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Fish or not fish—fisheries participation and harvest diversification under economic and ecological change

Tobias Schwoerer [a,*,1], Kevin Berry [b,2], Darcy G. Dugan [c], David C. Finnoff [d,3], Molly Mayo [e], Jan Ohlberger [f,4,5], Eric J. Ward [g,6]

[a] International Arctic Research Center, University of Alaska Fairbanks, PO Box 757340, Fairbanks, AK 99775-7340, USA
[b] College of Business and Public Policy, University of Alaska Anchorage, 3211 Providence Dr., Anchorage, AK 99508, USA
[c] Alaska Ocean Observing System, 1007 W 3rd Ave STE 100, Anchorage, AK 99501, USA
[d] Department of Economics, University of Wyoming, 1000 E University Ave, Laramie, WY 82071, USA
[e] Meridian Institute, PO Box 1829, Dillon, CO 80435, USA
[f] School of Aquatic and Fishery Sciences, University of Washington, 1122 NE Boat St, Box 355020, Seattle, WA 98195-5020, USA
[g] Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle WA, 98112, USA

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ABSTRACT

Fish harvesters respond to economic, regulatory, and environmental changes within complex and often highly uncertain decision-making processes. Analyzing and quantifying human decisions can improve our understanding and sustainable management of marine systems. Wild fish harvesters face high income volatility linked to natural variability in fish abundance, changing ocean environments, and world market dynamics. Past research has shown that owning additional permits reduces risk but at considerable cost, leaving such adaptation strategies unattainable for many harvesters. This study conducted a survey with Gulf of Alaska commercial salmon permit holders applying a discrete choice experiment to investigate the propensity of harvesters to switch target species within a given permit and to better understand participation under rapid environmental and economic change, increasingly outside historical ranges. Availability of target species, price, and historical harvest were found to be relatively more important than environmental changes affecting operations and income, even though these factors were of concern to the long-term viability of their fishing businesses. The resulting behavioral model allows fisheries managers to anticipate declines in participation relevant for managing marine resources under rapid change. It also improves understanding of fisheries participation and harvester perception of climate impacts, relevant for policy makers developing climate resilient fisheries and supporting adaptation across fishing communities. The results and approach are generalizable to other resource-dependent sectors adapting to change outside historic ranges.

1. Introduction

As climatic change continues to alter ocean environments in unprecedented ways leading to novel climates [1] and the potential for ecological surprises [1,2], understanding, quantifying, and integrating feedbacks between human and natural processes becomes even more important [3,4]. Integrating human dimensions into sustainability models is widely viewed as a pathway toward solutions and system resilience [5–7]. Yet, due to complexity and uncertainty in human decision making, integration into models informing environmental management remain challenging [3,6]. Some of the complexities are linked to resource users' response to economic, environmental, and political

* Corresponding author.
E-mail address: tschwoerer@alaska.edu (T. Schwoerer).
[1] **ORCID:** 0000-0003-3061-1091
[2] **ORCID:** 0000-0002-6904-4349
[3] **ORCID:** 0000-0003-0775-9733
[4] **ORCID:** 0000-0001-6795–240X
[5] Present address: Washington Department of Fish & Wildlife, 1111 Washington St. SE, Olympia, WA 98501 USA
[6] **ORCID:** 0000-0002-4359-0296

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pressures creating feedbacks within marine systems and risk for resource users [8,9].

For example, in wild fisheries, harvesters face high income volatility linked to natural variability in fish abundance, changing ocean environments, and world market dynamics [10–12]. The presence of critical system thresholds can lead to either precautionary management to protect valuable resources, or to more aggressive harvest due to the higher risk of losing the resource [13–15]. Quantifying human response to potential social and ecological regime shifts allows managers to anticipate human behavior and more appropriately adjust direction and magnitude of a policy response to prevent overharvesting [3].

This study conducted a survey with Gulf of Alaska commercial salmon permit holders to investigate fishing participation under rapid environmental and economic changes. The study used a discrete choice experiment [16], a multi-attribute technique that uses a set of hypothetical fishing scenarios describing potential future ocean and economic conditions. It measured human preferences and trade-offs [17–19] where applications in fisheries [20,21] so far focused on investigating management preferences. This study extends past applications by investigating the decision to fish given conditions outside historic ranges.

Commercial fisheries for wild salmon in the Gulf of Alaska illustrate the approach. These fisheries continue to experience a multitude of ecological and economic changes including marine heat waves [22,23], declining body size [24], fundamental changes in ecology [25,26], productivity and harvest declines [26,27], and social and economic dynamics resulting in lasting participation declines caused by the global increase in farmed salmon production in the 1990s [11,28].

Past research on participation has shown that owning additional permits reduces risk, or year-to-year variability in revenue, but may be cost prohibitive for many individuals [29,30]. In contrast, diversification by targeting multiple species on the same permit serves as an alternative to multi-permit ownership.[7] While this study investigates this alternative further in the context of rapidly changing environmental conditions, the study also contributes more broadly to recent research on adaptation pathways in Pacific Northwest fisheries [31,32]. Note, the term *fishermen* is used irrespective of gender, consistent with female harvesters referring to themselves as fishermen in North American fisheries [33].

1.1. Alaska commercial salmon fisheries and environmental changes

Most of Alaska's wild salmon fisheries are harvested within the state's coastal waters that extend to three nautical miles offshore and are managed by the Alaska Department of Fish and Game (ADFG). Since 1975 commercial salmon fishing permits have been issued by Alaska's Commercial Fisheries Entry Commission (CFEC) within a limited entry permit system [34]. Permits are issued by geographic management area and type of fishing gear. Permits can only be owned by individuals and permit holders must be on board vessels fishing in the permit area. Permits may not be leased or consolidated, meaning an individual may only fish one permit in a fishery using one gear type at a time [35].[8] Permits do not guarantee a portion of the overall catch in the fishery as under a quota system. Permits are transferable to other individuals through market transaction, by emergency (e.g., death of the permit holder), or through inheritance [35]. Permits cannot be sold back to the State of Alaska unless specific permit buyback programs aim to reduce fishing capacity [36]. Market transactions also come with considerable transaction costs resulting in sold permits to be relatively permanent and inhibiting permit holders from selling a permit in one year and purchasing the same permit a year or two later [35].

[7] Permit prices likely capture value related to the ability of decreasing income variability through targeting of different salmon species under one permit.

[8] Some exceptions have been made in setnet fisheries [35].

In most of Alaska's salmon management areas more than one of the five Pacific salmon species may be targeted by a given gear type resulting in many fisheries that have a primary target species while also offering the option of targeting a secondary species [37]. For example, in the Prince William Sound purse seine fishery, pink salmon (*Oncorhynchus gorbuscha*) dominate landings, but chum salmon (*O. keta*) can provide additional earnings given run timing and run size[30]. Pacific salmon are anadromous and provide for short commercial fishing seasons in coastal waters as fish return from the ocean to spawn in freshwater habitats, also preventing harvest in different management areas within one season [38].

Salmon are managed through escapement goals equal to the number of fish needed to escape capture by the fisheries so that they reproduce and perpetuate the population. An additional tool available to managers is hatchery augmentation, where juvenile salmon are reared in captivity under controlled conditions before being released into the ocean. The objectives of hatcheries vary by region, but may include enhancing wild salmon abundance levels, helping rebuild depleted stocks, or introducing a species where it has not occurred before [39].

The two most capital-intensive gear types in Alaska salmon fisheries are purse seiners and drift gillnetters [40]. Purse seiners are used to catch large volumes of fish where the fishing vessel encircles a school of fish with the top of the net being held up by a float line and a second smaller boat holding the net in place. Once a school of fish is enclosed the net is tightened at the bottom like a drawstring purse and then hoisted onboard [40]. Drift gillnetters predominately catch salmon by suspending curtain-like nets perpendicular to the direction fish are migrating. The net is being held up by a float-line while a lead line keeps the net vertically in the water column. Fish swimming into the net get their heads stuck, gilled. A less capital-intensive gear type is set gillnetting, which uses this same approach, yet operates from a fixed location at the beach intercepting migrating salmon as they move along the coast.

The Gulf of Alaska has experienced several marine heat waves between 2014 and 2019 coinciding with extreme phytoplankton events such as observed along the entire U.S. west coast in 2015 and in Prince William Sound in 2019 [41,42]. These events are believed to be representative of the future oceanic conditions under climate change, with the Gulf of Alaska expected to experience increased frequency and magnitude of these events [41,42]. Aside from phytoplankton, gelatinous zooplankton, known as jellyfish, are also benefitting from warmer ocean temperatures [43]. Jellyfish blooms occur in 10–20-year cycles associated with climatically driven regime shifts as documented in Alaska's Bering Sea [43,44]. There is some evidence that jellyfish compete with salmon for food resources in the Pacific Northwest [45]. It is currently uncertain what specific effect climate change has had on stock fluctuations for salmon due to various confounding factors, e.g., hatchery production [26]. Also, poor returns of Western Alaska salmon were recently attributed in part to warming ocean conditions and climatic changes [1,46].

Taking into account the characteristics of the fishery and the role of climatic events, the study's sample and survey design are described followed by the discrete choice model, and model estimation approach. The results section presents the survey results and highlights how climate-induced ocean change is affecting gear types differently in addition to varying perceptions about this change across gear types. Finally, policy implications and applicability of the approach are discussed.

2. Methods

2.1. Sample and survey design

The study sample included 2335 permanent commercial salmon permit holders in select Gulf of Alaska salmon fisheries including the Kodiak, Prince William Sound, Yakutat, and Southeast Alaska salmon management areas, the latter of which were combined for presentation [38]. Gear classes included purse seine, drift gillnet, set gillnet, and beach seine, predominately targeting pink, chum, and sockeye salmon [38]. Statewide troll permits were excluded since Trollers target individual fish of high quality and make up only 5% of the statewide harvest value [37]. Also, Cook Inlet was excluded due to allocation conflicts that may have influenced the results in unexpected ways [47].

The survey design was informed through 19 key informant interviews [48] where interviewees were selected given a range of commercial fishing experiences, salmon permit holdings, ages, geographies, gear types, and cultural backgrounds. Questions focused on professional experiences and observations related to changing ocean conditions, fisheries, and salmon management. Five key informants co-designed and pre-tested the survey instrument but were excluded from the actual survey [18,48,49]. Sawtooth Software's Lighthouse Studio 9 was used for survey design and the survey was hosted on Sawtooth's web hosting platform between March and May 2022 [50]. Attempting a census, permit owners were first contacted using mailing addresses received from the 2022 permit database [38]. A letter of invitation with a $2 bill enclosed was first mailed followed by two postcard mailings set apart by two weeks. Each contact mailing included a URL address with individualized password for completing the online survey. Lastly, a text-message follow-up used 1389 publicly available cellphone numbers purchased form a marketing firm and included three additional contacts times to be three days apart [38,51].

