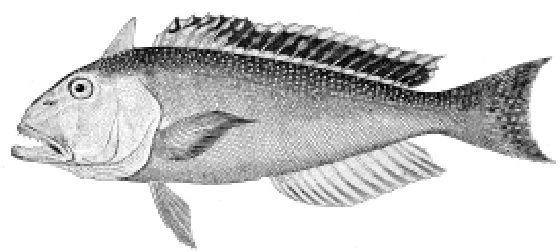
A. Assessment of Golden Tilefish, *Lopholatilus chamaeleonticeps,* in the Middle Atlantic-Southern New England Region



A Report of the
Southern Demersal Working Group
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, MA 02543

Executive Summary

The Southern Demersal Working Group met from 27-28 April, 2009 at the Northeast Fisheries Science Center, Woods Hole, Massachusetts to address the terms of reference agreed by the NRCC for tilefish. The following members were in attendance:

Dan Farnhan	F/V Kimberly
Chris Legault	NEFSC
Richard McBride	NEFSC
Jose´ Montañez	MAFMC
Josh Moser	NEFSC
Paul Nitschke	NEFSC (Assessment Lead)
John Nolan	F/V Seacapture
Laurie Nolan	F/V Seacapture
Michael Palmer	NEFSC
Barbara Rountree	NEFSC
Gary Shepherd	NEFSC
Martin Smith	Duke University (SSC lead, phone)
Katherine Sosebee	NEFSC
Mark Terceiro	NEFSC (Chair)
Tiffany Vidal	NEFSC
Susan Wigley	NEFSC

The current status for this stock is based on the ASPIC surplus production model which was the basis of the stock assessment for the last three assessments. The model is calibrated with CPUE series, as there are no fishery-independent sources of information on trends in population abundance. While the Working Group expressed concern about the lack of fit of the model to the VTR CPUE index at the end of the time series, we agreed to accept the estimates of current fishing mortality and biomass and associated reference points. The instability of model results in the scenario projections was also a source of concern. It was noted that the bootstrap uncertainty estimates do not capture the true uncertainty in the assessment. The ASPIC model indicates that the stock is rebuilt. However, the working group acknowledges that there is high uncertainty on whether the stock is truly rebuilt.

Terms of Reference

1. Characterize the commercial catch including landings, effort and discards. Characterize recreational landings. Evaluate utility of study fleet results as improved measures of CPUE.

Total commercial landings (live weight) increased from less than 125 metric tons (mt) during 1967-1972 to more than 3,900 mt in 1979 and 1980. Annual landings have ranged between 666 and 1,838 mt from 1988 to 1998. Landings from 1999 to 2002 were below 900 mt (ranging from 506 to 874 mt). An annual quota of 905 mt was implemented in November of 2001. Landings in 2003 and 2004 were slightly above the quota at 1,130 mt and 1,215 mt respectively. Landing from 2005 to 2008 have been at or below the quota. Landings in 2007 and 2008 were 751 mt and 736 mt respectively. During the late 1970s and early 1980s Barnegat, NJ was the principal tilefish port;

more recently Montauk, NY has accounted for most of the landings. Most of the commercial landings are taken by the directed longline fishery. Discards in the trawl and longine fishery are a minor component of the catch. Recreational catches have also been low for the last 25 years (i.e., less than 1 mt caught annually).

A fishery independent index of abundance does not exist for tilefish. Three different series of longline effort data were analyzed. The first series was developed by Turner (1986) who used a general linear modeling approach to standardize tilefish effort during 1973-1982 measured in kg per tub (0.9 km of groundline with a hook every 3.7 m) of longline fished obtained from logbooks of tilefish fishermen. Two additional CPUE series were calculated from the NEFSC weighout (1979-1993) and the VTR (1995-2008) systems. The number of vessels targeting tilefish has declined over the time series; during 1994-2003, five vessels accounted for more than 70 percent of the total tilefish landings. The length of a targeted tilefish trip had been generally increasing until the mid 1990s. At the time of the last assessment (2005) trip lengths have shorten to about 5 days. Since then trip length has been increasing.

Six market categories exist in the database. From smallest to largest they are: small, kitten, medium, large and extra large as well as an unclassified category. The proportion of landings in the kittens and small market categories increased in 1995 and 1996. Evidence of two strong recruitment events can be seen tracking through these market categories. At the time of the last tilefish assessment (2005) the proportion of large market category has declined since the early 1980s. However more recently most of the landings come from the large market category as the last strong year class (1999) has grown. Commercial length sampling has been inadequate over most of the time series. However some commercial length sampling occurred in the mid to late 1990s. More recently there has been a substantial increase in the commercial length sampling from 2003 to 2008.

Study fleet analysis is addressed in Appendix A1.

2. Estimate fishing mortality and total stock biomass for the current year, and for previous years if possible, and characterize the uncertainty of those estimates. Incorporate results of new age and growth studies.

As in SARC 41 the 2009 Working Group accepted the formulation that began the analysis in 1973, separated the Turner, weighout and VTR CPUE into three series and fixed the $B1/B_{MSY}$ ratio at 1 as the final run (base run). The working group expressed some concern over whether the CPUE in this fishery is more a reflection of changes in fishing practices and changes in spatial distribution of the fish rather than fluctuations in population size. Commercial length data indicate that increases in total biomass are predominantly due to a strong 1999 year class. It appears that most of the commercial catch over the 2002-2007 period were derived from this year class. Process error in the ASPIC model associated with the recent large year class has increased at the end of the time series due to an assumed constant recruitment/growth parameter.

The Working Group examined results obtained from an alternative forward projecting age/size structured model (SCALE) due to the difficulties with ASPIC model fitting the CPUE index at the end of the time series. An earlier version of this model was call catch-length model in SARC 41. The SCALE model incorporates population growth and length information into the model framework. This allows for the estimation of strong recruitment events which can be seen in the commercial length frequency distributions over time. However the overall lack of data and issues with independence of the data sources is a source of concern with the SCALE model results. The lack of a recruitment index, inability to estimate uncertainty using mcmc, and questions with the estimated flat top selectivity curve are also sources of uncertainty. However SCALE model results suggests that the surplus production model may have overestimated the productivity of the stock.

New age and growth study is addressed in Appendix A2.

3. Update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}). Comment on the scientific adequacy of existing and redefined BRPs.

Biological reference points estimated by the 2009 ASPIC BASE run are moderately different from the 2005 SAW 41 assessment. B_{MSY} is estimated to be 11,400 mt (a 22% increase), F_{MSY} is estimated to be 0.16 (a 24% decrease), and MSY is estimated to be 1,868 mt (a 6% decrease), compared to B_{MSY} = 9,384 mt, F_{MSY} = 0.21, and MSY = 1,988 mt from the 2005 SAW 41 assessment.

SCALE yield per recruit biological reference points suggest that SSB_{MSY} is between 9,878 mt and 15,108 mt for the combine sex run using F_{40} or F_{MAX} as the F_{MSY} proxy. The separate sex run suggests female SSB_{MSY} is between 5,335 mt and 7,100 mt. For both the single sex and separate sex run the F_{MSY} is between 0.079 and 0.128 and MSY ranging from 1,072 mt to 1,200 mt using either F_{40} or F_{MAX} as the F_{MSY} proxy.

4. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).

The biomass-based surplus production model (ASPIC) indicates that the tilefish stock biomass in 2008 has improved since the last assessment in 2005. Total biomass in 2008 is estimated to be 104% of B_{MSY} and fishing mortality in 2008 is estimated to be 38% of F_{MSY}. The tilefish stock is not overfished and overfishing is not occurring. The SARC 48 review panel accepted the ASPIC model but concluded that the ASPIC model is likely over optimistic and that the stock has not rebuilt above B_{MSY}.

SCALE model result suggests a different status determination. The 2009 BASE SCALE model run (separate sex run) and the combined sex run results indicate that the 2009 Golden tilefish stock is at a low biomass (29% to 47% of SSB_{MSY}) and is overfished with respect to the update SSB reference points. Both SCALE runs also suggest recruitment and growth overfishing (147% to 260% of F_{MSY}) is occurring with respect to the F_{40} or F_{MAX} updated biological reference points. However fishing mortality has been decreasing and biomass has been increasing since the beginning of the FMP in 2001.

5. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch).

a. Provide numerical short-term projections (2-3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out

projections, consider a range of assumptions about the most important uncertainties in the assessment (alternate states of nature).

b. If possible, comment on the relative probability of the alternate states of nature and on which projections seem most realistic.

c. For a range of candidate ABCs, compute the probabilities of rebuilding the stock by November 1, 2011.

d. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.

The Working Group examined several ASPIC projections, including the current TAC of 905 mt. The ASPIC model indicates the stock is rebuilt and F in 2008 is low. Therefore the projections suggest the stock will continue to build if catches remain below MSY (1,854 mt). Projection scenarios that incorporated a possible future CPUE index illustrate the concern with the model stability due to the year class effects in the CPUE index. The scenario projections suggest that uncertainty with the stock status determination is much higher than what is suggested from the bootstrap uncertainty distributions and the standard projections.

Several options (age-based AGRPRO, deterministic SCALE projection) are available for 63SCALE model projections depending on whether growth is model as a single sex or with the sexes separated. Continued stock rebuilding is projected in the SCALE model with status quo conditions. Uncertainty estimates were not possible likely due to the overall lack of data in the model. Results of the SCALE model should be considered as a possible alternative state of nature for judging the extent of the overall uncertainty in the assessment when setting an ABC.

6. Review, evaluate and report on the status of the research recommendations offered in recent SARC reviewed assessments. Identify new research recommendations, including recruitment estimation.

Most of the research recommendations were addressed through the new study fleet project and updated growth study. Several new research recommendations were also suggested at the working group meeting, including continuation of the tilefish study fleet program or possibly modifying the study fleet program into an industry based survey that could obtain a recruitment index as part of the sampling design. Research recommendations TOR 6 are summarized on pages 32-33.

Introduction

Golden tilefish, *Lopholatilus chamaeleonticeps*, inhabit the outer continental shelf from Nova Scotia to South America, and are relatively abundant in the Southern New England to Mid-Atlantic region at depths of 80 to 440 m. Tilefish have a narrow temperature preference of 9 to 14 C. Their temperature preference limits their range to a narrow band along the upper slope of the continental shelf where temperatures vary by only a few degrees over the year. They are generally found in and around submarine canyons where they occupy burrows in the sedimentary substrate. Tilefish are relatively slow growing and long-lived, with a maximum observed age of 46 years and a maximum length of 110 cm for females and 39 years and 112 cm for males (Turner 1986). At lengths exceeding 70 cm, the predorsal adipose flap, characteristic of this species, is larger in males and can be used to distinguish the sexes. Tilefish of both sexes are mature at ages between 5 and 7 years (Grimes et. al. 1988).

Golden Tilefish was first assessed at SARC 16 in 1992 (NEFSC 1993). The Stock Assessment Review Committee (SARC) accepted a non-equilibrium surplus production model (ASPIC). The ASPIC model estimated biomass-based fishing mortality (F) in 1992 to be 3-times higher than F_{MSY}, and the 1992 total stock biomass to be about 40% of B_{MSY}. The intrinsic rate of increase (r) was estimated at 0.22.

The Science and Statistical (S&S) Committee reviewed an updated tilefish assessment in 1999. Total biomass in 1998 was estimated to be 2,936 mt, which was 35% of B_{MSY} = 8,448 mt. Fishing mortality was estimated to be 0.45 in 1998, which was about 2-times higher than F_{MSY} = 0.22. The intrinsic rate of increase (r) was estimated to be 0.45. These results were used in the development of the Tilefish Fishery Management Plan (Mid-Atlantic Fishery Management Council 2000). The Mid-Atlantic Fishery Management Council implemented the Tilefish Fishery Management Plan (FMP) in November of 2001. Rebuilding of the tilefish stock to B_{MSY} was based on a ten-year constant harvest quota of 905 mt.

SARC 41 reviewed a benchmark tilefish assessment in 2005. The surplus production model indicated that the tilefish stock biomass in 2005 has improved since the assessment in 1999. Total biomass in 2005 is estimated to be 72% of B_{MSY} and fishing mortality in 2004 is estimated to be 87% of F_{MSY}. Biological reference points did not change greatly from the 1999 assessment. B_{MSY} is estimated to be 9,384 mt and F_{MSY} is estimated to be 0.21. The SARC concluded that the projections are too uncertain to form the basis for evaluating likely biomass recovery schedules relative to B_{MSY}. The TAC and reference points were not changed based on the SARC 41 assessment.

Term of Reference 1: Commercial Fishery

TOR 1: Characterize the commercial catch including landings, effort and discards. Characterize recreational landings. Evaluate utility of study fleet results as improved measures of CPUE.

See Appendix A1 for details on the utility of study fleet results as an improved measures of CPUE.

Data Sources

Commercial catch data

Total commercial landings (live weight) increased from less than 125 mt during 1967-1972 to more than 3,900 mt in 1979 and 1980 (Table A1, Figure A1). Landings stabilized at about 2,000 mt during 1982-1986. An increase in landings occurred in 1987 to 3,200 mt but subsequently declined to 450 mt in 1989. Annual landings have ranged between 454 and 1,838 mt from 1988 to 1998. Landings from 1999 to 2002 were below 900 mt (ranging from 506 to 874 mt). An annual quota of 905 mt was implemented in November of 2001. Landings in 2003 and 2004 were above the quota at 1,130 mt and 1,215 mt respectively. Landing from 2005 to 2008 have been at or below the quota. Landings in 2007 and 2008 were 751 mt ant 736 mt respectively. Over 75% of the landings came from Statistical Areas 537 and 616 since 1991 (Table A2). Since the 1980s, over 85% of the commercial landings of tilefish in the MA-SNE region have been taken in the longline fishery (Table

A3, Figure A2). During the late 1970s and early 1980s Barnegat, NJ was the principal tilefish port; more recently Montauk, NY has accounted for most of the landings. The shift in landings can be seen in the proportion of the landings by state in Table A4 and Figure A3. In the late 1970s and earlier 1980s a greater proportion of the landings were taken in quarters 1 and 2 (Table A5, Figure A4). Recent landings have been relatively constant over the year.

Commercial discard data

Very little discarding (< 1%) of tilefish was reported in the vessel trip report (VTR) from longline vessels that target tilefish and there is little reported discarding of tilefish in the trawl fishery in the VTR data (SARC 41). Recent observer directed tilefish longline trips also suggest that discards of tilefish is minimal. Observer trawl data produce more variable discard estimates across years for tilefish. Discard to kept ratios for trawl trips that either kept or discarded tilefish in the observer data varied from 0 in 1993 to 1.4 in 2001 (Table A6). Twelve of the sixteen years had less than 15 trips sampled that caught tilefish from 1989 to 2003. The number of observer trips that caught tilefish has increase from 2004 to 2008 (average 47). Trawl discards were not expanded to derive total discards due to the relativity minor component of the trawl landings to the total and due to the high uncertainty associated with the hindcast estimates.

Commercial CPUE data

Analyses of catch (landings) and effort data were confined to the longline fishery since directed tilefish effort occurs in this fishery (e.g. the remainder of tilefish landings are taken as bycatch in the trawl fishery). Most longline trips that catch tilefish fall into two categories: (a) trips in which tilefish comprise greater than 90% of the trip catch by weight and (b) trips in which tilefish accounted for less than 10% of the catch. Effort was considered directed for tilefish when at least 75% of the catch from a trip consisted of tilefish (NEFSC 1993).

Three different series of longline effort data were analyzed. The first series was developed by Turner (1986) who used a general linear modeling approach to standardize tilefish effort during 1973-1982 measured in kg per tub (0.9 km of groundline with a hook every 3.7 m) of longline obtained from logbooks of tilefish fishermen. Two additional CPUE series were calculated from the NEFSC weighout (1979-1993) and the VTR (1995-2008) systems as well as a combined 1979-2008 series. Effort from the weighout data was derived by port agents' interviews with vessel captains whereas effort from the VTR systems comes directly from mandatory logbook data. In this assessment and in the 1998 and 2005 tilefish assessments we used Days absent as the best available effort metric. In the 1998 assessment an effort metric based on Days fished (average hours fished per set / 24 * number of sets in trip) was not used because effort data were missing in many of the logbooks and the effort data were collected on a trip basis as opposed to a haul by haul basis. For this assessment effort was calculated as:

Effort = days absent (time & date landed - time & date sailed) - number of trips.

For some trips, the reported days absent were calculated to be a single day. This was considered unlikely, as a directed tilefish trip requires time for a vessel to steam to near the edge of the continental shelf, time for fishing, and return trip time (Grimes et al. 1980). Thus, to produce a realistic effort metric based on days absent, a one day steam time for each trip (or the number of trips) was subtracted from days absents and therefore only trips with days absent greater than one day were used.

The NEFSC Weighout and VTR CPUE series were standardized using a general linear model (GLM) incorporating year and individual vessel effects (Mayo et al. 1994). The CPUE was standardized to an individual longline vessel and the year 1984; the same year used in the last assessment. For the VTR series the year 2000 was used as the standard. Model coefficients were back-transformed to a linear scale after correcting for transformation bias (Granger and Newbold 1977). The full GLM output for the Weighout and the VTR CPUE series is included as Appendix A3.

The number of vessels targeting tilefish has declined over the time series (Table A7, Figure A5); during 1994-2003, five vessels accounted for more than 70 percent of the total tilefish landings (Table A8, Figure A6). The number of vessels targeting tilefish has remained fairly constant since the last assessment in 2005. The length of a targeted tilefish trip had been generally increasing until the mid 1990s. At the time of the last assessment (2005) trip lengths have shorten to about 5 days. Since then trip length has been increasing (Figure A5). In the weighout data the small number of interview is a source of concern; very little interview data exists at the beginning of the time series (Table A7, Figure A7). The 5 dominant tilefish vessels make up almost all of the VTR data with the exception of 2004 when there appears to be more vessels targeting tilefish (Figure A6). In some years there were higher total landings reported in the VTR data than the Dealer data for the 5 dominant tilefish vessels. After the FMP was implemented the IVR (Interactive Voice recorder) database was developed to monitor the quota. In 2005 the IVR database had the highest landings level despite that this system only applies to the limited access tilefish fishery. The IVR 2005 total was assumed to be a better estimate of the total landings in that year then the other data sources. The IVR total landing in 2005 was used as the total removals in all tilefish modeling.

The number of targeted tilefish trips declined in the early 1980s while trip length increased at the time the FMP was being developed in 2000 (Figures A5 and A8). During the last assessment in 2005 the number of trips became relatively stable as trip length decreased. Since the last assessment trip length has increased. The interaction between the number of vessels, the length of a trip and the number of trips can be seen in the total days absent trend in Figure A8. Total days absent remained relatively stable in the early 1980s, but then declined at the end of the weighout series (1979-1994). In the beginning of the VTR series (1994-2004) days absent increased through 1998 but declined to 2005. Since 2005 total days absent has increase somewhat. Figure A8 also shows that a smaller fraction of the total landings were included in the calculation of CPUE compared to the VTR series.

Figure A9 illustrates difference between the nominal CPUE and vessel standardized (GLM) CPUE with the weighout and VTR data combined. CPUE trends are very similar for most vessels that targeted tilefish (Figure A10). A sensitivity test of the GLM using different vessel combinations was done in SARC 41. The SARC 41 GLM was found not to be sensitivity to different vessels entering the CPUE series.

Very little CPUE data exist for New York vessels in the 1979-1994 weighout series despite the shift in landing from New Jersey to New York before the start of the VTR series in 1994. The small amount of overlap between the weighout and VTR series is illustrated in Figures A11 and A12. Splitting the weighout and VTR CPUE series can be justified by the differences in the way effort was measured and difference in the tilefish fleet between the series. In breaking up the series we omitted 1994 because there were very little CPUE data. The sparse 1994 data that existed came mostly from the weighout system in the first quarter of the year. Very similar trends exist in the four years of overlap between Turner (1986) CPUE and the weighout series (Figure A13).

Since 1979, the tilefish industry has changed from using cotton twine to steel cables for the backbone and from J hooks to circle hooks. The gear change to steel cable and snaps started on New

York vessels in 1983. In light of possible changes in catchability associated with these changes in fishing gear, the working group considered that it would be best to use the three available indices separately rather than combined into one or two series. The earliest series (Turner 1986) covered 1973-1982 when gear construction and configuration was thought to be relatively consistent. The Weightout series (1979-1993) overlapped the earlier series for four years and showed similar patterns (Figure A13) and is based primarily on catch rates from New Jersey vessels. The VTR (1995-2004) series is based primarily on information from New York vessels using steel cable and snaps.

In SARC 41 a month vessel interaction was significant but explained only a small amount of the total sum of squares (6%). Adding a month - vessel interaction term to the GLM model had very little influence on the results at SARC 41 and was not updated for this assessment. The GLM output for the Weighout and VTR CPUE series standardized for individual vessel effects can be seen in Appendix A3.

In this assessment the sensitivity of the assumed error structure used in VTR GLM CPUE index was explored. The nominal VTR CPUE data distribution does appear over-dispersed relative to normal or lognormal distribution, suggesting that a model with poisson or negative binomial distribution may be more appropriate (Figure A14). However the GLM CPUE indices using different error assumptions showed very little differences in the CPUE trends (Figure A15). Therefore the lognormal error distribution was retained.

Commercial market category and size composition data

Six market categories exist in the database. From smallest to largest they are: small, kitten, medium, large and extra large as well as an unclassified category. In 1996 and 1997, the reporting of tilefish by market categories increased, with the proportion of unclassified catch declining to less than 20% (Table A9, Figure A16). The proportion of landings in the small and kitten market categories increased in 1995 and 1996. Small and kitten market categories had similar length distributions and samples from 1995 to 1999 were combined. Evidence of several strong recruitment events can be seen tracking through the market category proportions (Figures A16 and A17). At SARC 41 the proportion of the large market category has declined since the early 1980s (Figure A16). Landings data obtained directly from the New York tilefish industry shows a similar decline in the proportion of the large market category between 1980 and 1990 (Figure A18). Landings by market category has shifted from smalls and kittens in 2004 to larges in 2007 and 2008 which is likely the result of a strong year class effect (Figure A17).

Extensive size sampling was conducted in 1976-1982 (Grimes *et al.* 1980, Turner 1986) however that data are not available by market category (Figure A19). Since then commercial length sampling has been inadequate in most years (Table A4). However some commercial length sampling occurred in the mid to late 1990s. More recently there has been a substantial increase in the commercial length sampling in 2003 and 2004. Commercial length sampling in New York has also increased since the last assessment in 2005 (Table A4). Expanded length frequency distributions from 1995 to 1999 from SARC 41 are shown in Figure A20. In this assessment expanded length frequency distributions were estimated form 2002 to 2008 (Figure A21 and A22). The stratification used in the expansion can be seen in table A10. The large market category length frequencies appear to have been relatively stable for years when more than 100 fish were measured. However the small market category exhibits shifts in the size distribution in certain years as strong year classes move through the fishery (Figure A23). The tracking of a year class can be seen as the cohort grows over the year in 2003 and 2004 (Figure A23). The strong 1998/1999 year class seen in the kept length frequency distributions from tilefish longline observer trips matches well with the expanded commercial length frequency distributions (Figures A24). In addition, the 2008 study fleet length distribution looks similar to the 2008 commercial landings distribution (Figure A25).

Smaller fish sizes are seen in the trawl gear length distributions for the small and kitten market category compared to longline gear (Figure A26). Therefore trawl length frequency distribution where not used to characterize the catch (Table A10). Longline tilefish fishermen often receive forecasts from the draggers of when a strong year class will be entering the fishery. There is some anecdotal information from draggers for the existence of a stronger year class in 2009.

Commercial length frequencies were expanded for years where sufficient length data exist (1995-1999 and 2002-2008) (Table AC10). The large length frequency samples from 1996 to 1998 were used to calculate the 1995 to 1999 expanded numbers at length while the large length samples from 2001 and 2003 were used to calculate the 2002 expanded numbers at length. Evidence of strong 1992/1993 and 1998/1999 year classes can be seen in the expanded numbers at length in the years when length data existed (1995-1999 and 2002-2008) (Figure A20). The matching of modes in the length frequency with ages was done using Turner's (1986) and Vidal's (2009) aging studies. In 2004 and 2005 the 1998/1999 year class can be seen growing into the medium market category and in 2006 and 2007 the year class has entered the large market category (Figure A20). From 2002 to 2007 it appears that most of the landings were comprised of this year class. The catch appears to be comprised of multiple year classes in 2008 after catch rates have declined in the VTR series. An increase in the landings and CPUE can be seen when the 1992/1993 and 1998/1999 year classes recruit to the longline fishery. As the year classes gets older the catch rates decline (Figure A13 and A21).

Recreational data

A small recreational fishery occurred briefly in the mid 1970s (< 100 mt annually, Turner 1986) but subsequent recreational catches have been quite low for the last 30 years (i.e., less than 1 mt caught annually) (Table A11). Party and charter boat vessel trip reports also show low numbers of tilefish being caught since 1994 (Table A12).

NEFSC Trawl survey data

Only a few fish per survey are caught during NEFSC bottom trawl surveys. This survey time series is not useful as an index of abundance for tilefish.

Term of Reference 2: Mortality and stock size estimates

TOR2: Estimate fishing mortality and total stock biomass for the current year and for previous years if possible, and characterize the uncertainty of those estimates. Incorporate results of new age and growth studies.

See Appendix A2 for details on the new age and growth study.

ASPIC Surplus production model

The ASPIC surplus production model (Prager 1994; 1995) was used to determine fishing mortality, stock biomass and biological reference points (F_{MSY}, and B_{MSY}) for the development of the tilefish FMP in 2001. SARC 41 in 2005 accepted the ASPIC model as a basis for determining whether the stock was on schedule for rebuilding by 2011.

As a first step in the surplus production modeling, the landings and index data from the 2005

SAW41 assessment were used as input in the latest version (5.33) of the ASPIC software and compared with the results from the 2005 SAW 41 assessment, which was run in ASPIC version 3.93. There were no significant differences in the results due to the ASPIC version update (Table A13). The three commercial fishery CPUE index series (Turner 1973-1982; NEFSC Weighout 1982-1993; and VTR 1995-2004) as configured in the 2005 SAW 41 assessment were retained in constructing the 2009 ASPIC model configurations. The VTR CPUE index of abundance and commercial fishery landings were updated through 2008 to create the 2009 BASE run. A bootstrap with 1000 iterations was used to estimate confidence intervals for annual F and stock biomass estimates and biological reference points. Several sensitivity runs were made to further evaluate the impact on results of the assumption for the B1/K ratio starting condition (equivalent to the B1/B_{MSY} ratio in the 2005 SAW 41 assessment ASPIC v3.93). A retrospective analysis of the BASE run was made to evaluate model performance.

The trends in fishing mortality (F; in the ASPIC model, this is the ratio of annual catch to average annual stock biomass) were very similar in the 2005 SAW 41 and in the 2009 BASE results through 2004. The 2005 SAW 41 F estimates generally followed the 75%ile of the 2009 BASE estimates of F (i.e., were generally somewhat higher), while the 2005 SAW 41 biomass estimates followed the 25%ile of the 2009 BASE estimates of biomass (i.e., were generally somewhat lower; Figures A27 and A28). The early period (Turner 1973-1982) indices fit better (higher r2 value) in the 2009 BASE run than in the 2005 SAW 41 assessment; conversely, the two later series (NEFSC Weighout 1982-1993 and VTR 1995-2008) fit worse (lower r2 values) (Figure A29). Catchability coefficients (q) decreased for all three index series (Turner by 34%; NEFSC Weighout by 22%; VTR by 34%). The biomass reference points (B_{MSY} and K) increased by 22% from the 2005 SAW 41 run to the 2009 BASE run, while FMSY decreased by 22% and MSY decreased by 6%. The 2009 BASE run estimates provide a more optimistic evaluation of stock status in 2004 than did the 2005 SAW 41 model estimates (e.g., the B_{2004}/B_{MSY} ratio; Table A13).

As in the last assessment, sensitivity runs were made to explore the effect of the value of the B1/K ratio on results (B1 is the stock biomass in the first year of the analysis time series; K is the carrying capacity of the stock, equivalent to the biomass when fishing mortality is zero over the long-term). In the 2009 BASE run configuration the B1/K ratio was fixed at 0.50 (equivalent to the B1/B_{MSY} ratio = 1.00 in the 2005 SAW 41 ASPIC v3.93). The BASE results were compared with runs fixing B1/K at 0.10, 1.00, and a run in which B1/K was estimated at 1.19. The run with B1/K fixed at 0.10 provides a value for the Root Mean Squared Error (RMSE) value over 50% higher than the BASE run and negative r2 values for all 3 CPUE index series. The estimates of K (carrying capacity), MSY (Maximum Sustainable Yield), and FMSY (fishing mortality rate providing MSY) for this run are infeasible given the historical pattern and magnitude of fishery landings and the life history characteristics of tilefish (Table A13, dashed lines in Figures A30 and A31).

