their gear as many times as necessary during the drift to land catch or maintain gear. Individual angler times per drift were recorded as total time hooks were in the water, which excludes any time that fishing gear was out of the water either to land a fish or work on the gear. Anglers were allowed to fish anywhere in the water column that they expected to catch the most fish and captains were encouraged to describe the depths of fish aggregations to them.

Effort information collection included station number, GPS location of the start and end of each drift, depth, disposition of vessel (anchored or drifting), drift speed and direction, number of anglers, total fishing time per station, and terminal tackle gear type. Individual angler's fishing time, catch by species, gear loss, and fishing depth (benthic or pelagic) were recorded for each angler and drift. Catch was identified to species, measured (fork length), and scanned for previously implanted tags. A caudal fin clipping no larger than one centimeter squared was collected, preserved on blotter paper, and recorded by individual fish for the first 50 individuals of all rockfish species, Kelp Greenling, Cabezon, and Lingcod encountered in each Marine Area visited. Fish that were not chosen for ancillary age structure sampling were released at capture location with a descending device when necessary. Released Yelloweye Rockfish were tagged with both an internal PIT tag and an external Floy tag. Released China Rockfish, Copper Rockfish, Deacon Rockfish, Quillback Rockfish, Tiger Rockfish, Vermilion Rockfish, Cabezon, and Kelp Greenling were tagged with a Floy tag and released.

The reduced vessel capacity in 2021 due to COVID-19 safety plans limited the collection of biological data on the smaller "six-pack" charter vessel to length-only data at stations in Marine Area 3 and around Cape Alava. All other tag and biological data procedures were forgone in this area.

Weather conditions including the intensity and direction of tide, wind, and swell were also recorded before fishing began at each station. A model SBE 19+ V2 water column profiler (CTD) was deployed at select stations surveyed in the 2021 spring survey. Stations that were central to groupings of stations were chosen for CTD deployment in an effort to represent conductivity, temperature, dissolved oxygen and chlorophyll A at multiple stations in a time effective manner. All survey stations were within 5 miles of a scheduled CTD deployment location; however, CTD deployment was initially put on hold in 2021 due to concerns over COVID-19 social distancing protocols and the required number of staff and minimal space available to launch the CTD safely. After a better understanding of workflow was observed on the water, it was determined that the CTD could be launched while following COVID-19 safety protocols. Once safety was assured, the CTD was cast at each deployment station when ocean and benthic conditions allowed after fishing effort for the station was complete.

Results

Over 21 charter days, 124 Black Rockfish Survey stations were successfully surveyed along the coast (Table 3). Average drift speeds at each station ranged from 0.1 to 1.8 knots, and all stations were fished while drifting. Five anglers fished all stations, and total angler rod hours at successfully surveyed stations ranged from 2.3 to 2.9.

As expected, Black Rockfish was by far the most predominant species captured across all Marine Areas in waters less than 30 fathoms (Table 4). Other high catch species included Canary Rockfish, Deacon Rockfish, Lingcod, and Yellowtail Rockfish. Less than 18 individuals of all other species encountered were captured, but species diversity did increase by Marine Area up the coast.

Total catch across all species was much higher than expected at stations in Marine Area 3 and at the southern extent of Marine Area 4. Both the port of La Push and Neah Bay were inaccessible to recreational anglers for most of 2020 and all of 2021 up to the completion of the survey due to tribal land closures related to the COVID-19 pandemic. The low/no fishing effort in the waters of Marine Areas 3 and 4 that are generally only accessible from these ports likely influenced the catch rates of this year's survey.

No water column profiles were collected during the four cruises completed from March 11 to 23 while safe operating procedures were considered. Thirty-two water column profiles coastwide were successfully collected after March 23 (Table 5). Higher than expected dissolved oxygen readings (>8 ml/l) were noted in profiles taken in Marine Areas 1, 2, and 3, in all depth bins surveyed and in samples collected down to 19.7 meters.

For more information about the Black Rockfish survey, contact Rob Davis (Robert.davis@dfw.wa.gov).

Table 3: Distribution (number) of stations surveyed in the 2021 Black Rockfish Survey by Marine Area and depth bin.

	0-10 Fathoms	11-20 Fathoms	21-30 Fathoms	31-40 Fathoms	Grand Total
Marine Area 1			2		2
Marine Area 2	9	34	20	3	66
Marine Area 3	11	14	2	1	28
Marine Area 4	11	13	3	1	28
Grand Total	31	61	27	5	124

Table 4: Total catch of groundfish species for the spring 2021 Black Rockfish Survey summarized by Marine Area and depth bin.

		Black Rockfish	Blue Rockfish	Cabezon	Canary Rockfish	China Rockfish	Copper Rockfish	Deacon Rockfish	Kelp Greenling	Lingcod	Quillback Rockfish	Redstripe Rockfish	Rock Sole	Silvergray Rockfish	Vermilion Rockfish	Widow Rockfish	Yelloweye Rockfish	Yellowtail Rockfish	Total
Marine Area 4	0-10 Fathoms	60	1	2	2	2	2	14		19			1					8	111
	11-20 Fathoms	108	2	2	23	6	9	20	4	29	1				1			15	220
	21-30 Fathoms	105			18		3	19	1	6								27	179
	31-40 Fathoms	2						18			1					2	1	4	28
	Total	275	3	4	43	8	14	71	5	54	2		1		1	2	1	54	538
Marine Area 3	0-10 Fathoms	527	2	6	5	4		63	3	17								10	637
	11-20 Fathoms	412	12	7	3	1		205	1	22					3		1	18	685
	21-30 Fathoms	3			1	1		24		12	2	1		1		6	2	38	91
	31-40 Fathoms				1					8							1	6	16
	Total	942	14	13	10	6		292	4	59	2	1		1	3	6	4	72	1429
Marine Area 2	0-10 Fathoms	104						2		2									108
	11-20 Fathoms	553							1	27								4	585
	21-30 Fathoms	219			2			3	2	14	5						1	7	253
	31-40 Fathoms	11						1		1	1						1	6	21
	Total	887			2			6	3	44	6						2	17	967
Marine Area 1	21-30 Fathoms	51																	51
	Total	2155	17	17	55	14	14	369	12	157	10	1	1	1	4	8	7	143	2987

Table 5. Range of water column ocean condition values observed in the spring of 2021 by station depth bin and Marine Area. Samples collected at a decent rate of one-half to two meters/second are summarized here.

Marine Area	Depth Bin	Total Profiles	Max Depth (M)	Dissolved Oxygen (ML/L) Min	Dissolved Oxygen (ML/L) Max	Temperature (°C) Min	Temperature (°C) Max	Salinity (PSU) Min	Salinity (PSU) Max	Chlorophyll (UG/L) Min	Chlorophyll (UG/L) Max
1	21-30	1	50.36	2.01	10.17	8.04	11.02	29.03	33.76	0.73	3.45
2	0-10	2	13.68	4.92	6.24	8.60	8.90	30.97	32.49	0.28	1.05
2	11-20	3	28.76	4.38	7.95	8.48	9.07	28.15	32.76	0.23	1.98
2	21-30	6	55.42	2.19	9.87	8.00	11.92	30.34	33.69	0.19	3.83
2	31-40	1	69.27	1.87	8.82	7.69	8.81	31.36	33.86	0.19	3.36
3	0-10	5	19.72	5.20	8.81	8.64	11.57	28.11	32.72	0.27	1.35
3	11-20	3	30.52	3.12	10.74	7.82	11.02	31.05	33.36	0.34	2.43
3	21-30	1	58.04	3.47	7.20	7.73	9.64	31.63	33.43	0.28	1.15
4	0-10	2	26.24	2.90	5.57	7.24	7.85	32.08	33.68	0.19	0.50
4	11-20	6	31.29	2.58	7.52	7.09	10.34	31.62	33.78	0.21	1.25
4	21-30	2	43.18	2.76	7.95	7.34	10.57	31.70	33.70	0.23	1.36

E. Coastal Demersal Groundfish Relative Abundance Rod-and-Reel Survey

Background

The Demersal Groundfish Survey, focused on species including China, Copper, Quillback, Tiger, Vermilion, and Yelloweye Rockfish, as well as Kelp Greenling and Cabezon, was cancelled in 2020 due to COVID-19, but continued with standardized methods in the fall of 2021.

Methods

The 2021 Demersal Groundfish survey was scheduled from mid-September to mid-October, consistent with the 2019 fall survey timing. The study area included the Washington Coast Marine Areas 2, 3, and 4, from the nearshore waters just outside of Grays Harbor to the confluence of the Sekiu River with the Strait of Juan de Fuca. Location depths were limited to under 40 fathoms. Within this study area, 64 specific GPS coordinates located at rocky reefs were chosen as unique index stations in the fall of 2019. All 64 stations were scheduled to be surveyed in the fall of 2021 at the GPS locations defined in 2019 (Figure 16).

Once stations were established in 2019, fishing effort remained largely unchanged for the fall Demersal Groundfish Survey. Methods of the Demersal Groundfish survey were identical to those described in the spring Black Rockfish Survey, with a few key method changes to better represent demersal species. These adjustments included a terminal tackle change to salmon mooching rigs baited with white worms and a restriction of all angler fishing effort to “on or near the bottom”; schools of fish in the water column were not targeted. All other data collection and fishing effort methods were kept consistent with the spring survey described above.

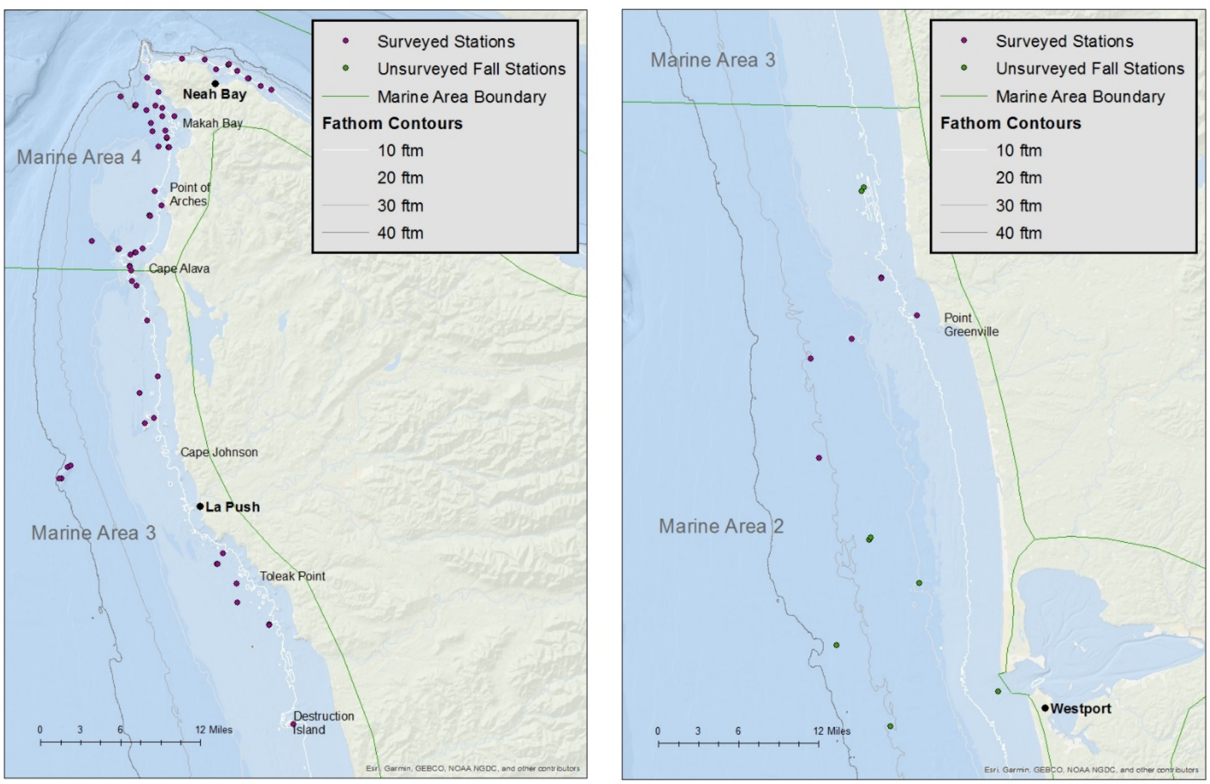

Figure 16: Demersal Groundfish Survey index stations on the northern (left) and southern (right) Washington coast. Unsurveyed stations were scheduled for the 2021 fall survey, but not fished.

Results

Over 9 charter days, 56 Demersal Groundfish Survey stations were successfully surveyed along the coast (Table 6). Eight stations were not surveyed in Marine Area 2 due to poor ocean conditions.

Average drift speeds at each station ranged from 0.1 to 1.2 knots. Five anglers fished all stations, and total angler rod hours at successfully surveyed stations ranged from 2.38 to 2.94.

Although Black Rockfish and Deacon Rockfish were notably the most predominant species caught, over 100 China Rockfish were also encountered (Table 7). Other prominent demersal species included Cabezon, Kelp Greenling, and Copper Rockfish. Catch was diverse in Marine Areas 3 and 4 with 12 different rockfish species, Cabezon, Kelp Greenling, and Lingcod encountered.

Twenty-four water column profiles were successfully collected in Marine Areas 2 - 4 (Table 8). Hypoxic water conditions were found at 3 of the 5 stations surveyed in Marine Area 2 at depths from 37 to 60 meters. Limited catch at these stations consisted of two Black Rockfish and one Copper Rockfish.

For more information about the Demersal Groundfish Survey, contact Rob Davis (Robert.davis@dfw.wa.gov).

Table 6: Distribution (number) of stations surveyed in the 2021 Demersal Groundfish Survey by Marine Area and depth bin.

	0-10 ftm	11-20 ftm	21-30 ftm	31-40 ftm	All Depths
Marine Area 2	1	1	2	1	5
Marine Area 3	7	7	1	3	18
Marine Area 4	14	13	6		33
Coastwide	22	21	9	4	56

Table 7: Total catch of groundfish species for the fall 2021 Demersal Groundfish Survey summarized by Marine Area and depth bin.