The survey contained three parts: 1) framing questions, 2) discrete choice experiment, and 3) socio-demographics, open-ended comments, and other questions (Appendix A). Part 1 included questions about observed ecological change, concerns about decreasing fish size, and phytoplankton (green algae) as well as jellyfish blooms. These changes were identified through interviews as key environmental changes affecting fishing operations [52,53]. They were intended to validate the discrete choice method in the second part of the survey (McFadden, 1973). In the second part, a background section described the upcoming choice tasks and provided information on attribute selection describing the scenarios. In each choice task, fishermen selected their favorite scenario among five scenarios, two fishing scenarios showing a target species each, and three non-fishing scenarios, specified as *wait a year*, *sell permit*, and *none* (Fig. 1). The *none*-scenario provided an opt-out for a more realistic real-life choice situation that captured possible grey areas of participation (Fig. 1). For example, *none* includes situations in which permit holders would decide to fish only part of a season because of depressed price levels at the start of fishing.

The choice design was limited to five overall scenarios consistent with the optimal number of scenarios diminishing task complexity and decreasing error variance [54,55]. The third part of the survey asked about alternative income sources when *wait a year* or *sell permit* scenarios were chosen, the believed likelihood a successor would continue to make money, and debt and income dependence. This section included separate questions about alternative income sources, debt level, and fishermen's income dependence which were programmed using a slider with a continuous scale between 0 and 100 (see Appendix A). The survey ended with open-ended comments.

With the assistance of Lighthouse Studio 9 and R programming, a choice design with 300 versions of the twelve randomized choice tasks was generated (Appendix B) [56,57]. Each of the fishing scenarios was first described by the targeted salmon species followed by attributes listed on the far-left column including the historical harvest level, species-specific average fish weight, species-specific price per pound, and the extent of phytoplankton and jellyfish blooms (Fig. 1). In each of the twelve choice tasks randomly selected from the 300 versions and presented to each respondent, the attributes varied across three levels (Table 1). In each choice task, respondents were asked: "Below are two hypothetical salmon fisheries describing observed conditions over the past 2 years. If you had a choice between the two fisheries, *wait a year*, or *sell your permit*, which one would you choose to fish?" This framing of the choice task allowed for presentation of historic conditions similar to the incomplete information fishermen have when deciding to fish. Aside from the three non-fishing scenarios, often referred to as opt-out scenarios [18], the two fishing scenarios presented in each choice set targeted one of three salmon species (pink, sockeye, or chum salmon). This design is consistent with the common set of two target species that permit holders would target with their gear as described earlier, even though due to randomization not every choice task presented the two target species respondents were familiar with in their fishery. The frequency of species being presented across scenarios was balanced.

Attribute levels covered values that are potentially outside the range with which respondents were familiar with, also known as end point design [18]. It is more likely to cover the actual values of changing environmental and economic conditions, including regime shifts [59, 60]. The final choice design had eight attributes, each with three levels allowing analysis of varying rates of change between the end points [18, 59,61] and balancing representation of attribute levels in each choice task [62]. Attribute levels outside historically observed ranges captured fishermen participation under more extreme conditions than currently observed and allowed for a better understanding of participation should threshold conditions occur.

Attribute levels were set in the following procedure. Harvest levels vary across salmon areas and years, so a generic description was used with 5-year average harvest for the highest, 50% of the 5-year average for the mid-level, and 10% of the 5-year average for the lowest harvest

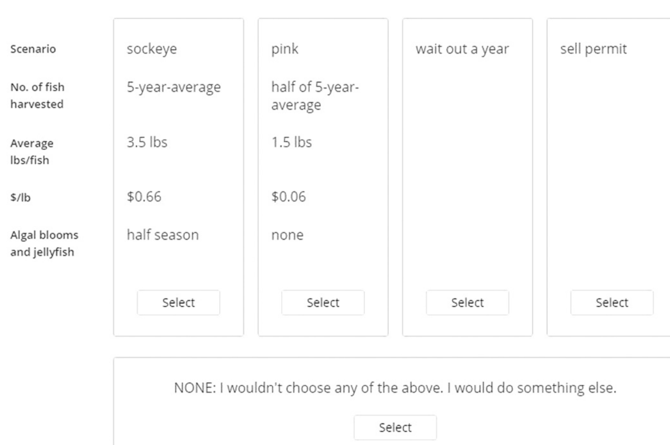

Fig. 1. Example of a choice task. Respondents were asked: "Below are two hypothetical salmon fisheries describing observed conditions over the past 2 years. If you had a choice between the two fisheries, *wait a year*, or *sell your permit*, which one would you choose to fish?".

Table 1
Attributes and attribute levels used in the discrete choice experiment design.

Attribute	Level 1	Level 2	Level 3
Scenario – fishing[a]	Sockeye salmon	Pink salmon	Chum salmon
Scenario - non-fishing[a]	Sell permit	Wait a year	None
Number of fish harvested	5-year average	Half of 5-year average	10% of 5-year average
Chum salmon size[b]	5.5 lbs	6 lbs	6.5 lbs
Sockeye salmon size[b]	3.5 lbs	4 lbs	4.5 lbs
Pink salmon size[b]	1.5 lbs	2 lbs	2.5 lbs
Chum salmon price[c]	$0.10/lb	$0.22/lb	$0.35/lb
Sockeye salmon price[c]	$0.40/lb	$0.66/lb	$0.91/lb
Pink salmon price[c]	$0.06/lb	$0.15/lb	$0.24/lb
Phytoplankton and jellyfish blooms	None	Half season	Full season

[a] Further referred to as the "Scenario attribute."
[b] Source: Guided by supplementary information published by [24].
[c] Alaska Department of Fish and Game ex-vessel price by salmon area [58].

level (Table 1). The statewide mean weight per fish in 2021 was 7.15 lbs for chum salmon, 3.5 lbs for pink salmon, and 5.03 lbs for sockeye salmon [63].[9] Salmon sizes declined between 1990 and 2010 on average by 2.4% and 2.1% for sockeye and chum salmon respectively over this time period. These species showed abrupt (non-linear) decline in body size, starting in 2000 and intensifying after 2010 [24]. Salmon size was set between 15% and 20% below current weights. Prices were set to half of the historical maximum ex-vessel price[10] at the highest and half of the historical minimum at the lowest level. The lower than historically observed prices ensured capturing economic conditions where fishermen may forgo participation in the fishery. The selection of a climate-related attribute was driven by reported fishermen observations about phytoplankton and jellyfish blooms affecting fishing operations. Since both are correlated with warming ocean conditions, impacts on fishing operations are similar, and there is a predicted increase in frequency and magnitude of these events in the study area, the two phenomena were combined in the form of one attribute. This approach limited the number of attributes and kept the experimental design small. Three time intervals were used to describe the attribute levels (Table 1) [65].

2.2. Discrete choice model

Random utility models measure the influence of attributes on respondents' scenario choices while accounting for heterogeneity between individual fishermen and groups of fishermen [16]. Fisherman n receives utility $V_n(X_i|\beta_n)$ by selecting scenario i, where X_i is a vector of attribute levels associated with scenario i and β_n is a vector of utility function parameters that describe fisherman n's preferences for scenario i over all other scenarios where $i \neq j$ and $j \in j = 1, \ldots, J$. Given a multinomial logit model where the dependent variable is choice among scenarios,[11] the probability that fisherman n would choose to participate in fishery scenario i in J scenarios is as follows:

$$p_{ni} = \frac{e^{\beta_n X_{ni}}}{\sum_{j=1}^{J} e^{\beta_n X_{nj}}} \quad (1)$$

where p_{ni} is the probability of choosing the i^{th} scenario, $\beta_n X_{ni}$ is the total utility of the chosen i^{th} scenario [18]. Note, the sum of p_{ni}, also known as the preference share, equals the fishing fleet's preference related to scenario i [19]. In the multinomial logit model, the pattern of substitutability between any scenarios is limited by the Independence of Irrelevant Alternatives (IIA) property [67]. Under IIA, a change in one scenario has the same proportional effect on all the other scenarios, meaning all scenarios are assumed to be equally dissimilar with one being more or less similar to each other [68]. Additionally we combine the correlated climate-related attributes in an attempt to limit the likelihood of violating the IIA.

2.3. Estimation and sensitivity analysis

Lighthouse Studio 9′s analysis pack was used for utility estimation, applying a Hierarchical Bayes (HB) approach to estimate main effects coefficients for all respondents combined and for each of seven fisheries [69,70]. HB borrows information from all respondents to improve individual utility estimates by averaging over less variant responses and pulling responses towards the sample mean. As a consequence, the utility distributions of relatively small groups, here fisheries, can be estimated [70].[12] Each respondent's choices are weighed based on the variance of each individual's responses, where more weight is placed on individuals with less variant responses [70]. The full probability of participation model in generalized form is the joint posterior distribution of all parameters as follows:

$$p(\alpha_n, D, \beta_n|y) \propto p(\alpha_n, D) \quad p(\beta_n|\alpha_n, D)p(y|\beta_n, \alpha_n, D) \quad (2)$$

where α_n is a vector of means of the distribution of individual utilities and D is a matrix of variances and covariances of the distribution of utilities across individual respondents [50,72]. The first probability statement on the right-hand side (Eq. 2) is the hyper prior for randomly drawing the parameters of the conditional normal priors, the second expression on the right. The third part of the right-hand side is the joint likelihood of the observed data, y, which only depends on the unknown parameter values β, α and D affecting y through β [70].

The Markov Chain Monte Carlo (MCMC) algorithm and Gibbs sampling available in Lighthouse Studio 9 was applied to simultaneously estimate parameters essential for deriving coefficients for each individual respondent's utility function [50,72]. The MCMC used a burn-in of 10,000 iterations before assuming convergence and saving an additional 10,000 iterations for determining the coefficients of each individual respondent's utility function and capturing uncertainty by estimating a 95% credible interval (see Appendix C for trace plots, see the archived dataset for individual utilities [71]) . Choice model results are presented in form of utility-derived relative attribute importance scores by gear type, summarizing how much relative impact each attribute had on choice [74] (Appendix C). The scores were calculated specific to each attribute and specific to each respondent and then standardized to sum to 100 allowing for comparisons across fisheries-specific models [61,73]. For example, if attribute A has a mean relative importance score of 10 and a standard deviation of 5 and attribute B a mean relative importance score of 20 and standard deviation of 2.5, then attribute B is twice as important to the average respondent compared to attribute A. Also, relative importance scores across the respondent pool are more tightly distributed for attribute B due to the lower standard deviation, showing more agreement across the respondent pool on attribute B's importance.

Sensitivity analysis, referred to as comparative statics in economics, investigated the marginal effects of attributes on respondent choice (Appendix C) [74]. This analysis used Lighthouse Studio 9′s simulation package applying the "share of preference" approach, equal to the sum of p_{ni} (Eq. 1) across respondents in each fishery [75] (Appendix C). Specifically, through simulation of respondent choices, fisheries participation and targeting of various species is simulated given changes in attribute levels (e.g., price shocks, extent of jellyfish blooms). To correct for sampling bias and to enable interpretation at the population level, post-stratification weights were applied [76]. A chi-square test was used to compare the sample proportions for each post-stratum with the population proportions taken from the permit database [38] (Appendix D).