The runs fixing B1/K = 1.00 and estimating B1/K = 1.19 provided results and diagnostics comparable to the BASE run with B1/K = 0.50. Estimates of F and biomass for 1979 and later years are nearly identical to the BASE run. The major differences are for 1973-1978, when the B1/K = 1.00 and B1/K = 1.19 runs obviously indicate that the stock declined from a high biomass level near K. Estimates of MSY and K for these sensitivity runs are about 10% (B_{MSY}) and 16% (K) lower than the BASE run, while estimates of F_{MSY} are 10-15% higher (Table A13, Figures A30 and A31). The runs fixing/estimating B1/K ratio near 1.00 in 1973 imply that the stock was near carrying capacity in the early 1970s, which is unlikely given the historical pattern and magnitude of fishery landings. The 2005 SAW 41 review concluded that the most likely assumption for the B1/K ratio was 0.50 (equivalent to B1/B_{MSY} = 1.00). That assumption is again supported by the current sensitivity analysis results, and so has been retained for the 2009 BASE run configuration.

A retrospective analysis (sequential removal of the last year of data) was conducted for the 2009 BASE run configuration with ten "peels" (ten years sequentially removed from the end of the analysis). The BASE run results are fairly stable for the 1999, 2002-2008 terminal years, both in terms of time series trends (Figures A32 and A33) and in the estimated catchability coefficients and reference points (left side of Table A14). For the 1998, 2000-2001 terminal years, however, the 2009 BASE run converged at a different solution but with a comparable value of the RMSE. For the 1998, 2000-2001 runs, the estimated catchability coefficients were about 25-50% of the 1999, 2002-2008 runs, and the estimated reference points were infeasible given the historic trend and magnitude of the fishery landings (right side of Table A14). These results indicate that the current 2009 BASE model solution is stable for the last several terminal years, but also indicates that future runs should continue to be examined in a similar manner (multiple retrospectives and sensitivity analyses) to evaluate performance.

The 2009 BASE run indicates that the tilefish stock biomass has continued to increase since the 2005 SAW 41 assessment (Figures A28 and A29). Fishing mortality (F = 0.06) is estimated to be 38% of F_{MSY} and stock biomass in 2008 (B = 11,910 mt) is estimated to be 4% above B_{MSY} (Table A13). Bootstrap (1000 iterations) estimates of the 2008 F were 0.05 (25%ile) to 0.07 (75%ile), with a median of 0.06 (50%ile; Figure A34). Bootstrap estimates of the 2008 stock biomass were 9,550 mt (25%ile) to 13,538 mt (75%ile), with a median of 11,767 mt (50%ile; Figure A35). The complete ASPIC model output with bootstrap results is included as Appendix A3.

Expanded landing length frequency distributions and trends in the VTR CPUE suggest recent strong year class effects in the fishery. The recent strong 1998/1999 year class results in increase process error with the fit to the VTR series in the ASPIC model since the surplus production model assumes constant growth/recruitment (Figure A30). The increase in error is reflected in the comparison of the r^2 from the SARC 41 ASPIC assessment (0.54) with the updated assessment (0.20).

SCALE Model

The working group investigated the use of an age and size structured forward projection model (SCALE) for assessing the tilefish stock due to the inability of the ASPIC surplus production model in fitting the observed year class effects. Incomplete or lack of age-specific catch and survey indices often limits the application of a full age-structured assessment (e.g. Virtual Population Analysis and many forward projecting age-structured models). Stock assessments will often rely on the simpler size/age aggregated models (e.g. surplus production models) when age-specific information is lacking. However the simpler size/age aggregated models may not utilize all of the available information for a stock assessment. Knowledge of a species growth and lifespan, along with total catch data, size composition of the removals, recruitment indices and indices on numbers and size composition of the large fish in a survey can provide insights on population status using a simple model framework.

The Statistical Catch At LEngth (SCALE) model, is a forward projecting age-structured model tuned with total catch (mt), catch at length or proportional catch at length, recruitment at a specified age (usually estimated from first length mode in the survey), survey indices of abundance of the larger/older fish (usually adult fish) and the survey length frequency distributions (NOAA Fisheries Toolbox 2008a). The SCALE model was developed in the AD model builder framework. The model parameter estimates are fishing mortality and recruitment in each year, fishing mortality to produce the initial population (Fstart), logistic selectivity parameters for each year or blocks of years and Qs for each survey index.

The SCALE model was developed as an age-structured model that does NOT rely on age-specific information on a yearly basis. The model is designed to fit length information, abundance indices, and recruitment at age which can be estimated by using survey length slicing. However the model does require an accurate representation of the average overall growth of the population which is input to the model as mean lengths at age. Growth can be modeled as sex-specific growth and natural mortality or growth and natural mortality can be model with the sexes combined. The SCALE model will allow for missing data.

Model Configuration

The SCALE model assumes growth follows the mean input length at age with predetermined input error in length at age. Therefore a growth model or estimates of mean length at age are essential for reliable results. The model assumes static growth and therefore population mean length/weight at age are assumed constant over time. A depiction of model assumed population growth at age using the input mean lengths at age and variation can be seen in Table A15).

The SCALE model estimates logistic parameters for a flattop selectivity curve at length in each time block specified by the user for the calculation of population and catch age-length matrices or the user can input fixed logistic selectivity parameters. Presently the SCALE model can not account for the dome shaped selectivity pattern

The SCALE model computes an initial age-length population matrix in year one of the model as follows. First the estimated populations numbers at age starting with age-1 recruitment get normally distributed at one cm length intervals using the mean length at age with the assumed standard deviation. Next the initial population numbers at age are calculated from the previous age at length abundance using the survival equation. An estimated fishing mortality (Fstart) is also used to produce the initial population. This F can be thought of as the average fishing mortality that occurred before the first year in the model. Now the process repeats itself with the total of the estimated abundance at age getting redistributed according to the mean length at age and standard deviation in the next age (age+1).

This two step process is used to incorporate the effects of length specific selectivities and fishing mortality. The initial population length and age distribution is constructed by assuming population equilibrium with an initial value of F, called F_{start}. Length specific mortality is estimated as a two step process in which the population is first decremented for the length specific effects of mortality as follows:

$$N^*_{a,len,y_1} = N_{a-1,len,y_1} e^{-\left(PR_{len} F_{start} + M\right)}$$

In the second step, the total population of survivors is then redistributed over the lengths at age *a* by assuming that the proportions of numbers at length at age *a* follow a normal distribution with a mean length derived from the input growth curve (mean lengths at age).

$$N_{a,len,y_1} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y_1}$$

where

$$\pi_{len,a} = \Phi\left(len + 1 \mid \mu_a, \sigma_a^2\right) - \Phi\left(len \mid \mu_a, \sigma_a^2\right)$$

where

$$\mu_a = L_\infty\left(1 - e^{-K(a - t_0)}\right)$$

Mean lengths at age can be calculated from a von Bertalanffy model from a prior study as shown in the equation above or mean lengths at age can be calculated directly from an age-length key. Variation in length at age a = σ_s^2 can often be approximated empirically from the growth study used for the estimation of mean lengths at age. If large differences in growth exist between the sexes then growth can be input as sex-specific growth with sex-specific natural mortality. However catch and survey data are still fitted with sexes combined.

This SCALE model formulation does not explicitly track the dynamics of length groups across age because the consequences of differential survival at length at age a do not alter the mean length of fish at age a+1. However, it does more realistically account for the variations in age-specific partial recruitment patterns by incorporating the expected distribution of lengths at age.

In the next step the population numbers at age and length for years after the calculation of the initial population use the previous age and year for the estimate of abundance. Here the calculations are done on a cohort basis. Like in the previous initial population survival equation the partial recruitment is estimated on a length vector.

$$N^*_{a,len,y} = N_{a-1,len,y-1} e^{-\left(PR_{len} F_{y-1} + M\right)}$$

second stage

$$N_{a,len,y} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y}$$

Constant M is assumed along with an estimated length-weight relationship to convert estimated catch in numbers to catch in weight. The standard Baranov's catch equation is used to remove the catch from the population in estimating fishing mortality.

$$C_{y,a,len} = \frac{N_{y,a,len} F_y PR_{len}\left(1 - e^{-\left(F_y PR_{len} + M\right)}\right)}{(F_y \; PR_{len}) + M}$$

Catch is converted to yield by assuming a time invariant average weight at length.

$$Y_{y,a,len} = C_{y,a,len} W_{len}$$

The SCALE model results in the calculation of population and catch age-length matrices for the starting population and then for each year thereafter. The model is programmed to estimate recruitment in year 1 and estimate variation in recruitment relative to recruitment in year 1 for each year thereafter. Estimated recruitment in year one can be thought of as the estimated average long term recruitment in the population since it produces the initial population. The residual sum of squares of the variation in recruitment $\sum(\mathrm{Vrec})^2$ is than used as a component of the total objective function. The weight on the recruitment variation component of the objective function (Vrec) can be used to penalize the model for estimating large changes in recruitment relative to estimated recruitment in year one.

The model requires an age-1 recruitment index for tuning or the user can assume relatively constant recruitment over time by using a high weight on Vrec. Usually there is little overlap in ages at length for fish that are one and/or two years of age in a survey of abundance. The first mode in a survey can generally index age-1 recruitment using length slicing. In addition numbers and the length frequency of the larger fish (adult fish) in a survey where overlap in ages at a particular length occurs can be used for tuning population abundance. The model tunes to the catch and survey length frequency data using a multinomial distribution. The user specifies the minimum size (cm) for the model to fit. Different minimum sizes can be fit for the catch and survey data length frequencies.

The number of parameters estimated is equal to the number of years in estimating F and recruitment plus one for the F to produce the initial population (Fstart), logistic selectivity parameters for each year or blocks of years, and for each survey Q. The total likelihood function to be minimized is made up of likelihood components comprised of fits to the catch, catch length frequencies, the recruitment variation penalty, each recruitment index, each adult index, and adult survey length frequencies:

$$\mathrm{L}_{\mathrm{catch}} = \sum_{years} \left(l\,\mathrm{n}(Y_{\mathrm{obs,y}} + 1) - \ln\left(\sum_{a} \sum_{len} \mathrm{Y}_{\mathrm{pred,len,a,y}} + 1 \right) \right)^2$$

$$L_{catch\_lf} = -N_{eff} \sum_{y} \left(\sum_{inlen}^{L_\infty} \left(\left(C_{y,len} + 1\right) \ln\left(1 + \sum_{a} C_{pred,y,a,len} \right) - \ln\left(C_{y,len} + 1\right) \right) \right)$$

$$\mathrm{L}_{\mathrm{vrec}} = \sum_{y=2}^{Nyears} \left(Vrec_y\right)^2 = \sum_{y=2}^{Nyears} \left(R_1 - R_y\right)^2$$

$$\sum L_{rec} = \sum_{i=1}^{Nrec} \left[\sum_{y}^{Nyears} \left(\ln\left(I_{rec_i, inage_i, y}\right) - \ln\left(\sum_{len}^{L_\infty} N_{y, inage_i, len} * q_{rec\,i} \right) \right)^2 \right]$$

$$\sum L_{adult} = \sum_{i=1}^{Nadult} \left[\sum_{y}^{Nyears} \left(\ln\left(I_{adult_i, inlen+_i, y}\right) - \left(\sum_{a} \sum_{inlen_i}^{L_\infty} \ln\left(N_{pred, y, a, len} * q_{adult\,i}\right) \right) \right)^2 \right]$$

$$\sum L_{lf} = \sum_{i=1}^{Nlf} \left[-N_{eff} \sum_{y} \left(\sum_{inlen_i}^{L_\infty} \left(\left(I_{lf_i, y, len} + 1\right) \ln\left(1 + \sum_{a} N_{pred, y, a, len} \right) - \ln\left(I_{lf_i, y, len} + 1\right) \right) \right) \right]$$

In equation L_{catch_lf} calculations of the sum of length are made from the user input specified catch length to the maximum length for fitting the catch. Input user specified fits are indicated with the prefix "in" in the equations. LF indicates fits to length frequencies. In equation L_{rec} the input specified recruitment age and in L_{adult} and L_{lf} the input survey specified lengths up to the maximum length are used in the calculation.

$$Obj\ fcn = \sum_{i=1}^{N} \lambda_i L_i$$

Lambdas represent the weights to be set by the user for each likelihood component in the total objective function.

Tilefish SCALE Model Configuration and results

Two growth studies are available for Golden tilefish (Figure A36 and A37). Turner's aging study was done during the development of the longline fishery (1978-1982). Vidal updated growth from fish collected recently after three decades of fishing in 2008 (Appendix A2). Inferences on the assumed natural mortality were made using Turner's aging work since landings were relativity low before this period. Tilefish have sexual dimorphic growth with the males growing larger than the females. There is some indication from the study fleet length distributions by sex that a greater proportion of the larger fish are males (Figures A38 and A39). Natural mortality may be higher on male than females judging from the number of older fish seen by sex in Turner's sample (Table A16 and A17). In general Turner saw fewer older males than females during his study. Vidal's study was done after a long period of fishing in which the directed longline fishery was active. Large fish were present in Vidal's sampling but very few older fish (>20) were aged. The lack of older fish in Vidal study made the estimation of L infinity more difficult. The sensitivity of the SCALE model results to the assumed growth model (Turner's and Vidal's) was examined (Table A18). The modeling of growth as a combined sex model or with sex specific growth was also investigated. A natural mortality rate of 0.15 on males and 0.1 on females was assumed in runs when sex specific growth was used. In the combined sex model a natural mortality rate of 0.1 was used. The assumed variation around the mean lengths at age can be seen in Table A15 and Figure A40. The sensitivity of the assumed variation (run 5) around the mean lengths at age was also examined with a run were the variation in the mean lengths at age was increased (Table A18). The length weight relationship was updated using the data collected from the study fleet and growth study (Figure A41). The update relationship was used in the SCALE model. However the update relationship did not differ greatly from Turner's estimate.

A model which used Vidal's growth by sex and estimated selectivity in two time blocks (1971-1981, 1982-2008) was used as the base run (Table A18 and Figure A42 through A46). The SCALE model was dimensioned from ages 1-35, lengths 1-120 cm from years 1971-2008 as either a combined sex or separate sex model. A recruitment index does not exist for tilefish so a straight line index (constant recruitment index) was used as a proxy for an index with the model allowed to loosely fit the recruitment index (Figure A42). A low penalty weight (0.05) on recruitment variation was use in fitting the recruitment. The SCALE model appears to be able to pick up a recruitment signal from the commercial expanded length frequency distributions. The same general recruitment trend is estimated by the model even when yearly selectivity blocks were used. However this model run was not used since large changes in selectivity on a yearly basis seem unrealistic. A proxy for a recruitment index was developed as a sensitivity run (Table A18; run 6). This was done by through the redistribution of the VTR CPUE index according to the proportion of the expanded landing length frequency distribution and then slicing out the 40-50 cm fish as an age 5 index of recruitment (Figure A47). The CPUE indices were fit to fish sizes that were approximate according to the landing length frequency distributions. Turner's CPUE series was fit to 47+ cm fish and the Weighout and VTR series were fit to 37+ cm fish.

The catch length frequency distributions are an important component of the SCALE model. Turner collected landing length frequency information in 1974 and from 1976 to 1982. Note that Turner's length frequency data is only available in 5 cm blocks. NEFSC expanded landing size information exist from 1995 to 1999 and from 2002 to 2008. There appears to be a shift to smaller fish sizes between 1981 and 1982 in Turner's size distributions. Two selectivity blocks were assumed in the SCALE model (1971-1981, 1982-2008). The sensitivity of assuming a single selectivity block (run 3) over the time series was also tested. However in some years this run has trouble fitting the left side of the catch length frequency distribution due to the apparent change in selectivity over the time series.

The SCALE model time series starts in 1971 at the beginning of the tilefish directed longline fishery. However the SCALE model estimates an Fstart close to 0.2. This estimated equilibrium F that is assumed to occur before the beginning the time series appears to be on the high end since there was only a small limited fishery before 1971. A strong retrospective pattern did not exist in the base run (Figure A48). Little differences in the results are seen among the different model configurations (Table A18). There is a general concern with the lack of data and with the data independence used in the SCALE model. The lack of tuning information may result in little difference between the sensitivity runs. The lack of data, in particular the lack of recruitment index, could be preventing the mcmc from producing realistic results so uncertainty estimates around a particular model run could not be estimated. The estimated selectivity curve is also a source of concern given the tilefish longline fleet has some ability to target certain fish sizes by fishing different areas and depths. The SCALE model estimates of F during the late 1990s appear to be unrealistically high (over ten times F_{MSY}), while estimates of biomass in that period were correspondingly unrealistically low.

Term of Reference 3: Biological Reference Points

TOR3: Update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}). Comment on the scientific adequacy of existing and redefined BRPs.

ASPIC Surplus Production Model

Biological reference points estimated by the 2009 BASE run are moderately different from the 2005 SAW 41 assessment (Table A19). B_{MSY} is estimated to be 11,400 mt (a 22% increase), F_{MSY} is estimated to be 0.16 (a 24% decrease), and MSY is estimated to be 1,868 mt (a 6% decrease), compared to B_{MSY} = 9,384 mt, F_{MSY} = 0.21, and MSY = 1,988 mt from the 2005 SAW 41 assessment. The bootstrap (1000 iterations) median estimate (50%ile) of B_{MSY} was 10,135 mt; quartiles were 8,974 mt (25%ile) and 11,436 mt (75%ile). The bootstrap mean estimate of B_{MSY} was 10,336 mt, with a standard deviation (sd) of 2,089 mt and coefficient of variation (cv; sd/mean) of 20%. The bootstrap median (50%ile) estimate of F_{MSY} was 0.19; quartiles were 0.16 (25%ile) and 0.23 (75%ile). The bootstrap mean estimate of F_{MSY} was 0.20, with a standard deviation (sd) of 0.06 and coefficient of variation (cv; sd/mean) of 30%. The bootstrap results indicated that deterministic point estimates of the reference points are likely to be more precise than those accepted for the 2005 SAW 41 assessment, and are negatively biased by about 9% for B_{MSY} and positively biased by about 21% for F_{MSY} (Table A19).

SCALE model

Non-parametric yield per recruit (F_{MAX}) and spawners per recruit (F_{40}) biological reference points (BRP) were developed for SCALE base run 1 (separate sex model, two selectivity blocks) and run 2 (combined sex model, two selectivity blocks) (Table A20). BRPs were estimated both within the SCALE model and by converting the YPR inputs (selectivity, maturity schedule, stock and catch weights) to age based equivalents for use in an age based yield per recruit model (Table A21). The update maturity schedule from Vidal was used in the SPR analysis (Figure A49). MSY and SSB_{MSY} BRPS were estimated from the product of the model estimated initial recruitment (long term average recruitment) and the YPR or SSB per recruit estimates. The conversion to an age based YPR recruit model and an age based projection using AGEPRO is only possible in SCALE runs which modeled growth with the sexes combined (Figure A50). Similar BRPs are seen between the two methods (age based and SCALE). Uncertainty in recruitment can be incorporated into the AGEPRO projection by resampling from the CDF of the recruitment estimates. Reference points can also be estimated from long term projections with the CDF of recruitment and a F_{MSY} proxy. An example for run 2 using the CDF for the entire time series of recruitment and F_{MAX} produced a higher estimate of SSB_{MSY} at 14,000 mt relative to the simple product calculation of around 10,000 mt in Table A20 (Figure A51). The SSB_{MSY} estimate for the separate sex run is based on female fish (run 1). Note that a female estimate of SSB_{MSY} is not possible using the age based YPR model. In addition the age based projections in AGRPRO can not account for the sex specific effects that exist in the separate sex model. However for the separate sex model a simple deterministic projection can be done within the SCALE model.

The estimates of F_{MAX} and F_{40} were similar to the estimates from SARC 41 (F_{MAX} = 0.138 and F_{40}=0.08). F_{MAX} is estimated from a well defined yield curve (Figure A52). The predicted terminal year age and length distributions were slightly truncated in comparison to the equilibrium distribution at F_{MAX} for both run1 and run 2 (Figure A53). Run 2 has a greater proportion of larger fish in the F_{MAX} equilibrium distribution relative to run 1 because run 1 assumes a higher natural mortality rate on males (Figure A52). SCALE YPR BRPs suggest that SSB_{MSY} is between 9,878 mt and 15,108 mt for the combine sex run using F_{40} or F_{MAX} as the F_{MSY} proxy (Table A20). The separate sex run suggests female SSB_{MSY} is between 5,335 mt and 7,100 mt. For both the single sex and separate sex run the F_{MSY} is between 0.079 and 0.128 and MSY ranging from 1,072 mt to 1,200 mt using either F_{40} or F_{MAX} as the F_{MSY} proxy.

Term of Reference 4: Stock Status

TOR4: Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).

ASPIC Surplus Production Model

The 2009 BASE model run results indicate that the Golden tilefish stock is not overfished and that overfishing is not occurring. With respect to the reference points from the 2005 SAW 41 assessment, fishing mortality in 2008 was estimated to be 0.06, 29% of F_{MSY} = 0.21, and total biomass in 2008 was estimated to be 11,910 mt, 127% of B_{MSY} = 9,384 mt. For this TOR note that for the ASPIC surplus production model it may not be appropriate to compare stock status relative to biological reference points from a different model run.

With respect to the updated reference points from the 2009 BASE run, fishing mortality in 2008 was estimated to be 0.06, 38% of F_{MSY} = 0.16. Total biomass in 2008 was estimated to be 11,910 mt, 104% of B_{MSY} = 11,400 mt (Table A13, Figure A54 and A55). The 50% confidence interval (range between the 25%ile and 75%ile) for the 2008 F/F_{MSY} ratio was between 0.25 and 0.42 and for the 2008 B/B_{MSY} ratio was between 0.87 and 1.46. The SARC 48 review panel accepted the ASPIC model but concluded that the ASPIC model is likely over optimistic and that the stock has not rebuilt above B_{MSY}.

SCALE Model

With respect to the existing reference points from the 2005 SAW 41 assessment, SCALE base run 1 fishing mortality in 2008 was estimated to be 0.188, 90% of F_{MSY} = 0.21, and total biomass in 2008 was estimated to be 4,950 mt, 53% of B_{MSY} = 9,384 mt. For this TOR note that this is a comparison of terminal year F (fully selected) and biomass from an age/size structured model relative to biological reference points from the SARC 41 surplus production model. This comparison results in a different status determination (no overfishing and not overfished) than if the update biological reference points were used.

With respect to the updated reference points from the SCALE BASE run (separate sex run), fishing mortality in 2008 was estimated to be 0.188, 147% of F_{MSY} = 0.128 using F_{MAX} as the proxy for F_{MSY}. Total female SSB in 2009 was estimated to be 2,520 mt, 47% of SSB_{MSY} = 5,335 mt using F_{MAX} as the proxy for F_{MSY}. With respect to the updated reference points from the SCALE (run2) combined sex run, fishing mortality in 2008 was estimated to be 0.205, 169% of F_{MSY} = 0.121 using F_{MAX} as the proxy for F_{MSY}. Total SSB in 2009 was estimated to be 4,399 mt, 41% of SSB_{MSY} = 10,794 mt using F_{MAX} as the proxy for F_{MSY}.

The 2009 BASE SCALE model run (separate sex run) and the combined sex run results indicate that the 2009 Golden tilefish stock is at a low biomass (29% to 47% of SSB_{MSY}) and is overfished with respect to the update SSB reference points. Both SCALE runs also suggest recruitment and growth overfishing (147% to 260% of F_{MSY}) is occurring with respect to the F_{40} or

F_{MAX} updated biological reference points. However fishing mortality has been decreasing and biomass has been increasing since the beginning of the FMP in 2001. Comparison of F to F_{MSY} and Biomass to B_{MSY} ratios over time between the ASPIC and SCALE model can be seen in figures A56 and A57.

Term of Reference 5: Projections

TOR 5: Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch).

a. **Provide numerical short-term projections (2-3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (alternate states of nature).**
b. **If possible, comment on the relative probability of the alternate states of nature and on which projections seem most realistic.**
c. **For a range of candidate ABCs, compute the probabilities of rebuilding the stock by November 1, 2011.**
d. **Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.**

ASPIC Surplus Production Model

Standard ASPIC model projections can either project fishery yield (i.e., total catch) for a given trajectory of F or project F for a given trajectory of yield. In neither case are any assumptions made about the future trajectory of the calibration indices - for tilefish, the commercial fishery VTR CPUE index series. For this assessment, two types of projections have been made. The first type is the standard ASPIC projection just described. The second type of projection makes assumptions about the future trajectory and magnitude of the VTR CPUE series in addition to projected F, catch, and biomass, and is intended to further respond to TOR5. The projections with the CPUE assumptions, however, result in changes in the overall model fit, re-scaling of the historical development of the stock, and different reference points. These results are therefore not directly comparable to the 2009 BASE run results, but should be useful in demonstrating how stock status might change in the future given some possible trends in fishery CPUE.

The standard projections were made for 2009-2011 assuming A) constant *status quo* catch = 905 mt, B) constant MSY catch = 1,868 mt, and C) constant F_{MSY} = 0.16. The *status quo* catch = 905 mt (1.995 million lb) has been the TAC since the FMP was implemented in 2001. Status determination was evaluated with respect to the updated reference points from the 2009 BASE run (threshold F_{MSY} = 0.16, target B_{MSY} = 11,400 mt, threshold B_{MSY} = 5,700 mt). Projection results for these three scenarios indicate 15%, 39%, and 45% chances that the stock will decline below the biomass target of B_{MSY} by 2011, and <1% chance that the stock will decline below the biomass threshold of ½ B_{MSY} by 2011. The projections indicate 0%, 40%, and 50% chances that F will exceed the fishing mortality threshold of F_{MSY} by 2011 (Table A22, Figures A58 and A59).

For the projections incorporating the CPUE index, runs were made with constant *status quo* catch = 905 mt, and 2009-2011 index assumptions of A) constant at the 1995-2008 average VTR CPUE = 2.095 (mt/da), B) constant at the 2001-2008 average VTR CPUE = 2.6475 C) increasing an average rate of +25% per year, D) decreasing at an average rate of 25% per year, constant at the 2008 value of 1.434 (mt/da), and F) constant at the 2008 value rounded up to 1.4 (mt/da). Options C and D were specified to loosely mimic the ~25% average annual rate of increase in VTR CPUE during 2000-2005 that was followed by a ~33% decrease during 2005-2008. Status determination was evaluated with respect to the different reference points calculated in each run. For runs A, B and E (different mean levels of CPUE), the estimates of F_{MSY} increase and B_{MSY} and MSY decrease, relative to the 2009 BASE run estimates. These scenarios indicate about a 10% or less chance that biomass will decline below the target biomass B_{MSY} by 2011, and <1% chance that biomass will decline below the biomass threshold ½ B_{MSY} by 2011. For scenario C (increasing CPUE), F_{MSY}, B_{MSY}, and MSY all decrease, but like scenarios A and B, the projection indicates about a 10% chance that biomass will decline below B_{MSY} by 2011, and <1% chance that biomass will decline below ½ B_{MSY} by 2011 (Table A23, Figures A60 and A61). CPUE projection scenario E is *status quo* for both the fishery TAC and CPUE index, and so is considered the most likely in the short-term. Scenario E provides estimates of fishing mortality, stock biomass, and reference points in line with those from scenarios A, B and C. Scenario F is similar to the status quo CPUE of scenario E with the exception that the CPUE was rounded up to1 decimal place (CPUE was 1.4 instead of 1.434). This minor difference resulted in a large change in the results of the ASPIC model (Figure A62).

Projection scenario D (decreasing CPUE) re-scales the stock size and changes the reference points by a larger amount than the other four CPUE projection scenarios, and is particularly relevant to TOR5d. F_{MSY} decreases by about 60%, while B_{MSY} increases by 32% and MSY decreases by about 50%. These changes indicate a stock with lower resilience and productivity when compared to the other scenarios, in that the recent *status quo* TAC = 905 mt is above the estimated MSY. For scenario D, the time series estimates of F and B indicate that the stock has been below B_{MSY} since the late 1980s and F has consistently been above F_{MSY} since about 2000. The scenario D projection indicates a greater than 75% chance that fishing mortality will be above F_{MSY} and biomass will be below the target B_{MSY} by 2011, and a greater then 50% chance that biomass will be below the threshold ½ B_{MSY} by 2011 (Table A23, Figures A58 and A59). This projection scenario illustrates that the stock is vulnerable to being classified as "overfished" (below the threshold ½ B_{MSY}) if the VTR CPUE continues to decrease during 2009-2011 even as the catch remains near the recent *status quo*.