		Black Rockfish	Blue Rockfish	Cabezon	Canary Rockfish	China Rockfish	Copper Rockfish	Deacon Rockfish	Kelp Greenling	Lingcod	Quillback Rockfish	Rock Sole	Tiger Rockfish	Vermilion Rockfish	Widow Rockfish	Yelloweye Rockfish	Yellowtail Rockfish	Grand Total
Marine Area 4	0-10 Fathom	80	1	16	6	42	13	11	18	15	3						2	207
	11-20 Fathom	60		11	18	39	16	23	13	11	6	1					10	208
	21-30 Fathom	22		3	21	10	10	7	5	3	5			3	1	2	19	111
	Total	162	1	30	45	91	39	41	36	29	14	1		3	1	2	31	526
Marine Area 3	0-10 Fathom	85		5		16	2	42	8	7				1			10	176
	11-20 Fathom	85		1	4	8	1	26	6	2							4	137
	21-30 Fathom	1			4			11		6					5	5	6	38
	31-40 Fathom	1		1				13	2	12	3		2	1	12	17	18	82
	Total	172		7	8	24	3	92	16	27	3		2	2	17	22	38	433
Marine Area 2	0-10 Fathom	7																7
	11-20 Fathom	19																19
	21-30 Fathom	2					1											3
	Total	28					1											29
Grand Total		362	1	37	53	115	43	133	52	56	17	1	2	5	18	24	69	988

Table 8: Range of water column ocean condition values observed in the fall of 2021 by station depth bin and Marine Area. Samples collected at a decent rate of one-half to two meters/second are summarized here.

Marine Area	Depth Bin	Total Profiles	Max Depth (M)	Oxygen (ML/L) Min	Oxygen (ML/L) Max	Temperature (°C) Min	Temperature (°C) Max	Salinity (PSU) Min	Salinity (PSU) Max	Chlorophyll (UG/L) Min	Chlorophyll (UG/L) Max
2	0-10	1	14.595	5.2769	5.8559	12.5964	12.847	30.3924	30.7021	0.3779	0.4414
2	11-20	1	22.883	3.064	5.9851	11.5975	12.9632	30.4906	31.8803	0.3303	0.4582
2	21-30	2	50.911	0.9048	6.2006	8.0056	13.1772	30.4603	33.527	0.2618	1.0295
2	31-40	1	59.46	0.8193	6.9609	7.9737	13.1485	31.3092	33.5332	0.249	2.5758
3	0-10	2	19.134	4.3368	6.8842	11.8711	13.4105	31.5917	32.8013	0.5614	3.0668
3	11-20	4	23.8	3.0155	6.1982	7.9148	12.5607	31.5623	33.3725	0.2599	0.9978
3	31-40	1	54.565	3.2672	5.5552	7.8122	11.4514	31.7828	33.2614	0.2321	0.8401
4	0-10	1	14.486	5.1858	5.7007	12.0781	12.7296	31.5079	31.7982	0.4136	0.5148
4	11-20	7	39.923	1.6925	5.9417	7.81	12.937	30.9513	33.7018	0.2083	0.9085
4	21-30	4	49.108	2.5376	5.9673	9.0696	13.2866	31.1899	33.2133	0.3194	0.7756

F. Coastal Nearshore Rockfish Distribution Study

Background

The exploration of the Washington coast for rockfish habitat undocumented in research surveys has been ongoing by the WDFW, with most new location exploration conducted in 2014 and 2015 utilizing varied survey methods. However, large areas of nearshore waters have remained unexplored in survey effort, particularly around the border of Marine Area 2 and 3, mostly due to the lack of information on any rocky habitat in this area. One full fishing day was scheduled around this area for a rockfish distribution study conducted at the end of the 2021 spring rod-and-reel survey season.

Methods

Survey fishing effort was spatially distributed within the confines of a survey grid scheme developed by the WDFW that consisted of 3-km^2 main cells arranged in a grid pattern superimposed over waters off the Washington coast from 0-40 fathoms. These 3-km^2 main grid cells are partitioned into nine smaller 1-km^2 sub-cells. Within this schema, multiple 3-km^2 grid cells were chosen for survey operations.

Survey effort data from 1997 to 2020 were used to indicate locations within 30 fathoms of water on the Washington coast that were spatially distant from all historic survey efforts. Nineteen different main grid cells, located at least 3 km from any main grid cell with previous WDFW rod-and-reel survey fishing effort, were indicated for future habitat exploration. Locations where multiple adjacent 3-km^2 main grid cells were found to be 3 km from any previous fishing location were selected in a grid pattern, choosing every other main grid cell.

The F/V Top Notch, whose captain has over 20 years of experience fishing for groundfish out of La Push, was contracted for the 2021 spring distribution study. Due to space limitations of this vessel and expected low catch rates, everyone on board fished all drifts. Standardized fishing gear from the Black Rockfish and Demersal Groundfish Surveys was used during the distribution study. At each chosen main grid cell, one sub-cell was fished exclusively with a shrimp fly rig consisting of two shrimp flies tied onto the mainline above a dropper weight, and a second sub-cell was fished exclusively with a salmon mooching rig baited with an artificial worm. These are the standardized terminal tackle of the Black Rockfish and Demersal Groundfish Surveys, respectively. The weight of sinkers used for each drift was chosen by the vessel's captain after taking into consideration depth and weather conditions but were kept consistent among anglers for each drift.

Each main grid cell chosen for this study was scouted for fish aggregations or hard bottom with the vessel's onboard sounding equipment for approximately 10 minutes before fishing began. This typically allowed for 2-3 sub-cells to be scouted in each main grid cell. When no fish or habitat were found during the scouting period, fishing commenced in unexplored sub-cells. Two different 1-km^2 sub-cells in each chosen main grid cell that would most likely provide groundfish catch were chosen for fishing operations by the captain. A minimum of one rod hour was devoted to each fished sub-cell, and all effort was conducted within the boundaries of each sub-cell.

Specific fishing locations within each sub-cell that would most likely provide groundfish catch were chosen by the vessel's captain. The distance of fishing drifts and number of drifts per sub-cell were determined by the captain to allow for repositioning on schools of fish or habitat or to remain in the selected sub-cell. Captains were allowed to slow drifts to maintain an effective fishing speed, maintaining a similar drift speed and direction for all drifts of a single set. All fishing effort was conducted within each station's cell boundaries.

Six anglers fished for the total fishing time at each sub-cell fished. For each drift, anglers started and ended fishing at the same time but were allowed to retrieve their gear as many times as necessary during the drift to land catch or maintain gear. Individual angler times per drift were recorded as total time hooks were in the water, which excludes any time that fishing gear was out of the water, either to land a fish or work on the gear. Anglers were allowed to fish anywhere in the water column that they expected to catch the most fish, and captains were encouraged to describe the depths of fish aggregations to them.

Results

Nine main grid cells were successfully surveyed during the 2021 spring rod-and-reel survey. Eight were completed in one full charter day spent on the border of Marine Area 2 and 3, and an additional cell was completed at the end of a shorter Black Rockfish Survey cruise day completed just south of La Push (Figure 17).

Average drift speeds of each set ranged from 0.2 to 1.2 knots, and total angler rod hours ranged from 1.0 to 1.2. No rocky habitat or fish aggregations were indicated during sounding examinations or fishing operations, and only one Pacific Halibut and one Butter Sole were caught with all fishing efforts. Additionally, no locations within two miles of the chosen cells were known by the captain to contain rocky habitat.

For more information about this survey, contact Rob Davis (Robert.davis@dfw.wa.gov).

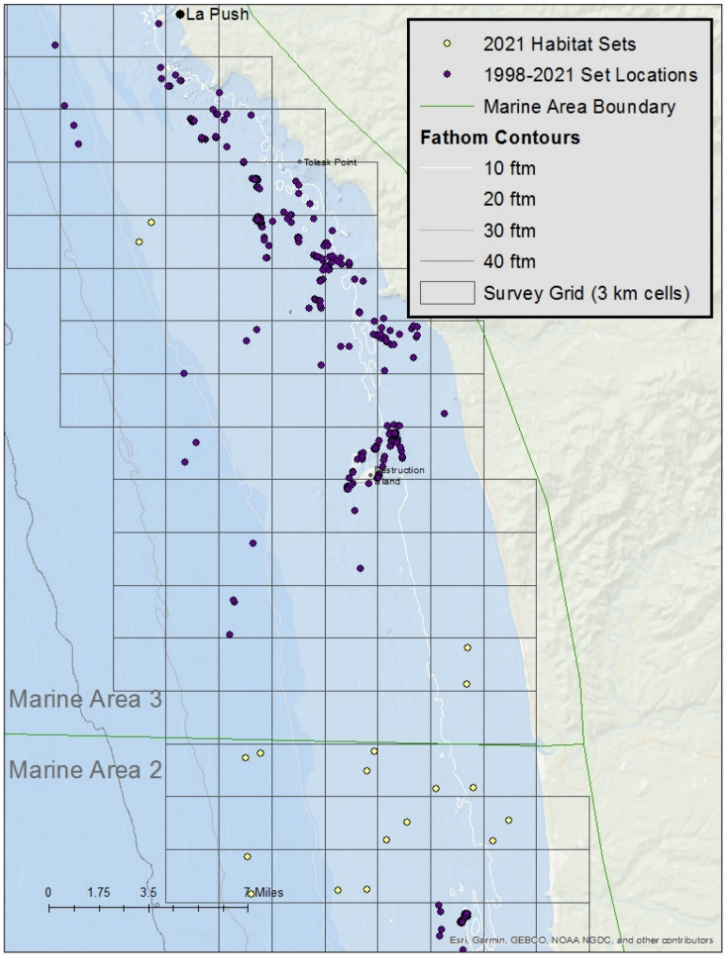

Figure 17: Set locations of the 2021 Distribution Study within the survey grid (3-kilometer main cells) scheme with all historic WDFW rod and reel set locations.

G. Coastal Hydroacoustic Rockfish Abundance Proof-of-Concept Study

Background

The groundfish species that inhabit Washington's nearshore waters (inside 30 fathoms or 55 meters) make up a diverse assemblage of species that are socially, economically, and ecologically important. Multiple rockfish species, Cabezon, Lingcod, and Kelp Greenling are regularly exploited in Washington's recreational bottomfish fishery necessitating robust monitoring programs to inform management decisions by tracking harvest and population abundances. Of the various tools used to track these resources, fishery-independent biological and abundance data are necessary to reduce sole reliance on fishery-dependent catch-per-unit-effort data in stock assessment models.

Of the methods available to generate fishery-independent data on marine fish populations, hydroacoustic techniques are particularly promising for assessments of nearshore schooling rockfish off the Washington coast. Acoustic surveys can cover large areas of water over high-relief rocky reefs that many other gear types cannot, and they can cover most of the water column quickly.

Acoustic measurements have little bias in size-selectivity, are not dependent on fish feeding behaviors for capture, and are non-extractive and thus ecologically friendly. However, limitations to this survey strategy are not insignificant. Due to backscatter created from the sea floor, fish near the sea floor in this 'acoustic dead zone' are difficult to differentiate and are likely underrepresented with acoustic surveys, making this gear type most suitable for schooling fish species. Additionally, ocean conditions such as swell, wind, and water clarity (bubbles/zooplankton) can all have major impacts on the quality of results, and a secondary gear type is typically needed to determine species composition.

The potential of acoustic surveys to represent a large portion of schooling rockfish populations over time with minimal variation prompted the investigation into this gear type on the outer coast of Washington. To address some concerns with the feasibility of using this gear in the difficult ocean conditions that are typical on the Washington coast, a small proof-of-concept study was designed and carried out in the spring of 2021. This study focused on the basics of implementation, typical data quality, and the possibility of incorporating hydroacoustic methods into the WDFW Black Rockfish Rod-and-Reel Survey. This report outlines acoustic and rod-and-reel activities carried out to answer some of these questions.

Methods

The acoustic proof-of-concept study was conducted during the 2021 Black Rockfish rod-and-reel survey season. Due to weather, charter vessel availability, and other survey priorities, only one day could be devoted to this study. Five index stations of the Black Rockfish rod-and-reel survey were selected for evaluation on April 1, 2021. All stations were positioned on rocky habitat in less than 30 fathoms of water on the central Washington coast from Point Grenville to Westport (Figure 18). The F/V Tornado that was chartered for the spring 2021 Black Rockfish rod-and-reel survey operations out of Westport was used to carry out both acoustic and rod-and-reel efforts. The Tornado is a 54' vessel captained by Dwight Sawin, who has well over 10 years of professional captain experience fishing for rockfish on the Washington Coast.

Select stations that had been previously surveyed in the 2021 Black Rockfish rod-and-reel survey were revisited for this study. At each station, nine 200-meter acoustic transects arranged in a grid pattern and centered on the station coordinates were conducted prior to fishing. Transect lines ran east and west and were spaced 25 meters apart. Target transect lines were developed and imported into a .nob file pre-survey, loaded into Rose Point navigational software, Coastal Explorer, and used by the captain in real-time to maintain course over the transect lines.

A BioSonics DT-X Extreme portable echosounder with a 120-kHz transducer was used for hydroacoustic data collection. This system was available for loan over the study period and is used in similar nearshore rockfish studies conducted in the NE Pacific Ocean, although a 210-kHz transducer is typically used.

The transducer was mounted on a 2-inch by 10-foot steel, schedule-40 pipe via a BioSonics transducer swivel mount. The pipe was fastened mid-ship on the port gunwale of the vessel through a custom swivel bracket that allowed for retrieval of the transducer during transit. The transducer was connected to the DT-X Extreme surface unit, which houses the echosounder transmitter, by a 25-foot digital transducer cable. When deployed, the transducer sat 5 feet below the water surface.

An external Garmin GPS receiver was mounted to the top of the pipe and routed into the transmitter for spatial correlation with acoustic observations. The surface unit system was powered by a 12-V marine battery. A Panasonic Toughbook was connected to the surface unit via an Ethernet cable to run Biosonics Visual Acquisition software for setting acoustic parameters and settings, and for viewing and logging the acoustic data in real time.