3. Results

This section first presents the survey response and then shows choice model results for three gear types to broadly explain how fisheries participation varies given the relative importance of economic and environmental drivers. Validity of the choice model is explained within the context of respondents' answers to framing questions. The last part investigates the sensitivity of fisheries participation in two fisheries, the

[9] Chum: 60,270,162 lbs and 8430,673 fish; Pink: 207,585,567 lbs and 59,294,355 fish; and sockeye: 234,106,855 lbs and 46,554,474 fish. In Prince William Sound, annual median weights for pink salmon between 1975 and 2016 ranged between 2.4lbs/fish and 3.6 lbs/fish [64].

[10] Ex-vessel prices are the prices fishermen receive when they deliver their catch at the dock.

[11] This design is also referred to as an alternative-specific design, therefore information on the species available for fishing scenarios and various opt-outs for non-fishing scenarios are included as attributes (Table 1) [18].

[12] The discrete choice data including utility distributions are available in the study's archived dataset [72].

Prince William Sound purse seine and the Kodiak set gillnet fishery. Note, Appendix E contains detailed results associated with five additional fisheries (Table E.1, Figs. E.1 and E.2).

3.1. Survey response

Of the 2335 mailed letters of invitation, 37 were undeliverable, 22 respondents no longer held a commercial salmon fishing permit, and 706 fishermen responded for a 31% overall response rate. Most respondents (n = 462) participated in the discrete choice experiment with 418 completing it. Twenty respondents who indicated they misunderstood the discrete choice experiment task were excluded from the analysis. Respondent age was distributed uniformly across age groups and distribution methods, except for invitees by mail in the 60–70-year age group who were twice as likely to respond compared to other age groups. Sample proportions were indifferent from population proportions across the four gear types (χ^2, p = 0.169) and significantly different across the nine fisheries (χ^2, p = 0.003). Kodiak beach seine and the Prince William Sound set gillnet fisheries were omitted from further analysis due to small sample sizes of n = 6 and n = 12, respectively (Fig. 2).

3.2. Survey and choice model results

Table 2 shows that the fitted models outperformed similar models of chance (see Root-likelihood fit statistic) and illustrates how relative importance varied across attributes by gear type. Overall, the scenario attribute was the most important across the sample. It distinguished fishing scenarios by target species (*sockeye, pink, chum salmon*) from non-fishing scenarios (*wait a year, sell permit*) and the *none*-scenario. Besides historical prices and harvest volumes, fisheries participation can also be affected by changes in environmental quality (e.g., phytoplankton/jellyfish blooms) that hinder fishing operations or result in smaller fish [24]. However, compared to prices and harvest volumes, these attributes played a smaller role for the decision to fish (Table 2, Table E.1, and Fig. E.1).

Table 2
Utility-derived relative attribute importance by gear type, mean (SD).

Attribute	Purse Seine	Drift Gillnet	Set Gillnet
Scenario	27.9 (9.4)	25.2 (6.6)	28.9 (6.6)
Chum salmon price	13.1 (3.1)	16.3 (2.9)	9.5 (2.5)
Sockeye salmon price	12.3 (5.2)	12.8 (4.8)	12.3 (3.1)
Pink salmon price	12.5 (5.7)	12.2 (3.4)	16.7 (6.5)
Number of fish harvested	13.6 (5.8)	10.0 (4.8)	8.2 (3.7)
Chum salmon size	4.4 (2.2)	5.4 (2.8)	8.3 (2.2)
Sockeye salmon size	5.8 (3.0)	4.4 (2.4)	6.4 (2.6)
Pink salmon size	5.1 (3.5)	9.7 (3.4)	4.2 (1.7)
Phytoplankton and jellyfish blooms	5.1 (2.5)	4.0 (1.8)	5.5 (2.2)
Count, n	152	214	94
Root-likelihood	0.68	0.65	0.72

See Appendix E for more detailed choice model results by fishery.

When asked what fishermen would do instead of fishing their commercial salmon permit, responses were similar between the *wait a year*

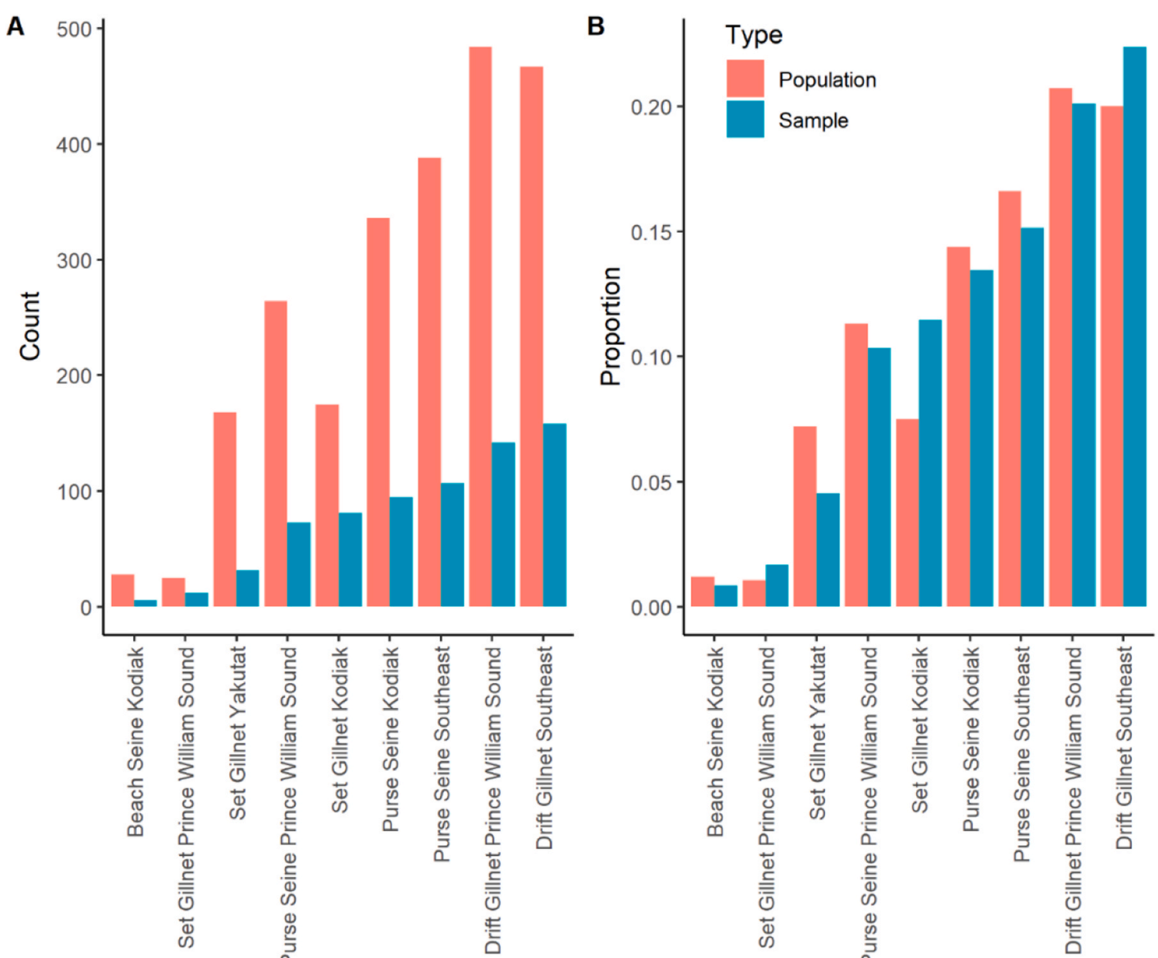

Fig. 2. Comparing population with sample proportions across fisheries, where A shows the count of respondents versus permit holders by fishery and B illustrates the sample and population proportions.

and *sell permit* scenarios (Fig. 3). In either case, over half of respondents would pursue non-fishing income, with many stating they would enter fulltime jobs they currently hold outside the fishing season. The second largest proportion would fish non-salmon fisheries such as halibut. Under the *sell permit* scenario, a larger proportion of respondents would retire, seek business opportunities in aquaculture, or switch fishing operations elsewhere than would *wait a year* (Fig. 3).

Prince William Sound purse seiners were more likely to continue fishing in direst of circumstances and were most averse to selling their permit whereas Kodiak set gillnetters were most likely to sell their permits (Fig. E.1 and Table E.1). Also, over two thirds, 69%, of Kodiak set gillnetters were willing to *wait a year* likely due to lower capital intensity and consequently lower fixed costs in the set gillnet fishery. Answers to framing questions on debt levels and income dependence support this finding. Stated debt levels were higher for more capital-intensive gear types such as purse seiners which also showed higher reliance on fishing income compared to other gear types (Table E.2). On average, respondents covered 71% of their household income through fishing with a stated debt rate of 23% (Table E.2).

For respondents who favored the *none*-scenario, open-ended comments at the end of the survey gave varying reasons for respondents selecting this opt-out (Appendix F). Some of these reasons can be interpreted as participating and others as not participating (*wait out a year*) in the fishery. Respondents wrote that they would wait until prices recovered and perhaps fish a partial season. Others assumed the stated prices were for delivery to processors but that they would likely switch to direct marketing at low prices and therefore selected the *none*. Some respondents also mentioned being caught off-guard by prices below expected ranges, wanting to opt-out when choosing between bad fishing scenarios not allowing them to cover operating costs. These respondents also reported not to pay close attention to attributes other than price after realizing the very low prices.

Purse seiners did not show a distinct preference for prices of one specific target species but placed more emphasis on the number of fish harvested relative to any other gear type. This result is consistent with their preferred target species, pink salmon, the most numerous of the Pacific salmon species (Table 3). For drift gillnetters, chum salmon prices were particularly important (Table 2) as the Southeast Alaska drift gillnet fleet largely depends on chum salmon (Table 3). This result is similar to pink salmon for set gillnetters in Kodiak, where pink is an important secondary target species aside from sockeye (Tables 2 and 3).

Fish size was less important for overall respondents' decision to fish, but this result varied by gear type and concerns about fish size declines were voiced in framing questions (Table 2, Table E.1). Fishermen on average were *somewhat concerned* about declining salmon size for the viability of their business. Their mean rating equaled 3.1, given a five-point scale ranging from *not at all concerned* (1) to *extremely concerned* (5) (n = 507). Especially for chum salmon, purse seine fisheries, and the Southeast drift gillnet fishery showed clear preferences for chum salmon size (Fig. E.1) due to chum salmon's importance in these fisheries (Table 3) and chum's generally larger body size compared to pink and sockeye salmon (Table 1). Drift gillnetters were also *moderately concerned* about salmon size decline (mean rating 3.6).

Kodiak set gillnetters had clear preference for larger pink salmon sizes (Fig. E.1), consistent with this species being an important secondary target species for this fishery (Table 3). Kodiak set gillnetters rated size declines as *moderately concerning* (mean rating 3.8), consistent with drift and set gillnet fisheries relying on appropriate mesh size for gilling salmon. A quarter of set and drift gillnetters (n = 84) rated size declines as *extremely* concerning in contrast to only 5% (n = 9) of purse seiners. Pink salmon size had little influence on purse seiners' scenario choices as shown by the relatively low importance scores (Table 2). Overall, purse seiners were least concerned about declining fish sizes with a mean rating of 2.7, with Prince William Sound purse seiners having the lowest mean rating of 2.6.