SCALE Model

As noted under TOR 3 age based projections can not be done in AGEPRO for SCALE separate sex model runs (base run 1). However, a deterministic projection can be done within the SCALE model by fixing the parameters in the model at the model solution and projecting into future years. Figure A63 and Figure A64 are examples of deterministic projections from run 1 at $F_{MSY} = F_{MAX} = 0.13$ and $F_{2008} = 0.19$, respectively. Combined sex model runs can be converted to an age based equivalent and projected using the AGEPRO projection program. Some uncertainty in recruitment can be accounted for in AGEPRO through resampling of the CDF of recruitment estimated from the SCALE model. Constant catch projections for run 2 (combined sex run) using agepro are shown in Figure A65. Note that using constant catches over 500 mt allows overfishing ($F_{MSY} = F_{MAX}$) in the first year of the projection.

Conclusions

The possibility of unknown refuge effects due to conflicts with lobster and trawl gear, effects of targeting incoming year classes, and the unknown effects on tilefish CPUE due to competition/interference from increased dogfish abundance introduce uncertainty in interpreting CPUE from this fishery as a measure of stock abundance. CPUE index of abundance and catch length frequency distributions are likely a reflection of both the population abundance and the unaccounted changes in fishing practice.

The Working Group accepted the ASPIC model solution but noted that there is very high uncertainty regarding whether the stock is rebuilt. The SARC 48 review panel concluded that the ASPIC model is likely over optimistic and that the stock has not rebuilt above B_{MSY}. The surplus production model inability to fit the decline in CPUE due to at year class effect at the end of the time series is a source of concern. The bootstrap uncertainty estimates from the ASPIC model likely do not capture the true uncertainty in this assessment. Results from the SCALE model which incorporates the species lifespan, growth, and recruitment dynamics evident in the commercial length distributions provide reason to be concerned that the stock is not rebuilt. However the overall lack of data within the scale model and questions on the estimated selectivity may result in a pessimistic stock status determination. The uncertainty in this assessment is encompassed by the results from two very different models which resulted in different status determinations. However increases in biomass and lower fishing mortality rates since the beginning of the FMP are evident in the results from both models. Consideration should be given to the possibility that the SCALE model results may be a reflection of the true state of nature when setting ABCs rather then using the results of the ASPIC surplus production model which states that the stock is rebuilt.

Term of Reference 6: Research Recommendations

TOR 6: Review, evaluate and report on the status of the research recommendations offered in recent SARC reviewed assessments. Identify new research recommendations, including recruitment estimation.

New research recommendations from 2009 SARC 48

1) Continue the development of an improved haul based fishery dependent cpue index (i.e., continue the current study fleet project) or design a tilefish longline survey as a semi fishery independent index of abundance that could be conducted by an existing longline vessel and the study fleet platform. If a tilefish longline survey is developed then size information should be incorporated into the survey design for the estimation of a recruitment and size specific index of abundance which could improve the tilefish assessment.

2). For the study fleet project and any potential semi fishery independent survey, include additional information on conflicts with lobster and trawl gear, the possibility of unknown effects on tilefish CPUE due to competition/interference from an increased abundance of dogfish, the unknown effects of bait type on tilefish CPUE (e.g., substitutes for the preferred squid).

3). Develop protocols to ensure consistency between dealer, VTR, and IVR reports of the tilefish landings.

4). Develop protocols to ensure consistency in market category designation among fishing ports.

5). Explore the influence of water temperature and other environmental factors on trend in the commercial fishery CPUE index of stock abundance.

Research recommendations from the 2005 SARC 41 review

1) Conduct a hook selectivity study to determine partial recruitment changes with hook size.

Determine catch rates by hook size. Update data on growth, maturity, size structure, and sex ratios at length.
Hook selectivity study was not done. Funding was initially available, but subsequently rescinded. Updated growth, maturity, and size structure studies were completed.
2) Collect data on spatial distribution and population size structure. This can help answer the question of the existence of a possible dome shaped partial recruitment pattern where larger fish are less vulnerable to the fishery due to spatial segregation by size.
This research recommendation was examined in the study fleet data.
3) Continue to develop the forward projecting catch-length model as additional length data becomes available. Investigate the influence of adding a tuning index of abundance and model estimated partial recruitment (logistic) to the catch-length model.
This research recommendation was completed. The improved catch-length model was renamed as the SCALE model.
4) Collect appropriate effort metrics (number and size of hooks, length of main line, soak time, time of day, area fished) on a haul basis to estimate commercial CPUE.
This research recommendation was examined with the study fleet analysis.
5) Initiate a study to examine the effects of density dependence on life history parameters between the 1978-82 period and present.
This research recommendation was examined with the update growth and maturity study.
6) Increased observer coverage in the tilefish fishery to obtain additional length data.
Observer coverage has improved in the tilefish fishery.
7) Develop a bioeconomic model to calculate maximum economic yield per recruit.
This research recommendation has not been initiated.

Research recommendations from 1999 Science and Statistical Committee review
1) Ensure that market category distributions accurately reflect the landings. Sampling of the commercial lengths has improved over the last six years. Small, kitten, and medium market category distributions can shift from one year to the next due to the growth of a strong yearclass. Intensive length sampling of the landings by market categories is needed to account for possible shifts in the distribution within a market category over time. Similar landings distributions were seen among the observer, study fleet, and commercial port sampling data sources.
2) Ensure that length frequency sampling is proportional to landings by market category.
Commercial length sampling has been sporadic during the beginning of the time series. In particular length samples from the large market category have been lacking. However commercial length sampling has greatly improved over the last six years with a higher proportion of the sampling coming from Montauk where most of the fish are landed.
3) Increase and ensure adequate length sampling coverage of the fishery.
See comments for research recommendations 1 and 2.
4) Update age- and length- weight relationships.
This TOR has been addressed.
5) Update the maturity-at-age, weight-at-age, and partial recruitment patterns.
This TOR has been addressed.
6) Develop fork length to total length conversion factors for the estimation of total length to weight relationships.
This work was addressed in SARC 41.
7) Incorporate auxiliary data to estimate r independent of the ASPIC model.
This TOR has not been addressed. SARC 41 questioned if this can be done or should be done.

However SARC 48 SCALE results suggest that r is overestimated in the ASPIC model.

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Tables

Table A1. Landings of tilefish in live metric tons from 1915-2008. Landings in 1915-1972 are from Freeman and Turner (1977), 1973-1989 are from the general canvas data, 1990-1993 are from the weighout system, 1994-2003 are from the dealer reported data, and 2004-2008 is from Dealer electronic reporting. - indicates missing data.

year	mt	year	mt	year	mt
1915	148	1960	1,064	2005	676
1916	4,501	1961	388	2006	907
1917	1,338	1962	291	2007	751
1918	157	1963	121	2008	736
1919	92	1964	596		
1920	5	1965	614		
1921	523	1966	438		
1922	525	1967	50		
1923	623	1968	32		
1924	682	1969	33		
1925	461	1970	61		
1926	904	1971	66		
1927	1,264	1972	122		
1928	1,076	1973	394		
1929	2,096	1974	586		
1930	1,858	1975	710		
1931	1,206	1976	1,010		
1932	961	1977	2,082		
1933	688	1978	3,257		
1934	-	1979	3,968		
1935	1,204	1980	3,889		
1936	-	1981	3,499		
1937	1,101	1982	1,990		
1938	533	1983	1,876		
1939	402	1984	2,009		
1940	269	1985	1,961		
1941	-	1986	1,950		
1942	62	1987	3,210		
1943	8	1988	1,361		
1944	22	1989	454		
1945	40	1990	874		
1946	129	1991	1,189		
1947	191	1992	1,653		
1948	465	1993	1,838		
1949	582	1994	786		
1950	1,089	1995	666		
1951	1,031	1996	1,121		
1952	964	1997	1,802		
1953	1,439	1998	1,334		
1954	1,582	1999	508		
1955	1,629	2000	504		
1956	707	2001	871		
1957	252	2002	843		
1958	672	2003	1,130		
1959	380	2004	1,215		

Table A2. Percent landings by statistical area. Landings before 1990 are taken from the general canvas data. Percent landings after 1993 are estimated from the AA tables.

year	unknown	626	622	616	537	526	525	other
1962	100%	0%	0%	0%	0%	0%	0%	0%
1963	65%	0%	0%	0%	4%	28%	0%	3%
1964	83%	0%	0%	0%	4%	14%	0%	0%
1965	83%	0%	0%	0%	1%	16%	0%	0%
1966	97%	0%	0%	0%	0%	1%	1%	0%
1967	96%	0%	0%	0%	0%	4%	0%	0%
1968	96%	0%	0%	0%	1%	0%	0%	3%
1969	93%	0%	0%	0%	2%	4%	0%	1%
1970	87%	0%	0%	0%	8%	5%	0%	0%
1971	99%	0%	0%	0%	0%	0%	0%	0%
1972	92%	0%	0%	1%	1%	0%	0%	6%
1973	0%	0%	0%	62%	16%	0%	0%	21%
1974	0%	0%	0%	51%	27%	0%	0%	22%
1975	0%	0%	0%	48%	34%	8%	0%	10%
1976	0%	0%	0%	58%	28%	13%	0%	1%
1977	1%	0%	0%	44%	32%	22%	0%	1%
1978	0%	0%	0%	29%	40%	31%	0%	0%
1979	0%	0%	0%	18%	37%	45%	0%	0%
1980	0%	0%	0%	22%	34%	44%	0%	0%
1981	0%	0%	0%	28%	37%	35%	0%	0%
1982	0%	0%	0%	19%	52%	27%	0%	2%
1983	0%	1%	0%	22%	54%	23%	0%	0%
1984	0%	1%	3%	9%	53%	34%	0%	1%
1985	0%	0%	2%	25%	33%	38%	2%	1%
1986	0%	0%	1%	28%	44%	25%	3%	1%
1987	0%	0%	0%	12%	53%	32%	1%	2%
1988	0%	1%	2%	21%	41%	32%	0%	2%
1989	0%	0%	1%	63%	9%	26%	1%	1%
1990	0%	2%	0%	15%	14%	36%	0%	33%
1991	0%	0%	1%	64%	25%	1%	0%	10%
1992	0%	0%	1%	22%	70%	5%	1%	1%
1993	0%	0%	2%	14%	72%	7%	3%	2%
1994	0%	1%	1%	11%	78%	1%	2%	6%
1995	0%	0%	2%	26%	53%	0%	1%	19%
1996	0%	0%	0%	29%	61%	5%	0%	4%
1997	0%	0%	0%	18%	67%	0%	0%	15%
1998	0%	0%	0%	11%	68%	3%	1%	18%
1999	0%	0%	0%	32%	48%	0%	1%	18%
2000	0%	0%	0%	41%	38%	1%	0%	20%
2001	0%	0%	0%	61%	26%	4%	0%	9%
2002	0%	0%	0%	36%	40%	7%	1%	17%
2003	0%	0%	0%	42%	34%	2%	1%	21%
2004	0%	0%	0%	25%	53%	5%	1%	16%
2005	0%	12%	0%	25%	47%	0%	0%	16%
2006	0%	8%	0%	28%	46%	1%	0%	16%
2007	0%	0%	2%	31%	47%	0%	0%	20%

Table A3. Landings of tilefish (mt, live) by gear. Landing before 1990 are from the general canvas data. Percent by gear per year are also given.

	Gear				Percent by Gear		
Year	longli	traw	other	Total	longline	trawl	other
1962		167	2	169	0%	99%	1%
1963		121		121	0%	100%	0%
1964		596		596	0%	100%	0%
1965		614		614	0%	100%	0%
1966		437		437	0%	100%	0%
1967		51		51	0%	100%	0%
1968		30		30	0%	100%	0%
1969		30		30	0%	100%	0%
1970		57	1	58	0%	99%	1%
1971		62	1	62	0%	99%	1%
1972	93	26	2	121	77%	21%	2%
1973	370	24	1	394	94%	6%	0%
1974	531	33	22	586	91%	6%	4%
1975	588	111	11	710	83%	16%	2%
1976	950	58	1	1,010	94%	6%	0%
1977	1,772	309	1	2,082	85%	15%	0%
1978	2,938	309	10	3,257	90%	9%	0%
1979	3,362	449	156	3,968	85%	11%	4%
1980	3,794	94	0	3,889	98%	2%	0%
1981	3,366	128	5	3,499	96%	4%	0%
1982	1,935	49	6	1,990	97%	2%	0%
1983	1,857	8	11	1,876	99%	0%	1%
1984	2,003	6	1	2,009	100%	0%	0%
1985	1,929	31	0	1,961	98%	2%	0%
1986	1,874	76	0	1,950	96%	4%	0%
1987	3,029	180	0	3,210	94%	6%	0%
1988	1,319	42		1,361	97%	3%	0%
1989	421	33	0	454	93%	7%	0%
1990	850	22	0	871	98%	2%	0%
1991	1,164	25	0	1,189	98%	2%	0%
1992	1,497	155	0	1,653	91%	9%	0%
1993	1,597	241	0	1,838	87%	13%	0%
1994	764	22	0	786	97%	3%	0%
1995	618	47	1	666	93%	7%	0%
1996	1,005	111	4	1,121	90%	10%	0%
1997	1,716	79	7	1,802	95%	4%	0%
1998	1,193	134	7	1,334	89%	10%	1%
1999	470	28	10	508	93%	6%	2%
2000	460	38	7	504	91%	7%	1%
2001	819	52	0	871	94%	6%	0%
2002	759	83	1	843	90%	10%	0%
2003	1,004	124	2	1,130	89%	11%	0%
2004	905	211	99	1,215	75%	17%	8%
2005	495	20	161	676	73%	3%	24%
2006	717	32	158	907	79%	3%	17%
2007	711	8	32	751	95%	1%	4%
2008	557	11	167	736	76%	2%	23%

Table A4. Landings of tilefish (mt, live) by state. Number of length measurements are in parentheses. Landings before 1990 are from general canvas data. Percent by state per year are also given.

Year	ME	MA	RI	NY	NJ	other	Total		Percent by State: ME	MA	RI	NY	NJ	other
1962	0	28	31	57	42	12	169		0%	16%	18%	34%	25%	7%
1963	0	42	46	13	14	6	121		0%	35%	38%	10%	12%	5%
1964	0	102	424	37	30	2	596		0%	17%	71%	6%	5%	0%
1965	0	106	478	20	9	2	614		0%	17%	78%	3%	1%	0%
1966	0	13	366	55	3	2	437		0%	3%	84%	13%	1%	0%
1967	0	2	27	8	8	5	51		0%	4%	54%	16%	17%	9%
1968	0	1	23	3	3	0	30		0%	4%	76%	9%	11%	0%
1969	0	2	13	4	10	0	30		0%	7%	44%	15%	35%	0%
1970	0	8	36	3	10	1	58		0%	13%	62%	5%	17%	2%
1971	0	0	21	25	15	1	62		0%	1%	34%	40%	24%	2%
1972	0	2	3	6	111	0	121		0%	1%	2%	5%	92%	0%
1973	0	51	17	3	323	0	394		0%	13%	4%	1%	82%	0%
1974	0	163	21	22	380	0	586		0%	28%	4%	4%	65%	0%
1975	0	174	101	2	434	0	710		0%	24%	14%	0%	61%	0%
1976	0	212	56	23	718	0	1,010		0%	21%	6%	2%	71%	0%
1977	0	84	354	314	1,331	0	2,082		0%	4%	17%	15%	64%	0%
1978	0	95	292	969	1,900	0	3,257		0%	3%	9%	30%	58%	0%
1979	0	22	432	1,365	2,148	0	3,968		0%	1%	11%	34%	54%	0%
1980	0	1	87 (37)	1,451	2,348	2	3,889 (37)		0%	0%	2%	37%	60%	0%
1981	0	6	126	1,284 (25)	2,083	1	3,499		0%	0%	4%	37%	60%	0%
1982	6	5	42 (87)	643	1,288	6	1,990 (87)		0%	0%	2%	32%	65%	0%
1983	0	12	7	844 (158)	1,001	12	1,876		0%	1%	0%	45%	53%	1%
1984	0	1	5	1,094	898 (116)	11	2,009 (116)		0%	0%	0%	54%	45%	1%
1985	2	10	207 (247)	958	777 (163)	6	1,961 (410)		0%	0%	11%	49%	40%	0%
1986	3	1	183 (70)	1,076 (107)	687	1	1,950 (177)		0%	0%	9%	55%	35%	0%
1987	0	7	269 (380)	1,996	924 (203)	13	3,210 (583)		0%	0%	8%	62%	29%	0%
1988	0	33	100 (98)	868	353	6	1,361 (98)		0%	2%	7%	64%	26%	0%
1989	0	1	28	249	174	1	454		0%	0%	6%	55%	38%	0%
1990	7	7	19	606	232	3	874		1%	1%	2%	69%	27%	0%
1991	4	1	19	720	444	1	1,189		0%	0%	2%	61%	37%	0%
1992	8	3	146	963 (36)	530	3	1,653 (36)		0%	0%	9%	58%	32%	0%
1993	59	14	276 (100)	1,003	485	1	1,838 (100)		3%	1%	15%	55%	26%	0%
1994	25	3	51	580	127	0	786		3%	0%	6%	74%	16%	0%
1995	8	1	20	560 (432)	76	1	666 (432)		1%	0%	3%	84%	11%	0%
1996	6 (108)	0	88 (219)	924	98 (328)	5	1,121 (655)		1%	0%	8%	82%	9%	0%
1997	13 (244)	0	54 (422)	1,577 (159)	82 (1,154)	74	1,802 (1,979)		1%	0%	3%	88%	5%	4%
1998	15	4	82 (320)	1,073 (74)	123 (606)	38	1,334 (1,000)		1%	0%	6%	80%	9%	3%
1999	3	2	75 (212)	377	40 (161)	12	508 (373)		1%	0%	15%	74%	8%	2%
2000	7	0	57	423 (143)	14	3	504 (143)		1%	0%	11%	84%	3%	1%
2001	0	0	33 (103)	833 (217)	4	1	871 (320)		0%	0%	4%	96%	0%	0%
2002	4	9	59 (482)	740 (850)	23	8	843 (1,332)		0%	1%	7%	88%	3%	1%
2003	2 (343)	12	104 (168)	848 (1,862)	157 (1,205)	6	1,130 (3,578)		0%	1%	9%	75%	14%	1%
2004	0 (31)	117 (19)	142 (388)	596 (789)	323 (2,159)	37	1,215 (3,386)		0%	10%	12%	49%	27%	3%
2005	0 (9)	3	12 (27)	454 (1,123)	122 (2,307)	85	676 (3,466)		0%	0%	2%	67%	18%	13%
2006	0 (14)	52 (446)	8 (55)	524 (2,176)	226 (3,076)	96	907 (5,767)		0%	6%	1%	58%	25%	11%
2007	1 (6)	0 (5)	7 (133)	632 (5,257)	108 (2,018)	2	751 (7,419)		0%	0%	1%	84%	14%	0%
2008	2	0	32 (607)	544 (3,316)	154 (1,271)	4	736 (5,194)		0%	0%	4%	74%	21%	1%

Table A5. Landings of tilefish (mt, live) by quarter. General canvas data are not included. Percent by quarter per year are also given.

	Quarter								
Year	1	2	3	4	Total	1	2	3	4
1977	1,017	961	93	12	2,082	49%	46%	4%	1%
1978	905	1,128	432	793	3,257	28%	35%	13%	24%
1979	1,351	1,055	538	1,024	3,968	34%	27%	14%	26%
1980	1,524	1,263	505	596	3,889	39%	32%	13%	15%
1981	1,352	1,091	474	581	3,499	39%	31%	14%	17%
1982	1,028	433	239	289	1,990	52%	22%	12%	15%
1983	577	726	289	284	1,876	31%	39%	15%	15%
1984	1,032	491	293	193	2,009	51%	24%	15%	10%
1985	551	632	496	281	1,961	28%	32%	25%	14%
1986	542	597	437	374	1,950	28%	31%	22%	19%
1987	1,048	873	723	565	3,210	33%	27%	23%	18%
1988	737	292	160	172	1,361	54%	21%	12%	13%
1989	147	61	78	167	454	32%	13%	17%	37%
1990	258	240	184	189	871	30%	28%	21%	22%
1991	326	437	182	244	1,189	27%	37%	15%	21%
1992	426	433	401	393	1,653	26%	26%	24%	24%
1993	634	664	267	273	1,838	34%	36%	15%	15%
1994	301	275	72	138	786	38%	35%	9%	18%
1995	214	148	108	195	666	32%	22%	16%	29%
1996	366	215	231	308	1,121	33%	19%	21%	28%
1997	442	571	370	419	1,802	25%	32%	21%	23%
1998	537	361	228	209	1,334	40%	27%	17%	16%
1999	162	135	116	96	508	32%	27%	23%	19%
2000	143	141	76	144	504	28%	28%	15%	29%
2001	190	235	222	223	871	22%	27%	26%	26%
2002	287	197	172	188	843	34%	23%	20%	22%
2003	314	314	242	260	1,130	28%	28%	21%	23%
2004	530	272	187	226	1,215	44%	22%	15%	19%
2005	178	119	170	209	676	26%	18%	25%	31%
2006	281	200	188	238	907	31%	22%	21%	26%
2007	196	175	177	203	751	26%	23%	24%	27%
2008	292	191	116	137	736	40%	26%	16%	19%

Table A6. Observer trawl trips which either kept and/or discarded tilefish in kgs. Discard to kept ratio, the number of trips and observed hauls are also shown.

year	discard kgs	kept kgs	d/k ratio	No. trips	No. hauls
1989	114	131	0.88	8	43
1990	9	85	0.11	4	11
1991	252	449	0.56	19	69
1992	182	856	0.21	22	84
1993	21	4,625	0.00	13	77
1994	14	119	0.11	7	23
1995	20	23	0.90	6	13
1996	57	1,515	0.04	11	53
1997	196	1,082	0.18	13	71
1998	45	522	0.09	11	92
1999	31	153	0.20	14	47
2000	116	112	1.04	8	25
2001	654	456	1.44	10	54
2002	5	58	0.08	3	6
2003	278	1,276	0.22	16	69
2004	420	1,777	0.24	50	205
2005	1,099	1,367	0.80	98	237
2006	439	472	0.93	44	143
2007	84	145	0.58	21	49
2008	275	451	0.61	24	57

Table A7. Total commercial and vessel trip report (VTR) landings in live mt and the commercial catch-per-unit effort (CPUE) data used for tilefish. Dealer landings before 1990 are from the general canvas data. CPUE data from 1979 to the first half of 1994 are from the NEFSC weighout database, while data in the secound half of 1994 to 2004 are from the vtr system (below the dotted line). Effort data are limited to longline trips which targeted tilefish (= or >75% of the landings were tilefish) and where data existed for the days absent. Nominal CPUE series are calculated using landed weight per days absent minus one day steam time per trip. Da represents days absent.

	Weighout		Commerical CPUE data subset								
year	& Dealer landings	vtr landings	interview landings	No. interviews	% interview trips	No. vessels	subset landings	days absent	No. trips	da per trip	nominal cpue
1979	3,968		0.0	0	0.0%	20	1,807	1,187	330	3.6	1.93
1980	3,889		0.8	1	0.3%	18	2,153	1,390	396	3.5	1.99
1981	3,499		35.0	4	1.2%	21	1,971	1,262	333	3.8	1.95
1982	1,990		90.7	13	5.7%	18	1,267	1,282	229	5.6	1.10
1983	1,876		85.8	16	8.9%	21	1,013	1,451	179	8.1	0.73
1984	2,009		140.1	25	18.2%	20	878	1,252	138	9.1	0.72
1985	1,961		297.1	64	30.6%	25	933	1,671	209	8.0	0.59
1986	1,950		120.7	31	16.5%	23	767	1,186	188	6.3	0.71
1987	3,210		198.5	38	18.5%	30	1,014	1,343	206	6.5	0.82
1988	1,361		148.2	30	19.4%	23	422	846	154	5.5	0.56
1989	454		92.8	11	15.7%	11	165	399	70	5.7	0.46
1990	874		32.4	8	11.9%	11	241	556	68	8.2	0.45
1991	1,189		0.8	3	2.8%	7	444	961	107	9.0	0.48
1992	1,653		58.0	9	8.6%	13	587	969	105	9.2	0.62
1993	1,838		71.9	11	10.5%	10	571	959	105	9.1	0.61
1994	-		0	0	0.0%	7	127	385	42	9.2	0.34
1994	786	30				4	26	76	9	8.4	0.36
1995	666	547				5	470	964	100	9.6	0.50
1996	1,121	865				8	822	1,318	134	9.8	0.64
1997	1,810	1,439				6	1,427	1,332	133	10.0	1.09
1998	1,342	1,068				9	1,034	1,517	158	9.6	0.70
1999	525	527				10	516	1,185	133	8.9	0.45
2000	506	446				11	427	942	110	8.6	0.47
2001	874	705				8	691	1,046	116	9.0	0.68
2002	851	724				8	712	951	114	8.3	0.78
2003	1,130	790				7	788	691	101	6.8	1.22
2004	1,215	1,153				12	1,136	811	134	6.1	1.54
2005	676	808				11	802	470	93	5.1	1.95
2006	907	870				12	852	682	105	6.5	1.35
2007	751	710				12	691	727	101	7.2	1.01
2008	736	622				12	620	1,034	113	9.2	0.62

Table A8. Dealer, VTR, and IVR tilefish total landings (live metric tons) compared to the total landings from the five dominant tilefish vessels. Percent of five dominant vessels to the total are also shown.

year	Dealer total (live mt)	Dealer top 5 vessels	Dealer % landing of top 5 vessels to total	VTR total (live mt)	VTR top 5 vessels	VTR % landing of top 5 vessels to total	IVR total (live mt)	IVR top 5 vessels	IVR % landing of top 5 vessels to total
1994	786	485	62%	31	17	57%	-	-	-
1995	666	522	78%	549	538	98%	-	-	-
1996	1,121	803	72%	865	799	92%	-	-	-
1997	1,810	1,292	71%	1,439	1,416	98%	-	-	-
1998	1,342	948	71%	1,068	1,003	94%	-	-	-
1999	508	399	79%	527	486	92%	-	-	-
2000	504	459	91%	446	428	96%	-	-	-
2001	871	817	94%	705	684	97%	-	-	-
2002	843	733	87%	724	687	95%	766	727	95%
2003	1,130	784	69%	790	732	93%	894	779	87%
2004	1,215	561	46%	1,153	688	60%	944	687	73%
2005	676	473	70%	808	596	74%	868	670	77%
2006	907	555	61%	870	569	65%	901	595	66%
2007	751	609	81%	710	601	85%	762	651	85%
2008	736	535	73%	622	466	75%	709	542	76%

Table A9. Landing (metric tons) by market category. Small kitten market category was added to kittens.

year	small	kittens	medium	large	xl	unclassified	total
1990	24	14	103	45	0	687	871
1991	43	16	154	85	0	891	1,189
1992	193	136	88	86	0	1,149	1,653
1993	237	131	206	66	4	1,193	1,838
1994	8	11	89	54	7	617	786
1995	26	73	88	91	2	386	666
1996	169	423	149	156	2	221	1,121
1997	249	878	257	110	2	306	1,802
1998	97	375	699	103	6	54	1,334
1999	37	143	197	106	8	17	508
2000	17	193	153	114	8	19	504
2001	11	553	160	124	6	18	871
2002	26	341	311	128	3	34	843
2003	132	644	170	144	5	34	1,130
2004	169	248	523	129	9	137	1,215
2005	6	12	335	149	1	173	676
2006	8	9	233	369	1	287	907
2007	17	81	148	397	4	105	751
2008	68	99	194	297	18	60	736

Table A10. Number of lengths (1995-2008), samples (2002-2008), and metric tons landed per sample (2002-2008) for Golden tilefish. Number of lengths includes borrowing across years in bold. Trawl lengths were not used in the expansion. Large lengths used from 1995 to 1999 were taken from years 1996, 1997, and 1998. Large lengths in 2002 also used large lengths from 2003. Unclassified were redistributed according to mkt and qtr proportions.