Water temperature and salinity measurements were taken just before the first station was sampled for use in the configuration of the echosounder, which remained unchanged throughout the day. These environmental factors were taken with a YSI sensor lowered approximately 5 feet below the surface of the water. Acoustic data acquisition was configured with a 0.4-ms transmit pulse duration, a ping rate of 1.4, a calibration correction of 0 dB, a threshold level of 80 dB, and a ping range of 1 to 70 meters.

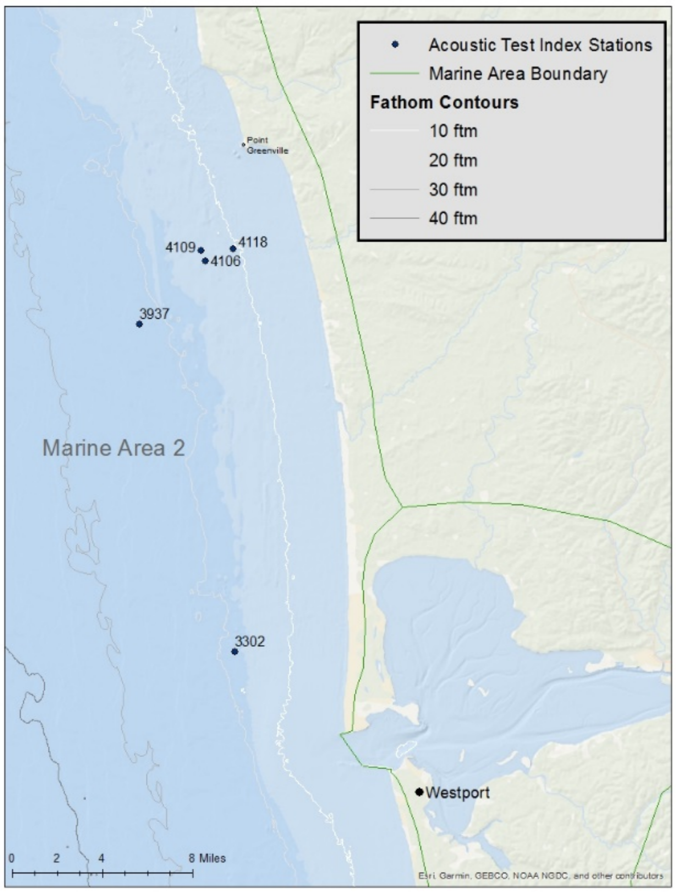

Figure 18: Black Rockfish index stations used for the acoustic test study in 2021.

Just before the vessel reached the first transect of each station, the echosounder was lowered into the water and turned on, and logging to a unique .rtpx file for each station was initiated. The vessel speed was maintained at ~5 knots for all transects. Acoustic data continuously logged during the sampling of the entire transect grid of each station, which included traversing from one transect to the next. Start and end points of each transect were documented as waypoints in the Visual Acquisition software. Once all transects were complete for a station, the file was saved, the system was turned off, and the transducer was lifted out of the water before fishing effort began.

Rod-and-reel fishing gear, tackle, and effort remained mostly consistent with the spring Black Rockfish Survey methods. The standard four drifts per station were reduced to three to allow for more stations to be surveyed with both gear types on the single day available for this study. All other fishing effort methods remained unchanged. Rod-and-reel catch and effort information were collected at each station for all species encountered following the Black Rockfish Survey protocols.

Results

In the one charter day allotted to this study, five stations were successfully surveyed with both acoustic and rod-and-reel gear according to the methods described above. The acoustic hardware was adequate for the survey design, although the 10-foot transducer pole and 25-foot transducer cable were somewhat short for the size of the F/V Tornado and should be lengthened for any future work.

Weather conditions were moderate to light for what is typically seen in spring survey work on the Washington coast. Wind speed ranged between 3-7 knots and the swell ranged from 4-5 feet over the course of the day, having minimal effect on the echogram output outside of typical undulations in benthic echoes produced from swell. Additionally, some midwater backscatter, likely due to zooplankton or bubbles, was noted at the first stations visited (4118 and 4109) that coincided with ebb tides near the mouth of the Moclips River.

Obvious schools of fish were only seen at one station (3937) in real-time viewing of the Visual Acquisition software. The raw acoustic data from this station was sent for a basic analysis with the Biosoinics software VisAcq to Biosonics, Inc., who provided the summary figures of these data presented below. Most of the large school was represented in four of the nine transects (spaced 25 meters apart) at this station, indicating a very localized congregation of fish schooling just over a large pinnacle (Figure 19).

The histogram of echoes produced from this analysis provided a believable distribution of fish size over the pinnacle (Figure 20). However, it was noted that the ping rate used was too slow for fish tracking and a faster ping rate should be used in the future.

Conditions were favorable for rod-and-reel fishing as well. Average drift speeds at each station ranged from 0.4 to 0.8 knots, and all stations were fished while drifting. Total angler rod hours at each station ranged from 2.0 to 2.1 (Table 9). However, catch was lower than expected at all stations fished (Table 10), and catch rates did not obviously trend with the abundances indicated in the echogram of each station. The largest school by far seen in the acoustic data at station 3937 was easily targeted following the standardized rod-and-reel survey methods but produced the least amount of fish over the five stations.

For more information about this survey, contact Rob Davis (Robert.davis@dfw.wa.gov).

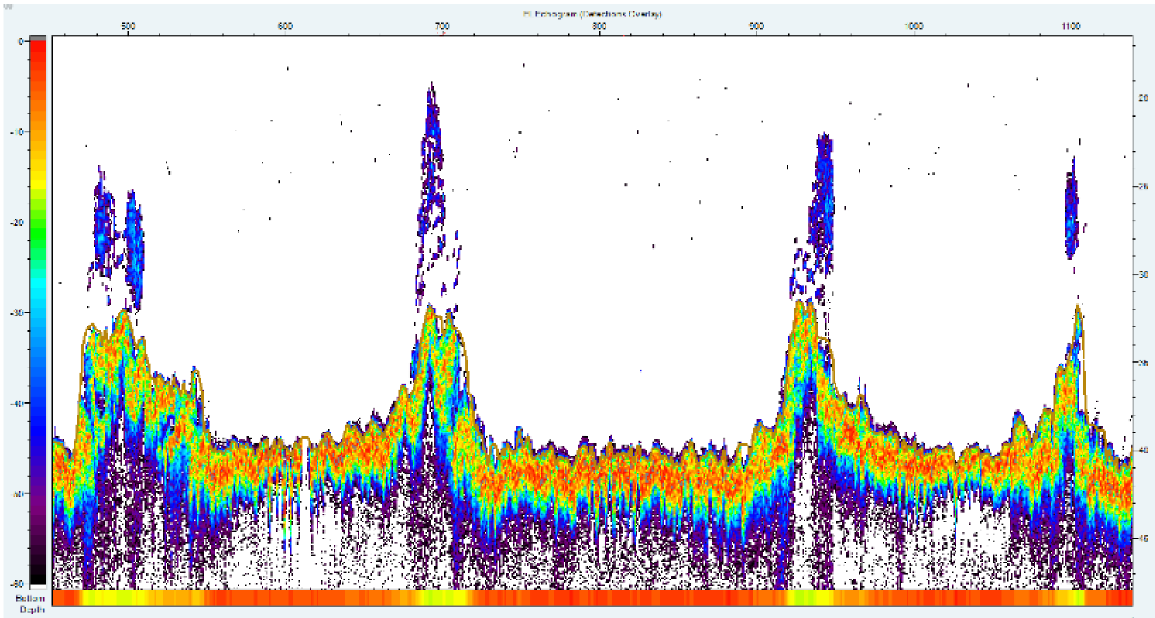

Figure 19: Echogram of four transects conducted over a single large school of fish at station 3937.

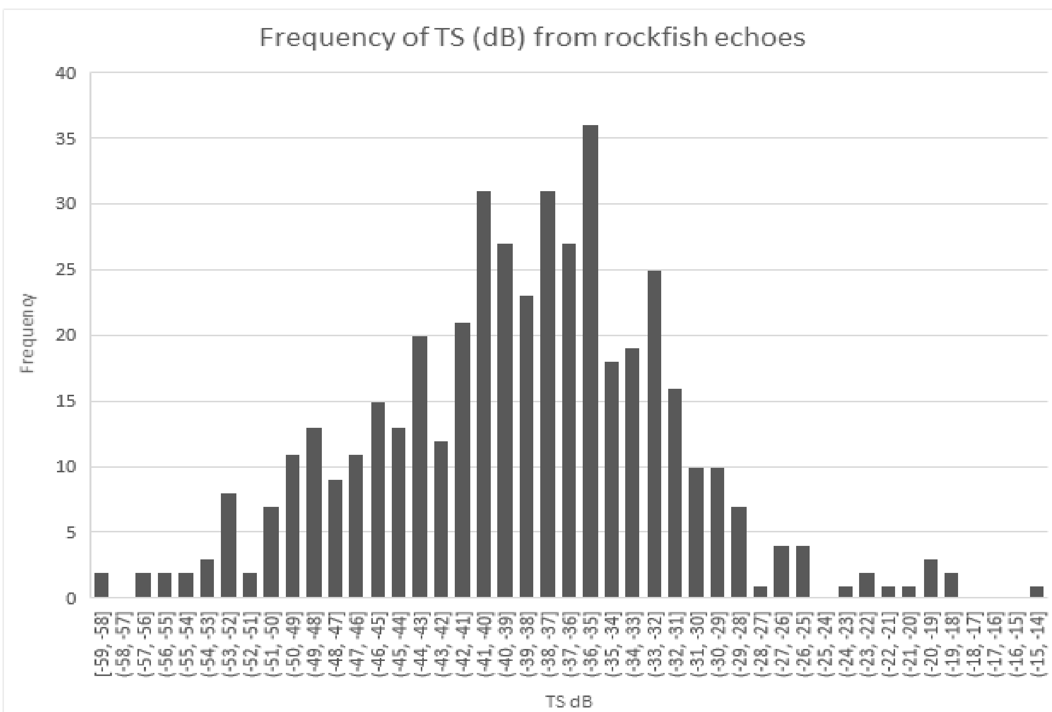

Figure 20: Histogram of echoes collected from four transects covering the large rockfish school at station 3937.

Table 9: Rod-and-reel effort at each station fished.

Date	Station	Marine Area	Total Minutes Fished	Depth (Feet)	Anchor/ Drift	Average Drift Speed	Toal Angler Time
4/1/2021	3302	2	26	115	D	0.7	123.33
4/1/2021	3937	2	26	115	D	0.7	120.70
4/1/2021	4106	2	25.75	67	D	0.4	121.82
4/1/2021	4109	2	26	94	D	0.4	124.55
4/1/2021	4118	2	26.75	71	D	0.8	125.98

Table 10: Total catch of species at each station fished.

	Station					Grand Total
	3302	3937	4106	4109	4118	
Black Rockfish	9	1	1	3	6	20
Buffalo Sculpin				1		1
Flathead Sole	1					1
Lingcod		1	5	1	2	9
Pacific Halibut					1	1
Yelloweye Rockfish		1				1
Grand Total	10	3	6	5	9	33

H. Nearshore Coastal Pelagic Species Acoustic Trawl Methodology Survey of the California Current off Washington and Oregon

In 2021, the WDFW Marine Fish Science unit placed biologists onboard the F/V LISA MARIE in a collaborative survey conducted by the NOAA/Southwest Fishery Science Center (SWFSC), the West Coast Pelagic Conservation Group (WCPCG) – a commercial fishery industry coalition, and the WDFW. The work accomplished in 2021 was a continuation of a “proof of concept” study initiated by industry in 2017 to extend acoustic surveying and sampling of the coastal pelagic species (CPS) assemblage to the nearshore, complementing the offshore NOAA/SWFSC California Current Ecosystem survey (CCES). The CCES acoustic trawl methodology survey conducted annually by the NOAA Southwest Fisheries Science Center (SWFSC) is a critical tool for understanding the abundance and distribution of Coastal Pelagic Species (CPS) such as Pacific Sardine, Northern Anchovy, Pacific Herring, Pacific Mackerel, Jack Mackerel, and mesopelagic fishes. Acoustic and biological data collected by WDFW biologists aboard the F/V LISA MARIE in the 2019 nearshore survey was successfully used in the 2020 Pacific Sardine stock assessment. The WCPCG was able to extend the federal Saltonstall-Kennedy grant received in 2020 to continue and expand the effort in 2021 as this survey was cancelled in 2020 due to the COVID-19 pandemic. As a requirement of the Saltonstall-Kennedy grant, a full report of this survey is forthcoming.

For more information about this survey, contact Kristen Hinton (Kristen.hinton@dfw.wa.gov).

III. FISHERY MONITORING

A. Puget Sound Port Sampling/Creel Surveys of Recreational Fisheries

Estimates are made for the recreational harvest of bottomfish, Pacific Halibut, salmonids, and other fishes caught in Puget Sound on an annual basis in Washington waters. Catch composition is estimated in two-month "waves" throughout the year via angler intercept surveys (i.e., creel sampling) and phone surveys. Staffing for angler intercept surveys, contracting of the phone surveys, and all estimation procedures are the responsibility of the Fish Program. *For more details, contact Anne Stephenson (Puget Sound; Ann.stephenson@dfw.wa.gov) or Eric Kraig (estimation; Eric.kraig@dfw.wa.gov).*

B. Ocean/Coastal Port Sampling/Creel Surveys of Recreational and Commercial Fisheries

WDFW supports groundfish stock assessments and management of fisheries through multiple interrelated groups that collect and process biological and catch data: the Fish Program's Ocean Sampling Program, and the Coastal Marine Fish Science (CMFS) Unit's commercial fishery sampling group and recreational fishery sampling group.

Ocean Sampling Program for Recreational Fisheries – The Ocean Sampling Program (OSP) is responsible for catch estimation of ocean salmon and groundfish recreational fisheries. OSP uses port exit counts, primarily, and dockside angler interviews of recreational landings at Ilwaco-Chinook, Westport, La Push, and Neah Bay to track quota attainment for Chinook and Coho Salmon, and to estimate catch of groundfish species. In addition, dockside samplers collect biological and tag data from salmon, and length data from groundfish. *For more details, please contact Kyle Vandegraaf (*kyle.vandegraaf@dfw.wa.gov).