The phytoplankton and jellyfish attribute was 38% more important to set gillnetters than to drift gillnetters (Table 2). The implication of this results is that set gillnetters place a weight on phytoplankton and jellyfish that is 38% more important to them than the importance of this attribute is to drift gillnetters. Respondent answers to related framing questions support this result (Table 4). Overall, respondents reported that jellyfish blooms have similar impacts to phytoplankton blooms, but impacts vary across gear types with jellyfish impacts being rated more severely compared to phytoplankton (Table 4). Respondents reported to be adapting to these changes by investing in more expensive nets, decreasing knot size, and switching to monofilament nets (where permitted) for easier cleaning. Additionally, fishing businesses switch to larger more expensive floats that keep nets from sinking. Fishermen reported wearing protective gear like gloves, goggles, and face coverings when dealing with jellyfish, slowing down various parts of the fishing operation including the pace of fishing gear retrieval and picking fish from the net.

3.3. Sensitivity analysis

The following sensitivity analysis aims to demonstrate the

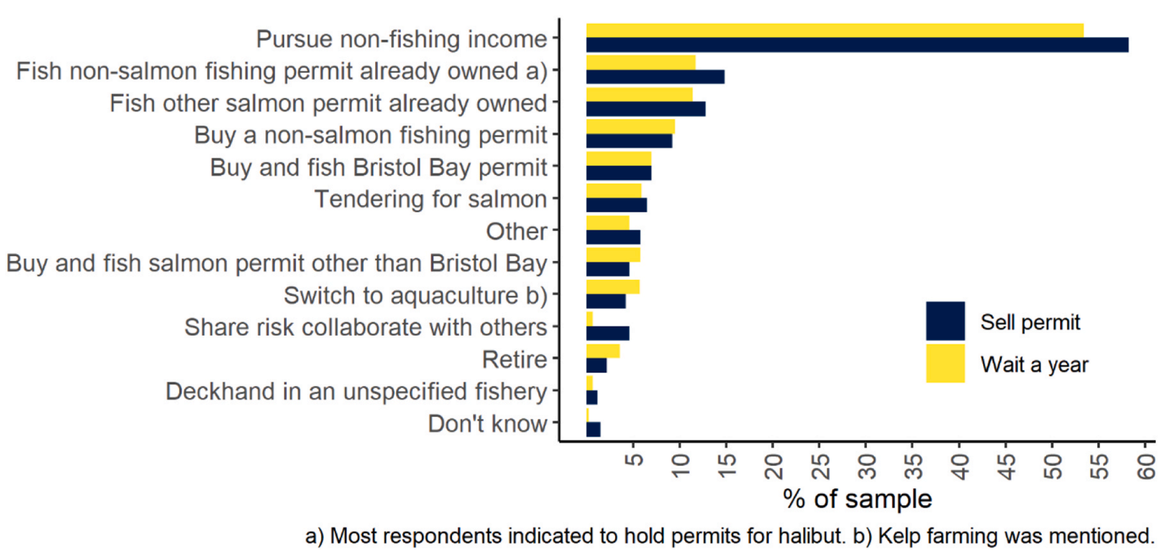

Fig. 3. Stated alternative livelihoods related to *wait a year* (n = 414) or *sell permit* (n = 413).

Table 3
Primary target species reported by respondents per fishery, n = 409.

	Sockeye	Pink	Chum	Coho	Chinook	Count	Permits issued[b]
Purse seine							
Prince William Sound	0%	98%	2%	0%	0%	44	264
Kodiak	25%	75%	0%	0%	0%	36	369
Southeast	0%	89%	11%	0%	0%	45	403
Drift gillnet							
Prince William Sound	73%	0%	26%	1%	0%	95	539
Southeast	12%	< 1%	84%	4%	1%	100	476
Set gillnet							
Prince William Sound	100%	0%	0%	0%	0%	9	30
Kodiak	79%	21%	0%	0%	0%	56	181
Southeast[a]	82%	0%	0%	18%	0%	22	168
All respondents	40%	30%	28%	2%	< 1%		

[a] Fishery is in the Yakutat management area.
[b] Number of permits issued in 2022 amounting to a total of 2466.

Table 4
Mean rating of the effects of phytoplankton and jellyfish blooms on fishing operations, where 1—not a problem, 2—minor problem, 3—moderate problem, and 4—serious problem.

Type of event and duration	Drift Gillnet	Purse Seine	Set Gillnet	All gear
Phytoplankton (n = 106)				
Weeklong	2.4	1.9	3.1	2.5
Half season	3.1	2.2	3.5	3.0
Full season	3.3	2.4	3.5	3.1
Jellyfish (n = 143)				
Weeklong	2.6	2.4	2.8	2.5
Half season	3.1	3.0	3.2	3.1
Full season	3.3	3.2	3.4	3.3
Count (n)	300	275	175	

importance of variations in economic and environmental factors in the case of two fisheries, the Prince William Sound purse seine and Kodiak set gillnet fishery. The sensitivity analysis revealed that between 6% and 10% of fishermen would have sold their permits in the Prince William Sound purse seine fishery (Fig. 4) and between 11% and 17% in the Kodiak set gillnet fishery (Fig. 5). The remaining choices between *wait a year* and targeting a primary or secondary species vary greatly as prices and historic harvest levels increase. Prices also have a much larger effect on participation choices than environmental factors expressed by the phytoplankton and jellyfish attribute. This result is true even in fisheries that are more affected by these environmental changes such as the set gillnet fishery (Fig. 5).

When pink salmon prices are very low (6 cents/lb) and are combined with very low historic harvest (10% of 5-year average), only half of the permits issued would be fished with a quarter targeting pink salmon and another quarter targeting chum salmon (Fig. 4A). The remainder would *wait a year.* As pink salmon prices rise to above 15 cents/lbs but abundance stays low, participation in the pink salmon fishery would rise but level out with 41% targeting pink salmon and 18% targeting chum salmon (Fig. 4A). At 5-year average harvest, lowest pink salmon prices would result in only a very small proportion of fishermen targeting chum (8%) and a much larger proportion (47%) targeting pink salmon (Fig. 4B). As prices reach above the 15 cents/lb threshold, participation in the pink salmon fishery would quickly rise, reaching 77% at 24 cents/lb. At that price, very few permit holders would target chum salmon given chum salmon prices of 22 cents/lb and historical two-year chum salmon harvests at 50% of the 5-year historical average (Fig. 4B).

This result highlights the dependence on large volumes of pink salmon in this fishery but also the willingness of some of the fleet to adapt and target chum salmon, a secondary species. At historically low chum salmon harvest (10% of 5-year average) none of the permit holders would target chum salmon as long as pink salmon prices are at 15 cents/lbs or higher and two-year historic pink salmon harvests are at least 50% of the 5-year average (Fig. 4C). More permit holders would switch to chum salmon given the past two years of chum salmon harvests were within the historical 5-year average. Participation in the chum salmon fishery would reach 7% even at low chum salmon prices of 10 cents/lb and reach 30% at even higher prices of 35cents/lbs for chum salmon, given pink salmon would be at 15 cents/lbs and the past two years of pink salmon harvests would be at 50% of the historic 5-year average (Fig. 4D).

Fig. 5 demonstrates the sensitivity of participation in Kodiak's set gillnet fishery targeting sockeye salmon. The estimated coefficients indicated a strong aversion to phytoplankton and jellyfish blooms, consistent with this fishery's historical challenges regarding these phenomena [52,53]. For reasons stated above, Kodiak's set gillnetters were also somewhat more concerned about declining fish sizes than other fisheries. Participation in the most unfavorable conditions on price and harvest volume would be at 14% but rise to 35% as prices more than double from 40 cents/lb to 91 cents/lb (Fig. 5A). As harvests increase from 10% of 5-year average to 5-year average levels, the participation curve would shift up reaching 50% at 91 cents/lb (Fig. 5B). Both phytoplankton and jellyfish blooms (Fig. 5C) and declines in salmon size (Fig. 5C and D) had less influence on participation than prices and historical harvest (Fig. 5A and B). Assuming medium price and harvest levels, the lengthening of blooms from one week to an entire season would decrease participation by 7% given 3.5 lbs per sockeye salmon. Similarly, a size decline of one pound per fish would decrease participation by 8% (Fig. 5C and D).

4. Discussion

The fielded survey aimed to elicit choice data that captured the most important decision factors in a hypothetical choice situation that is closely aligned with what fishermen would face. The high response rate, high completion rate related to the discrete choice experiment, the consistency of the choice model results with attitudinal and other data, and respondents' open-ended comments suggest that the survey and its questions overall were relevant to respondents. Also, fishermen who indicated they would sell their permits in the scenarios are more likely to retire, seek business opportunities in aquaculture, or switch fishing operations elsewhere than fishermen who indicated they would *wait a year* (Fig. 3). This result implies that fishermen are skilled capitalists who place highest value onto their high-risk high-return fishing activity [30]. Thus, the analyzed choices can be considered to have been less influenced by heuristics and more by utility maximization. Fishermen responded within their professional capacity hinting that the choice