Number of lengths.

year	half	sm	ki	med	lg	xl	total
1995	1		244	208	**332**		
	2						784
1996	1		312	100	**332**		
	2						744
1997	1		958	688	**332**		
	2						1978
1998	1		202	407	**332**		
	2						941
1999	1		211	155	**332**		
	2						698

Number of lengths.

year	half	sm	ki	med	lg	xl	total
2002	1		353	206	**492**		
	2						1051
2003	1	735	385	396	467	32	
	2		522	958			3495
2004	1	788	115	882	432		
	2	106	197	427			2947
2005	1		393	1378	825		
	2			763			3359
2006	1	112	346	1856	1284		
	2	218		1079	752		5647
2007	1	396	379	1128	898	25	
	2	220	1152	1871	1316		7385
2008	1	93	719	1356	1506	20	
	2		369	339			4402

Number of samples

half	sm	ki	med	lg	xl	total
1		6	2	**8**		
2						16
1	5	4	3	7	2	
2		6	5			32
1	4	1	6	7		
2	1	2	4			25
1		6	10	12		
2			8			36
1	3	6	14	11		
2	2		11	8		55
1	4	4	12	12	1	
2	1	5	9	8		56
1	1	9	16	28	3	
2		4	6			67

mt/samples

half	sm	ki	med	lg	xl	total
1		61	156	**19**		
2						54
1	26	98	22	21	3	
2		42	21			34
1	37	209	50	20		
2	23	20	55			43
1		3	19	12		
2			18			14
1	2	1	9	19		
2	2		9	21		11
1	1	6	6	18	4	
2	12	11	8	23		12
1	49	8	7	11	6	
2		12	13			10

Table A11. Recreational Golden tilefish data from the Marine Recreational Fishery Statistics Suvey (MRFSS).

year	number fish measured	landed no. A and B1	Released B2	A and B1 kg
1982	0	984	0	98
1983	0	0	0	0
1984	0	0	0	0
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	0	0	0	0
1989	0	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	0	0
1993	0	0	0	0
1994	0	608	0	0
1995	0	0	0	0
1996	0	10,167	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	0	0	0	0
2001	0	148	0	0
2002	0	20,068	1,338	0
2003	18	722	0	2,126
2004	3	112	0	317
2005	0	0	0	0
2006	0	1,208	0	0
2007	2	1,515	0	6,720
2008	0	0	0	0

Table A12. Number of tilefish reported in the Party/charater vessel trip reports.

year	ME	MD	NH	NJ	NY	NC	RI	VA	other	total
1994	275	0	636	0	0	0	0	0	0	911
1995	0	0	0	0	176	0	541	0	0	717
1996	0	0	0	0	81	0	0	0	0	81
1997	0	0	0	0	380	0	0	0	20	400
1998	0	0	0	0	121	52	102	0	20	295
1999	0	6	0	0	88	34	1	0	0	129
2000	0	0	0	39	108	139	0	0	0	286
2001	0	0	0	100	122	1,164	0	0	0	1,386
2002	0	0	0	383	425	0	0	0	0	808
2003	0	0	0	905	71	0	3	0	15	994
2004	0	0	0	624	12	0	0	254	0	898
2005	0	0	0	364	82	25	72	16	14	573
2006	0	133	0	66	265	30	0	12	2	508
2007	0	5	0	457	447	313	0	138	88	1,448
2008	0	30	0	140	383	60	2	10	22	647

Table A13. ASPIC surplus production model run comparison and sensitivity.

Run ID	2005 SAW 41 ASPIC v3.93	2005 SAW 41 ASPIC v5.33	**2009 SAW 48 ASPIC v5.33 BASE; B1/K = 0.5**	2009 SAW 48 ASPIC v5.33 B1/K = 0.1	2009 SAW 48 ASPIC v5.33 B1/K = 1.0	2009 SAW 48 ASPIC v5.33 EST B1/K = 1.19
Diagnostics						
RMSE	0.3069	0.3069	**0.3496**	0.5362	0.3357	0.3401
turner r2	0.180	0.180	**0.224**	-0.715	0.545	0.593
Weighout r2	0.703	0.703	**0.652**	-0.129	0.680	0.684
vtr r2	0.538	0.538	**0.201**	-0.058	0.230	0.232
Turner q	0.0133	0.0133	**0.0088**	0.0108	0.0076	0.0074
Weighout q	0.2246	0.2246	**0.1754**	0.1046	0.1771	0.1762
VTR q	0.3921	0.3921	**0.2604**	0.1684	0.2622	0.2632
Results						
B1:K ratio	0.50	0.50	**0.50**	0.10	1.00	1.19
MSY (mt)	1,988	1,988	**1,868**	11,220	1,706	1,680
r	0.4236	0.4238	**0.3278**	4.0000	0.3502	0.3514
FMSY	0.2118	0.2119	**0.1639**	2.0000	0.1751	0.1757
K (mt)	18,770	18,766	**22,790**	11,220	19,490	19,130
BMSY (mt)	9,384	9,383	**11,400**	5,608	9,745	9,565
B2004/BMSY	0.65	0.65	**0.78**	1.95	0.86	0.87
F2004/FMSY	0.87	0.87	**0.56**	0.05	0.81	0.81
B2008/BMSY	n/a	n/a	**1.04**	1.97	1.17	1.18
F2008/FMSY	n/a	n/a	**0.38**	0.03	0.35	0.36

Table A14. 2009 BASE run retrospective estimated parameters.

	Turner	Qs Weighout	VTR		Turner	Qs Weighout	VTR
1999	0.0079	0.1584	0.3333	1998	0.0025	0.0478	0.1479
2002	0.0085	0.1721	0.3408	2000	0.0025	0.0480	0.1503
2003	0.0094	0.1983	0.3572	2001	0.0024	0.0438	0.1319
2004	0.0104	0.2254	0.3925				
2005	0.0111	0.2487	0.4427				
2006	0.0192	0.2430	0.4272				
2007	0.0101	0.2134	0.3484				
2008	0.0088	0.1754	0.2604				
Mean	0.0107	0.2043	0.3628	Mean	0.0024	0.0465	0.1434
Max	0.0192	0.2487	0.4427	Max	0.0025	0.0480	0.1503
Min	0.0079	0.1584	0.2604	Min	0.0024	0.0438	0.1319

	MSY	K	RMSE		MSY	K	RMSE
1999	1,780	26,030	0.3022	1998	38	103,900	0.3086
2002	1,831	23,980	0.2915	2000	38	103,700	0.2968
2003	1,916	20,940	0.2990	2001	38	107,100	0.3023
2004	1,990	18,710	0.3073				
2005	2,048	17,230	0.3111				
2006	2,034	17,560	0.3067				
2007	1,963	19,510	0.3173				
2008	1,868	22,790	0.3496				
Mean	1,929	20,844	0.3106	Mean	38	104,900	0.3026
Max	2,048	26,030	0.3496	Max	38	107,100	0.3086
Min	1,780	17,230	0.2915	Min	38	103,700	0.2968

Table A15. Numbers at age and length from SCALE base run 1 which used sex specific growth curves.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
133																																				1
132																																1	1	1	1	1
131																													1	1	1	2	2	2	3	3
130																											1	1	2	2	3	4	5	6	6	7
129																										1	1	3	4	6	8	9	11	12	13	14
128																									1	2	4	6	9	13	16	20	23	25	26	27
127																								1	3	5	9	15	21	27	33	39	43	46	47	48
126																							1	3	7	13	21	31	42	53	63	70	76	79	80	79
125																						1	3	8	16	29	44	62	80	97	110	119	125	126	124	120
124																					1	3	8	19	36	59	87	115	142	163	179	187	190	187	180	171
123																					2	7	19	41	73	114	157	198	232	256	270	274	269	258	243	225
122																				1	6	18	43	84	140	203	264	315	352	373	378	371	354	330	303	275
121																			1	4	14	40	89	161	248	336	412	467	497	505	493	467	432	393	352	312
120																			2	10	33	86	172	286	408	517	597	642	652	634	596	546	490	434	379	329
119																		1	5	24	73	169	309	471	624	739	804	819	793	740	669	593	516	445	380	322
118																		2	14	54	149	309	514	721	885	981	1006	971	897	801	698	598	505	424	353	293
117																	1	6	33	114	280	524	794	1024	1167	1210	1168	1070	942	806	677	560	459	375	305	248
116																	2	16	74	225	491	826	1140	1352	1429	1385	1260	1094	919	754	609	487	388	308	244	195
115																	6	38	155	413	799	1210	1519	1656	1624	1473	1263	1039	832	654	509	393	304	235	182	142
114																1	15	86	300	701	1207	1645	1881	1885	1715	1455	1175	917	700	528	395	296	222	167	126	97
113																4	36	180	540	1107	1693	2078	2162	1993	1682	1335	1015	752	547	396	286	207	151	111	83	62
112															1	10	83	349	904	1623	2207	2437	2308	1956	1533	1138	816	573	399	277	194	137	98	71	53	40
111															2	27	176	628	1405	2211	2670	2654	2289	1784	1298	902	611	409	274	185	127	90	65	49	38	30
110															5	64	348	1051	2028	2795	3001	2686	2109	1513	1023	669	431	279	184	126	90	68	55	46	40	36
109														1	15	140	637	1633	2718	3283	3134	2525	1807	1196	757	472	297	195	137	104	86	76	70	66	63	60
108														2	37	288	1086	2356	3383	3581	3040	2208	1446	891	539	335	224	167	139	127	122	120	119	117	115	111
107														5	86	549	1718	3158	3911	3630	2744	1804	1092	646	399	276	223	205	203	206	211	214	215	212	208	201
106														15	188	971	2523	3931	4201	3423	2312	1393	808	498	359	313	310	326	344	360	371	375	373	367	356	342
105													1	37	380	1594	3443	4546	4196	3010	1839	1053	643	478	442	465	508	551	585	608	618	618	608	591	568	541
104													4	89	714	2432	4364	4886	3904	2490	1423	853	638	615	675	760	840	903	943	963	964	949	921	885	842	795
103													10	196	1246	3446	5139	4887	3404	1984	1157	846	828	939	1084	1217	1321	1388	1419	1421	1397	1354	1297	1231	1160	1085
102													27	400	2018	4537	5626	4564	2823	1612	1115	1076	1246	1472	1680	1839	1941	1987	1986	1947	1881	1795	1697	1592	1484	1376
101												1	66	760	3036	5549	5737	4014	2315	1481	1354	1578	1907	2215	2448	2592	2653	2644	2581	2479	2352	2210	2061	1911	1763	1620
100												4	151	1339	4244	6312	5471	3398	2026	1671	1914	2360	2795	3125	3322	3396	3370	3269	3116	2932	2732	2527	2325	2130	1945	1772
99												12	322	2194	5513	6689	4933	2904	2078	2234	2795	3387	3841	4105	4191	4134	3975	3752	3493	3220	2947	2684	2436	2205	1993	1799
98												33	635	3339	6659	6634	4306	2712	2551	3172	3947	4562	4914	5013	4911	4673	4356	4000	3637	3284	2953	2647	2370	2120	1897	1697
97												80	1165	4720	7492	6220	3819	2958	3466	4424	5248	5724	5845	5687	5345	4907	4432	3961	3517	3111	2747	2425	2141	1893	1676	1487
96											2	183	1985	6205	7881	5635	3691	3711	4764	5848	6508	6678	6458	5991	5403	4785	4188	3642	3158	2737	2373	2063	1797	1570	1376	1209
95											5	388	3141	7593	7813	5138	4081	4946	6296	7229	7507	7237	6626	5861	5073	4333	3676	3110	2634	2236	1905	1629	1400	1209	1049	914
94											16	763	4621	8671	7418	4998	5048	6527	7827	8320	8045	7284	6315	5326	4423	3644	2996	2467	2040	1696	1419	1195	1013	865	742	641
93											43	1394	6323	9289	6953	5416	6518	8214	9079	8899	8008	6810	5589	4494	3581	2846	2268	1817	1468	1195	982	815	681	574	488	418
92											109	2368	8059	9429	6727	6465	8284	9699	9796	8843	7404	5912	4594	3522	2693	2064	1594	1243	980	782	631	515	425	354	298	253
91										1	253	3738	9596	9242	7014	8051	10028	10678	9822	8161	6357	4767	3507	2564	1881	1391	1041	790	608	475	377	303	247	203	169	142
90										3	544	5491	10733	9014	7952	9915	11392	10933	9148	6995	5069	3569	2486	1733	1220	870	631	466	350	268	209	165	133	108	89	74
89										11	1082	7514	11385	9078	9488	11680	12068	10402	7913	5568	3754	2482	1637	1088	735	506	355	255	188	141	108	84	66	53	44	36
88										33	1985	9603	11647	9698	11361	12947	11892	9193	6357	4117	2582	1603	1001	634	411	273	186	130	93	68	51	39	31	24	20	16
87										90	3368	11512	11771	10951	13163	13403	10890	7546	4743	2826	1649	962	568	343	213	137	90	61	43	31	23	17	13	10	8	7
86										226	5284	13043	12089	12674	14446	12915	9264	5752	3286	1802	978	536	300	173	103	64	41	27	18	13	9	7	5	4	3	3
85									1	517	7681	14133	12865	14493	14860	11570	7320	4072	2115	1067	539	277	147	81	46	27	17	11	7	5	4	3	2	2	1	1
84									4	1085	10372	14896	14171	15927	14255	9629	5371	2678	1264	587	276	133	67	35	19	11	7	4	3	2	1	1	1	1		
83									12	2091	13072	15584	15816	16543	12723	7444	3661	1635	701	300	131	59	28	14	7	4	2	1	1	1						
82									38	3701	15487	16463	17393	16096	10555	5345	2317	927	362	142	58	25	11	5	3	1	1									
81									109	6029	17445	17667	18405	14606	8135	3564	1362	488	173	63	24	9	4	2	1											
80									282	9052	18971	19091	18449	12333	5824	2207	743	239	77	26	9	3	1	1												
79									667	12578	20267	20391	17358	9681	3872	1270	377	108	32	10	3	1														
78								1	1438	16265	21572	21106	15251	7060	2391	678	177	46	12	3	1															
77								6	2825	19741	22980	20833	12480	4783	1371	336	78	18	4	1																
76								20	5070	22756	24316	19399	9498	3010	730	155	32	7	1																	
75								64	8330	25261	25158	16927	6718	1759	361	66	12	2																		
74								185	12575	27359	25019	13786	4415	955	166	26	4	1																		
73								486	17532	29128	23574	10456	2695	481	71	10	1																			
72								1153	22741	30440	20834	7376	1528	225	28	3																				
71							1	2477	27702	30924	17158	4837	804	98	10	1																				
70							3	4823	32028	30123	13115	2947	393	40	4																					
69							13	8539	35480	27758	9284	1668	179	15	1																					
68							46	13795	37870	23938	6077	877	75	5																						
67							147	20432	38922	19173	3676	428	30	2																						
66							424	27919	38273	14191	2054	194	11	1																						
65							1095	35442	35651	9676	1059	82	4																							
64							2543	42090	31132	6066	505	32	1																							
63							5311	47014	25255	3493	222	12																								
62						2	10002	49512	18901	1846	90	4																								
61						9	17044	49091	12987	895	34	1																								
60						38	26380	45611	8166	398	12																									
59						137	37237	39447	4688	162	4																									
58						432	48130	31530	2454	61	1																									
57						1214	57154	23143	1171	21																										
56						3029	62478	15518	508	7																										
55						6727	62885	9468	201	2																										
54						13320	58182	5241	72																											
53					1	23561	49332	2627	24																											
52					8	37305	38180	1191	7																											
51					35	52960	26861	488	2																											
50					141	67512	17112	180																												
49					491	77349	9838	60																												
48					1499	79669	5090	18																												
47					4007	73743	2365	5																												
46					9384	61278	985	1																												
45					19267	45645	368																													
44					34698	30423	123																													
43				1	54838	18109	37																													
42				4	76089	9608	10																													
41				20	92708	4536	2																													
40				101	99199	1903																														
39				422	93213	708																														
38				1506	76902	233																														
37				4574	55687	68																														
36				11830	35378	18																														
35				26053	19708	4																														
34				48859	9621	1																														
33				78035	4114																															
32				106141	1540																															
31				122953	504																															
30				121298	144																															
29			2	101911	36																															
28			23	72918	8																															
27			184	44429	2																															
26			1125	23051																																
25			5222	10183																																
24			18426	3830																																
23			49423	1226																																
22			100782	334																																
21			156238	78																																
20			184138	15																																
19			164986	3																																
18			112384																																	
17			58199																																	
16			22912																																	
15	1	6858																																	
14	18	1560																																	
13	306	270																																	
12	3239	35																																	
11	20808	4																																	
10	81232																																		
9	192696																																		
8	277760																																		
7	243288																																		
6	129488																																		
5	41878																																		
4	8230																																		
3	983																																		
2	71																																		
1	3																																		

Table A16. Empirical mean lengths at age and sample size from Turner et. al. (1983).

	Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
female	empirical mean length	-	-	38	47	52	58	64	65	66	68		90	-	-	84	77	-	84	82	-	-	-	-	-	-	-	-	-	92	89	91	89	95	-	88
	n	-	-	14	47	61	40	65	52	11	1		1	-	-	1	1	-	1	1	-	-	-	-	-	-	-	-	-	1	1	1	3	1	-	2
male	empirical mean length	-	-	40	50	53	60	71	74	79	86	89	93	-	-	99	102	104	-	96	109	-	108	-	-	108	96	-	-	-	-	-	-	-	-	-
	n	-	-	4	51	55	17	44	41	23	5	1	1	-	-	5	1	1	-	2	2	-	1	-	-	1	1	-	-	-	-	-	-	-	-	-

Table A17. Oldest fish aged from Turner's PHD dissertation (1986) and Vidal's MS (2009).

Dissertation 1986 S Turner		Number of females younger than 31	Number of females older than 31
oldest male: 39	1978	234	7
oldest female: 46	1979	87	4
	1980	177	3
	1982	194	21

		Number of males younger than 31	Number of males older than 31
	1978	216	0
	1979	148	1
	1980	91	0
	1982	187	1

T. Vidal (2008)
oldest male: 23
oldest female: 21

Table A18. Six SCALE sensitivity runs. Natural mortality was assumed to be 0.1 in combined sex runs and for females in the separate sex runs. The assumed natural mortality rate for males was 0.15 in the separate sex runs. TV = T. Vidal, ST = S. Turner, vb = von Bertalanffy, sel bl = selectivity blocks, var = variation, resid = residuals, par = parameters.

Run	1 (Base run)			2			3			4			5			6		
Description	(TV vb, 2 sex, 2 Sel bl)			(TV vb, 1 sex, 2 Sel bl)			(TV vb, 2 sex, 1 Sel bl)			(ST vb, 2 sex, 2 Sel bl)			(Base + high mean len@age var)			(Base + rec index)		
	weight	qs	resid or par	weight	qs	resid or par	weight	qs	resid or par	weight	qs	resid or par	weight	qs	resid or par	weight	qs	resid or par
Total Objective function			68.23			70.96			76.70			68.34			69.77			63.27
total catch	4		0.23	4		0.23	4		0.23	4		0.25	4		0.24	4		0.15
catch len freq 1+	400		45.31	400		48.21	400		52.36	400		45.22	400		46.84	400		44.05
Variation in recruit penalty (Vrec	0.05		7.79	0.05		8.75	0.05		5.92	0.05		8.41	0.05		8.29	0.05		12.58
Age 5	1	3.0E-06	6.01	1	3.3E-06	5.72	1	3.1E-06	5.92	1	3.0E-06	6.67	1	3.0E-06	6.36	1	4.1E-06	2.31
Turner 47+ (1973-1982)	2	4.1E-07	0.21	2	4.5E-07	0.24	2	3.8E-07	0.26	2	3.5E-07	0.18	2	4.2E-07	0.21	2	4.1E-07	0.31
Weighout 37+ (1979-1993)	2	8.9E-07	0.22	2	9.7E-07	0.22	2	9.3E-07	0.23	2	8.2E-07	0.24	2	9.2E-07	0.22	2	8.8E-07	0.28
VTR 37+ (1995-2008)	4	1.7E-06	0.79	4	1.8E-06	0.72	4	1.7E-06	0.79	4	1.6E-06	0.68	4	1.7E-06	0.72	4	1.8E-06	0.88
survey/catch len freq 65+	100		11.56	100		11.83	100		13.03	100		11.46	100		11.44	100		11.00
Fstart			0.20			0.26			0.13			0.10			0.20			0.18
Recruitment year 1 (1971, 000s)			783			624			946			787			765			721
Selectivity Alpha (L50) 71-81			53.97			53.74			41.80			53.70			53.94			54.27
Selectivity Beta (slope) 71-81			0.35			0.35			0.69			0.35			0.36			0.33
Selectivity Alpha (L50) 82-08			41.38			41.49			-			41.35			41.11			41.40
Selectivity Beta (slope) 82-08			0.81			0.80			-			0.58			0.75			0.81
2008 F			0.19			0.20			0.20			0.18			0.19			0.21
2008 Biomass (000s mt)			4950			4518			4784			5200			4867			4422

Table A19. Biological reference point estimates from the 2000 SSC committee review, 2005 SARC 41 assessment, and the 2009 BASE run.

	SSC 2000 1999	SARC 41 2004	SARC 48 2008
BMSY			
Point	8,448	9,384	11,400
Boot mean	-	9,764	10,336
Boot sd	-	5,152	2,089
Boot median	-	9,193	10,135
Boot 25%ile	-	8,379	8,974
Boot 75%ile	-	10,263	11,436
Boot bias	-	4%	-9%
FMSY			
Point	0.22	0.21	0.16
Boot mean	-	0.24	0.2
Boot sd	-	0.21	0.06
Boot median	-	0.22	0.19
Boot 25%ile	-	0.19	0.16
Boot 75%ile	-	0.25	0.23
Boot bias	-	15%	21%
MSY	1,858	1,988	1,868
r	0.45	0.42	0.33
Turner Q	0.009	0.010	0.009
Weighout	0.222	0.225	0.175
VTR Q	-	0.392	0.260

Table A20. Stock status and biological reference points using F40% and Fmax from both the SCALE model and the age based YPR model. A female only BRP can not be done with run 1 using the age based YPR model.

SCALE run	1 Base		2			
Description	(Vidal growth, 2 sex, 2 Sel block)		(Vidal growth, 1 sex, 2 Sel block)			
YPR model	SCALE	SCALE	AGE based	AGE based	SCALE	SCALE
F_{MSY} proxy	$F_{40\%}$	Fmax	$F_{40\%}$	Fmax	$F_{40\%}$	Fmax
F_{MSY}	0.085	0.128	0.079	0.121	0.082	0.121
YPR	1.37	1.45	1.83	1.92	1.85	1.92
SSB per Recruit	9.07	6.82	23.20	15.83	24.22	17.30
Initial Recruits (000s)	783	783	624	624	624	624
MSY (mt)	1,072	1,137	1,142	1,200	1,153	1,200
SSB_{MSY} (mt)	7,100	5,335	14,473	9,878	15,108	10,794
SSB_{09} (mt)	2,520	2,520	4,399	4,399	4,399	4,399
F_{08}	0.188	0.188	0.205	0.205	0.205	0.205
SSB_{09}/SSB_{MSY}	35%	47%	30%	45%	29%	41%
F_{08}/F_{MSY}	221%	147%	260%	170%	250%	169%

Table A21. Converted input (selectivity, maturity from Vidal, population and catch mean weights) to the age based YPR model from the SCALE run 2. Terminal year + 1 stock size at age is also shown.

age	Stock Size on 1 Jan 2009	Selectivity	Proportion Mature	Mean Weights Spawning Stock	Mean Weights Catch
1	623,830	0.000	0.000	0.002	0.003
2	564,465	0.000	0.000	0.053	0.085
3	510,749	0.001	0.005	0.253	0.417
4	442,060	0.376	0.129	0.662	0.783
5	425,544	0.978	0.672	1.295	1.303
6	421,569	1.000	0.956	2.130	2.130
7	169,889	1.000	0.995	3.131	3.131
8	102,072	1.000	0.999	4.251	4.251
9	100,136	1.000	1.000	5.446	5.446
10	138,090	1.000	1.000	6.675	6.675
11	71,028	1.000	1.000	7.904	7.904
12	6,162	1.000	1.000	9.100	9.100
13	2,870	1.000	1.000	10.249	10.249
14	1,144	1.000	1.000	11.336	11.336
15	267	1.000	1.000	12.354	12.354
16	190	1.000	1.000	13.296	13.296
17	43	1.000	1.000	14.161	14.161
18	7	1.000	1.000	14.951	14.951
19	2	1.000	1.000	15.668	15.668
20	1	1.000	1.000	16.314	16.314
21	1	1.000	1.000	16.896	16.896
22	0	1.000	1.000	17.417	17.417
23	0	1.000	1.000	17.881	17.881
24	0	1.000	1.000	18.295	18.295
25	0	1.000	1.000	18.663	18.663
26	0	1.000	1.000	18.988	18.988
27	0	1.000	1.000	19.277	19.277
28	0	1.000	1.000	19.532	19.532
29	0	1.000	1.000	19.757	19.757
30	0	1.000	1.000	19.955	19.955
31	0	1.000	1.000	20.130	20.130
32	0	1.000	1.000	20.284	20.284
33	0	1.000	1.000	20.418	20.418
34	0	1.000	1.000	20.537	20.537
35	0	1.000	1.000	20.642	20.642

Table A22. Projection results using the standard ASPIC projection model (conditioned on yield or F).
Catch and biomass in metric tons (mt).

A) C = 2008 TAC = 905 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.07	0.06	0.08	0%	13,030	10,480	14,210	35%	<1%
2010	905	0.06	0.06	0.08	0%	13,930	11,420	14,720	25%	0%
2011	905	0.06	0.06	0.07	0%	14,760	12,200	15,260	15%	0%

B) C = MSY = 1,868 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	1,868	0.14	0.13	0.18	36%	13,030	10,480	14,210	35%	<1%
2010	1,868	0.14	0.14	0.18	38%	12,990	10,480	13,810	37%	<1%
2011	1,868	0.14	0.14	0.18	40%	12,950	10,470	13,590	39%	<1%

C) F = FMSY = 0.16

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	2,112	0.16	0.15	0.21	50%	13,030	10,480	14,210	35%	<1%
2010	2,071	0.16	0.15	0.21	50%	12,750	10,230	13,660	39%	<1%
2011	2,038	0.16	0.15	0.21	50%	12,530	9,995	13,290	45%	<1%

Table A23. Projection results incorporating assumptions about future values of the VTR CPUE index of abundance. Catch in metric tons and biomass in 000s metric tons. Scenario F was CPUE was rounded to one decimal place.

A) CPUE = 1995-2008 FMSY = 0.165 BMSY = 9,853 mt MSY = 1,627 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.070	0.065	0.079	0%	12,836	11,259	13,844	16%	<1%
2010	905	0.069	0.064	0.077	0%	13,082	11,595	14,134	13%	<1%
2011	905	0.067	0.062	0.075	0%	13,322	11,896	14,349	10%	0%

B) CPUE = 2001-2008 FMSY = 0.168 BMSY = 9,759 mt MSY = 1,643 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.071	0.066	0.082	0%	12,496	10,768	13,502	17%	<1%
2010	905	0.069	0.065	0.077	0%	12,874	11,412	13,843	13%	<1%
2011	905	0.068	0.063	0.075	0%	13,210	11,913	14,142	9%	0%

C) CPUE = +25% FMSY = 0.158 BMSY = 10,070 mt MSY = 1,590 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.071	0.065	0.082	0%	12,598	10,751	13,820	20%	0%
2010	905	0.069	0.064	0.078	0%	12,936	11,348	14,087	15%	0%
2011	905	0.067	0.063	0.075	0%	13,255	11,780	14,342	12%	0%

D) CPUE = -25% FMSY = 0.060 BMSY = 15,000 mt MSY = 897 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.139	0.084	0.213	84%	6,620	4,357	10,981	84%	57%
2010	905	0.143	0.085	0.223	85%	6,440	4,157	10,741	84%	59%
2011	905	0.148	0.087	0.238	86%	6,211	3,924	10,523	85%	60%

E) CPUE = 2008 FMSY = 0.197 BMSY = 8,989 mt MSY = 1,774 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.069	0.064	0.075	0%	12,980	12,022	14,038	<1%	6%
2010	905	0.068	0.063	0.074	0%	13,081	12,074	14,233	<1%	0%
2011	905	0.068	0.063	0.074	0%	13,174	12,124	14,398	<1%	0%

F) CPUE = 2008 round FMSY = 0.104 BMSY = 12,060 mt MSY = 1,254 mt

Year	C (mt)	F	F25%ile	F75%ile	P > FMSY	B (mt)	B25%ile	B75%ile	P < BMSY	P < 1/2 BMSY
2009	905	0.088	0.066	0.130	38%	10,125	6,789	13,436	64%	18%
2010	905	0.084	0.065	0.125	36%	10,505	7,115	13,840	63%	15%
2011	905	0.083	0.063	0.119	34%	10,844	7,454	14,156	61%	12%

Figures

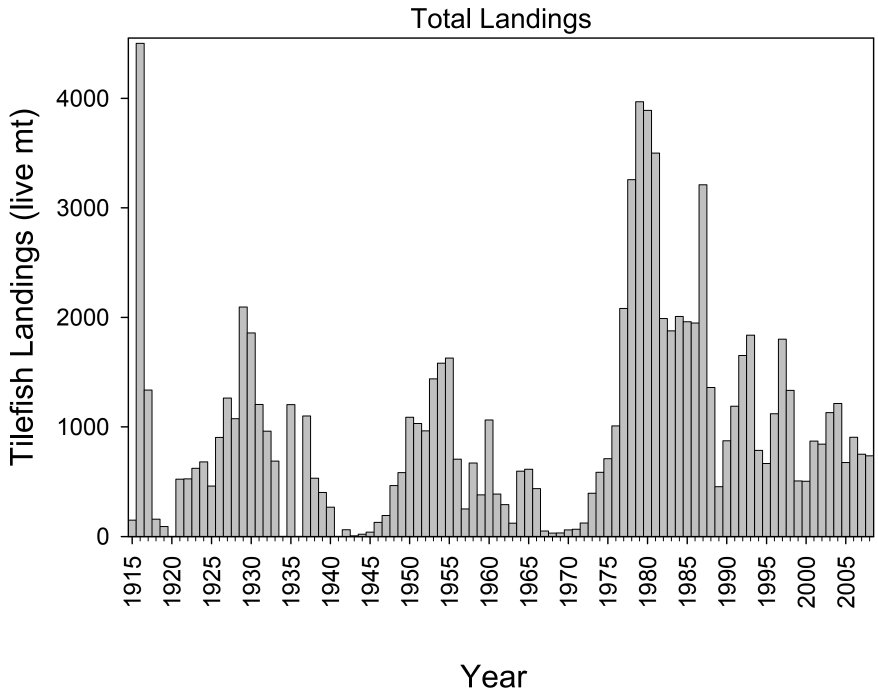


Figure A1. Landings of tilefish in metric tons from 1915-2004. Landings in 1915-1972 are from Freeman and Turner (1977), 1973-1989 are from the general canvas data, 1990-1993 are from the weighout system, 1994-2003 are from the dealer reported data, and 2004-2008 is from dealer electronic reporting.