CMFS Unit Commercial Fishery Sampling – Data on commercial groundfish, CPS, and Hagfish fisheries are collected by CMFS group technicians at all primary coastal ports: Westport, Ilwaco, Chinook, Bellingham, Blaine, Neah Bay, and La Push. This past year we had a changeover in staff; we hired a new port sampler and currently we have one open recruitment for another port sampler. The commercial sampling team has two major objectives: (1) to collect biological data – such as sizes, otoliths, and gonads – from commercially landed groundfish to support research and stock assessments; and (2) to collect groundfish catch data via commercial fisheries logbooks, fish receiving tickets, and species composition sampling of mixed-species market categories, which support fisheries monitoring and in-season management decision making.

The CMFS Unit produces periodic reports intended to inform fishery managers and fishery assessment authors by describing the biological and catch data collection methods and an inventory of data collected. Descriptions of port and fishery dynamics offer context for the changes to data collection methods. Collectively the series of reports serve to document changes in fishery monitoring and sampling goals, and approaches and procedures in response to evolving fishery management science and management needs. The most recent report, published June 2020, summarizes activities and accomplishments from 2015 through 2018 (Downs et al. 2020).

The CMFS Unit also monitors commercial coastal pelagic fishery landings in support of stock assessments and fishery management at Ilwaco and Westport. The only active fishery during the reporting period was the baitfish fishery, which harvests Northern Anchovy from the northern subpopulation (NSNA) distributed off Washington, Oregon, and northern California coasts. The NSNA are subject to management under the Pacific Fishery Management Council Coastal Pelagic Species Fishery Management Plan. NSNA have never been formally assessed, primarily due to the extremely low level of catch; thus, the status of the subpopulation is unknown. Biological sampling of landings was started in 2014 to provide time series data for potential assessment in the future as the need arises. Samples of 100 fish are collected weekly during the fishery season (roughly May to September). Fewer samples were collected in 2020 due to reduced fishing activity associated with the COVID-19 pandemic. Table 11 presents an inventory of the number of fish sampled and data collected as annual mean weight and length.

Table 11: An inventory of biological data and annual mean weight and length for Northern Anchovy sampled in the coastal bait fish fishery.

Year	Number sampled Length/Weight/Maturity	Number Aged	Mean Weight (g)	Mean Length (mm)
2015	1150	129	23	129
2016	1126	649	20	118
2017	933	929	14	111
2018	950	792	15	114
2019	1800	1790	16	112
2020	500		13	106
2021	1001		15	112

References cited

Downs, D., K. Hinton, J. Fuller, T. Zepplin, K. Lawson, L. Wargo, T.S. Tsou. 2020. Washington Coastal Commercial Groundfish Fisheries Monitoring Program: Progress Report 2015-2018. Washington Department of Fish and Wildlife. Fish Program Report Number FPA 20-07.

CMFS Unit Recreational Fishery Sampling – The CMFS Unit's recreational groundfish sampling program directly supports research and stock assessment by collecting biological data from recreationally caught groundfish species landed at Westport, La Push, and Neah Bay. Comprehensive biological information includes fork length in centimeters, weight in grams, sex information, and age structure collection (otolith or Lingcod dorsal fin ray). This biological information enhances data collection efforts of the WDFW Ocean Sampling Program previously described.

IV. RESERVES

Marine Reserve Monitoring and Evaluation – Due to changes in program priorities and staffing limitations brought on by intensive ROV survey work since 2011, very little directed monitoring of marine protected areas and reserves has occurred in Puget Sound in recent years, except for the synthesis report of LeClair et al (2018). No monitoring activities were conducted in 2021; however, the PSMFS Unit is currently collaborating with the Seattle Aquarium and Point Defiance Zoo and Aquarium to evaluate the potential for resuming dive surveys in 2022.

References Cited

LeClair, L., R. Pacunski, L. Hillier, J. Blaine, and D Lowry. 2018. Summary of findings from periodic scuba surveys of bottomfish conducted over a sixteen-year period at six nearshore sites in central Puget Sound. Washington Department of Fish and Wildlife Technical Report. Olympia, WA. FPT 18-04. 189 pp.

V. REVIEW OF AGENCY GROUNDFISH RESEARCH, ASSESSMENT, AND MANAGEMENT

A. Hagfish

The Washington Hagfish Commercial Fishery, which opened in 2005 under developmental regulations, is small in scale, exporting hagfish for both frozen and live-fish food markets in Korea. Hagfish are caught in long-lined barrels constructed from olive oil or pickle barrels modified with an entrance tunnel and dewatering holes (Figure 21). Fishing occurs on soft, muddy habitat along the entire outer coast of Washington and northern Oregon. The fishery operates, by rule, only in offshore waters deeper than 50 fathoms and is open access. Licensed Washington fishers can fish federal waters off of Oregon and land catch into Washington. Live hagfish vessels typically fish grounds closer to their homeports, while at-sea freezing allows some vessels to fish further afield.

The fishery predominantly catches Pacific Hagfish, but Black Hagfish are landed incidentally. A few trips attempting to target Black Hagfish were successful in the recent past, and a small-scale market is developing for the frozen product. Pacific Hagfish predominate from 50-80 fa, while Black Hagfish have been targeted with deeper sets, up to 300 fa; Pacific and Black Hagfish ranges appear to overlap between 80 and 100 fathoms. Currently, however, fish ticket landing data cannot distinguish between species, as only one species code exists. The median CPUE is about 4.5 pounds, but instances of high CPUE are not uncommon, as evidenced by reports of “plugged” barrels.

Biological sampling data collected from Pacific and Black Hagfish consist of length, weight, maturity, and egg counts for females at maturity stages 4 through 7; however, only Pacific Hagfish data are reported here. Male and female hagfish present similar size distributions (Figure 22). The largest specimen sampled was a 67-cm female, and the smallest a 24-cm specimen, sex unknown. An evaluation of maturity suggests year-round spawning. Fecundity is low, with the number of eggs in females at maturity stages 6 & 7 (Table 12) averaging 25 eggs per female. Few females with developed eggs have been sampled; the 2017-2021 sample contained 12% mature females.

Management of the fishery is challenged by a lack of life history information, partial fishery controls, and high participant turnover. Active fishery monitoring and sampling began in 2009. Due to limited agency resources, only fishery-dependent data programs – including logbooks, fish receiving tickets, and biological sampling of catch – have been developed to inform management. Efforts have been undertaken to refine and improve these programs, including improving systematic sampling, developing species composition protocols, and shifting to use the maturity scale developed by Martini and Beulig (2013).

For more information about the Hagfish fishery, contact Donna Downs (Donna.downs@dfw.wa.gov).

References Cited:

Martini, F., and A. Beulig. 2013. Morphometrics and Gonadal Development of the Hagfish Eptatretus cirrhatus in New Zealand. PLoS ONE 8(11): e78740. https://doi.org/10.1371/journal.pone.0078740.

Figure 21: Barrels used in the WA commercial hagfish fishery.

Table 12: Average egg count per mature female Pacific Hagfish collected from Washington landings during 2017-2021.

Pacific Hagfish	Sample Count	Egg count minimum	Egg count maximum	Egg count average
Maturity stage 6	132	9	49	25
Maturity stage 7	16	5	39	19
Total	148			25

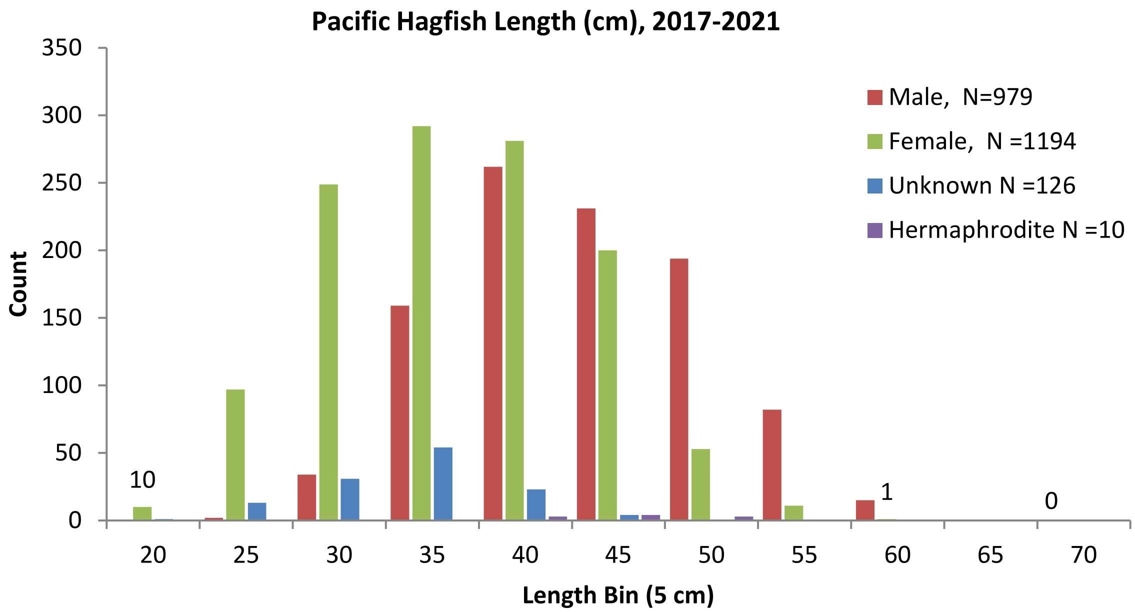

Figure 22: Length (cm) of male and female Pacific hagfish, 2017-2021.

B. North Pacific Spiny Dogfish and other sharks

No specific, directed research or management to report. Spiny Dogfish are regularly seen in ROV videos and caught in the Puget Sound Bottom Trawl Survey, where they are counted, weighed, and measured; a tissue plug for genetics is also taken from select individuals. Other shark species occasionally encountered include Brown Catsharks and Sixgill Sharks.

C. Skates

No specific, directed research or management to report. Longnose and Big Skates are regularly seen in ROV videos and caught in the Puget Sound Bottom Trawl Survey, where they are counted, weighed, and measured. Sandpaper skates are also occasionally encountered.

D. Pacific Cod

No specific, directed research or management to report. Pacific Cod are regularly caught (primarily in the Strait of Juan de Fuca) in the Puget Sound Bottom Trawl Survey, where they are counted, weighed, and measured; otoliths for age analysis are also taken from moribund individuals.

E. Walleye Pollock

No specific, directed research or management to report. Walleye Pollock are regularly seen in ROV videos and caught in the Puget Sound Bottom Trawl Survey, where they are counted, weighed, and measured. Rough population estimates are produced as part of the survey analysis.

F. Pacific Whiting (Hake)

No specific, directed research or management to report. Pacific Hake are regularly seen in ROV videos and caught in the Puget Sound Bottom Trawl Survey, where they are counted, weighed, and measured. Rough population estimates are produced as part of the survey analysis.

G. Grenadiers

No specific, directed research or management to report.

H. Rockfishes

Research – Multiple surveys – including ROV, hook-and-line, and hydroacoustic techniques –are conducted in order to study rockfish populations both within Puget Sound and along the coast. See section II: C-G above for more information on these surveys.

Management – In 2012, NOAA issued a 5-year incidental take permit (ITP) to WDFW that provided for a limited take of ESA-listed rockfish in Puget Sound recreational fisheries and commercial shrimp trawls. Renewal documents were submitted to NOAA in mid-2016, which included an additional request for take coverage in the recreational and commercial shrimp pot fisheries, but due to a disagreement with NOAA resulting from a change in fishery regulations in the Pacific Halibut fishery that allowed for take of lingcod within the DPSs that could potentially impact listed rockfish, the permit review process was halted until the disagreement was resolved in late 2019. However, since the submission of the renewal documents in 2016, a new recreational shrimp fishery has emerged that required extensive updates to the Fishery Conservation Plan (FCP) that accompanies the ITP application. The updated FCP was completed in October 2021 and submitted to NOAA for review in November 2021.

I. Thornyheads

No specific, directed research or management to report.

J. Sablefish

No specific, directed research or management to report. While Sablefish used to be caught regularly – albeit in small numbers – in the Puget Sound bottom trawl survey, they were not encountered from 2011-2016, despite the annual survey efforts. Starting in 2017, however, the survey has begun to encounter them again: 8 were caught in 2017, 2 in 2018, 8 in 2019, and 3 in 2021.

K. Lingcod

Lingcod Age Structure Processing Lab – The Coastal Marine Fish Science Unit processes lingcod fins collected from Washington (coastal and Puget Sound) commercial and recreational fisheries, and periodically from Oregon fisheries by contract. Lingcod fins are processed for ageing using the fin cross-section method. The process includes four steps: drying, gluing, sectioning, and mounting. Each dried and glued fin is secured in a sectioning saw (Beuhler Isomet 1000), and seven-to-ten cross-sections (2.0 mm) are cut. The sections are mounted onto microscope slides with Cytoseal, dried for at least 24 hours, and sent to age readers. Sectioned fins are aged using the surface-read method. During the reporting period, the lab cut and mounted 1,471 fins, and 855 are either dried or glued.

Formal Stock Assessment in Puget Sound – Over the past several years concerns have been raised by the public about Lingcod populations within Puget Sound, especially in the San Juan Archipelago and Central Puget Sound off Edmonds. Specifically, some constituents are concerned that the current management regime is not protective enough, as legal-sized fish (26-36") are becoming less frequent in the catch after only a few weeks into the six-week season (May 1 – June 15). Though declining trends in CPUE are apparent in some regions, the issue seems largely to be a result of increased fishing pressure/effort, especially near urban centers, since 2010. In addition to the slot limit and short season noted above, the daily bag limit is one fish per angler and fishing is not allowed deeper than 120' to reduce barotrauma impacts on rockfish. The WDFW considers this a highly conservative management regime.