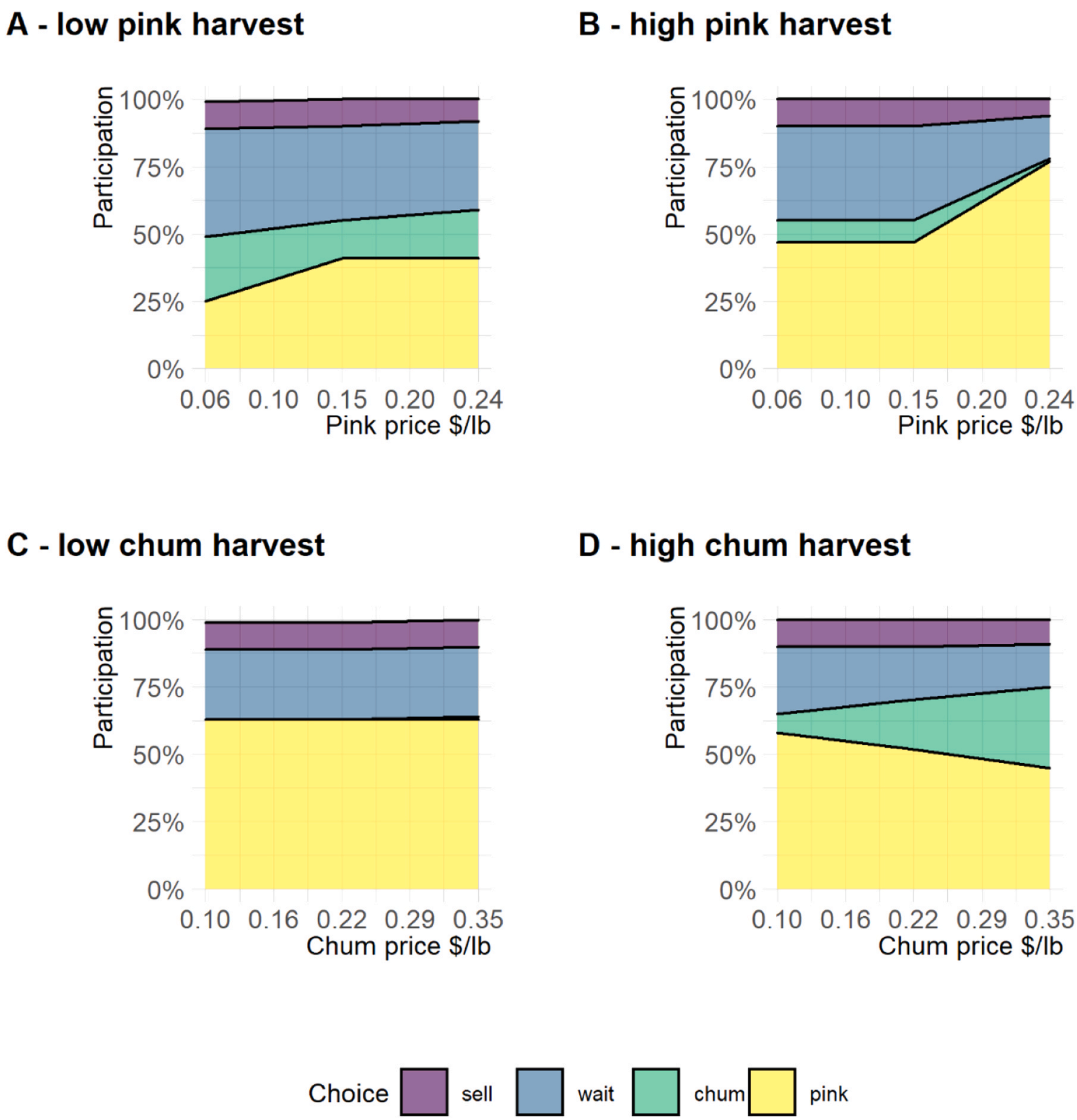

Fig. 4. Participation in the Prince William Sound purse seine fishery given varying ex-vessel prices, pink salmon harvest (A and B) and chum salmon harvest (C and D). Low harvest is 10% of 5-year average and high harvest is 5-year average. For A and B, chum prices are set at $0.22/lb and harvest at 50% of 5-year average. For C and D, pink salmon prices are set at $0.15/lb and harvest at 50% of 5-year average.

model's theoretical assumptions were met [77].

While environmental changes such as phytoplankton, jellyfish blooms, and declining fish sizes are concerning to fishermen for the long-term viability of their fishing business, concerns varied by fishery. The combined use of a discrete choice experiment and attitudinal questions illuminated this nuanced nature of decision making across many gear types and fisheries that differ widely in species availability, fish size, run size, and economic and environmental conditions (Table 2).

Shore-based fishing operations such as set gillnetters have limited ability to adapt to phytoplankton and jellyfish blooms due to the stationary nature of their operations. Consequently, these fisheries are more likely to rate the impact of phytoplankton and jellyfish blooms as a serious problem in comparison to other gear types, who consider it a minor to moderate problem (Table 7). Also, fisheries deploying gillnets are especially affected by declining fish sizes, requiring new investment in nets with tighter mesh allowing smaller fish heads to still be gilled. In addition, gillnetters must hand pick salmon from their net, thus smaller fish size results in higher labor cost per pound harvested using this gear.

For set and drift gillnetters, phytoplankton and jellyfish blooms make nets visible to fish which avoid being caught. Nets affected by these blooms also need cleaning in between uses. Consequently, the blooms reduce the time nets are in the water during time-limited fishing openers, decreasing capture rates and the duration of effective deployment. Additional handling puts more wear and tear on equipment, reducing the useful life of fishing gear and leading to increased costs. Jellyfish toxins are known to cause burns on exposed skin and threaten eyes through air born toxic particles that in some cases can lead to medical emergencies [98]. Jellyfish were reported to also cause catch reductions for purse seiners, weighing down the net's floatline and causing the previously caught salmon to escape over the top of the net.

Overall, little is known about how the above mentioned environmental changes are going to affect fisheries in the future [78,79]. Observations by this study contributed a baseline for the effects of phytoplankton and jellyfish blooms. The results demonstrate the need for more research investigating the hidden costs of adaptation to

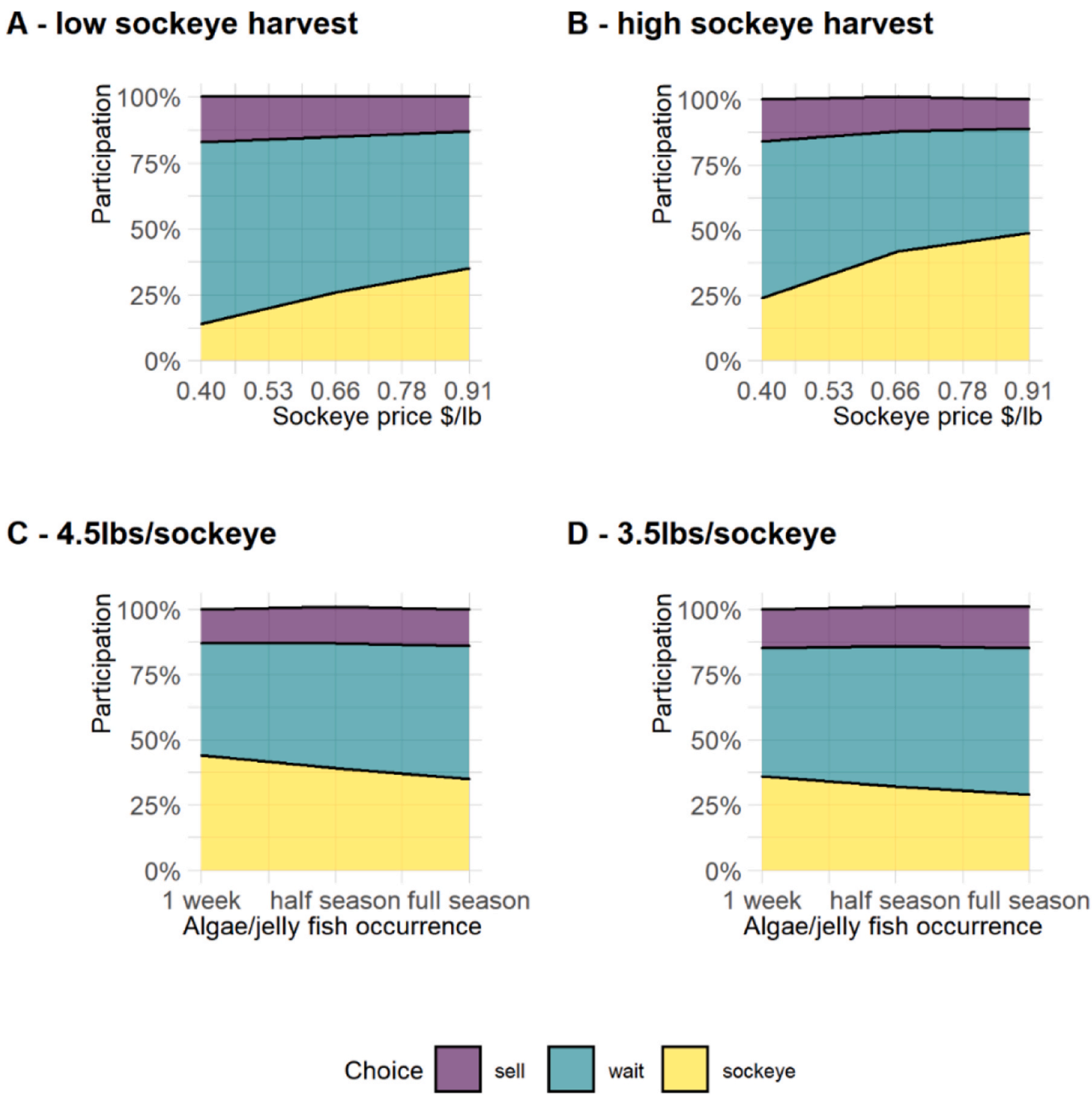

Fig. 5. Participation in the Kodiak set gillnet fishery given varying ex-vessel prices and sockeye harvest (A and B), extent of algae and jelly fish blooms, and sockeye sizes (C and D). Low harvest is 10% of 5-year average and high harvest is 5-year average. For A and B, algae/jelly are set to occur half the season and sockeye are set at 4 lbs/fish. For C and D, sockeye prices are set at $0.66/lb and harvest set at 50% of 5-year average.

climate-related ocean change. The effects on fishing operations in the Gulf of Alaska appear to be significant enough to promote the development of technological and policy solutions to alleviate the costs of adaptation and to prepare for climate readiness [78,79].

Pink salmon size had little influence on purse seiners' scenario choices. This result was strongest in the Prince William Sound purse seine fleet, a fishery that has largely relied on hatchery production [39]. Hatchery fish can compensate size declines that so far have yet to be observed for pink salmon, purse seiners' primary target species [24]. Also, smaller fish sizes do not affect purse seiners costs since these operations do not handle individual fish the way gillnetters do. Purse seiners also showed higher reliance on fishing income compared to other gear types and were more likely to fish in the direst economic and environmental conditions, perhaps related to the capital intensity of this gear type and relatively fewer permits relative to capital intensity of the purse seine fishery compared to other fisheries (Table 3). In addition, disaster declaration bailouts as recently issued for the 2020 Prince William Sound pink salmon fishery, could also influence the decision to continue fishing in the direst of circumstances [80]. Also, a smaller supply of permits and consequently a smaller market for Prince William Sound purse seine permits may lead permit holders to be more likely to hold on to their permits as fewer permits may be available for purchase in case fishermen decided to re-enter the fishery.

4.1. Validity

Even though choice model results were consistent with responses to framing questions, validating the approach, for some respondents, especially those who preferred the opt-out scenario, attribute non-attendance and heuristics, played a role in choice selection [81]. Open-ended comments at the end of the survey indicated that most respondents fully comprehended the scenarios, potentially minimizing hypothetical bias. Respondents did not face real risk related to their hypothetical decisions as stated during survey response [82]. Also, the analysis did not account for individual's willingness to seek or avoid risk within the hypothetical decision making processes observed [83]. Yet, for the analysis of how ecological and economic factors affect participation and switching between species, hypothetical biases are likely present but may average out across the sample.

For the specific application to fishing choices where the interest of the investigation lies on proportional changes in fishing participation across fishing and non-fishing scenarios, the IIA assumption's effect on proportions is likely to average out across the large sample of respondents resulting in a similar ranking of scenarios across respondents as would be expected under a model that relaxes the IIA assumption. However, the exact proportions of scenario choices across respondents may look slightly different if the IIA assumption is relaxed. For example, purse seiners strongly disliked selling their permit over other scenarios thus the IIA assumption likely skewed preferences artificially toward *selling the permit*, likely overestimating this proportion.

4.2. Applicability

The presented approach and analysis showed how fisheries participation can be predicted for environmental and economic conditions that may fall outside historic ranges. The approach provides policy makers the ability to anticipate drastic changes in fisheries production with implications for livelihoods, economies, and society linked to food supply chains and associated food security [79]. Also, the study showed that fishermen's diversification by allowing multiple species to be targeted on the same permit presents an alternative to owning multiple costly permits, allowing fisherman to spread risk. This result is similar to farm diversification strategies where farmers diversify across crops, regions, climatic conditions, and income opportunities aside from farming [84]. In this context, the study is generalizable to other sectors of resource dependent industries that are adapting to change, especially agriculture [84,85]. Adaptation to climate change through farm diversification is facilitated by access to non-farm income, market orientation and information, available land resources, and local knowledge related to cropping and livestock holding to name a few [84]. These adaptation-enabling factors are similar to the ones found by this study.