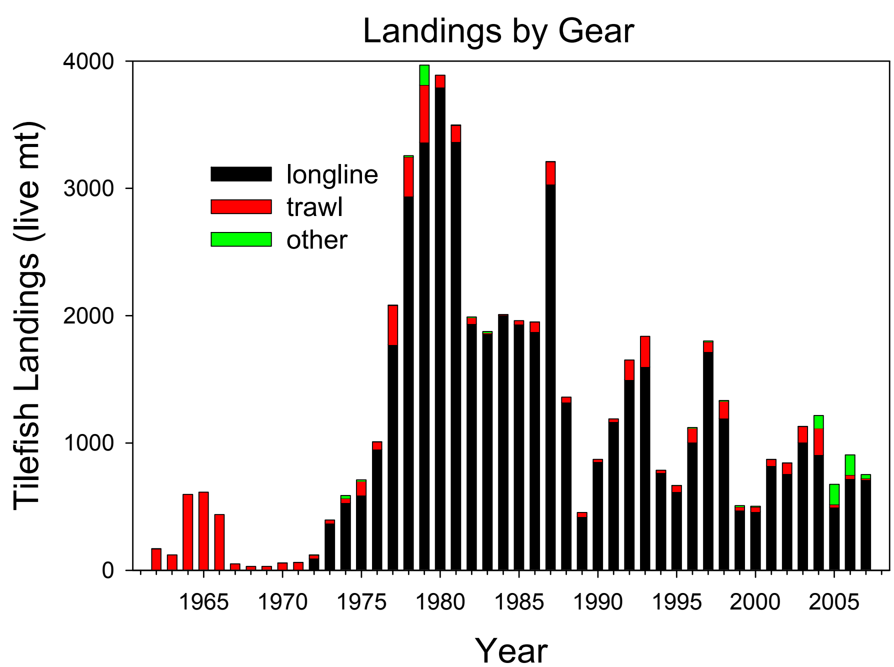


Figure A2. Landings of tilefish (mt, live) by gear. Landing before 1990 are from the general canvas data.

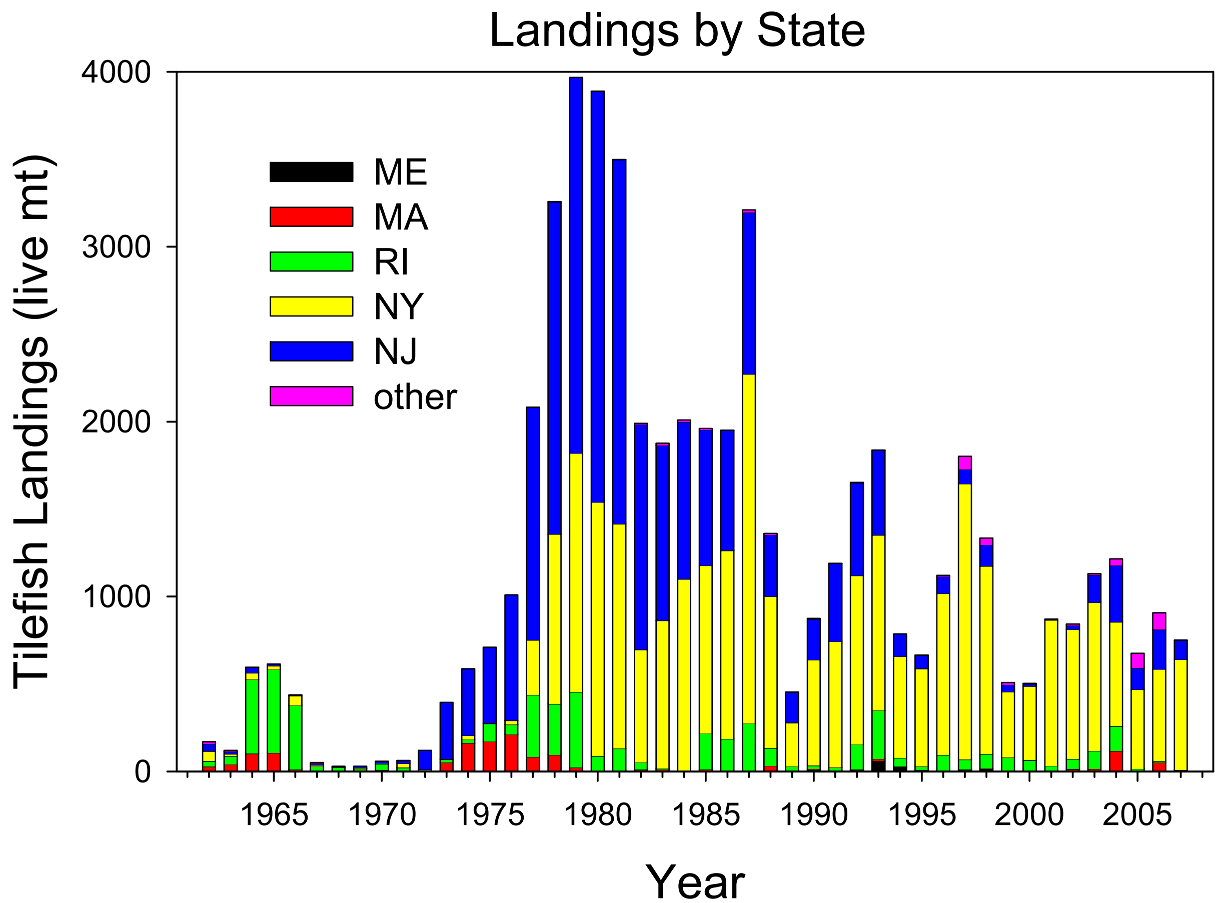


Figure A3. Landings of tilefish (mt, live) by State. Landings before 1990 are from the general canvas data.

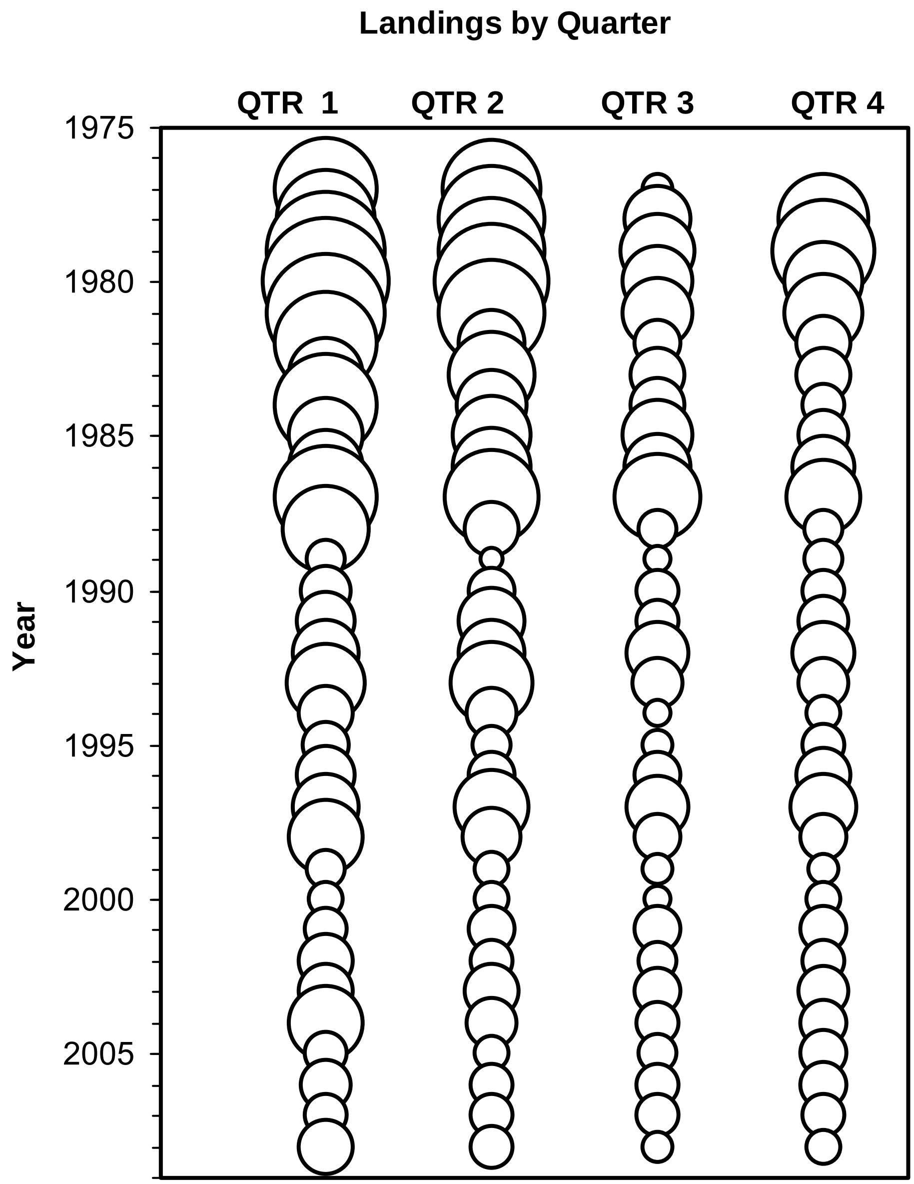


Figure A4. Bubble plot of Golden tilefish landings by quarter.

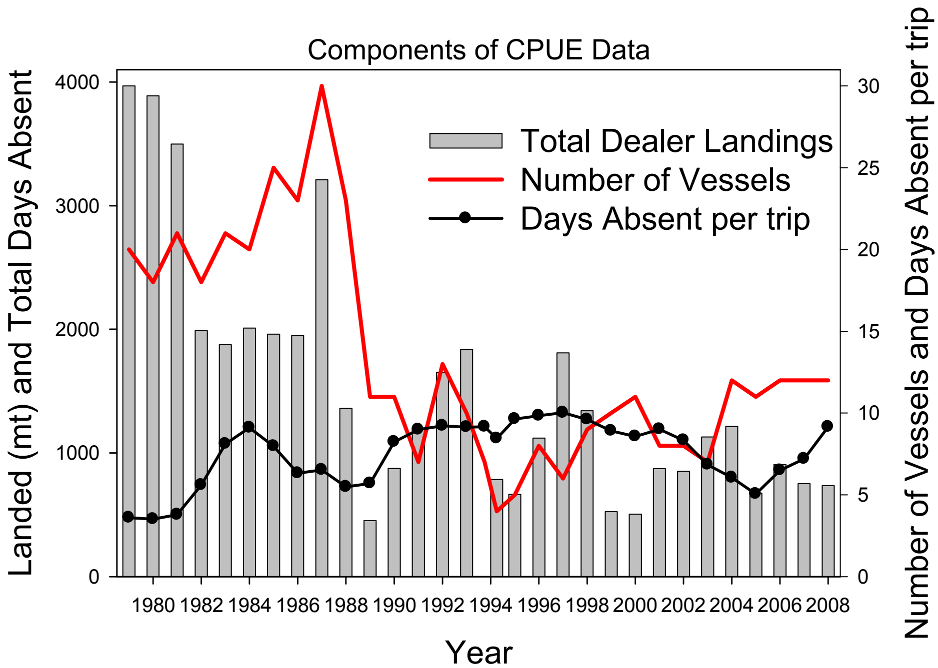


Figure A5. Number of vessels and length of trip (days absent per trip) for trips targeting tilefish (= or >75% tilefish) from 1979-2008. Total Dealer landings are also shown.

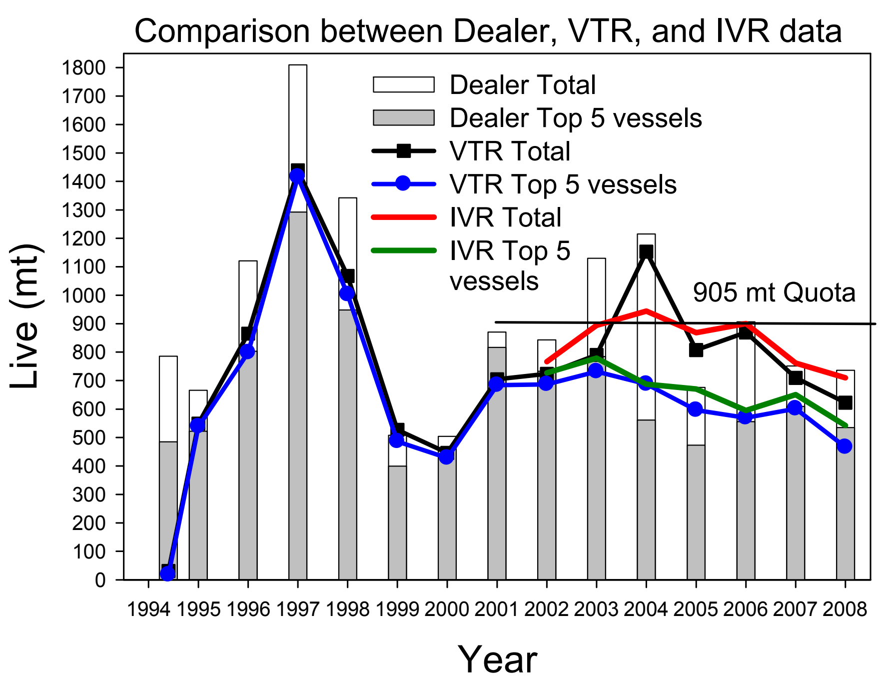


Figure A6. Comparison of dealer, VTR, and IVR total landings in live metric tons. Total landings limited to the top five dominant tilefish vessels are also shown.

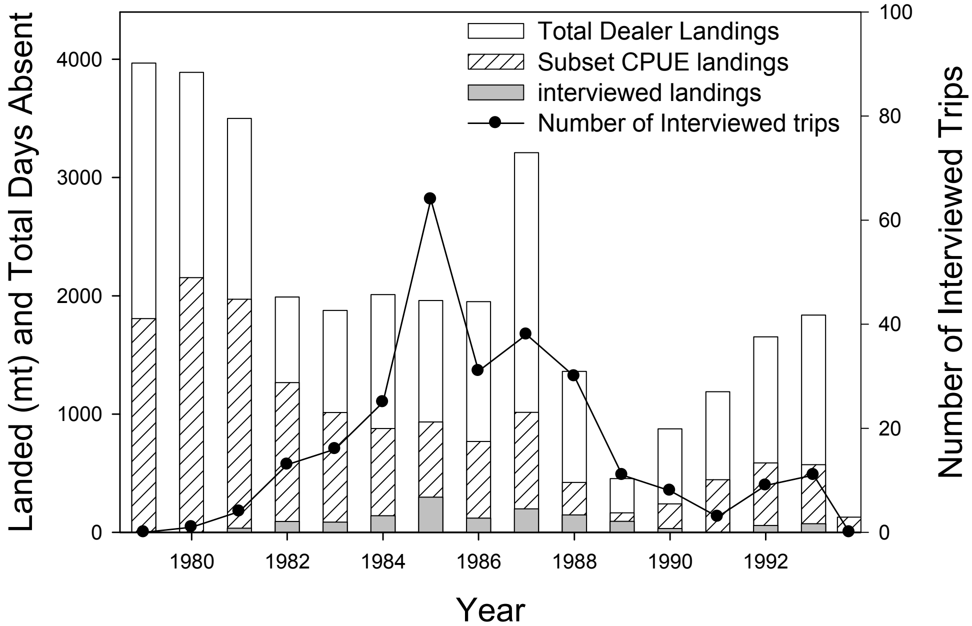


Figure A7. Number of interviewed trips and interviewed landings for trips targeting tilefish (= or >75% tilefish) for the Weighout data from 1979-1994. Total Weighout landings and the subset landings used in CPUE estimate are also shown.

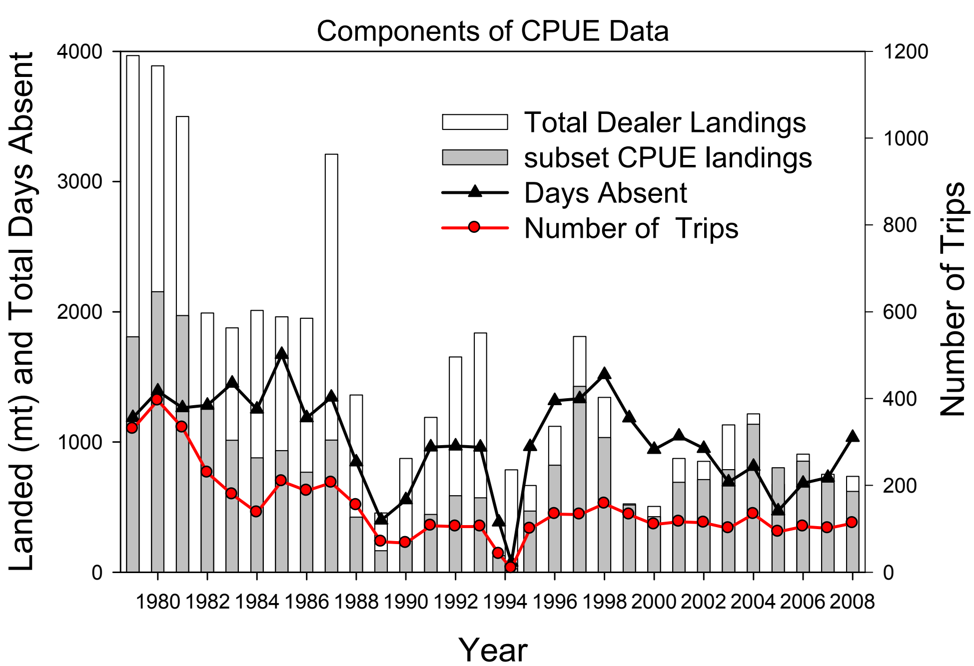


Figure A8. Total number of trips and days absent for trips targeting tilefish (= or >75% tilefish) from 1979-2008. Total Dealer and CPUE subset landings are also shown

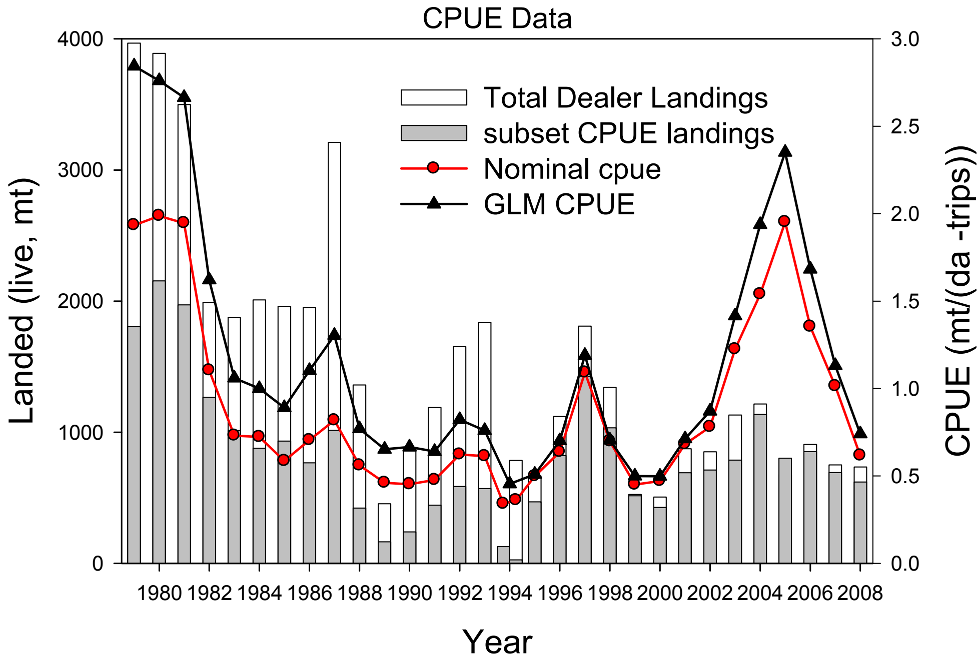


Figure A9. Nominal CPUE (1994 split by Weighout and VTR series) and vessel standard CPUE (GLM) for trips targeting tilefish (= or >75% tilefish) from 1979-2008. Total Dealer and CPUE subset landings are also shown.

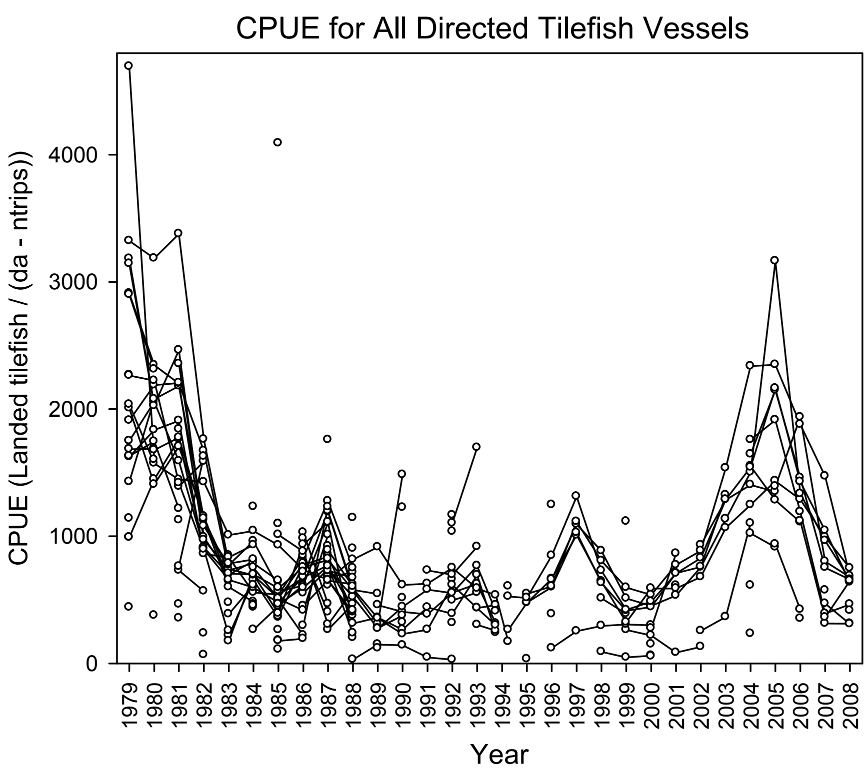


Figure A10. All individual tilefish vessel CPUE data for trips targeting tilefish (= or >75% tilefish) from 1979-200

Figure A11. Depiction of individual vessels (rows) targeting tilefish over the weighout and VTR series. Year 1994 is split by the two series. Below the horizontal line are vessels which are predominantly found in the VTR series.

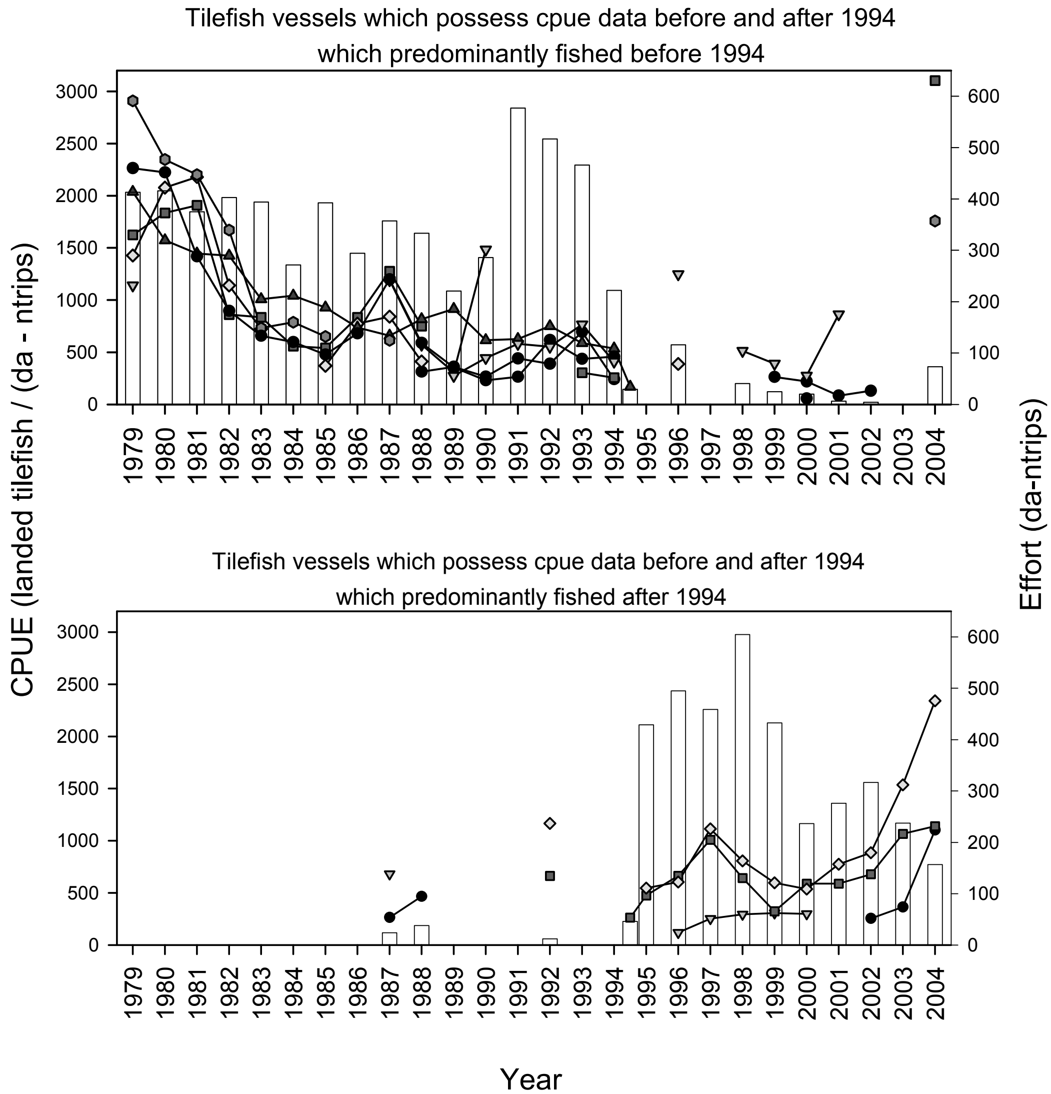


Figure A12. Individual tilefish vessel CPUE and effort data (Bars) for trips targeting tilefish (= or >75% tilefish) from 1979-2004 which are found in both the weighout and VTR series. Top graph are vessels found predominantly in the weighout series. Bottom graph are vessels found predominantly in the VTR series.