The WDFW has completed an evaluation of Lingcod populations using a Stock Synthesis model, which is a size- and age-structured population assessment tool. This type of model is commonly used for coastal fisheries and is data intensive. The model structure for Puget Sound Lingcod utilizes commercial and recreational landings, length frequency data, age data, and catch-per-unit-effort data to evaluate historic and current trends in the population. When finalized, managers will be able to use the output from the Stock Synthesis model to inform management decisions for Lingcod in Puget Sound. The report is currently under review and will be finalized in 2023.

Pre-season Lingcod Rod-and-Reel Test Fishing Survey– In April 2019, the PSMFS Unit conducted a four-day test fishing survey targeting Lingcod in Marine Catch Area 7 (San Juan Islands) prior to the opening of the recreational Lingcod fishing season. This was a pilot study with a primary goal of obtaining basic catch per unit effort (CPUE) and length frequency data for Lingcod under simulated recreational fishery conditions for potential use in a Puget Sound Lingcod stock assessment, and to evaluate the claim made by several recreational anglers that "no more legal sized fish are around." Secondary goals included documenting bycatch and obtaining genetic samples from select fish species to inform demographic models of Puget Sound bottomfish. A second, more comprehensive pre-season survey that included additional sites in Central and Sound Puget Sound was planned for April 2020 but was prevented due to the COVID-19 pandemic.

The relaxation of Covid restrictions allowed for the PSMFS Unit to conduct the 2021 pre-season survey in the San Juan Islands, although due to poor weather and limited staff time, this effort was smaller than in 2019. However, 51 fish were caught in the survey, with only two of these fish being of legal size. Pre-season surveys were also conducted over several days in Central and South Puget Sound, but very few lingcod were caught. A post-season survey was conducted in the San Juan Islands in June 2021 at several sites fished in the pre-season survey, with 10 Lingcod being captured, three of which were of legal size. While these surveys were successful at capturing Lingcod for the collection of size information, age structures, and genetic samples, a cost-benefit analysis showed that the survey was unsustainable and would not provide consistent fishery-independent data required for future stock assessments. The PSMFS Unit is now developing a new survey design that is scheduled to be tested in the Spring of 2022.

For more information on this survey, contact Bob Pacunski (Robert.pacunski@dfw.wa.gov).

L. Atka mackerel

No specific, directed research or management to report.

M. Flatfishes

No specific, directed research or management to report. Several species of flatfish are regularly seen in ROV videos, and 18 species have been caught in the Puget Sound Bottom Trawl Survey, where they are counted, weighed, and measured. Rough population estimates are produced as part of the survey analysis. The most dominant flatfish species throughout Puget Sound is English Sole, which has been encountered at all depths and in all regions; the 2021 trawl survey estimate for English Sole throughout Puget Sound was 10,073 mt.

N. Pacific halibut & IPHC activities

WDFW had little to no involvement with IPHC sampling activities in 2021. Nothing to report.

O. Other groundfish and forage fish work

Anchovy – Northern Anchovy (northern subpopulation) fisheries in Washington are conducted to provide live bait for recreational and commercial fisheries, and packaged bait for retail to recreational fishermen. Distinguished by gear type, fisheries for anchovy include a lampara-gear fishery and a seine-gear fishery. The lampara-gear fishery is primarily comprised of Albacore Tuna fishers that catch and hold anchovy in onboard live-wells to meet their own bait needs. The purse-seine fishery harvests and holds live bait in dockside net pens for retail sale to recreational and commercial fishers. The fishery occurs in federal waters (3-200 miles), inside three miles (state waters) on the southern Washington coast, as well as within the estuaries of Grays Harbor and Willapa Bay, and in the lower Columbia River. Participation in the fishery is not limited. The northern subpopulation of Northern Anchovy has never been formally assessed through a model-based method, as historically the WDFW did not monitor baitfish landings. To build a time series in support of potential assessment, in 2014 the CMFS Unit began monitoring the commercial baitfish fishery at both Westport and Ilwaco, although the majority of sampling occurs at Westport. An inventory of samples collected, and mean length and weight data are presented in Table 13. More complete reporting of these data can be found in an agency technical report in progress.

Table 13: Number of samples, number aged and mean weight and length of Northern Anchovy sampled from the commercial baitfish fishery, 2015 – 2021.

Year	Number sampled Length/Weight/Maturity	Number Aged	Mean Weight (g)	Mean Length (mm)
2015	1150	129	23	129
2016	1126	649	20	118
2017	931	929	14	111
2018	950	792	15	114
2019	1799	1790	16	112
2020	500		13	106
2021	1001		15	112

For more details on coastal anchovy, contact Kristen Hinton (Kristen.hinton@dfw.wa.gov).

Pacific Sand Lance Research – There are no directed fisheries or estimates of abundance for Pacific Sand Lance in Washington, but Washington Department of Fish and Wildlife continues it efforts to better understand this important forage fish, and document and protect its critical habitat. In 2021, with support from a National Estuary Program (NEP) grant and a Washington Conservation Corps crew funded by Washington Department of Natural Resources, we finished analysis of a pilot study to identify sand lance burying habitat. This study used two survey methods, shore based, and boat based, to sampling nearshore substrate for buried sand lance. Both methods were effective, and buried sand lance were observed in Bellingham Bay, Whidbey Basin, Hood Canal, and central Puget Sound. The results of this study were presented to a special meeting of the Puget Sound Ecosystem Monitoring Program's Forage Fish and Food Webs work group and provided in our final report to NEP; *Puget Sound Sand Lance Habitat Characterization and Mapping NTA 2018-0242* (Olson, Biondo, and Dionne 2021). Attendees of the special meeting indicated that if information like that provided by these surveys were more widely available, it could be useful for the implementation of the State's Hydraulic Project Approval Program, and other habitat conservation programs, but additional resources are required to undertake the sampling and model development to provide this information.

Surf Smelt – While there are no estimates of biomass or established indices of abundance for smelt in Puget Sound, there are both commercial (beach seine) and recreational (dip net, jigging) fisheries that primarily target surf smelt. Since 2014, the recreational fishery has been limited to the hours between 6am and 10pm, has been open only five days a week, and has a daily bag limit of 10 pounds per person. The commercial fishery has also been limited to the hours between 6am and 10pm, has been open only four days a week, has region specific seasons and closures (Figure 23), and has had an annual quota of 60,000 pounds that is reset on January 1 of each year. Since the commercial quota was established in 2014, it has been reached – and the fishery subsequently closed – by mid-October each year, until the onset of the pandemic in 2020, since which the quota has not been reached. The total landings for 2020 were only 30,876 pounds, and 25,227 pounds for 2021. This continued decrease in landings is most likely due to reduced demand due to the COVID-19 pandemic and the departure of one of the primary commercial harvesters.

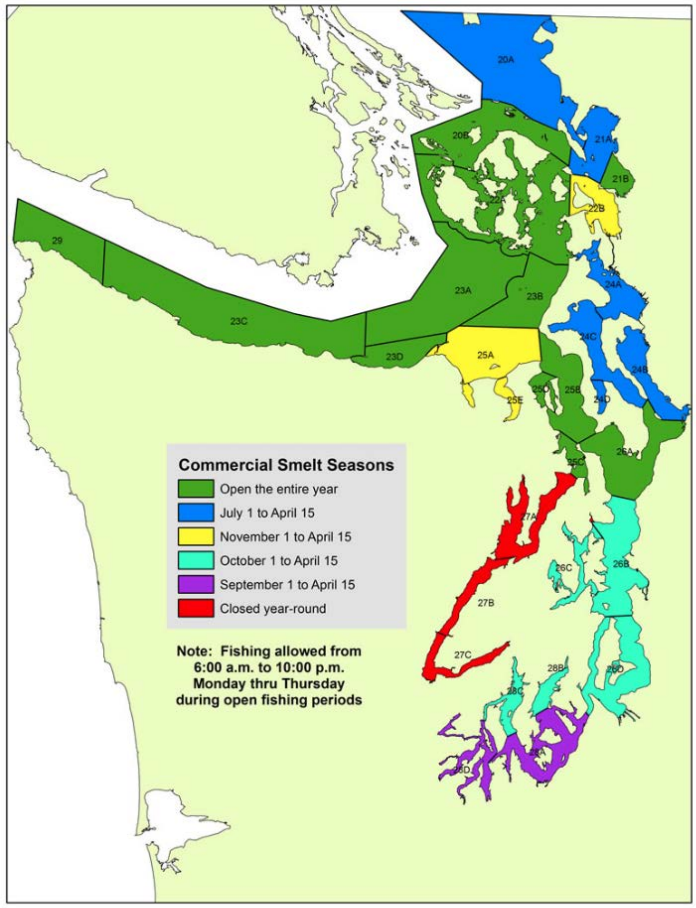

Figure 23: Map of commercial smelt fishery management regions and respective season openings.

Historical Groundfish Fishery Compendium and Catch Reconstructions – Understanding and quantifying the historic fishery removals from a stock is essential to generating a time series of these data, which is, in turn, a crucial input to a variety of stock assessment methods and catch-based management approaches. Estimating population-specific removals is exceptionally hard, though, especially for periods with limited record keeping, aggregation of species into market categories, and aggregation of catch by outdated or poorly described geographic area. Sampling protocols, fishery diversity, catch versus landing location, dead discards, and species identification are significant additional complications that vary across time and space, and for which the level of reporting detail can vary widely.

Given that many groundfish stocks are distributed coast-wide and a complete time series of removals is needed, there is a need to coordinate approaches across the states of Washington, Oregon, and California to confront removal reconstruction challenges and establish common practices. Both California and Oregon have attempted historical removal reconstructions and continue making necessary revisions. Washington's first attempt in reconstructing commercial landings for Lingcod and rockfish market categories was completed to support 2017 PFMC groundfish stock assessments. Efforts are continuing to reconstruct flatfish catch histories. At least one report detailing data sources and analytical assumptions, and one report providing details on the history of fishery technology and prosecution, are expected to be completed in the next year. Additionally, significant progress has been made on a report documenting the history of the fishery, fishing technology, and harvest patterns for groundfish in Puget Sound. A definitive compendium on the topic is anticipated to be complete by the end of 2022.

VI. ECOSYSTEM STUDIES

Puget Sound Ecosystem Monitoring Program (PSEMP) update – The Toxics Biological Observation System (TBiOS) team at WDFW has been conducting regular status and trends (S&T) monitoring of toxic contaminants in a wide range of indicator species in Puget Sound, including assessments of health effects on biota, since 1989. In the past year, TBiOS' regular S&T monitoring included assessments of English sole (a benthic indicator) in 2021, and Pacific herring (a pelagic food-web indicator) in 2022. Data from the English sole and Pacific herring studies are summarized online at the Puget Sound Partnership's Toxics in Fish Vital Sign website. The Toxics in Fish Vital Sign is a communication tool that helps distill TBiOS' complex contaminant monitoring information into usable metrics for ecosystem recovery managers.

In addition to benthic and pelagic indicator species, TBiOS continues to monitor contaminants in Puget Sound's nearshore environment using two indicators, juvenile Chinook salmon and bay mussels. To ascertain the effects of contaminants on the early life-stages of salmon, TBiOS conducted the fourth assessment of juvenile Chinook salmon from 6 of 12 major rivers and deltas of Puget Sound in 2021. The sampling effort for the 2021 juvenile Chinook salmon study was reduced due to the COVID-19 pandemic and thus only a subset of major rivers and deltas were sampled compared to 12 for the 2016 study. In addition, TBiOS conducted the fifth Puget Sound-wide assessment of contaminants using transplanted (i.e., caged) mussels over the winter of 2021/2022.

TBiOS also conducted two special studies in the past year, including an account of contaminants in seaward-migrating juvenile Chinook salmon in the Puyallup and White River watersheds and Commencement Bay to determine the extent and magnitude of contaminant exposure along their migration pathway through a developed urban watershed. Additionally, particulate organic matter (POM) and zooplankton (krill: *Euphausia pacifica*) were sampled along a distance gradient from putative sources of polychlorinated biphenyls (PCBs) in the Duwamish River, along the Seattle waterfront, into Elliott Bay and the central Puget Sound basin as part of a project to enhance the capabilities of the Salish Sea Model (SSM) developed by the Pacific Northwest National Laboratory (PNNL). Publications and reports for a number of these studies are available at the TBiOS list of publications website, as well as at the aforementioned Toxics in Fish Vital Sign website.

For additional information on TBiOS research, contact Jim West (james.west@dfw.wa.gov).

United States Navy Drydock Salmon Entrainment Study – Puget Sound Naval Shipyard at Naval Base Kitsap Bremerton (NAVBASE Bremerton) contains six dry docks that are used to clean, inspect, and service ships ranging from small submarines to aircraft carriers (Figure 11). These dry docks are completely man-made and are episodically flooded to move ships in and out of them. Prior sampling for salmonids at NAVBASE Bangor has shown that a variety of groundfish may also be entrained during these operations, though no ESA-listed rockfish were encountered. Fish that are entrained may be killed when passing through the inflow/outflow turbines, consumed by birds during dewatering, or left to die after dewatering is complete. While some salvage efforts do occur, they are infrequent and poorly documented.

In January 2020 the PSMFS Unit was contracted to conduct a salmon entrainment study in the drydocks at NAVBASE Bremerton. Although salmon were the primary focus of the study, data were also collected on other entrained fish species. WDFW completed the final sampling event in February 2022 and are currently working on the final data analysis and report writing. In total, seven successful sampling events were conducted in four different drydocks: DD5 was sampled on 03 June 2020 and 23 June 2021; DD3 was sampled on 02 September 2020 and 18 September 2020; DD6 was sampled on 09 March 2021 and 11 September 2021; and DD2 was sampled on 23 February 2022. Significant issues were experienced in the final two events that prevented WDFW from doing the fish collection; instead, fish were collected and data recorded by the Navy Environmental team.