Fishermen's decision to fish is largely driven by the limitations of their equipment and permit allowing them to target certain species and depends on prices for the delivered catch and harvest levels. Fishermen's responsiveness to price and harvest changes is also partly explained by the fact that fishing households cover over 70% of their household income through fishing at a debt rate of 23%. In reality, fishermen also face great uncertainty regarding price and harvest levels and frequently act on incomplete information, similar to farmers [84]. Even though the discrete choice experiment framed the price and harvest attribute in terms of historical averages to simulate reality, fishermen often receive post-season payouts from processors based on the quality of the fish delivered and shared profits that affect price but are difficult for fishermen to anticipate before deciding over participation in a fishery. Also, prices are sometimes announced mid-season, leaving decisions to be based on historic experience. These latter factors are secondary compared to the main price attribute and thus were not included in the study.

The estimated participation rates can be used to infer potential effort changes in the fishery given the described future economic and ecological conditions. Inference of potential harvest capacity changes needs to consider the likely increase in catch per unit effort (CPUE) as participation drops below current levels. The increase in capitalization observed since the 1970 s, could lead to fewer boats harvesting similar levels comparable to the harvest of a larger fleet racing for fish [86,87]. Even though Alaska's fisheries have substantially consolidated since the 1990 s, capital stuffing remains [88–90]. In addition, the estimated proportion of permits being sold to other fishermen would result in an uncertain number of new entries, where respondents' believed chance of successfully generating fishing income was rated to be 39% (Table E.2). Integration of more advanced behavioral models beyond rational choice theory, particularly in quantitative form, remain a major challenge and were outside the scope of this study [91].

In fisheries where multiple management objectives play a role, the human dimensions are often addressed through engagement or participatory governance aimed at optimizing multi-objective management and addressing between-species trade-offs [92,93]. Examples of fisheries with multiple management objectives include those deploying different gear types, fisheries that target multiple species, or fisheries with various social goals such as commercial and subsistence fisheries for wild Alaska salmon. Here the study provided a quantitative approach for incorporating human dimensions in fisheries management, contributing to the broad literature on stakeholder involvement in fisheries worldwide, a fundamental component of sustainable fisheries management [94,95]. Fisheries managers have relied on the ecological knowledge of fisheries participants for solving complex management situations, for example when ecological and economic conditions trend outside historically observed ranges [96].

The approach condensed the complex nature of prices and exposure to international markets and, when combined with historic harvest levels and important environmental factors, identifies barriers to participation. The resulting behavioral model allows policy makers to anticipate rapid declines in participation, which for local communities relying on fisheries for their primary income can have detrimental economic consequences [12].

The results demonstrate how participation is a function of price, harvest, and other variables and can help design policy that is geared towards preventing rent-seeking and over-capitalization. Both are common issues in Alaska's commercial salmon fisheries [97].

5. Conclusions

This study demonstrated an approach relevant for reducing human dimension-related uncertainty by providing human behavioral data for integration into management decision models when economic and ecological conditions are outside historic ranges. As climatic change continues to alter ocean environments in unprecedented ways and wild fisheries are subject to global market forces driven by societal needs, fisheries management is challenged by developing and enforcing harvest rules that enhance both ecological and social wellbeing. The simulated fisheries participation showed that fishermen are highly responsive to prices and harvest volumes and may switch target species or stop fishing under conditions outside the historic norm. Better understanding such changes in resource user capacity can provide resource managers with a more nuanced approach to management where uncertainties related to human dimensions are reduced.

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CRediT authorship contribution statement

Tobias Schwoerer: Conceptualization, Investigation, Methodology, Software, Formal analysis, Writing – original draft, Writing – review & editing, Data curation, Funding acquisition, **Kevin Berry**: Conceptualization, Writing – review & editing, Funding acquisition. **Darcy Dugan**: Conceptualization, Writing – review & editing, **David Finnoff**: Conceptualization, Project administration, Supervision, Funding acquisition, Writing – review & editing, **Molly Mayo**: Conceptualization, Investigation, Writing – review & editing, **Jan Ohlberger**: Conceptualization, Writing – review & editing. **Eric Ward**: Conceptualization, Writing – review & editing, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data are archived at https://doi.org/10.18739/A2GF0MX8D.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2023.105833.

References

[1] M.A. Litzow, M.J. Malick, N.A. Bond, C.J. Cunningham, J.L. Gosselin, E.J. Ward, Quantifying a novel climate through changes in PDO-climate and PDO-salmon relationships, Geophys. Res. Lett. 47 (2020), https://doi.org/10.1029/2020gl087972.

[2] N.S. Jacobsen, K.N. Marshall, A.M. Berger, C. Grandin, I.G. Taylor, Climate-mediated stock redistribution causes increased risk and challenges for fisheries management, ICES J. Mar. Sci. 79 (2022) 1120–1132, https://doi.org/10.1093/icesjms/fsac029.

[3] J.R. Nielsen, E. Thunberg, D.S. Holland, J.O. Schmidt, E.A. Fulton, F. Bastardie, A. E. Punt, I. Allen, H. Bartelings, M. Bertignac, E. Bethke, S. Bossier, R. Buckworth, G. Carpenter, A. Christensen, V. Christensen, J.M. Da-Rocha, R. Deng, C. Dichmont, R. Doering, A. Esteban, J.A. Fernandes, H. Frost, D. Garcia, L. Gasche, D. Gascuel, S. Gourguet, R.A. Groeneveld, J. Guillén, O. Guyader, K.G. Hamon, A. Hoff, J. Horbowy, T. Hutton, S. Lehuta, L.R. Little, J. Lleonart, C. Macher, S. Mackinson, S. Mahevas, P. Marchal, R. Mato-Amboage, B. Mapstone, F. Maynou, M. Merzéréaud, A. Palacz, S. Pascoe, A. Paulrud, E. Plaganyi, R. Prellezo, E.I. van Putten, M. Quaas, L. Ravn-Jonsen, S. Sanchez, S. Simons, O. Thébaud, M. T. Tomczak, C. Ulrich, D. van Dijk, Y. Vermard, R. Voss, S. Waldo, Integrated ecological-economic fisheries models-Evaluation, review and challenges for implementation, Fish Fish (2017) 1–29, https://doi.org/10.1111/faf.12232.

[4] D. Finnoff, J. Tschirhart, Identifying, preventing and controlling invasive plant species using their physiological traits, Ecol. Econ. 52 (2005) 397–416, https://doi.org/10.1016/j.ecolecon.2004.06.021.

[5] S.M. Constantino, M. Schlüter, E.U. Weber, N. Wijermans, Cognition and behavior in context: a framework and theories to explain natural resource use decisions in social-ecological systems, Sustain. Sci. 16 (2021) 1651–1671, https://doi.org/10.1007/s11625-021-00989-w.

[6] C. Schill, J.M. Anderies, T. Lindahl, C. Folke, S. Polasky, J.C. Cárdenas, A.-S. Crépin, M.A. Janssen, J. Norberg, M. Schlüter, A more dynamic understanding of human behaviour for the Anthropocene, Nat. Sustain. 2 (2019) 1075–1082, https://doi.org/10.1038/s41893-019-0419-7.

[7] D. Victor, Climate change: embed the social sciences in climate policy, Nat. Publ. Group UK (2015), https://doi.org/10.1038/520027a.

[8] I.M. Otto, J.F. Donges, R. Cremades, A. Bhowmik, R.J. Hewitt, W. Lucht, J. Rockström, F. Allerberger, M. McCaffrey, S.S.P. Doe, A. Lenferna, N. Morán, D. P. van Vuuren, H.J. Schellnhuber, Social tipping dynamics for stabilizing Earth's climate by 2050, Proc. Natl. Acad. Sci. 117 (2020) 2354–2365, https://doi.org/10.1073/pnas.1900577117.

[9] D. Finnoff, J.F. Shogren, B. Leung, D. Lodge, The importance of bioeconomic feedback in invasive species management, Ecol. Econ. 52 (2005) 367–381, https://doi.org/10.1016/j.ecolecon.2004.06.020.

[10] E. Lindkvist, K.E. Pellowe, S.M. Alexander, E. Drury O'Neill, E.M. Finkbeiner, A. Girón-Nava, B. González-Mon, A.F. Johnson, J. Pittman, C. Schill, N. Wijermans, Ö. Bodin, S. Gelcich, M. Glaser, Untangling social-ecological interactions: A methods portfolio approach to tackling contemporary sustainability challenges in fisheries, Fish Fish 23 (2022) 1202–1220, https://doi.org/10.1111/faf.12678.

[11] A.H. Beaudreau, E.J. Ward, R.E. Brenner, A.O. Shelton, J.T. Watson, J.C. Womack, S.C. Anderson, A.C. Haynie, K.N. Marshall, B.C. Williams, Thirty years of change and the future of Alaskan fisheries: shifts in fishing participation and diversification in response to environmental, regulatory and economic pressures, Fish Fish (2019), https://doi.org/10.1111/faf.12364.

[12] S.A. Sethi, M. Reimer, G. Knapp, Alaskan fishing community revenues and the stabilizing role of fishing portfolios, Mar. Policy 48 (2014) 134–141, https://doi.org/10.1016/j.marpol.2014.03.027.

[13] S. Polasky, A. de Zeeuw, F. Wagener, Optimal management with potential regime shifts, J. Environ. Econ. Manag. 62 (2011) 229–240, https://doi.org/10.1016/j.jeem.2010.09.004.

[14] K. Berry, D. Finnoff, Choosing between adaptation and prevention with an increasing probability of a pandemic, J. Econ. Behav. Organ. 132 (2016) 177–192, https://doi.org/10.1016/j.jebo.2016.06.007.

[15] R.D. Horan, D. Finnoff, K. Berry, C. Reeling, J.F. Shogren, Managing wildlife faced with pathogen risks involving multi-stable outcomes, Environ. Resour. Econ. 70 (2018) 713–730, https://doi.org/10.1007/s10640-018-0227-y.

[16] D. McFadden, Conditional logit analysis of qualitative choice behavior, in: P. Zarembka (Ed.), Frontiers in Econometrics, Academic Press, New York, 1973, pp. 105–142. ⟨http://elsa.berkeley.edu/reprints/mcfadden/zarembka.pdf⟩.

[17] S. Hess, A. Daly, Handbook of Choice Modelling, Edward elgar, Cheltenham, UK, 2014.

[18] D.A. Hensher, J.M. Rose, W.H. Greene, Applied Choice Analysis: A Primer, Cambridge University Press, Cambridge, UK, 2005.

[19] E. Lancsar, J. Louviere, T. Flynn, Several methods to investigate relative attribute impact in stated preference experiments, in: Soc. Sci. Med, 2007, pp. 1738–1753, https://doi.org/10/ctw7xw.

[20] B. Beardmore, W. Haider, L.M. Hunt, R. Arlinghaus, Evaluating the ability of specialization indicators to explain fishing preferences, Leis. Sci. 35 (2013) 273–292, https://doi.org/10.1080/01490400.