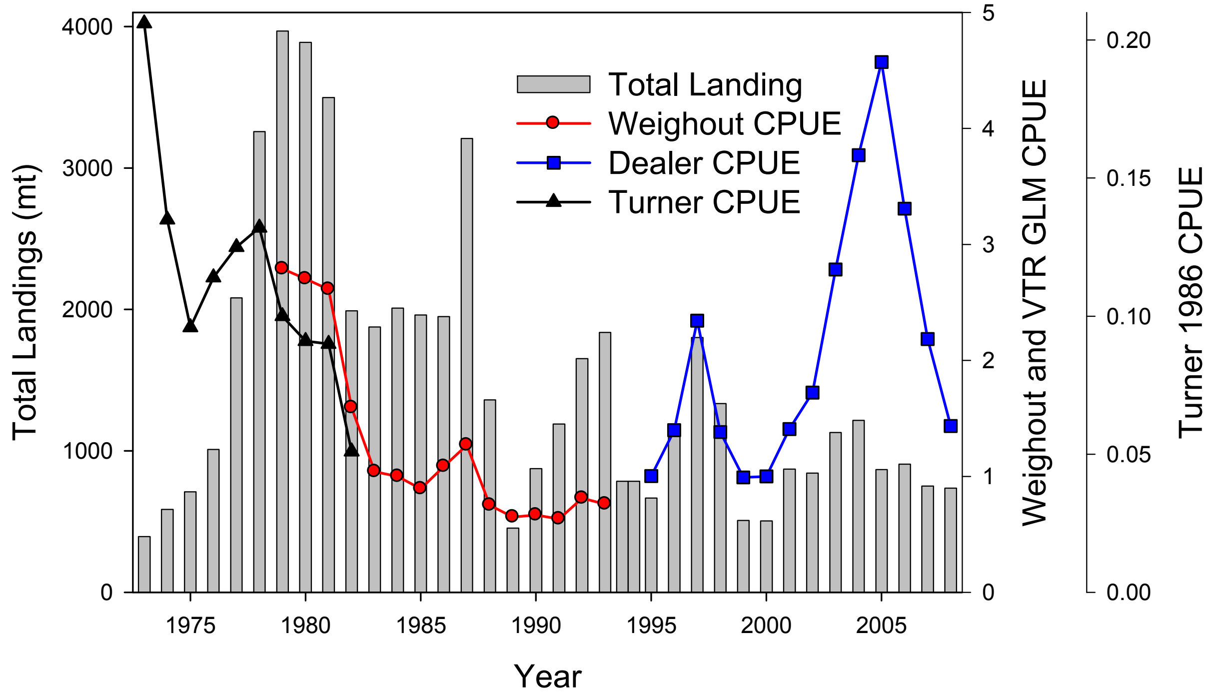


Figure A13. GLM CPUE for the Weighout and VTR data split into two series. Four years of overlap betweenTurner's and the Weighout CPUE series can be seen. Assumed total landings are also shown. Landing in 2005 was taken form the IVR system.

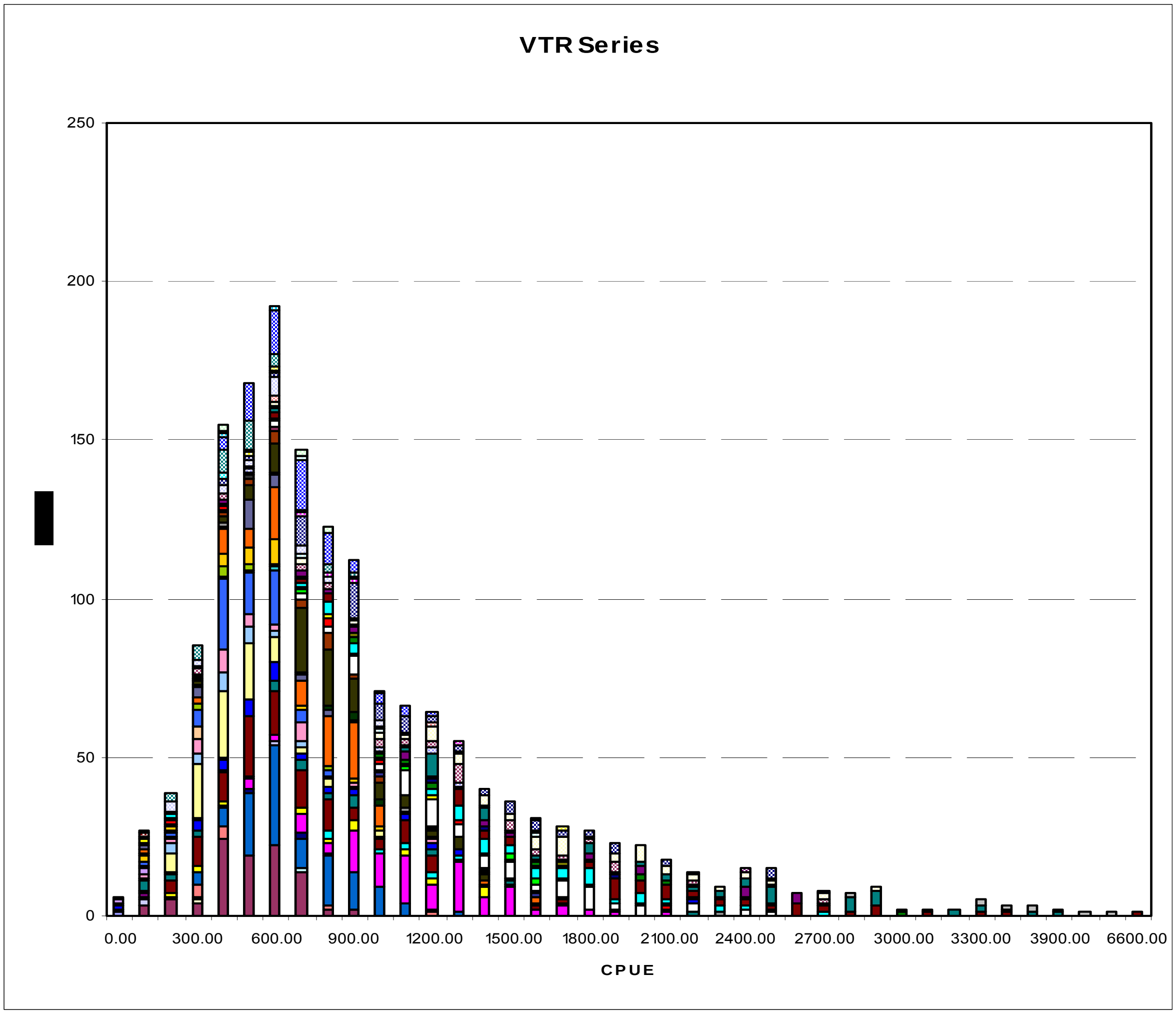


Figure A14. Frequency distribution of the nominal VTR CPUE.

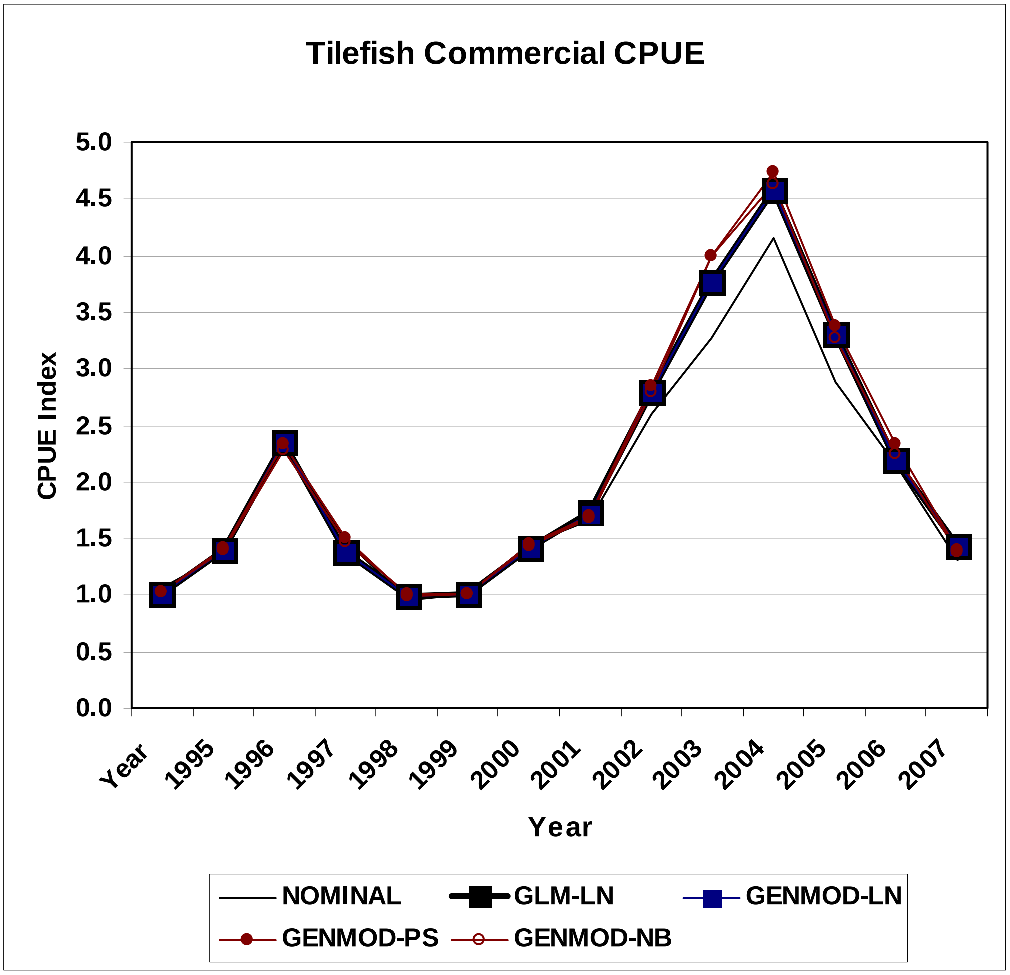


Figure A15. Effect of the assumed error distribution on the vessel standardized GLM CPUE indices.

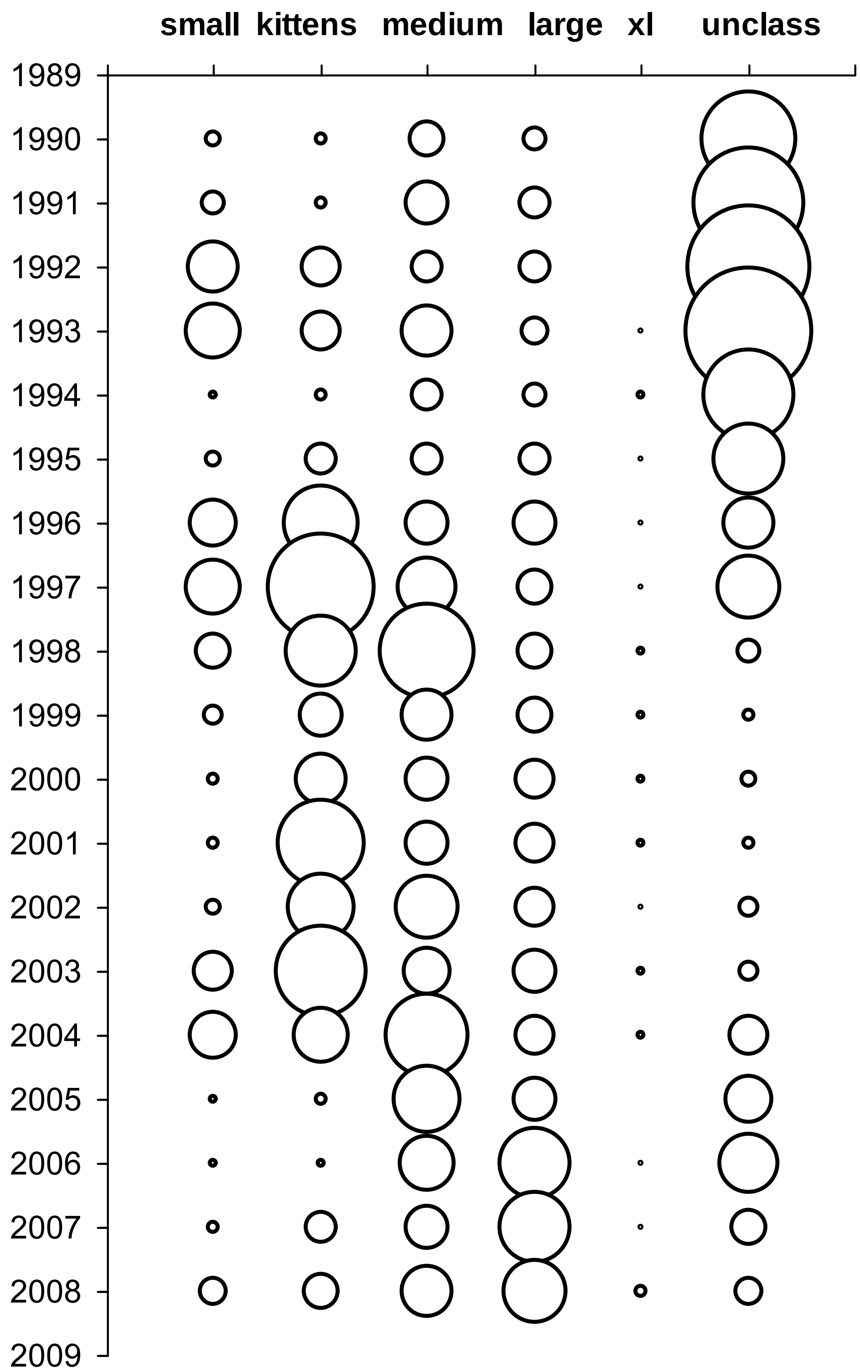


Figure A16. Bubble plot of Golden tilefish landings by market category.

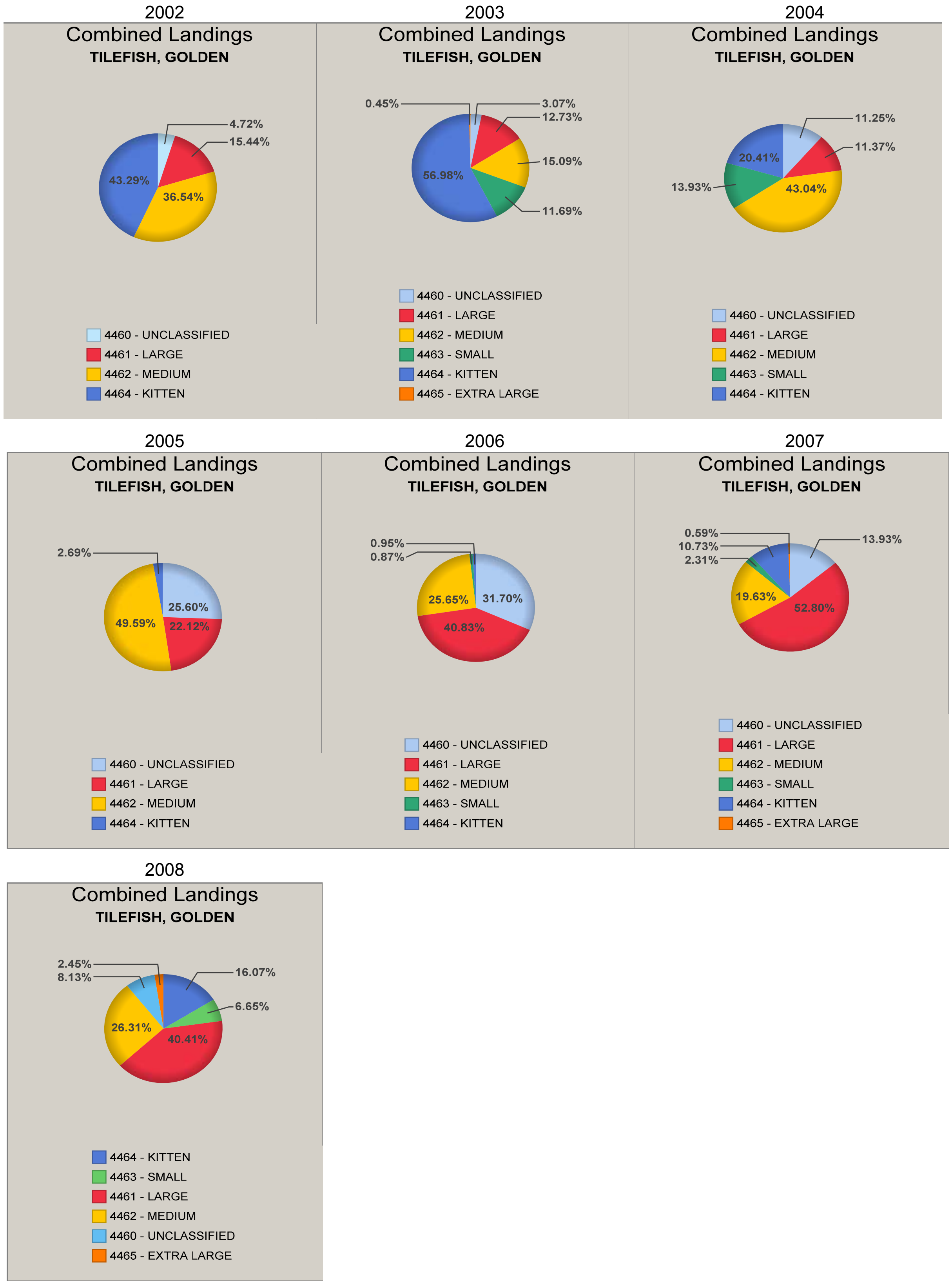


Figure A17. Proportion of landings by market category from 2002-2008.

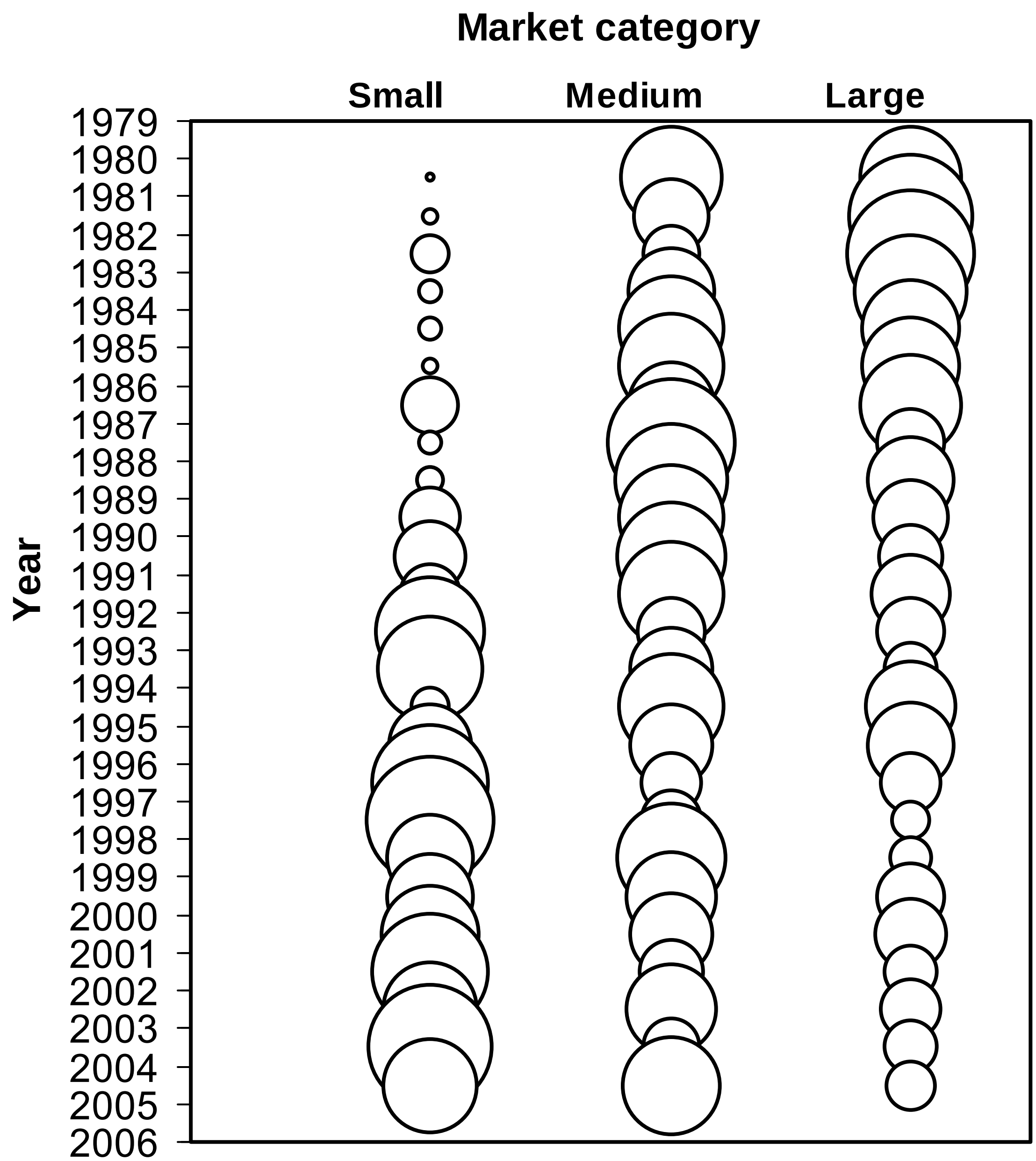


Figure A18. Bubble plot of percent Golden tilefish longline landings by market category. Data from 1980 to 1990 comes from New York tilefish fishermen. Data form 1991-2003 was taken from the dealer data. Data form 2004 are from dealer electronic reporting. Unclassified landings were redistributed according to the other market categories.

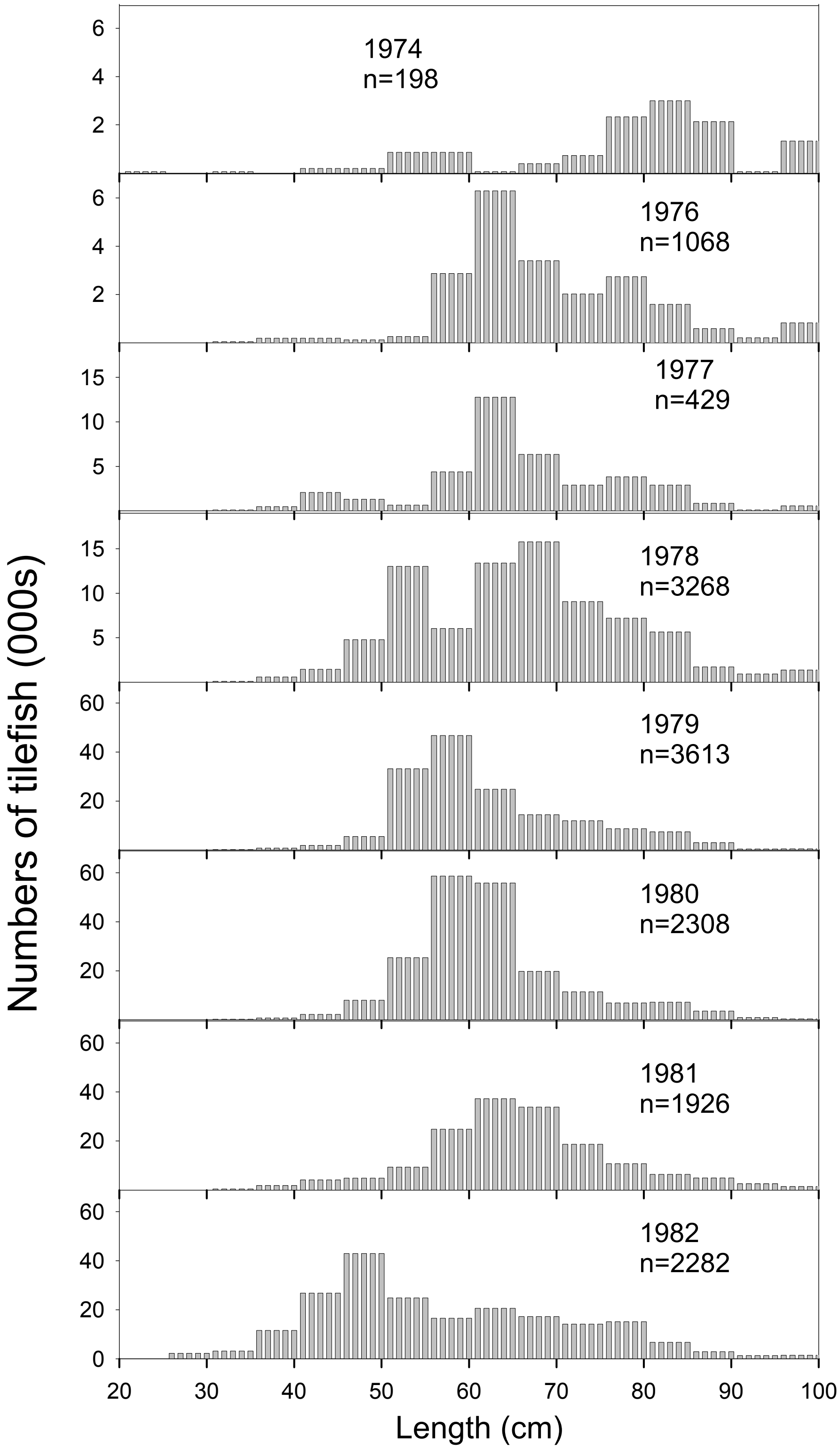


Figure A19. Expanded length frequency distributions using Turner (1986) length samples by 5 cm intervals. Hudson Canyon and Southern New England samples were combined.

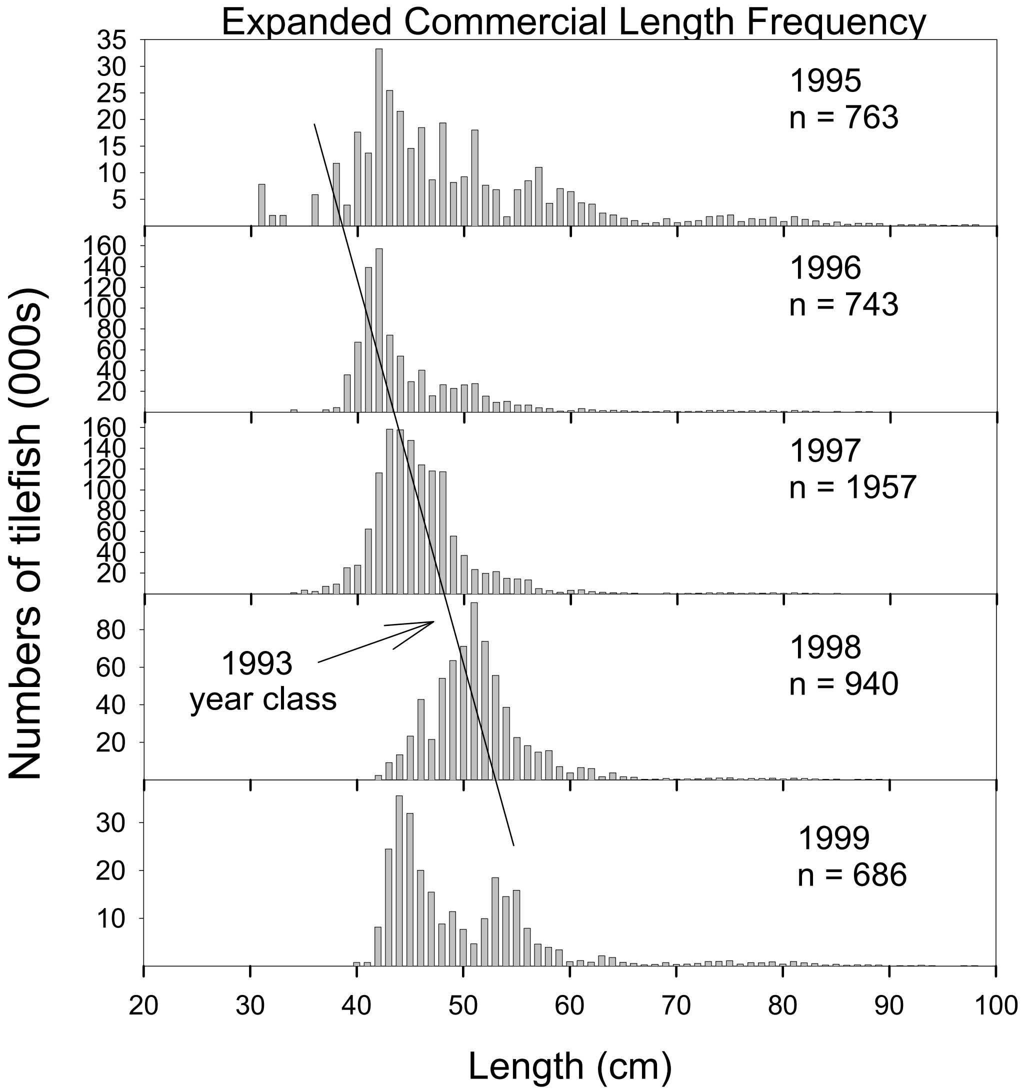


Figure A20. Expanded length frequency distributions by year. Large market category length used from 1995 to 1999 were taken from years 1996, 1998, and 1998. Smalls and kittens were combined and large and extra large were also combined.