In total, 185 Chinook, 8 Coho, and 2 Chum Salmon were encountered (note: the number of Chinook in the 23 June 2021 event was estimated from a subsample). Most of these salmon were juveniles, with a mean length of 190 mm; however, the overall range in lengths was 77-765 mm. Of the Chinook, 141 fish were hatchery-origin and 44 fish were unclipped and assumed to be wild (a small proportion of hatchery Chinook are not clipped but have coded-wire tags implanted). Every effort was made to release all salmon quickly and alive. A secondary target species group is forage fish, of which four primary species were encountered: Northern Anchovy, Pacific Herring, Pacific Sand Lance, and Surf Smelt. Of these, Pacific Herring were the most numerous and frequently encountered species, occurring in all but the 2/2022 sampling event and ranging vastly in total counts: 130 fish were caught in DD5 on 6/3/20, 39 in DD3 on 9/2/20, an estimated almost 19,000 in DD3 on 9/18/20, 125 in DD6 on 5/6/21, 12 in DD5 on 6/23/21, and 513 in DD6 on 9/14/2021. Other species regularly encountered include a variety of sculpins and perch, as well as a few flatfish and rockfish (non-ESA) species. The original contract was set to conclude in February 2022; however, due to logistical challenges associated with the Covid-19 pandemic and two failed sampling attempts due to unplanned Navy activities occurring within the dry docks, the contract was extended until 6 September 2022 to allow PSMF Unit staff time to complete one more dry dock sampling event and prepare the final report.

For more information on the Naval Dry Dock survey, please contact Jen Blaine (Jennifer.blaine@dfw.wa.gov).

Figure 24: Locations of the six service dry docks at Naval Base (NAVBASE) Bremerton on the Kitsap Peninsula in central Puget Sound.

VII. PUBLICATIONS

In 2021-22 staff of the MFS Unit published the documents indicated below.

Lowry, D., R. Pacunski, A. Hennings, J. Blaine, T. Tsou, L. Hillier, J. Beam, and E. Wright. 2022. Assessing bottomfish and select invertebrate occurrence, abundance, and habitat associations in the U.S. Salish Sea with a small, remotely operated vehicle: results of the 2012-13 systematic survey. FPT 22-03. Washington Department of Fish and Wildlife, Olympia, WA. 67pp.

Petrou, E., et al. (including T. Sandell). 2021. Functional genetic diversity in an exploited marine species and its relevance to management. Proceedings of the Royal Academy of Sciences B. 288:20202398.

VIII. CONFERENCES AND WORKSHOPS

In 2021-22, staff of the MFS Unit presented at, participated in research presented at, and/or arranged symposia at, several regional scientific meetings. Most meetings were held virtually due to the COVID-19 pandemic. The MFS Unit also organized and/or presented at the following education and outreach events/meetings during the reporting period:

Date	Event	Where	Topic	Type (student, community, etc)
5/11/2021	Salish Sea Stewards	Virtual	Forage Fish	Community
7/29/2021	Show and Tell WA-YA	Tumwater Historic Park	Forage fish and Sharks	Student
8/3/2021	ROV Show and Tell WA-YA	Shilshole Area	Rockfish/ROV	Student
8/16/2021	Beach Sampling WA-YA	Evergreen Beach	Ecology of PS	Student
8/28/2021	Shark Presentation	Estuarium, Olympia	Sharks of WA	Community
9/1/2021	PSP Leadership Council	Virtual	Forage Fish	Management Community
10/20/2021	Harbor Wildwatch Rockfish Presentation	Virtual	ROV and Rockfish of PS	Community
3/31/2022	Whidbey Island Beach Watchers Training	Virtual	Marine Fish communities of Whidbey Basin	Community Naturalists
4/5/2022	PSP Marine Waters Workshop	Virtual	2021 Bottom Trawl Survey	Research/ Management Community
4/6/2022	Jefferson County MRC Forage Fish Update	Virtual	Forage Fish of WA with MRC updates	Community Naturalists

IX. COMPLETE STAFF CONTACT INFORMATION

WDFW permanent marine fish management and research staff include (updated 4/2021):

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Committee of Age Reading Experts

2022 Committee Report

Prepared for the Sixty-second Annual Meeting of the

Technical Subcommittee of the Canada-USA Groundfish Committee

April 19 – 20, 2022

Prepared by
Delsa Anderl
2019-2022 CARE Chair

National Oceanic Atmospheric Administration
National Marine Fisheries Service
Resource Ecology and Fisheries Management
Alaska Fisheries Science Center
Age and Growth Program
7600 Sand Point Way NE
Seattle, Washington
98115

A. CARE Overview

1. History

The Committee of Age-Reading Experts (CARE) is a subcommittee of the Canada-USA Groundfish Committee's Technical Subcommittee (TSC) charged with the task to develop and apply standardized age determination criteria and techniques and operate within the Terms of Reference, approved by the TSC in 1986, and the CARE Charter, developed in 2000 and approved by the CARE in 2004.

2. Report Period

This report covers the work period of April 7, 2021 – April 8, 2022. This interim reporting period was prepared by current CARE Chair Delsa Anderl. Current officers through June 30, 2022 (elected at April CARE 2019 Meeting) are:

- Chair – Delsa Anderl (AFSC-Seattle)
- Vice-Chair – Andrew Claiborne (WDFW-Olympia)
- Secretary – Nikki Atkins (NWFSC-Newport)

3. CARE Conference

CARE meets biennially for a conference that usually lasts three days. However, due to COVID-19 pandemic restrictions, the CARE biennial meeting that was supposed to take place in April 2021 was postponed to November 2022 or until all members are allowed to travel and meet inside government buildings. Conferences typically consist of one and a half "business" days and one and a half days for a hands-on calibration workshop at microscopes to review and standardize age reading criteria with any extra time scheduled for a specific focus group or workshop.

i. CARE Check-in

A virtual CARE member check-in similar to the spring 2021 virtual meeting was not held in spring 2022, in anticipation of the full meeting scheduled for November 2022.

The list of recommendations outlined by the TSC to CARE, CARE to CARE, and CARE to TSC were not addressed at the 2021 check-in but will be addressed at the November 2022 meeting.

ii. Agency Reports:

A. Alaska Department of Fish & Game (ADF&G)

There are four main groundfish age programs within the Alaska Department of Fish and Game that operate autonomously: the Kodiak ADF&G Age Lab, the Homer Commercial and Homer Sport Age Labs, and the Age Determination Unit (ADU, based in Juneau).

***ADF&G - Kodiak*– (Sonya El Mejiati)**

The Kodiak ADF&G otolith age laboratory and port sampling programs are both overseen by the same project leader. The Kodiak port sampling program is responsible for collecting biological samples and catch information from state managed commercial fisheries of shellfish and groundfish species harvested in the Kodiak, Chignik, and South Alaska Peninsula management areas. Shellfish species include Tanner crab, Dungeness crab, red sea cucumbers, and occasionally BSAI king and snow crab (for the Dutch Harbor ADF&G office). The main groundfish species include black rockfish, dark rockfish, and Pacific cod. Prince William Sound (PWS) walleye pollock and Pacific cod landed in Kodiak are also sampled on occasion to assist the Homer ADF&G office. All otolith samples collected by the Kodiak sampling crew are aged in the Kodiak age lab, except for the PWS samples that are sent to the Homer office. Each year a total of about 2,000 Pacific cod from all management areas, 1,000 black rockfish and 500 dark rockfish mainly from the Kodiak Area, some lingcod (opportunistic sampling), and a few miscellaneous rockfish species are collected and aged in Kodiak.

Age readers are employed for 3-4 months between January and April. In 2022 there were two age readers: Sonya El Mejjati (project leader) and Jessica Horn. Mike Knutson moved on to pursue an education in data programming but also remains in his seasonal position with the ADF&G Tanner crab trawl survey program in Kodiak. Since the start of the COVID-19 pandemic, the Kodiak ADF&G building remained open with the option to telework. In 2020, more than half of the building employees chose to telework. Most staff are now back in their offices and labs, and in the absence of direction from the State, our mask policy follows the CDC guidelines, leaving mask use optional. In the age lab, we like to be mindful of coworkers' preferences, we try to follow risk level in the community, and we choose to wear masks when fighting or getting over a cold.

Precision testing is done on 40% of all samples and on 100% of samples that are aged by new readers. All differences between readers are resolved. The lab uses the standard break-and-burn method for rockfish. For Pacific cod, one otolith is broken, and the other is cut with an Isomet saw; halves of each otolith are baked rather than burned for 12 min at 400ºF using a standard toaster oven to prevent otoliths from bursting or cracking. The baking process is time consuming but makes growth patterns easier to interpret. Starting in 2017, morphometric measurements have been collected for all species (otolith length, width, and weight, excluding crystalized or broken otoliths). This information is plotted against age and has helped find some data outliers, species identification errors, and typographical errors that occurred during sampling. In the last few years, Joan Brodie, Sonya El Mejjati, and Carrie Worton (research division) have spent countless hours looking at potential data outliers for black and dark rockfish sampled over the years to determine species identification mistakes. Some otolith samples from the ADU lab and Homer sportfish lab that stood out as outliers were also sent to the Kodiak age lab for species identification checks and re-ageing and are part of our 2022 CARE exchanges.

ADF&G – Sportfish – (Martin Schuster)

Martin Schuster supervises the Homer Sport Age Lab that includes two other groundfish age readers: Marian Ford (primary production reader), and Tim Blackmon (aging technician). The port sampling program collects biological samples including age structures (otoliths and fin rays) from groundfish species harvested by the sport fishery in Cook Inlet and Prince William Sound management areas. Samples are collected by field technicians in the ports of Homer, Anchor Point, Ninilchik, Seward, Kodiak, Whittier, and Valdez. The lab also receives black rockfish otoliths to age from the Sitka port sampling program.

In 2021, the Homer lab prioritized the aging of black and yelloweye rockfish in response to an ADF&G Statewide Rockfish Initiative, but also aged dark, dusky, quillback, and other rockfish species as time allowed. A total of 2,636 otoliths were aged for this season. The project also started weighing all of the black rockfish otoliths that have been collected to detect species misidentification. Lingcod fin rays are crosssectioned and mounted on slides for aging. A total of 531 fin ray slides were aged for the 2021 season. The Homer lab participated in a lingcod otolith/fin ray exchange with the ADU lab with the hope of transitioning to using otoliths for lingcod ages.

During the past year, Marian continued to do most of the age reading from home, while Martin and Tim worked in the office and lab while wearing masks and social distancing.

***ADF&G- Age Determination Unit (ADU, Juneau)* – (Kevin McNeel)**

Kevin McNeel supervises the ADU with three other groundfish age readers: Chris Hinds, Cathy Mattson, and Juliet Harrison. The ADU also accessed technicians and biologists from other Mark Tag and Age Lab programs to process samples and estimate age. During the past year, personnel continued teleworking and estimated ages and processed structures remotely and at home, and age resolutions and training were done remotely through screensharing apps (Microsoft Teams) and microscope cameras. During the last year, the lab focused on four groundfish species: sablefish, lingcod, Pacific cod, yelloweye rockfish, black rockfish, and weathervane scallops but continued to process slope rockfish as time allowed. The ADU also participated in a lingcod otolith/fin ray exchange with ADFG-Homer-Sport, a rougheye rockfish exchange with AFSC, and a couple of black rockfish exchanges with ADF&G-Kodiak and ADFG-Homer-Sport.

For age-related research, the ADU is continuing work on rockfish chronologies for Prince William Sound, is wrapping up a North Pacific Research Board funded project reconstructing reproductive histories of individual fish through bone hormone profiles, is collaborating with other labs to compare age criteria for lingcod fin rays and otoliths, and is collaborating with other ADF&G labs to develop procedures to identify black rockfish misidentification using otolith measurements. The ADU is also collaborating with the Alaska Fisheries Science Center to investigate gadid life history through a long-term rearing study in Little Port Walter, AK.

***ADF&G- Commercial* – (Elisa Russ)**

In 2021, the Homer ADF&G commercial groundfish age lab had three age readers: Elisa Russ (project leader), Andrew Pollak (primary production reader), and Aaron Slater (black rockfish; hired in September 2021). The port sampling program collects biological samples including age structures (primarily otoliths) from state-managed groundfish and shellfish species harvested in Cook Inlet and Prince William Sound management areas (Central Region). Sampling goals are 550 otoliths collected from primary groundfish species – Pacific cod, sablefish, lingcod, walleye pollock, and rockfish. Groundfish sampling occurs in the ports of Homer, Seward, Whittier, Cordova, Kenai, and Kodiak.

Groundfish species aged in Homer include demersal shelf rockfish (primarily yelloweye and quillback rockfish), pelagic shelf rockfish (primarily black rockfish), and walleye pollock. In 2021, the Homer age lab continued to prioritize black and yelloweye rockfish age work in response to an ADF&G Statewide Rockfish Initiative (SRI) focusing on black and yelloweye rockfish assessment as the keystone species. A total of 2,060 ages were produced in 2021 with age data now current through 2021 for black rockfish and 2020 for yelloweye rockfish. Due to losing Kerri Foote in spring of

2020 to a new career in California and not hiring a new age reader until fall of 2021 (who also serves as a port sampler), production age reading was down from the previous year.

Precision testing is done on 20% of all samples and on 100% of samples that are aged by new readers. All differences beyond 1 year are resolved, unless there is bias, in which case all differences are resolved. Otoliths are stored dry, cut using an Isomet saw, and baked; burning is used to refresh otoliths during precision testing. Morphometric measurements have been collected for all species (otolith length, width, and weight, excluding crystalized or broken otoliths) since 2018. This information is analyzed to help identify outliers and errors in age, species identification, or data entry.

The continuation of the COVID-19 pandemic in Alaska continued to present challenges for the ADF&G project, as it did for everyone. Travel to other ports (primarily Seward and Whittier) resumed in 2021, with staff driving in separate vehicles when two samplers were needed to minimize close contact. All port sampling and age reading staff voluntarily submitted to regular testing and any exposure was handled using State of Alaska protocols similar to CDC guidelines for quarantining. Safety vests stating to keep a distance of 6 feet and masks were worn by port sampling staff. Much of the staff at the ADF&G Homer office continued teleworking, and for those who continued to work in the office, masks, frequent hand sanitizing, and social distancing were required in all public areas.