[21] J. Duffield, C. Neher, S. Allen, D. Patterson, B. Gentner, Modeling the behavior of marlin anglers in the western pacific, Mar. Resour. Econ. 27 (2012) 343–357, https://doi.org/10.5950/0738-1360-27.4.343.

[22] M.A. Litzow, M.E. Hunsicker, E.J. Ward, S.C. Anderson, J. Gao, S.G. Zador, S. Batten, S.C. Dressel, J. Duffy-Anderson, E. Fergusson, R.R. Hopcroft, B.J. Laurel, R. O'Malley, Evaluating ecosystem change as Gulf of Alaska temperature exceeds the limits of preindustrial variability, Prog. Oceanogr. 186 (2020), 102393, https://doi.org/10.1016/j.pocean.2020.102393.

[23] R.M. Suryan, M.L. Arimitsu, H.A. Coletti, R.R. Hopcroft, M.R. Lindeberg, S. J. Barbeaux, S.D. Batten, W.J. Burt, M.A. Bishop, J.L. Bodkin, R. Brenner, R. W. Campbell, D.A. Cushing, S.L. Danielson, M.W. Dorn, B. Drummond, D. Esler, T. Gelatt, D.H. Hanselman, S.A. Hatch, S. Haught, K. Holderied, K. Iken, D.B. Irons, A.B. Kettle, D.G. Kimmel, B. Konar, K.J. Kuletz, B.J. Laurel, J.M. Maniscalco, C. Matkin, C.A.E. McKinstry, D.H. Monson, J.R. Moran, D. Olsen, W.A. Palsson, W. S. Pegau, J.F. Piatt, L.A. Rogers, N.A. Rojek, A. Schaefer, I.B. Spies, J.M. Straley, S. L. Strom, K.L. Sweeney, M. Szymkowiak, B.P. Weitzman, E.M. Yasumiishi, S. G. Zador, Ecosystem response persists after a prolonged marine heatwave, Sci. Rep. 11 (2021) 6235, https://doi.org/10.1038/s41598-021-83818-5.

[24] K.B. Oke, C.J. Cunningham, P. a H. Westley, M.L. Baskett, S.M. Carlson, J. Clark, A. P. Hendry, V.A. Karatayev, N.W. Kendall, J. Kibele, H.K. Kindsvater, K. M. Kobayashi, B. Lewis, S. Munch, J.D. Reynolds, G.K. Vick, E.P. Palkovacs, Recent declines in salmon body size impact ecosystems and fisheries, Nat. Commun. 11 (2020) 4155, https://doi.org/10.1038/s41467-020-17726-z.

[25] M.A. Litzow, L. Ciannelli, P. Puerta, J.J. Wettstein, R.R. Rykaczewski, M. Opiekun, Non-stationary climate-salmon relationships in the Gulf of Alaska, Proc. Biol. Sci. 285 (2018), https://doi.org/10.1098/rspb.2018.1855.

[26] J. Ohlberger, E.J. Ward, R.E. Brenner, M.E. Hunsicker, S.B. Haught, D. Finnoff, M. A. Litzow, T. Schwoerer, G.T. Ruggerone, C. Hauri, Non-stationary and interactive effects of climate and competition on pink salmon productivity, Glob. Chang. Biol. 28 (2021) 2026–2040, https://doi.org/10.1111/gcb.16049.

[27] G.T. Ruggerone, J.R. Irvine, B. Connors, Did recent marine heatwaves and record high pink salmon abundance lead to a tipping point that caused record declines in North Pacific salmon abundance and harvest in 2020? North Pac. Anadromous Fish. Comm. Tech. Rep. 17 (2021) 78–82. ⟨https://www.researchgate.net/profile/Gregory-Ruggerone/publication/356626576_Did_Recent_Marine_Heatwaves_and_Record_High_Pink_Salmon_Abundance_Lead_to_a_Tipping_Point_that_Caused_Record_Declines_in_North_Pacific_Salmon_Abundance_and_Harvest_in_2020/links/61aabd54ca2d401f27c23a63/Did-Recent-Marine-Heatwaves-and-Record-High-Pink-Salmon-Abundance-Lead-to-a-Tipping-Point-that-Caused-Record-Declines-in-North-Pacific-Salmon-Abundance-and-Harvest-in-2020.pdf⟩.

[28] G. Knapp, C.A. Roheim, J.L. Anderson, The great salmon run: Competition between wild and farmed salmon, TRAFFIC North America World Wildlife Fund, Washington, D.C., 2007.

[29] S.C. Anderson, E.J. Ward, A.O. Shelton, M.D. Adkison, A.H. Beaudreau, R. E. Brenner, A.C. Haynie, J.C. Shriver, J.T. Watson, B.C. Williams, Benefits and risks of diversification for individual fishers, Proc. Natl. Acad. Sci. 114 (2017) 10797–10802, https://doi.org/10.1073/pnas.1702506114.

[30] E.J. Ward, S.C. Anderson, A.O. Shelton, R.E. Brenner, M.D. Adkison, A. H. Beaudreau, J.T. Watson, J.C. Shriver, A.C. Haynie, B.C. Williams, Effects of increased specialization on revenue of Alaskan salmon fishers over four decades, J. Appl. Ecol. 55 (2018) 1082–1091, https://doi.org/10.1111/1365-2664.13058.

[31] L.K. Nelson, A.C. Cullen, L.E. Koehn, S. Harper, J. Runebaum, M. Bogeberg, A. Strawn, P.S. Levin, Understanding perceptions of climate vulnerability to inform more effective adaptation in coastal communities, PLOS Clim. 2 (2023), e0000103, https://doi.org/10.1371/journal.pclm.0000103.

[32] M. Szymkowiak, A. Steinkruger, Alaska fishers attest to climate change impacts in discourse on resource management under marine heatwaves, Environ. Sci. Policy 140 (2023) 261–270, https://doi.org/10.1016/j.envsci.2022.12.019.

[33] T.A. Branch, D. Kleiber, Should we call them fishers or fishermen? Fish Fish. 18 (2017) 114–127, https://doi.org/10.1111/faf.12130.

[34] F. Homan, Limited Entry in Alaska's Commercial Fisheries, (2005). ⟨https://www.cfec.state.ak.us/pregs/StateLimitedEntry.pdf⟩ (accessed February 8, 2019).

[35] G. Knapp, Local permit ownership in Alaska salmon fisheries, Mar. Policy 35 (2011) 658–666, https://doi.org/10.1016/j.marpol.2011.02.006.

[36] D.P. Dupont, Rent Dissipation in Restricted Access Fisheries, J. Environ. Econ. Manag. 19 (1990) 26–44.

[37] CFEC, Commercial Fisheries Entry Commission Basic Information Table, (2021). ⟨http://www.cfec.state.ak.us/bit/X_S03E.htm⟩ (accessed November 10, 2021).

[38] CFEC, Alaska Commercial Fisheries Entry Commission Permit Database, (2022). ⟨https://www.cfec.state.ak.us/plook/#permits⟩ (accessed April 13, 2022).

[39] L. Wilson, Alaska Salmon Fisheries Enhancement Annual Report 2021, Alaska Department of Fish and Game, 2022. ⟨https://www.adfg.alaska.gov⟩.

[40] ADFG, What kind of fishing boat is that?, 2009.

[41] V.L. Trainer, S.K. Moore, G. Hallegraeff, R.M. Kudela, A. Clement, J.I. Mardones, W.P. Cochlan, Pelagic harmful algal blooms and climate change: Lessons from nature's experiments with extremes, Harmful Algae 91 (2020), 101591, https://doi.org/10.1016/j.hal.2019.03.009.

[42] X. Du, R. Campbell, S. Kibler, Seasonal changes of microphytoplankton community in prince william sound, Alaska in 2019, Estuaries Coasts 46 (2023) 388–403, https://doi.org/10.1007/s12237-022-01144-z.

[43] J.E. Purcell, Jellyfish and ctenophore blooms coincide with human proliferations and environmental perturbations, Ann. Rev. Mar. Sci. 4 (2012) 209–235, https://doi.org/10.1146/annurev-marine-120709-142751.

[44] R.D. Brodeur, M.B. Decker, L. Ciannelli, J.E. Purcell, N.A. Bond, P.J. Stabeno, E. Acuna, G.L. Hunt, Rise and fall of jellyfish in the eastern Bering Sea in relation to climate regime shifts, Prog. Oceanogr. 77 (2008) 103–111, https://doi.org/10.1016/j.pocean.2008.03.017.

[45] J.J. Ruzicka, E.A. Daly, R.D. Brodeur, Evidence that summer jellyfish blooms impact Pacific Northwest salmon production, Ecosphere 7 (2016), e01324, https://doi.org/10.1002/ecs2.1324.

[46] C.J. Cunningham, P.A.H. Westley, M.D. Adkison, Signals of large scale climate drivers, hatchery enhancement, and marine factors in Yukon River Chinook salmon survival revealed with a Bayesian life history model, Glob. Chang. Biol. 24 (2018) 4399–4416, https://doi.org/10.1111/gcb.14315.

[47] H.L. Harrison, P.A. Loring, Larger than life: the emergent nature of conflict in Alaska's upper cook inlet salmon fisheries, SAGE Open 4 (2014), 2158244014555112, https://doi.org/10.1177/2158244014555112.

[48] P. Lavrakas, Key informant, Teller Road, Thousand Oaks California 91320 United States of America, in: Encyclopedia of Survey Research Methods, Sage Publications Inc, 2008, p. 2455. Teller Road, Thousand Oaks California 91320 United States of America, ⟨http://methods.sagepub.com/reference/encyclopedia-of-survey-research-methods/n260.xml⟩.

[49] A.V. Norström, C. Cvitanovic, M.F. Löf, S. West, C. Wyborn, P. Balvanera, A. T. Bednarek, E.M. Bennett, R. Biggs, A. de Bremond, B.M. Campbell, J.G. Canadell, S.R. Carpenter, C. Folke, E.A. Fulton, O. Gaffney, S. Gelcich, J.-B. Jouffray, M. Leach, M. Le Tissier, B. Martín-López, E. Louder, M.-F. Loutre, A.M. Meadow, H. Nagendra, D. Payne, G.D. Peterson, B. Reyers, R. Scholes, C.I. Speranza, M. Spierenburg, M. Stafford-Smith, M. Tengö, S. van der Hel, I. van Putten, H. Österblom, Principles for knowledge co-production in sustainability research, Nat. Sustain 3 (2020) 182–190, https://doi.org/10.1038/s41893-019-0448-2.

[50] Sawtooth, Lighthouse Studio, Sawtooth Software, Inc., Sequim, WA, 2022. ⟨http://www.sawtoothsoftware.com⟩.

[51] D.A. Dillman, J.D. Smyth, L.M. Christian. Internet, Phone, Mail, and Mixed-Mode Surveys: the Tailored Design Method, fourth ed., John Wiley & Sons, Inc, Hoboken, NJ, 2014.

[52] A.L. Lecher, K.R.M. Mackey, A. Paytan, River and submarine groundwater discharge effects on diatom phytoplankton abundance in the Gulf of Alaska, Hydrology 4 (2017) 61, https://doi.org/10.3390/hydrology4040061.