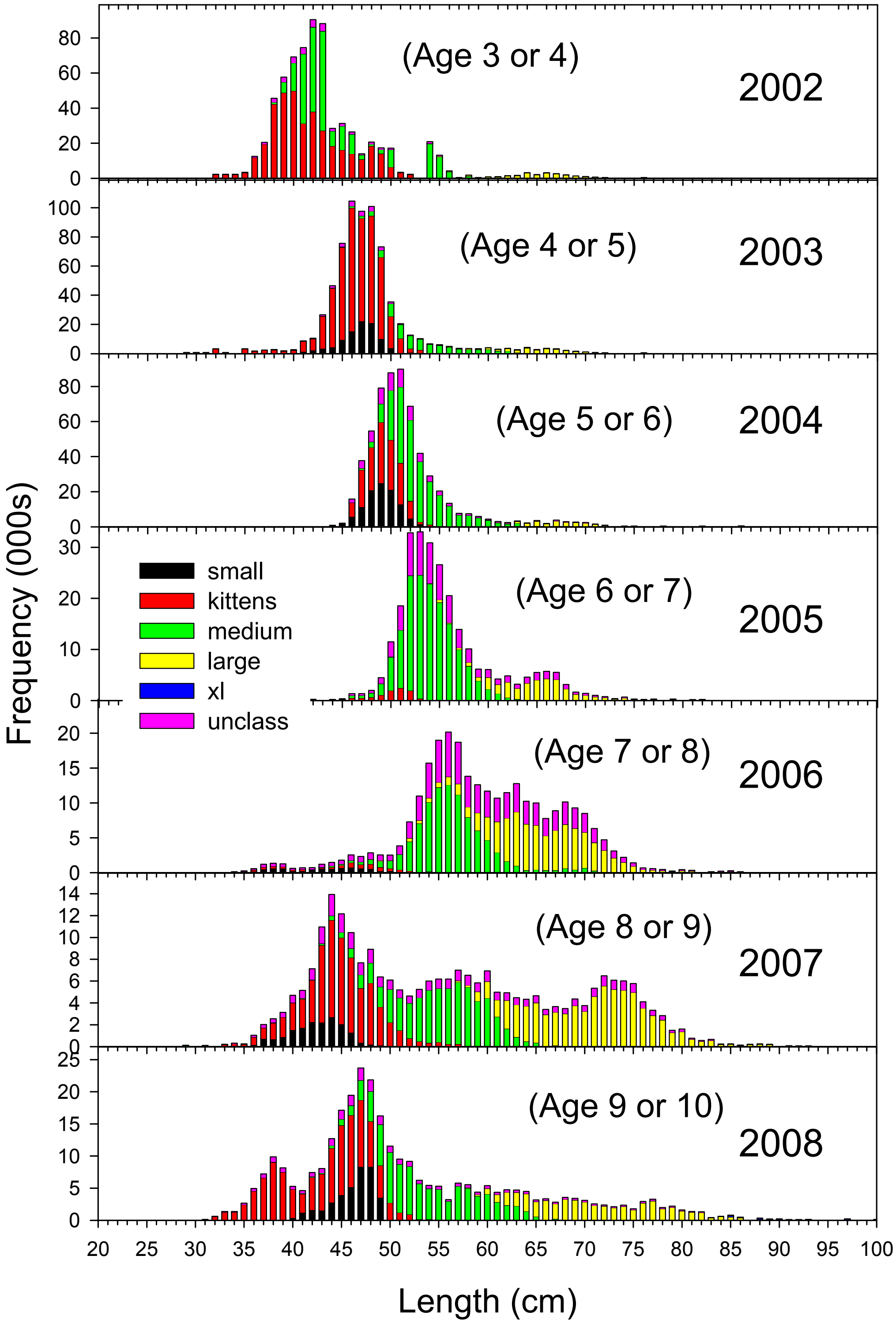


Figure A21. Expanded length frequency distributions by year. Y-axis is allowed to rescale.

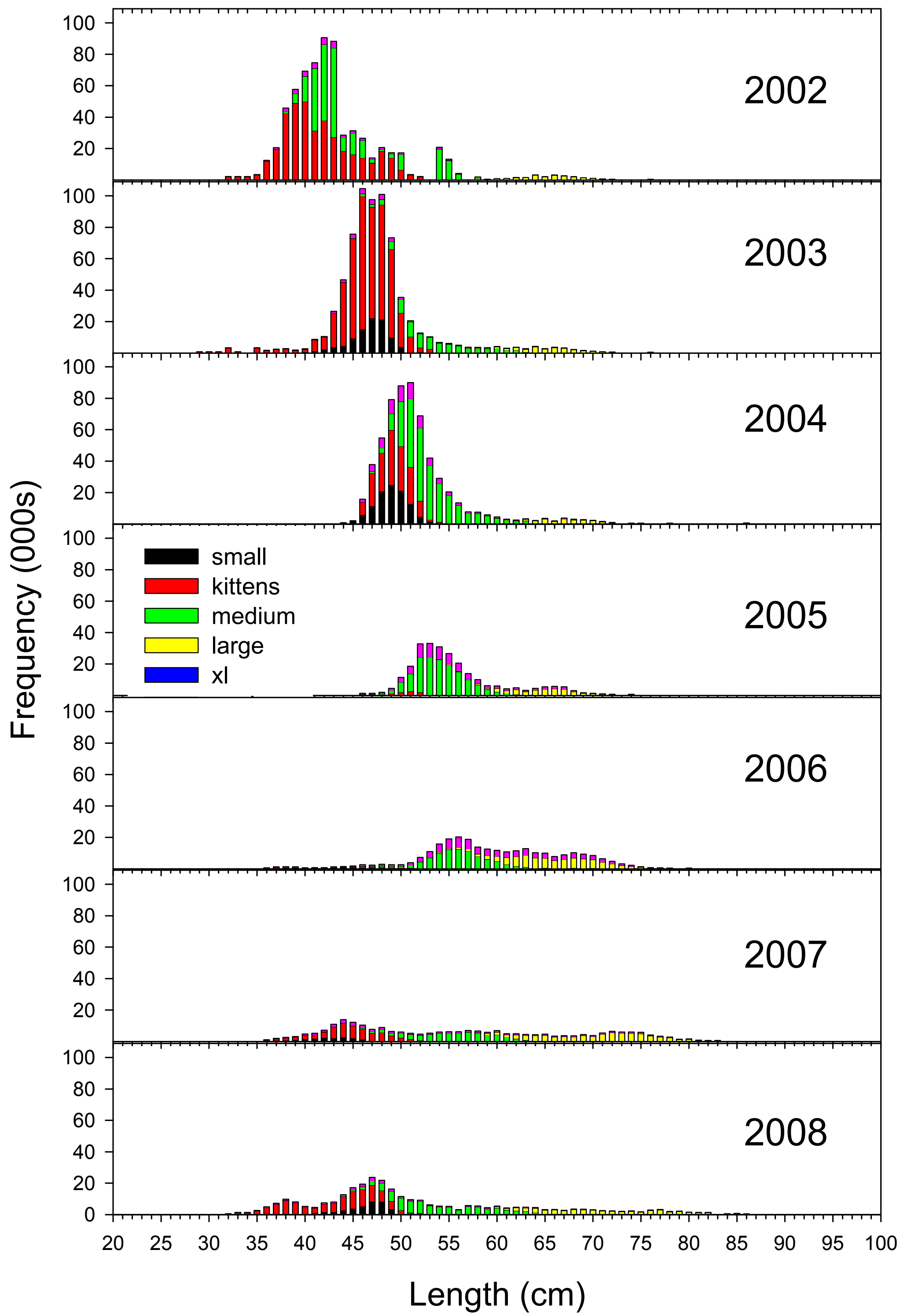


Figure A22. Expanded length frequency distributions by year. Y-axis scale is fixed.

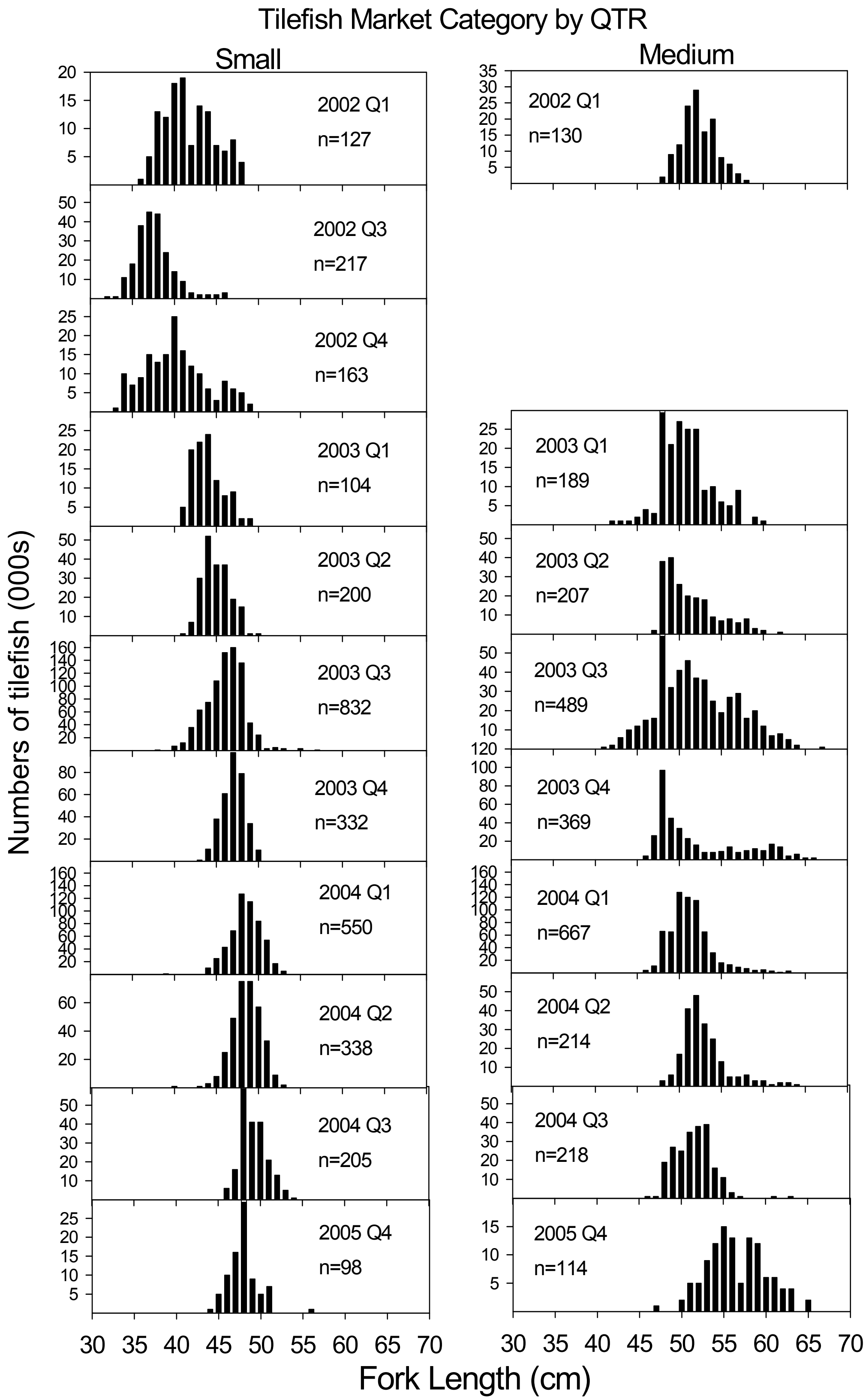


Figure A23. Small and medium tilefish market category length frequency distributions by quarter. Lengths from New York from 2000 to 2004 were converted to fork length.

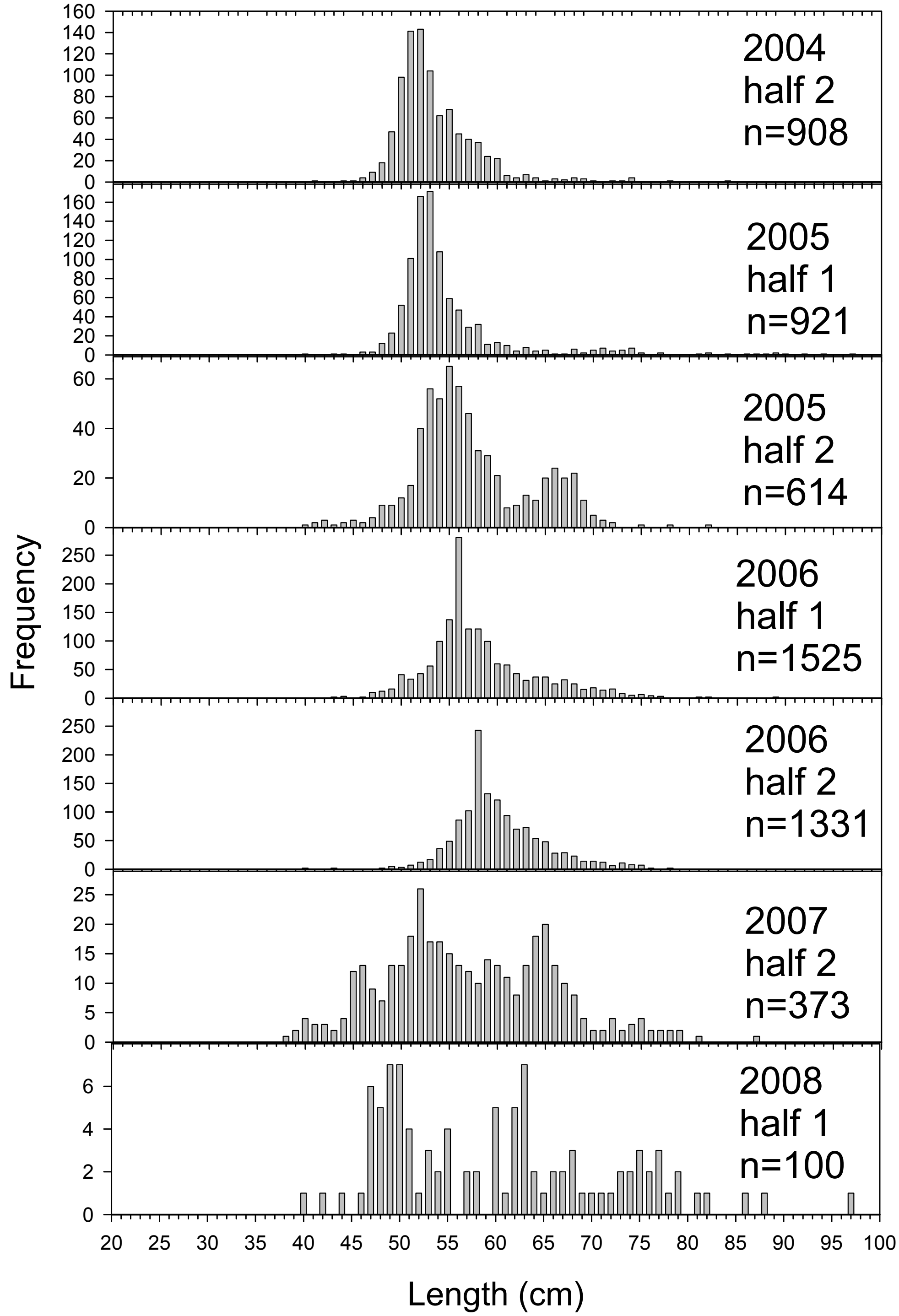


Figure A24. Observer kept length frequency distributions.

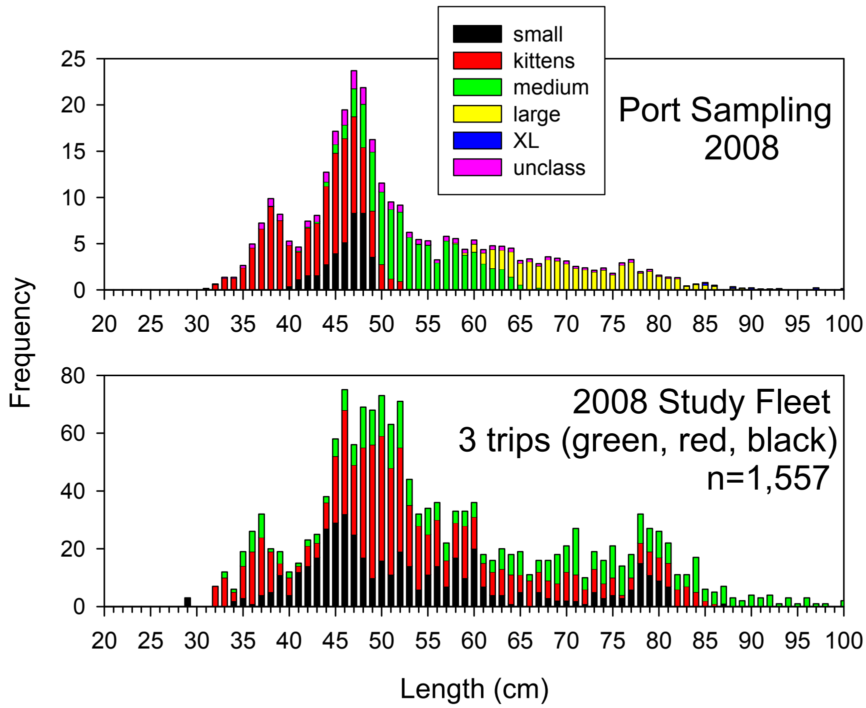


Figure A25. Comparison of study fleet length frequency with expanded landings distribution for 2008.

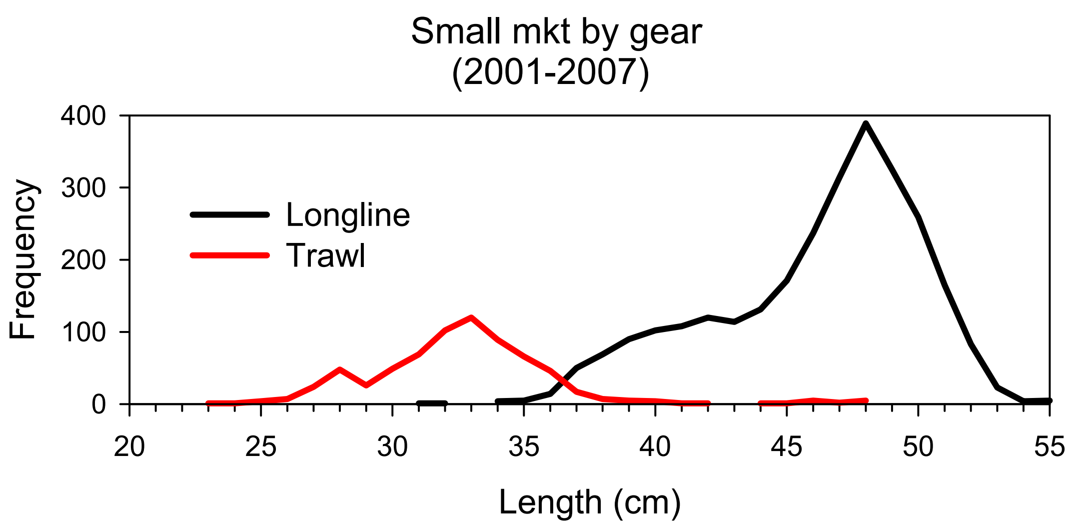


Figure A26. Length frequency distribution of trawl and longline landed fish from the small market category from 2001 to 2007.

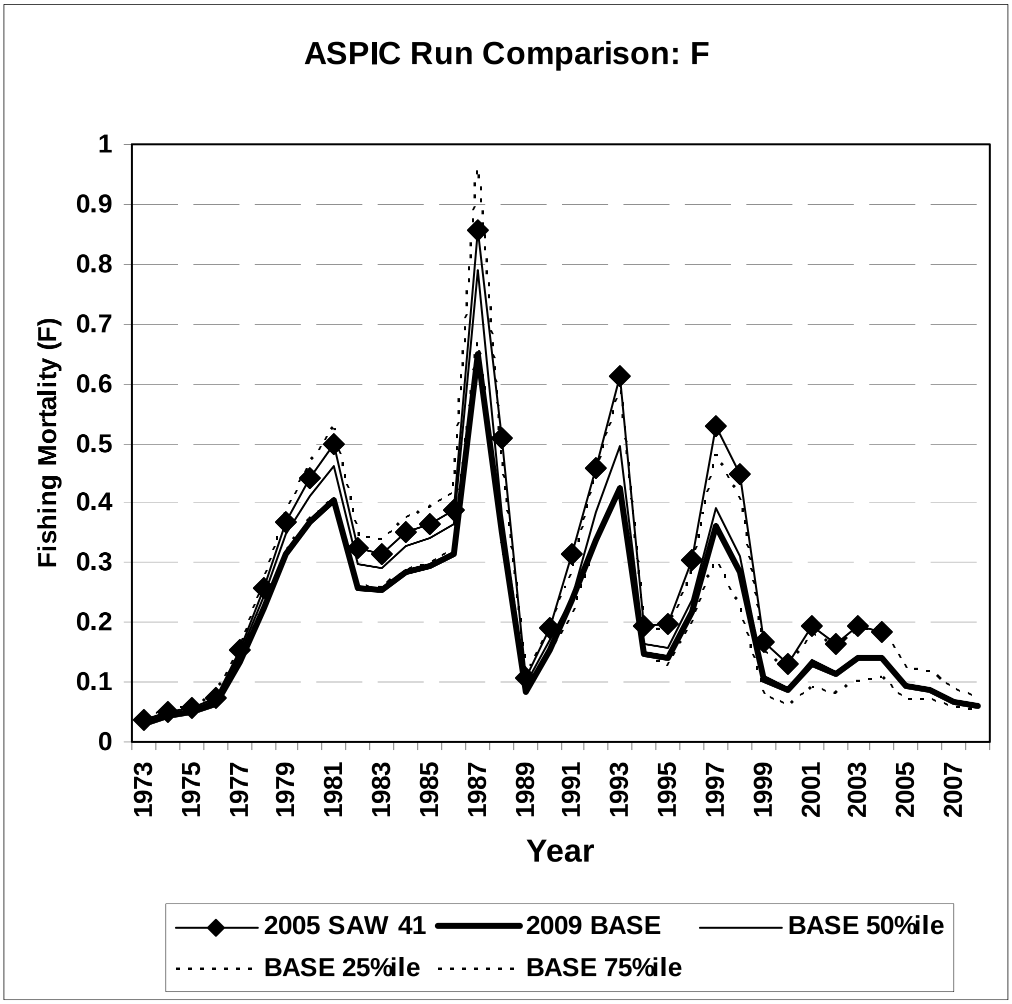


Figure A27. Comparison of the 2005 SAW 41 estimates of fishing mortality (F) with 2009 BASE run estimates.

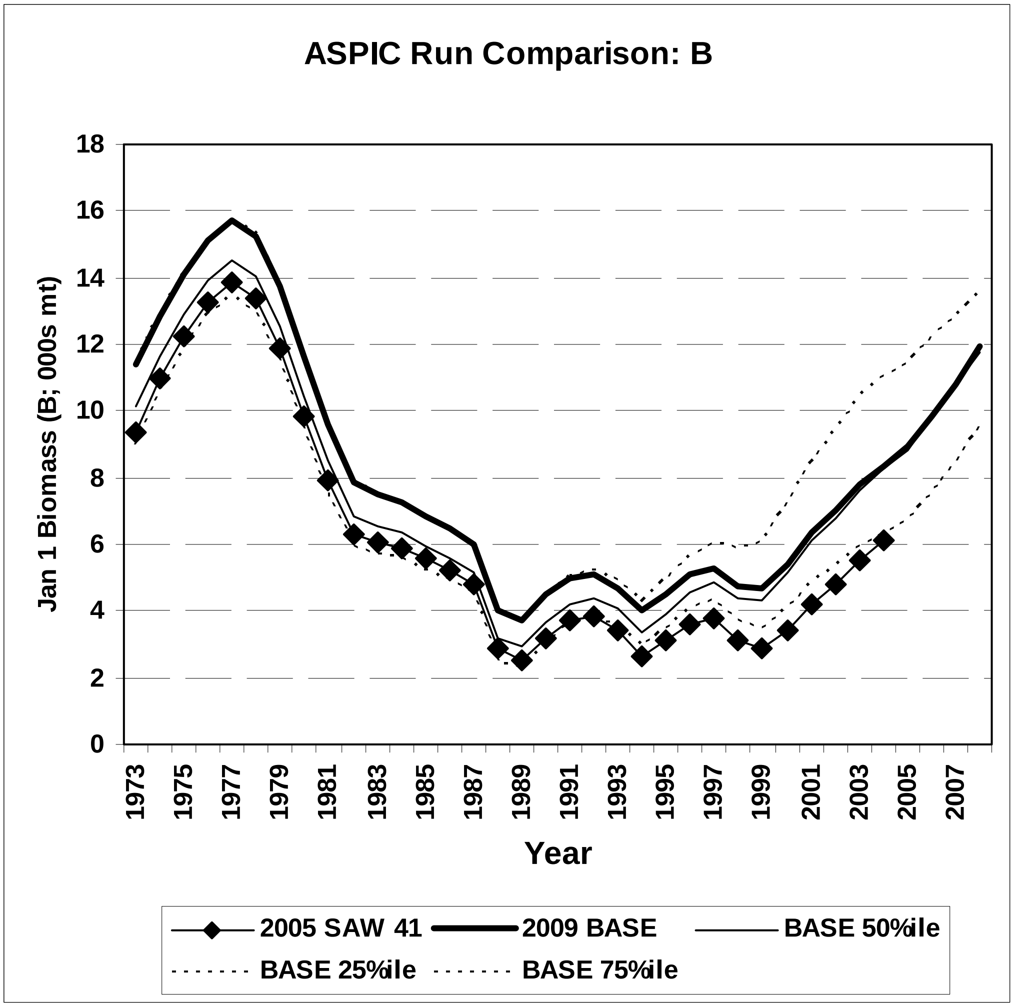


Figure A28. Comparison of the 2005 SAW 41 estimates of stock biomass (B) with 2009 BASE run estimates.

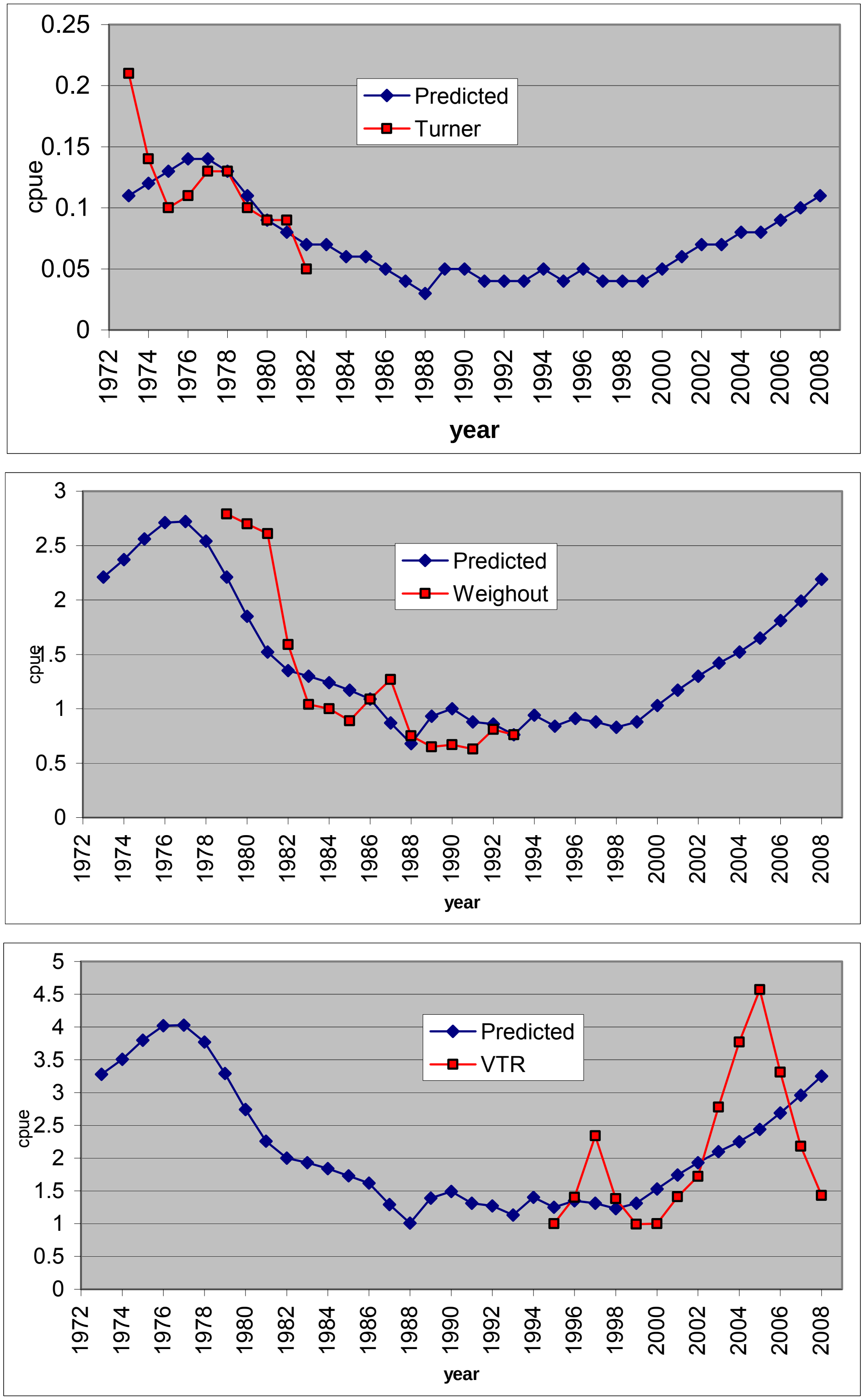


Figure A29. Fit of the ASPIC base run 1 with the three (Turner's, Weighout, and VTR) cpue series.