Primary age reading staff returned to the Homer lab with their microscopes in September 2021; Elisa Russ and Andrew Pollak began training Aaron Slater in person in October 2021 wearing masks and after getting negative COVID-19 test results – necessary because of working in close contact at the teaching scope. Time spent in the lab continued to be scheduled with only one person working there at a time, except during training when masks were worn. We realized that age reading efficiency actually improved when staff were working from home, likely because time was dedicated solely to age reading without office distractions and also because port sampling had been curtailed until safer conditions were present. Some staff returned to working in the office in the fall, including Andrew Pollak who worked closely with Aaron Slater reviewing results of precision testing as Aaron's aptitude increased. Aaron was able to begin production age reading of black rockfish in early December, which resulted in completion of ageing of all black rockfish sampled through 2021.

B. Sclerochronology Lab (SCL) – (Stephen Wischniowski)

Pacific Biological Station (PBS), Fisheries and Oceans Canada (CDFO), Nanaimo BC

The SCL was onsite over the last reporting period as it is considered an essential service. However, lab capacity under COVID-19 restrictions was reduced to 50% to allow compliance with CDFO Health and Safety measures in regard to social distancing. This has severely hampered the age estimation of groundfish species that require the "break-and-burn" methodology. There are only two lab spaces at PBS with suitable environments that CDFO Health and Safety has allowed us to operate with an open flame. Coupled to this were increased absences for sick leave for "flu-like" symptoms. Confusing guidelines, poor communications and a lack of COVID-19 antigen tests kits early in the pandemic resulted in many staff remaining in isolation for 14 days before being allowed to return to work.

SCL staff dynamics

- Nine staff
- Two senior staff to retire 2023 and 2024 – this will be the last of the senior staff with 25 or more years' experience

Species of focus during March 2021 to March 2022

- *Clupea pallasi* – Pacific Herring
- *Sebastes maliger* – Quillback Rockfish
- *S. flavidus* – Yellowtail Rockfish
- *S. pinniger* – Canary Rockfish
- *S. alutus* – Pacific Ocean Perch
- *Anoplopoma fimbria* - Sablefish
- *Merluccius productus*- Pacific Hake
- *Oncorhynchus tschawytscha* – Chinook Salmon
- *O. keta* – Chum Salmon
- *O. nerka* – Sockeye Salmon
- *O. kisutch* – Coho Salmon

The SCL Direct Data Entry application for groundfish moved from beta testing into full production mode. Direct Data Entry (DDE) has been a long-term priority for the SCL that dates back to the previous program manager Shayne MacLellan. Prior efforts towards implementation of DDE over the last ~20 years have been unsuccessful because of the lack of technology historically and due to recent funding limitations. The vision of DDE has changed since its original conception, where the main objectives were to

- increase work throughput and efficiencies
- eliminate paper usage
- eliminate/reduce transcriptional errors
- eliminate client key punching
- add real time statistical analysis for increased QA/QC
- provide immediate access to historical data

These attributes are foundational in the implementation of DDE and will continue to be important. However the hidden advantage of computerized workstations is the increased capacity to record data that historically was too cumbersome and time consuming to collect. Computerized age workstations will provide the ability to record otolith weight and imaging information, supplemental data that will facilitate real-time quality control measures within the daily routine of producing age estimates.

There is a direct and often linear relationship between otolith weight and age. The utility of otolith weight facilitates the real-time evaluation of outliers during the age determination process, providing the ability to re-examine outliers that do not fit the weight-age relationship before data is released to the client.

The utility of Otolith Shape Analysis (OSA) from otolith images has in recent years become a powerful tool for the identification of species based on morphometric measurements of the otolith. A recent SCL/GF pilot study has had great success in identifying the species within the *S. aleutianus/melanostictus* complex based on OSA, otolith weight, fish length, and age. More recently, its utility has been implemented in the identification of populations within species that reveal no genetic disparity.

Climate change is certain to increase the difficulty of estimating fish age. The SCL has observed in several species an increasingly "noisier" pattern; based on the timing of these occurrences, this change can potentially be attributed to the onset of a changing climate. To reduce ageing error and provide more certainty in the data produced will require the SCL to move away from a "single" determinant of age. Otolith weight and shape can be considered analogues to age and when used synergistically will deliver a more robust, higher quality set of data.

C. International Pacific Halibut Commission (IPHC) – (Joan Forsberg)

The number of IPHC age readers was reduced from four to three in 2021. Together, readers age an average of 25,000 to 30,000 otoliths per year. In 2021, a total of 26,282 otoliths were aged.

Pandemic issues:
The IPHC office gradually began opening to onsite work for fully-vaccinated staff in the summer of 2021; however, most of the age reading has continued offsite.

The IPHC expects to collect a similar number of otoliths in 2022. We also plan to provide a video showing Pacific halibut age reading techniques as requested by the TSC.

D. Washington Department of Fish and Wildlife (WDFW) – (Andrew Claiborne)

WDFW's Fish Ageing Lab

- Andrew Claiborne—Age Lab Team Lead and Age Reader (salmon and trout)
- Christina Jump—Age Reader (freshwater), salmon data entry
- Austin Anderson—Age Reader (salmon and trout), research projects
- Jenny Topping—Age Reader (groundfish lead)
- Vacant—Age Reader (groundfish), groundfish data entry

Staff_Changes
WDFW currently has two age reader positions that focus on groundfish. In January of 2022, Sandy Rosenfield retired as our senior groundfish age reader. Sandy first joined the department as an age reader 50 years ago and was one of the first female scientists at WDFW. We are sad to lose such a vital part of our team and CARE but wish Sandy the best in retirement. WDFW promoted Jenny Topping into our senior groundfish age reader position in February 2022. Jenny Topping has over 20 years' experience ageing groundfish and working alongside Sandy. WDFW is currently hiring the groundfish age reader position vacated by Jenny Topping.

Species and Numbers Aged Since 2020 CARE to TSC Report

Species Name	n
Black Rockfish	4,425
Copper Rockfish	1,077
Lingcod	7,547
Northern Anchovy	2,023
Pacific Sardine	109
Quillback Rockfish	2,411
Vermilion Rockfish	808
Yelloweye Rockfish	214
Yellowtail Rockfish	3,416
Atlantic Spiny Dogfish	2,000
Total	*24,030*
Salmon, Trout, Freshwater	~75,000

Research Work and Special Projects

- Assisted NOAA NEFSC Atlantic spiny dogfish assessment by providing age determinations and training to NEFSC staff on spine processing. We processed ~2,000 spines for the project and calibrated age readers using known-age samples.

- Completed scale analysis age validation study and report for chum and sockeye salmon per research work funded by the Pacific Salmon Commission. Manuscript is in preparation.

- Collected ~370 paired lingcod otoliths and fin rays in 2019 for a structure comparison that is being initiated through CARE. We have aged all fin rays during the last assessment cycle and have started ageing the otoliths using a combination of break-and-burn and surface reads.

E. Alaska Fisheries Science Center (AFSC) – (Delsa Anderl & Thomas Helser)

AFSC includes 19 staff members, of which 3 are affiliates. The program is divided into two sub-programs that includes the traditional age reading group of six age readers led by Delsa Anderl and a research group of seven FTEs led by program manager, Thomas Helser. Managing the flow and collection of large amounts of data generated by the entire program is a data manager, Jon Short.

Due to the COVID-19 pandemic, AFSC continues to be on mandatory telework since March 23, 2020. Access to campus is still restricted, so all age readers continue to work at home and have adapted well to the situation. Some age readers have even found themselves to be more productive in the home environment. The biggest challenge to age readers is to continue to exercise quality control practices, which entail sample exchanges between two readers, discrepancy resolution, and discussion of ageing criteria application so as to achieve acceptable precision. The pandemic has necessitated doing much of the quality control process virtually.

In the last year, the age reading group lost a long-time age reader, Charles Hutchinson, to retirement and gained a new reader, Andrew Chin. Andrew and the experienced readers were trained to age species new to them by other readers who have extensive experience in those species. Progress on the program's otolith reference collections expanded to include more species, and in some cases, completed a collection. Plans to produce several instructional PowerPoint slides with embedded video on the ageing of select species are being developed.

Production ages for the AFSC 2021 assessment cycle totaled 25,755 ages. The total number of otoliths aged was below previous years due to lack of survey collections. Survey cruises did not happen in 2020 due to pandemic restrictions. The breakdown of species includes:

Common_Name	Number Aged
Alaska Plaice	2
Arrowtooth Flounder	1,986
Atka Mackerel	2,170
Blackspotted Rockfish	212
Dusky Rockfish	440
Harlequin Rockfish	227
Northern Rock Sole	528
Northern Rockfish	1,344
Pacific Cod	2,569
Pacific Ocean Perch	1,640
Rex Sole	1,760
Rougheye Rockfish	1,201
Sablefish	2,377
Walleye Pollock	8,639
Yellowfin Sole	660

As part of a NOAA-funded 5-year strategic initiative (SI), scientists at the AFSC are investigating the use of Fourier transform near infrared spectroscopy (FT-NIRS). The strategic initiative entitled, "A revolutionary approach for improving age determination efficiency in fish using Fourier transform near infrared spectroscopy" led by Dr. Thomas Helser is a nationwide effort that involves seven biological labs focused on operationalizing this technology within the NOAA Fisheries ageing estimation enterprise. Fourier transform near infrared spectroscopy is a non-destructive, vibrational spectroscopy technique that has been used in agriculture, pharmaceuticals, and medicine for several decades, but with more recent novel applications to ageing fish. FT-NIRS functions by exciting covalent bonds in a sample with NIR electromagnetic energy (4,000 to 12,500 cm^{-1}), resulting in measurable vibrational frequencies that are unique to the molecular bonds in the material being analyzed (O-H, C=O, C-H, C-N, and N-H), and serve as a "fingerprint" associated with the target property such as fish age. Fish age estimation uses a calibration set of otoliths with associated traditionally estimated ages to "train" a predictive model using multivariate partial least squares (PLS) regression or other structural equations by simultaneously reducing spectral signatures and maximizing the correlation with age. This process produces a linear correlation model to predict the age of a fish based on a rapid scan (usually < 60 seconds) of a whole otolith.

Since we last reported, we have expanded the application of FT-NIRS to estimate age of a number of fish species in multiple large marine ecosystems, and we have made advances using the same technology to rapidly estimate reproductive status and energy density (% lipid) from scans of ovary and body tissues, respectively. Moreover, several new areas of research at AFSC involve: *i*) coupling FT-NIRS technologies with machine learning, specifically deep neural networks, to substantially improve age predictions, *ii*) elucidating the molecular constituents within fish otoliths and other structures responsible for information content in spectra using proteomics, metabolomics, and lipidomics research, and *iii*) conducting "ground-truthing" studies by rearing known-age gadids at the Little Port Walter Field Station in Alaska. Together, these studies will underpin the science needed to advance the application of this technology toward greater acceptance from stakeholders (e.g., fishery management councils, fishers, public, etc.), the scientific community and toward operational readiness within NOAA Fisheries.

Achievements of the strategic initiative team related to groundfish include:

- Scanning over 26,000 walleye pollock and 16,000 Pacific cod otoliths with FT-NIRS instrumentation from 2014-2018 and integrating FT-NIRS age predictions into stock assessments to evaluate model outcome differences between FT-NIRS and traditional age estimates.
- Development of a simulation framework to: 1) assess impacts of ageing uncertainty in reference data on FT-NIRS age model predictions, and 2) develop standards and best practices regarding quality controls, reporting requirements, and predictive model updating procedures.
- Using known-age data from tagged sablefish to improve ageing model predictions for that species.
- Exploring the use of FT-NIRS spectral and biological data fusion using machine-learning models to improve age prediction.
- Rapid estimation of reproductive status from ovaries and energy density from muscle or liver.
- Using Raman spectroscopy as complementary to FT-NIRS data analysis.
- Ground-truthing spectral data with target life history properties such as fish age, reproductive status, and condition using lab-based and captive rearing studies.

F. Oregon Department of Fish & Wildlife (ODFW) – (Mark Terwilliger)

Aging Activities:

Production Aging: Early in 2021, emphasis was placed on finishing ageing of vermilion rockfish in preparation for a full assessment. Break-and-burn ages were produced for the remaining 573 fish captured by the sport fleet (captured from 2009-2020). Double reads were performed on a 20% subsample that included fish aged in 2020 (236 test reads on 1,196 total sport vermilion rockfish). Within-reader average percent agreement was 55.93% and average percent error (APE) was 2.12%. ODFW also participated in a CARE exchange with PSMFC, SWFSC, and WDFW, resulting in an additional 170 exchange ages.

Effects of COVID-19 on sport lingcod ageing continued into 2021. In 2020, ODFW developed a new technique for mounting fin rays that did not require the use of a fume hood, and 260 samples each from 2009, 2010, 2011, 2013, 2017, 2018, and 2019 were sent to Laurel Lam at the NWFSC for aging. Laurel was able to age all but those from 2009-2011. ODFW performed a re-read of 208 of Laurel's ages (split approximately 50% by sex) and obtained an average percent agreement of 54.81% and an APE of 4.91%. Fin rays from 2009-2011 were subsequently aged by ODFW (780 total with 156 double reads). Within-reader average percent agreement (and APE) were 61.54% (3.40%), 73.08% (2.73%), and 60.78% (3.39%) for 2009, 2010, and 2011, respectively.

The remainder of production aging in 2021 centered around black rockfish in preparation for the 2023 assessment:

Year Captured	Commercial ages	Commercial 2nd reads	Avg. % agreement (% APE)	Sport ages	Sport 2nd reads	Avg. % agreement (% APE)
2017	1011	202	61.00% (2.74%)	0	0	NA
2018	1048	207	63.77% (2.27%)	1203	241	69.29% (2.08%)
2019	0	0	NA	1159	232	70.26% (2.07%)

Lingcod aging structure comparison: In 2021, ODFW began collecting sagittal otoliths and fin rays from lingcod captured by commercial and sport fleets coastwide for a study to determine the potential of discontinuing using fin rays to age lingcod. Our goal was to obtain 360 fish (180 of each sex) from four coastal areas (north coast: Astoria/Garibaldi, south coast: Bandon/Port Orford/Gold Beach/Brookings, Charleston, and Depoe Bay/Newport). To date, we have collected 156 paired structures from the north coast, 66 from the south coast, 49 from Charleston, and 141 from Depoe Bay/Newport. Overall, the sex ratio was approximately 2:1 female to male, and we have collected few very small (<350 mm) or large (>1000 mm) fish. A meeting with other West Coast aging labs is planned for March 2022 to discuss plans moving forward.