[53] D.J. Summers, Year in Review: Federal agenda dominated by halibut bycatch concerns, Alaska Journal of Commerce. (2015). ⟨https://www.alaskajournal.com/2015-12-16/year-review-federal-agenda-dominated-halibut-bycatch-concerns⟩ (accessed April 15, 2022).

[54] C. Chung, T. Boyer, S. Han, How many choice sets and alternatives are optimal? Consistency in choice experiments, Agribusiness 27 (2011) 114–125, https://doi.org/10.1002/agr.20252.

[55] W.S. Breffle, R.D. Rowe, Comparing choice question formats for evaluating natural resource tradeoffs, Land Econ. 78 (2002) 298–314, https://doi.org/10.2307/3147275.

[56] Sawtooth Software, Alternative-Specific Designs, (2022). ⟨https://sawtoothsoftware.com/help/lighthouse-studio/manual/acbc-alternative-specific-designs.html⟩ (accessed April 14, 2022).

[57] R Core Team, R: A language and environment for statistical computing, R Foundation for Statistical Computing, 2022. ⟨https://www.R-project.org/⟩.

[58] ADFG, Statewide Salmon Gross Earnings by Species Commercial Salmon Fisheries, (2021). ⟨https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmon_grossearnings_byspecies⟩ (accessed April 14, 2022).

[59] R.A. Bentley, E.J. Maddison, P.H. Ranner, J. Bissell, C.C.S. Caiado, P. Bhatanacharoen, T. Clark, M. Botha, F. Akinbami, M. Hollow, R. Michie, B. Huntley, S.E. Curtis, P. Garnett, Social tipping points and Earth systems dynamics, Front. Environ. Sci. Eng. China 2 (2014), https://doi.org/10.3389/fenvs.2014.00035.

[60] F. Berkes, J. Colding, C. Folke, Navigating Social-Ecological Systems: Building Resilience for Complexity and Change, Cambridge University Press, 2008. ⟨https://play.google.com/store/books/details?id=Y5FnAq9kjxgC⟩.

[61] T. Schwoerer, J. Little, G.D. Hayward, Quantifying expert opinion with discrete choice models: Invasive elodea's influence on Alaska salmonids, J. Environ. Manag. 271 (2020), 110924, https://doi.org/10.1016/j.jenvman.2020.110924.

[62] R. Johnson, J. Huber, L. Bacon, Adaptive choice-based conjoint, (2003). ⟨https://content.sawtoothsoftware.com/assets/9f5a5e9b-d900-4281-a520-9225db036d63⟩.

[63] ADFG, Commercial Salmon Species Combined Historical Harvest Rankings, Alaska Department of Fish and Game, (2021). ⟨https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmon_combined_historical⟩ (accessed June 27, 2021).

[64] T. Schwoerer, Regional salmon weight derived from commercial catch data, Alaska (2019) 1975–2016, https://doi.org/10.5063/F1NC5ZGW.

[65] G. Edwards, Alaska department of fish and game, Board Fish. Comments Propos. 67 (2019), in: ⟨https://www.adfg.alaska.gov/static/regulations/regprocess/fisheriesboard/pdfs/2019-2020/kodiak/pcs500-595.pdf⟩.

[67] P.C. Boxall, W.L. Adamowicz, Understanding heterogeneous preferences in random utility models: a latent class approach, Environ. Resour. Econ. 23 (2002) 421–446, https://doi.org/10.1023/A:1021351721619.

[68] J.A. Hausman, G.K. Leonard, D. McFadden, A utility-consistent, combined discrete choice and count data model: Assessing recreational use losses due to natural resource damage, J. Public Econ. 56 (1995) 1–30.

[69] B.K. Orme, K. Chrzan, Part-Worth Utility Estimation. Becoming an Expert in Conjoint Analysis: Choice Modeling for Pros, Sawtooth Software, Inc., Orem, UT, 2017, pp. 131–155.

[70] A. Gelman, J.B. Carlin, H.S. Stern, D.B. Dunson, A. Vehtari, D.B. Rubin, Bayesian Data Analysis, Chapman & Hall/CRC, New York, 2013.

[71] T. Schwoerer, A discrete choice survey with Gulf of Alaska commercial salmon permit holders conducted in 2022, (2023). https://doi.org/10.18739/A2GF0MX8D.

[72] B.K. Orme, The CBC/HB system for hierarchical bayes estimation, Sawtooth Softw. Tech. Pap. Ser. (2009) 1–27. ⟨http://www.sawtoothsoftware.com/support/technical-papers/hierarchical-bayes-estimation/cbc-hb-technical-paper-2009⟩.

[73] B.K. Orme, Interpreting the results of conjoint analysis, in: Getting Started with Conjoint Analysis: Strategies for Product Design and Pricing Research, Research Publishers LLC, Madison, WI, 2010, pp. 77–88.

[74] E. Silberberg, S. Wing. The Structure of Economics: A Mathematical Analysis, third ed., McGraw-Hill Professional,, Blacklick OH, 2000.

[75] J. Huber, B.K. Orme, R. Miller, Dealing with Product Similarity in Conjoint Simulations, Sawtooth Software, inc., Sequim, WA, 1999. ⟨https://www.sawtoothsoftware.com/download/techpap/prodsim.pdf⟩ (accessed April 5, 2019).

[76] K.D. Royal, Survey research methods: A guide for creating post-stratification weights to correct for sample bias, J. Contin. Educ. Health Prof. 2 (2019) 48, https://doi.org/10.4103/EHP.EHP_8_19.

[77] J. Levin, P. Milgrom, Introduction to choice theory, (2004). ⟨https://web.stanford.edu/~jdlevin/Econ%20202/Choice%20Theory.pdf⟩ (accessed November 14, 2022).

[78] M. Szymkowiak, Adaptations and well-being: Gulf of Alaska fishing families in a changing landscape, Ocean Coast. Manag 197 (2020), 105321, https://doi.org/10.1016/j.ocecoaman.2020.105321.

[79] E. Ojea, S.E. Lester, D. Salgueiro-Otero, Adaptation of fishing communities to climate-driven shifts in target species, One Earth 2 (2020) 544–556, https://doi.org/10.1016/j.oneear.2020.05.012.

[80] ADFG, Federal Fishery Disasters, Alaska Department of Fish and Game, (n.d.). ⟨https://www.adfg.alaska.gov/index.cfm?adfg=hottopics.fisherydisasters⟩ (accessed June 2, 2023).

[81] A. Tversky, D. Kahneman, Judgment under Uncertainty: Heuristics and Biases, Science 185 (1974) 1124–1131, https://doi.org/10.1126/science.185.4157.1124.

[82] N. Hanley, S. Mourato, R.E. Wright, Choice modelling approaches: a superior alternative for environmental valuatioin? J. Econ. Surv. 15 (2002) 435–462, https://doi.org/10.1111/1467-6419.00145.

[83] D. Kahneman, A. Tversky, Prospect theory: an analysis of decision under risk, Econometrica 47 (1979) 263–292, https://doi.org/10.1111/j.1536-7150.2011.00774.x.

[84] K. Waha, M.T. van Wijk, S. Fritz, L. See, P.K. Thornton, J. Wichern, M. Herrero, Agricultural diversification as an important strategy for achieving food security in Africa, Glob. Chang. Biol. 24 (2018) 3390–3400, https://doi.org/10.1111/gcb.14158.

[85] M. van Zonneveld, M.-S. Turmel, J. Hellin, Decision-making to diversify farm systems for climate change adaptation, Front. Sustain. Food Syst. 4 (2020), https://doi.org/10.3389/fsufs.2020.00032.

[86] J. Karpoff, Low-interest loans and the markets for limited entry permits in the alaska salmon fisheries, Land Econ. 60 (1984) 69–80, https://doi.org/10.2307/3146094.

[87] R.E. Townsend, On "capital-stuffing" in regulated fisheries, Land Econ. 61 (1985).

[88] C. Carothers, A survey of US halibut IFQ holders: market participation, attitudes, and impacts, Mar. Policy 38 (2013) 515–522, https://doi.org/10.1016/j.marpol.2012.08.007.

[89] G. Knapp, Trends in Alaska Salmon Markets, (2012). ⟨https://www.adfg.alaska.gov/static/fishing/PDFs/commercial/gk_trends_4–12-12.pdf⟩.
[90] C.F.E.C. ADFG, T. Schwoerer, Commercial vessel characteristics by year, state, Alsk. Census Area City (2018) 1978–2017, https://doi.org/10.5063/F14F1P2Q.
[91] M. Schlüter, A. Baeza, G. Dressler, K. Frank, J. Groeneveld, W. Jager, M.A. Janssen, R.R.J. McAllister, B. Müller, K. Orach, N. Schwarz, N. Wijermans, A framework for mapping and comparing behavioural theories in models of social-ecological systems, Ecol. Econ. 131 (2017) 21–35, https://doi.org/10.1016/j.ecolecon.2016.08.008.
[92] S.P. Cox, A.R. Kronlund, Practical stakeholder-driven harvest policies for groundfish fisheries in British Columbia, Canada, Fish. Res. 94 (2008) 224–237, https://doi.org/10.1016/j.fishres.2008.05.006.
[93] B.D. Mapstone, L.R. Little, A.E. Punt, C.R. Davies, A.D.M. Smith, F. Pantus, A. D. McDonald, A.J. Williams, A. Jones, Management strategy evaluation for line fishing in the Great Barrier Reef: balancing conservation and multi-sector fishery objectives, Fish. Res. 3 (2008) 315–329, https://doi.org/10.1016/j.fishres.2008.07.013.
[94] H. Schwermer, F. Barz, Y. Zablotski, A literature review on stakeholder participation in coastal and marine fisheries, YOUMARES 9-The Oceans: Our Research, Our Future. (2020) 21–43. https://library.oapen.org/bitstream/handle/20.500.12657/22870/1007291.pdf?sequence=1#page=37.
[95] D.R. Goethel, S.M. Lucey, A.M. Berger, S.K. Gaichas, M.A. Karp, P.D. Lynch, J. F. Walter III, J.J. Deroba, S. Miller, M.J. Wilberg, Closing the feedback loop: on stakeholder participation in management strategy evaluation, Can. J. Fish. Aquat. Sci. (2018), https://doi.org/10.1139/cjfas-2018-0162.
[96] S. Mäntyniemi, P. Haapasaari, S. Kuikka, R. Parmanne, J. Kaitaranta, Incorporating stakeholders' knowledge to stock assessment: central Baltic herring, Can. J. Fish. Aquat. Sci. 70 (2013) 591–599, https://doi.org/10.1139/cjfas-2012-0316.
[97] M. Herrmann, J. Greenberg, C. Hamel, H. Geier, Extending federal crop insurance programs to commercial fisheries: the case of Bristol Bay, Alaska, Sockeye Salmon, N. Am. J. Fish. Manag. 24 (2004) 352–366, https://doi.org/10.1577/M02-086.1.
[98] A. Remigante, R. Costa, R. Morabito, G. La Spada, A. Marino, S. Dossena, Impact of Scyphozoan Venoms on Human Health and Current First Aid Options for Stings, Toxins 10 (2018), https://doi.org/10.3390/toxins10040133.