Oregon Statewide Black Rockfish Survey: In anticipation for the 2023 assessment, ODFW conducted a survey of Oregon's nearshore environment with the purpose of providing an abundance estimate for black rockfish. The survey incorporated acoustics, CTD casts, video camera drops, and hook-and-line drift sampling. All fish caught by hook-and-line were measured, sexed, and subsequently aged. Of 825 fish caught, 116 black rockfish and 122 deacon rockfish were aged in 2021 (no double reads). Aging and further analyses will continue in 2022.

Age Validation: The 2015 stock assessment for California, Oregon, and Washington stocks of black rockfish identified the need for validation and verification of annuli as a recommended avenue for research in order to improve upon future assessments. In May 2020, we began a collaborative study with the Canadian Centre for Isotopic Analysis at the University of Alberta to validate annuli on otoliths of black rockfish (a semi-pelagic rockfish), cabezon (a difficult-to-age sculpin), and copper rockfish (a demersal rockfish) using secondary ion mass spectroscopy (SIMS) to measure oxygen isotope ratios ($\delta^{18}O$) in otoliths over the lifespan of the fish. Because an otolith is acellular, metabolically inert, and grows throughout the life of the fish, any elements or compounds accreted onto its surface are permanently retained. Otoliths therefore contain a complete record of the temperature and chemical composition of the ambient water a fish experienced over its lifespan. A known inverse relationship exists between water temperature and $\delta^{18}O$, so our goal was to relate seasonal peaks in the $\delta^{18}O$ signal (corresponding to cold water temperatures) to annual growth marks on the otolith.

Lab work was completed in early 2021, and study results indicate that otolith $\delta^{18}O$ values obtained via SIMS is an effective tool for validating the periodicity of annual increments in these nearshore species. SIMS analyses showed strong seasonal temperature cycles across the probe transects for all three species, with peaks in the $\delta^{18}O$ signal occurring close to locations of identified growth marks on the otoliths and generally one strong signal peak and trough between marks (Figure 1). Production aging of otoliths from these species has shown that annulus formation typically occurs in mid- to late-spring each year and the fish examined in this study followed that trend. Timing of annulus formation corresponded to an increase in the seasonal upwelling index off Oregon and resulting colder water temperatures.

Although growth marks were associated with peaks in $\delta^{18}O$, the signal could be highly variable and irregular between the core and the first annulus; therefore, it was necessary to determine where the first annulus occurred along each transect before a peak and trough could be assigned to a calendar year and an age could be validated. The variability in $\delta^{18}O$ values prior to age-1 may be due to the life history strategies of these species, which includes an extended pelagic larval and juvenile stage as well as recruitment into shallow habitats with dynamic temperature regimes.

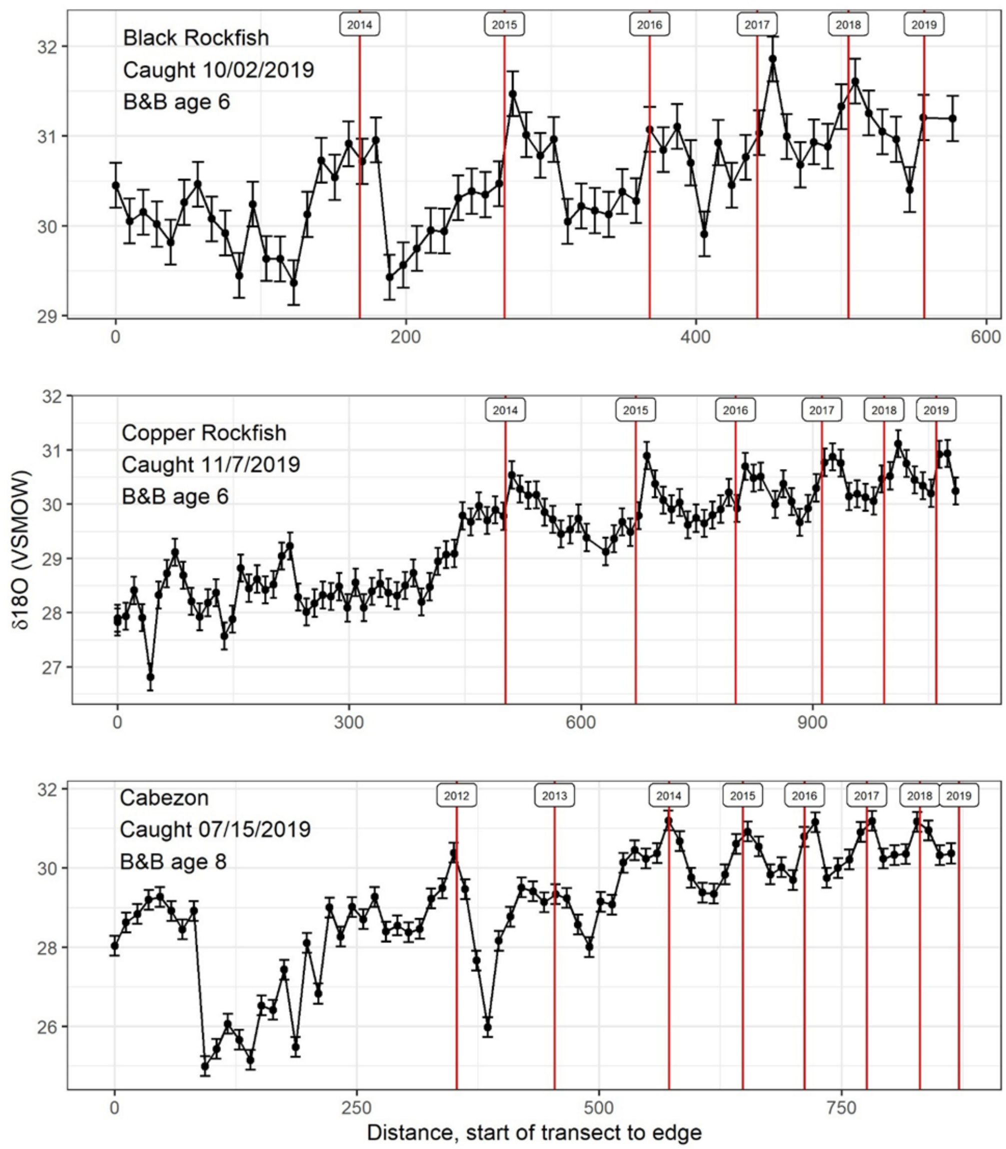

Figure 1. Measurements of $\delta^{18}O$ values (‰ VSMOW) from a representative black rockfish, copper rockfish, and cabezon. Error bars represent ±2σ. Red vertical lines represent locations of growth marks along the SIMS transect, with corresponding calendar year of formation above each line. Probe transect stopped prior to the edge for this cabezon sample, where a growth mark was present. Growth marks are found on the otolith edge in late spring of each year.

G. Northwest Fisheries Science Center Newport (NWFSC) – (Patrick McDonald)

Status

We continued to work from home during the calendar year 2021. We were given the ability to return to onsite work for lingcod fin ray preparation to support the 2021 assessment and for further collection of otolith weights. Patrick McDonald is the lead and ageing staff include Betty Kamikawa, Nikki Paige, Tyler Johnson, James Hale, and Denise Parker. The lab finalized support for the 2021 assessments.

We provided age data to support research evaluating the use of biological information from bottom trawl surveys and at-sea observer programs to augment coastwide Pacific hake acoustic surveys. The lab participated in a multi-agency collaborative project to evaluate the use of otoliths as a viable age structure for lingcod. A virtual meeting was held with participants providing a background of the structures they have or are going to collect. Further meetings are planned for 2022. The NWFSC has close to 300 paired lingcod otolith/fin ray structures collected during normal sampling protocols from the 2016 and 2017 bottom trawl surveys.

We continued to send samples to AFSC to collect near infrared spectra for our participation in the NOAA Strategic Initiative. AFSC has scanned US West Coast surveys of Pacific hake, canary rockfish, sablefish, and Dover sole. The fielding of a near infrared spectrometer to Newport is expected in the summer of 2022.

Assessments supported through age reading in 2021

2021

- Copper Rockfish
- Vermilion Rockfish
- Quillback Rockfish
- Dover Sole
- Sablefish
- Lingcod

2022

- Pacific Hake

Numbers of aged otoliths for 2021

2021: Total numbers are 33,291 (production and double reads combined)

Exchanges Participated - 2021

Pacific hake – We were able to age 100 Pacific hake sent to us from CDFO. We attempted to send 100 of our Pacific hake to CDFO, but the sample was rejected due to a lack of an import permit. We had very good agreement (83%) between our lead hake age reader and the CDFO ages. The average age of the sample was 8.22 yr and bias was even (net bias positive 1%). This was an official CARE exchange.

Vermilion rockfish – We aged 366 vermilion rockfish from the SWFSC. This was a request by the SWFSC to assess ageing error. These samples were originally aged by the SWFSC. This was not logged as a CARE exchange, and results were reported to the SWFSC stock assessment author.

Personnel/Staffing

We hired an additional age reader in July 2021 to assist with Pacific hake ageing. We now have five full-time agers and one team lead.

H. Southwest Fisheries Science Center (SWFSC) – (Melissa Monk)

Melissa Monk remains the contact for otolith requests and manages the otolith library at the SWFSC Santa Cruz. The exchange of vermilion rockfish otoliths in preparation for the 2021 vermilion rockfish stock assessment provided insight and needed information for the stocks assessments. Further analyses and a publication are forthcoming.

The SWFSC is working to develop ageing criteria for chilipepper rockfish (*Sebastes goodei*). David Stafford is currently re-reading a number of chilipepper rockfish otoliths from multiple years of the NMFS NWFSC trawl survey and working on this effort. Chilipepper rockfish will be the first species we explore for the FT-NIRS strategic initiative. Due to COVID-19 restrictions, we are still working to complete set up of the spectrometer in Santa Cruz.

B. Age Structure Exchanges

Age structure exchanges occur periodically to assess calibration among CARE age-reading agencies. Depending on results, specimens of interest (e.g., demonstrated biases) are then reviewed and discussed. Exchanges are tracked by the CARE Vice-Chair. Data from exchanges are available on the CARE website.

There were 10 age structure exchanges initiated in 2020, two in 2021, and one so far in 2022. Seven of the 2020 and one of the 2021 exchanges have been finalized and have been added to the CARE website's 'Structure Exchange table'.

Table 1. CARE age structure exchanges

Exchange ID #	Species	N	Capture Area	Originating Agency	Coordinator	Participating Agency (Cooperators)	Exchange Complete (y/n)
2020 Exchanges							
20-001	Dover sole	50	US west coast	NWFSC-PSMFC	Nikki Atkins	AFSC	Y
20-002	Dover sole	50	Alaska	AFSC	Delsa Anderl	NWFSC	N
20-003	Sablefish	41	Gulf of Alaska	AFSC	Delsa Anderl	ADFG-Juneau, NWFSC, DFO	Y
20-004	Rougheye rockfish	30	Alaska	ADF&G - Juneau	Cathy Mattson	AFSC	N
20-005	Rougheye rockfish	30	Alaska	AFSC	Chris Gburski	ADF&G - Juneau	N
20-006	Yelloweye rockfish	-	Alaska	ADF&G- Homer	Elisa Russ	ADF&G - Juneau	N
20-007	Vermillion rockfish	50	WA Coast	WDFW	Jenny Topping	NWFSC, ODFW, SWFSC	Y
20-008	Vermillion rockfish	60	CA North Pt. Conception	SWFSC	Melissa Monk	WDFW, NWFSC, ODFW	Y
20-009	Vermillion rockfish	60	CA S. Pt. Conception	NWFSC-PSMFC	Patrick McDonald	WDFW, SWFSC, ODFW	Y
20-010	Vermillion rockfish	42	Oregon	ODFW	Mark Terwilliger	NWFSC, WDFW, SWFSC	Y
2021 Exchanges							
21-001	Pacific hake	100	Canada	CDFO	Audrey Ty	NWFSC-PSMFC	Y
21-002	Black rockfish	30	Sitka	ADFG-Juneau	Kevin McNeel	ADFG-Homer	N
2022 Exchanges							
22-001	Black rockfish	90	Alaska	ADFG-Juneau	Kevin McNeel	ADFG-Homer	N

C. CARE Website Committee update

The Website Committee has added 2 new members and now includes: Jon Short (Webmaster, AFSC), Nikki Paige (Forum moderator, NWFSC), Jamie Hale (NWFSC), and Andrew Chin (AFSC). The CARE website is hosted through the PSMFC web server and has been undergoing transfer from Joomla to WordPress. This new WordPress site will be active around the third week of April.

D. Lingcod Working Group update

A Lingcod Working Group initially convened in June 2021 to explore standardization of a common ageing structure, methodology, and ageing criteria among five CARE agencies tasked to provide lingcod ages for stock assessments. Currently, some agencies determine ages using fin rays and others use otoliths. A plan is being developed to study whether ages derived from these two structures are compatible, to determine the efficacy of collecting one structure vs. the other, and to validate the criteria applied in the age determination process. Agencies involved include: ADFG, NWFSC, WDFW, CDFO, & ODFW.

A follow-up working group meeting happened on March 30, 2022. A Lingcod Working Group report will be drafted prior to the tentative November 2022 CARE meeting.

E. CARE Structure Exchange Invoice

Maintaining the CARE Structure Exchange data is tasked to the CARE vice-chair. The current vice-chair and previous vice-chair have proposed a similar but streamlined invoice-reporting data form. This new form will be introduced at the upcoming November 2022 CARE meeting for approval.