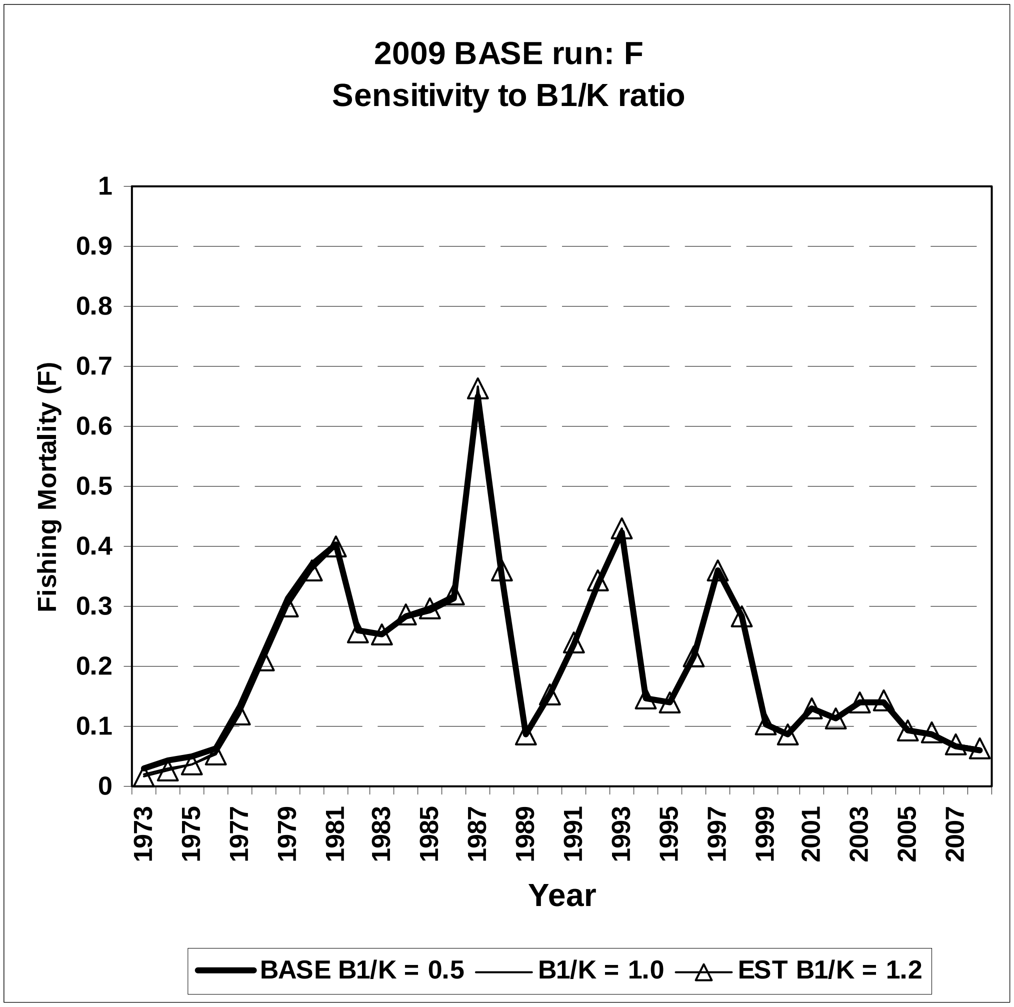


Figure A30. Sensitivity of 2009 BASE run estimated fishing mortality (F) using different values of the time series starting biomass (B1) to carrying capacity (K) ratio. The B1/K = 0.1 run is not shown since this run produced infeasible results by hitting a model bound.

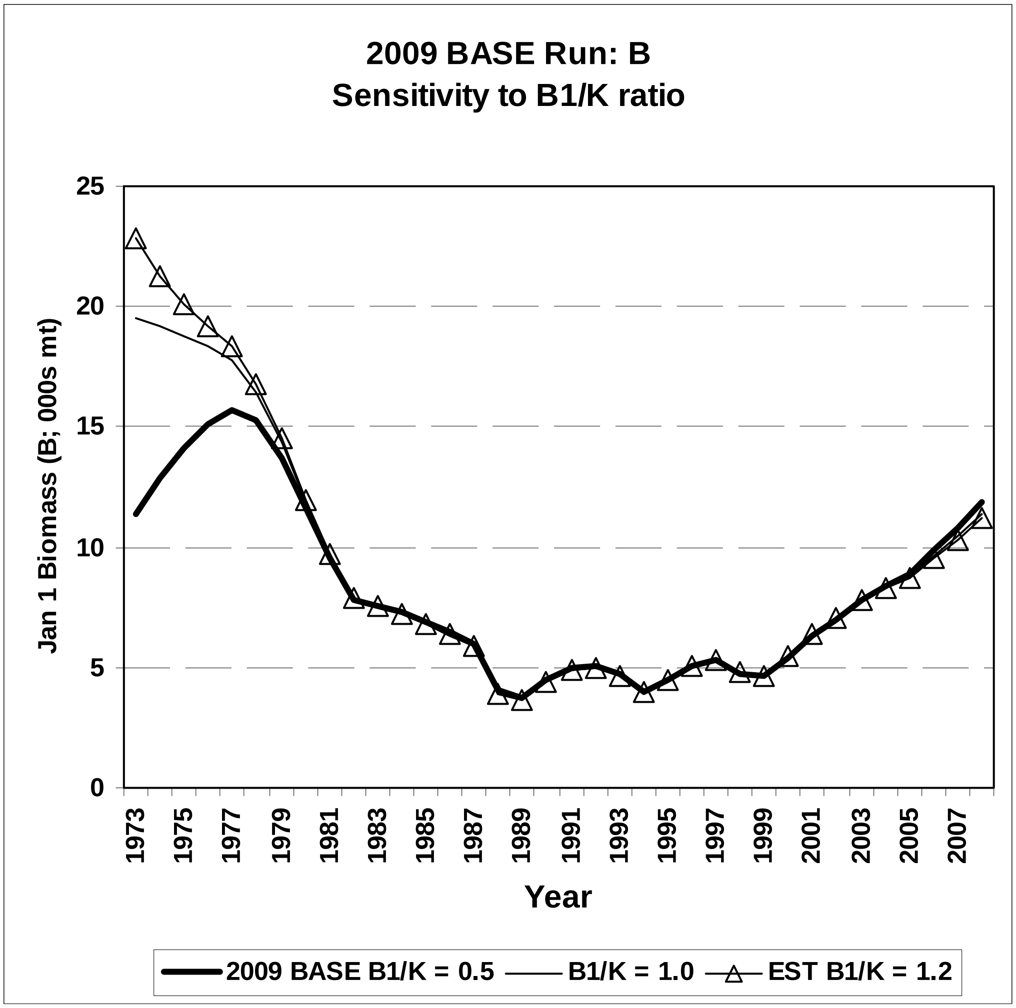


Figure A31. Sensitivity of 2009 BASE run estimated stock biomass (B) for different values of the time series starting biomass (B1) to carrying capacity (K) ratio. The B1/K = 0.1 run is not shown since this run produced infeasible results by hitting a model bound.

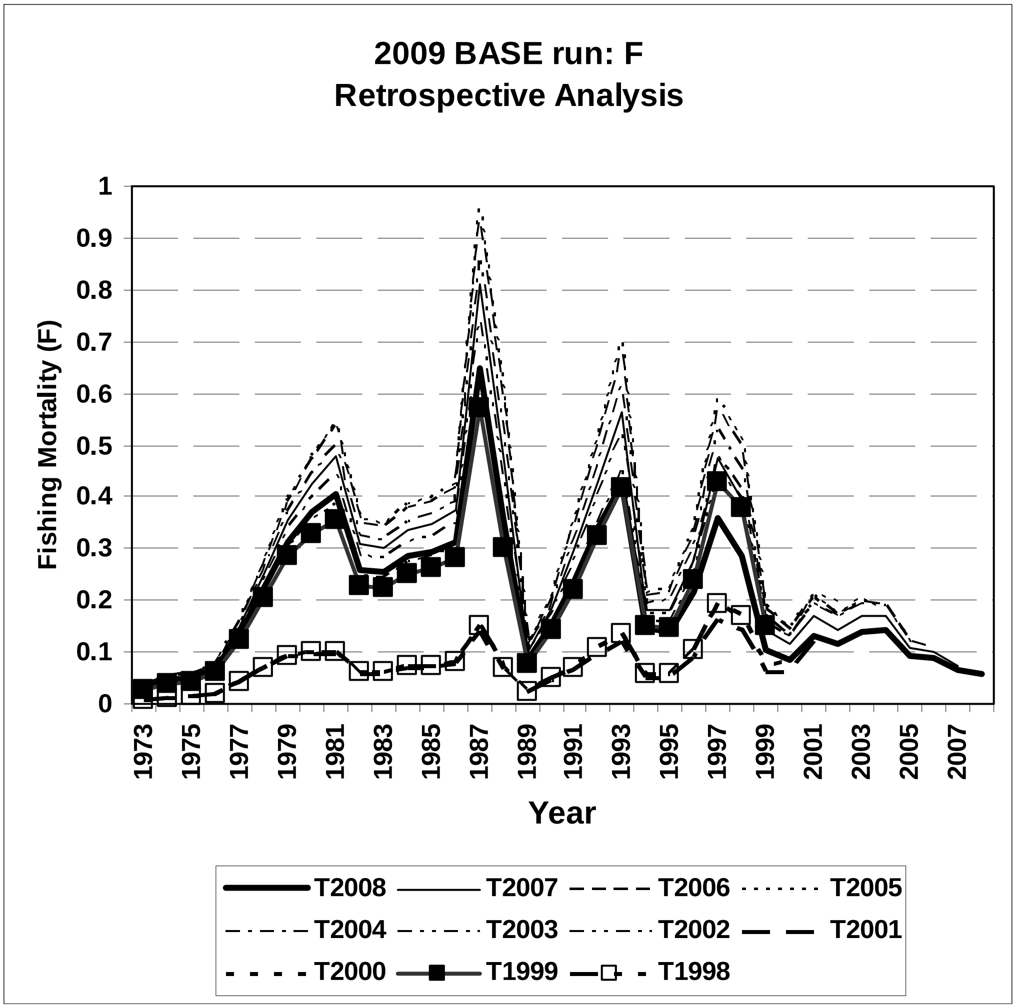


Figure A32. Retrospective analysis results for the 2009 BASE run: fishing mortality (F).

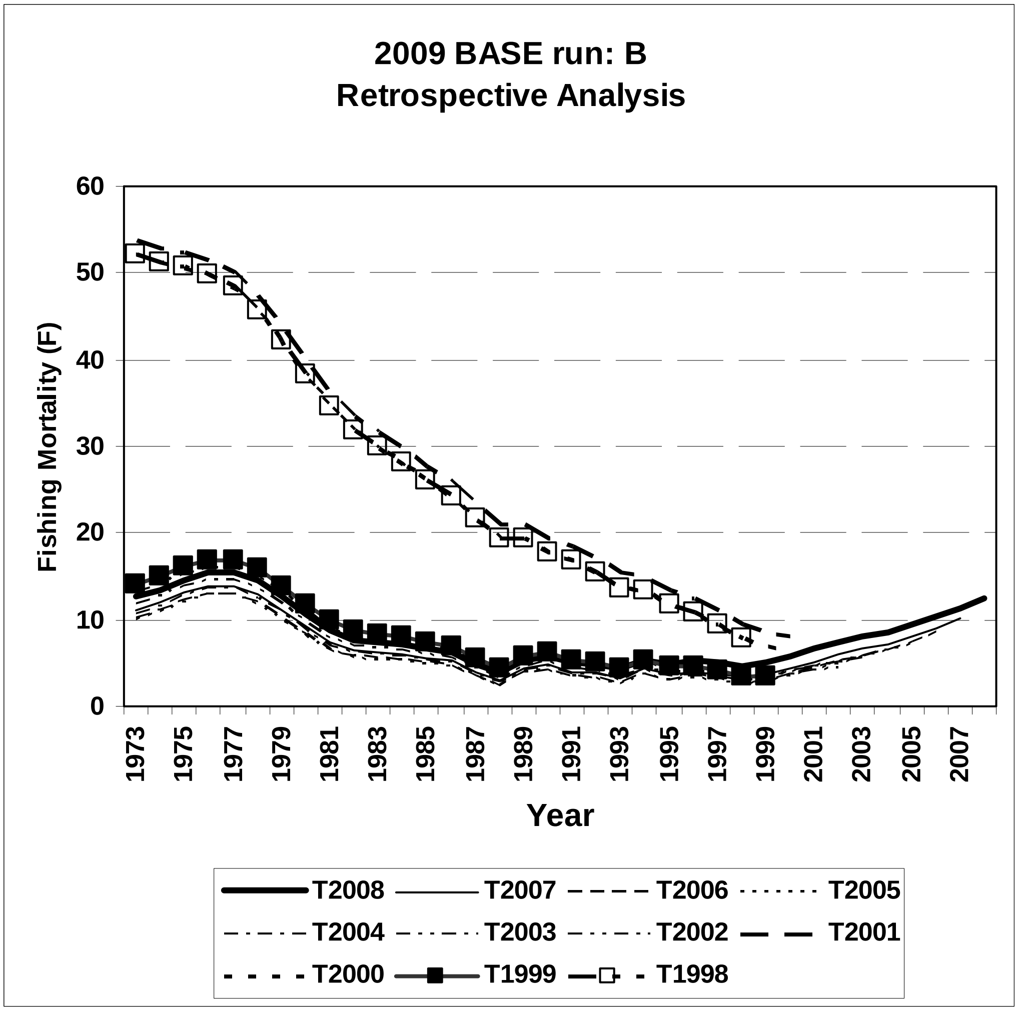


Figure A33. Retrospective analysis results for the 2009 BASE run: stock biomass (B).

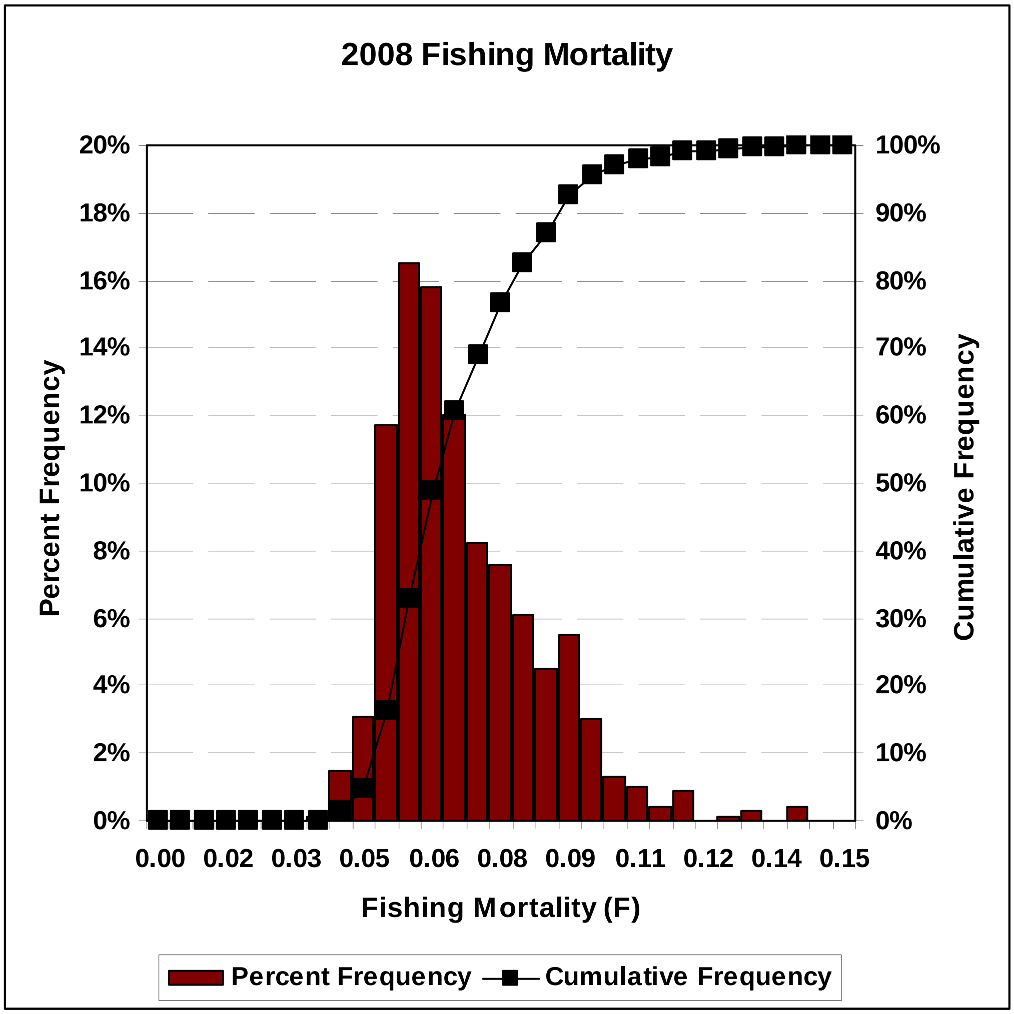


Figure A34. Bootstrap estimates (1000 iterations) of the precision of 2008 fishing mortality from the 2009 BASE run. Vertical bars display the range of the bootstrap estimates; the percent confidence intervals can be taken from the cumulative frequency. The 2008 point estimate of fishing mortality = 0.059.

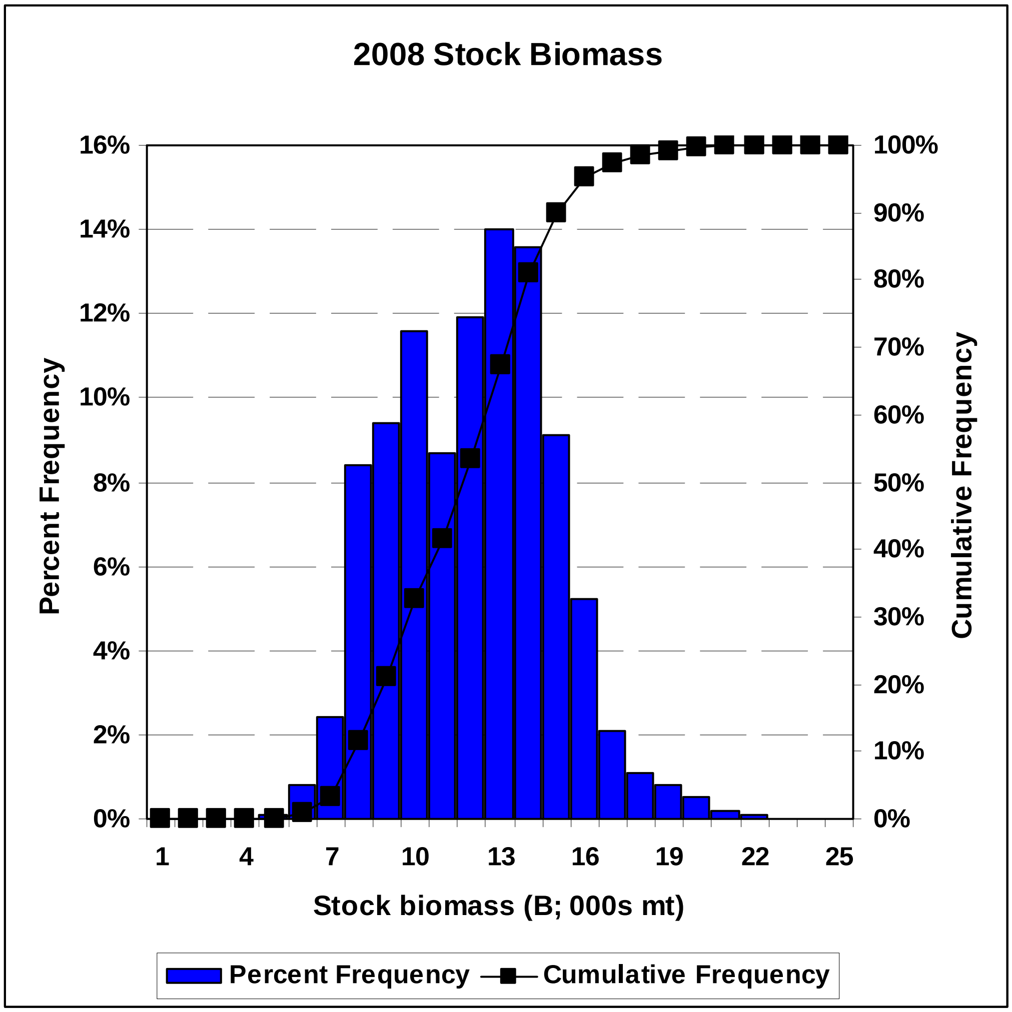


Figure A35. Bootstrap estimates (1000 iterations) of the precision of 2008 stock biomass from the 2009 BASE run. Vertical bars display the range of the bootstrap estimates; the percent confidence intervals can be taken from the cumulative frequency. The 2008 point estimate of stock biomass = 11.910 thousand mt.

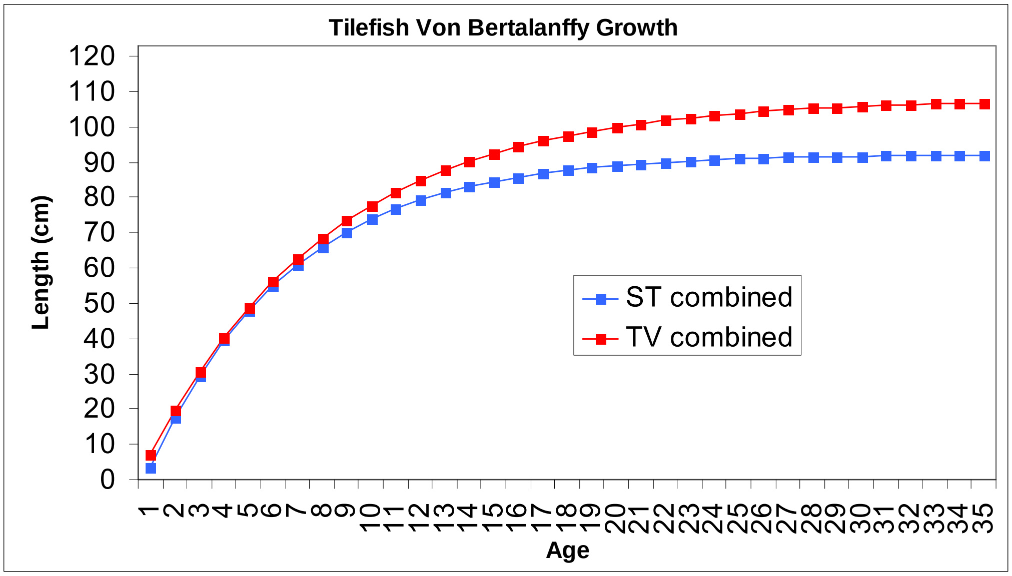


Figure A36. Comparison of Vidal's (2008) and Turner's (1986) von Bertalanffy growth curve with the sexes combined.

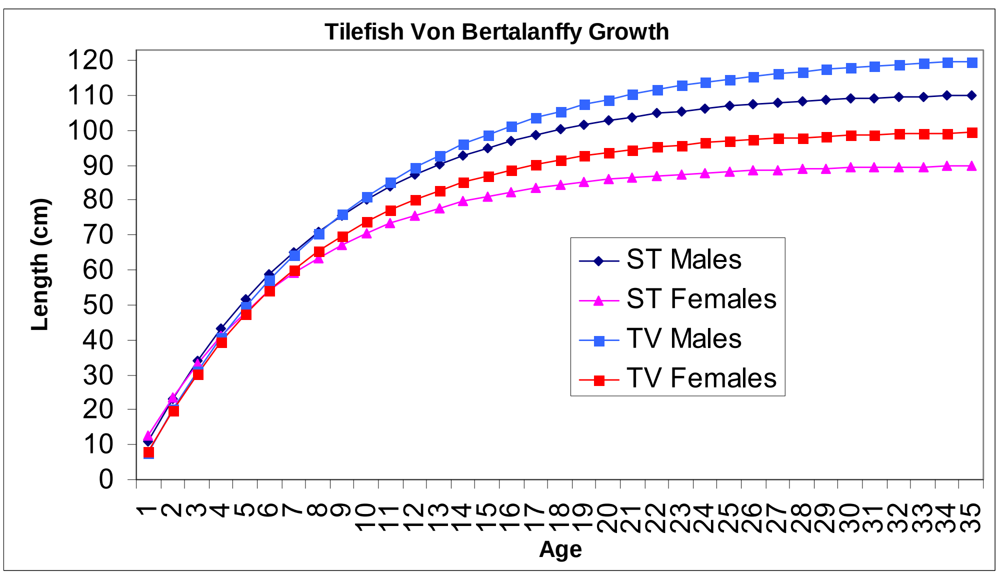


Figure A37. Comparison of Vidal's (2008) and Turner's (1986) von Bertalanffy growth curve with the sexes separated.

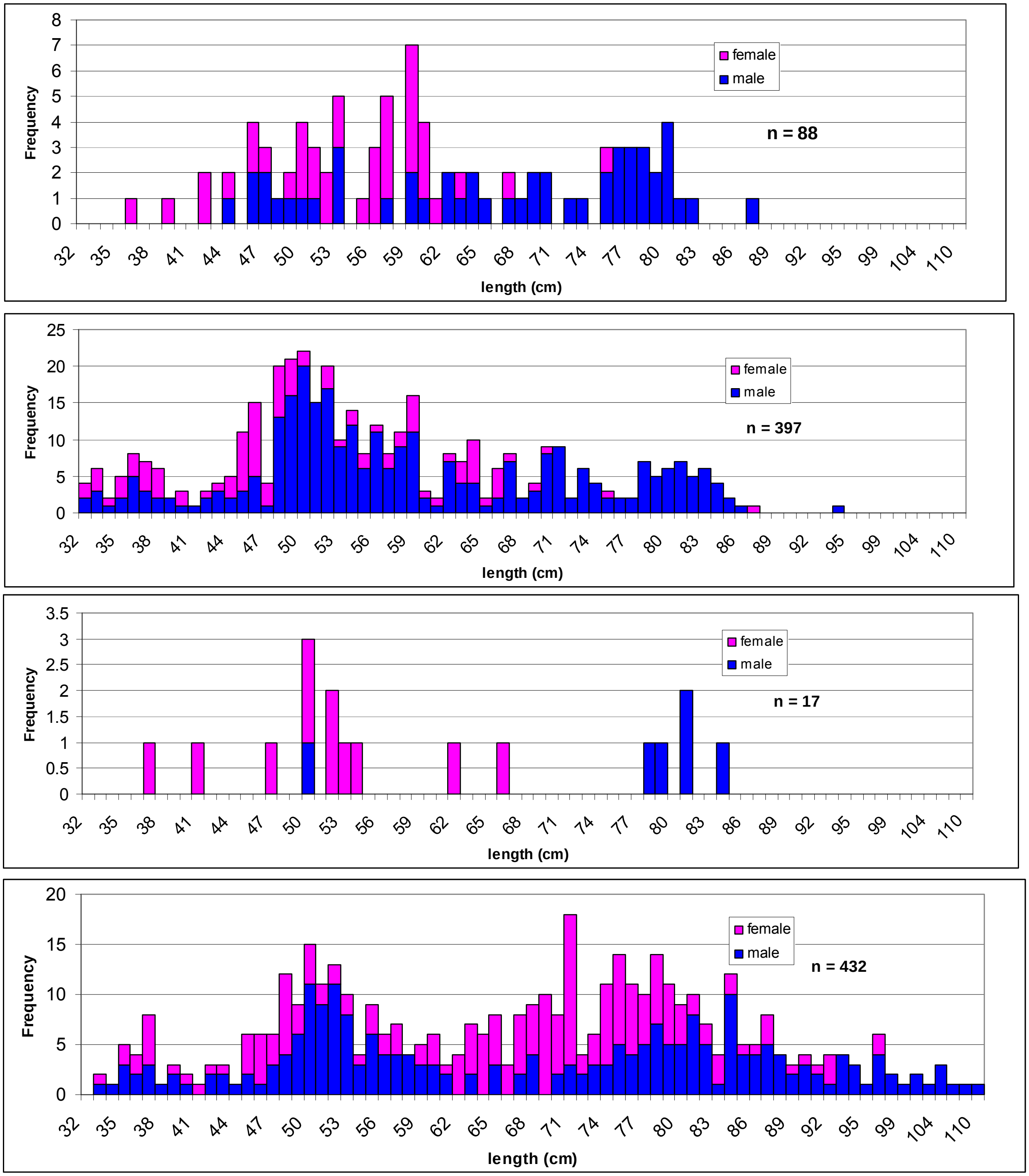


Figure A38. Study fleet length distributions by sex and trip.

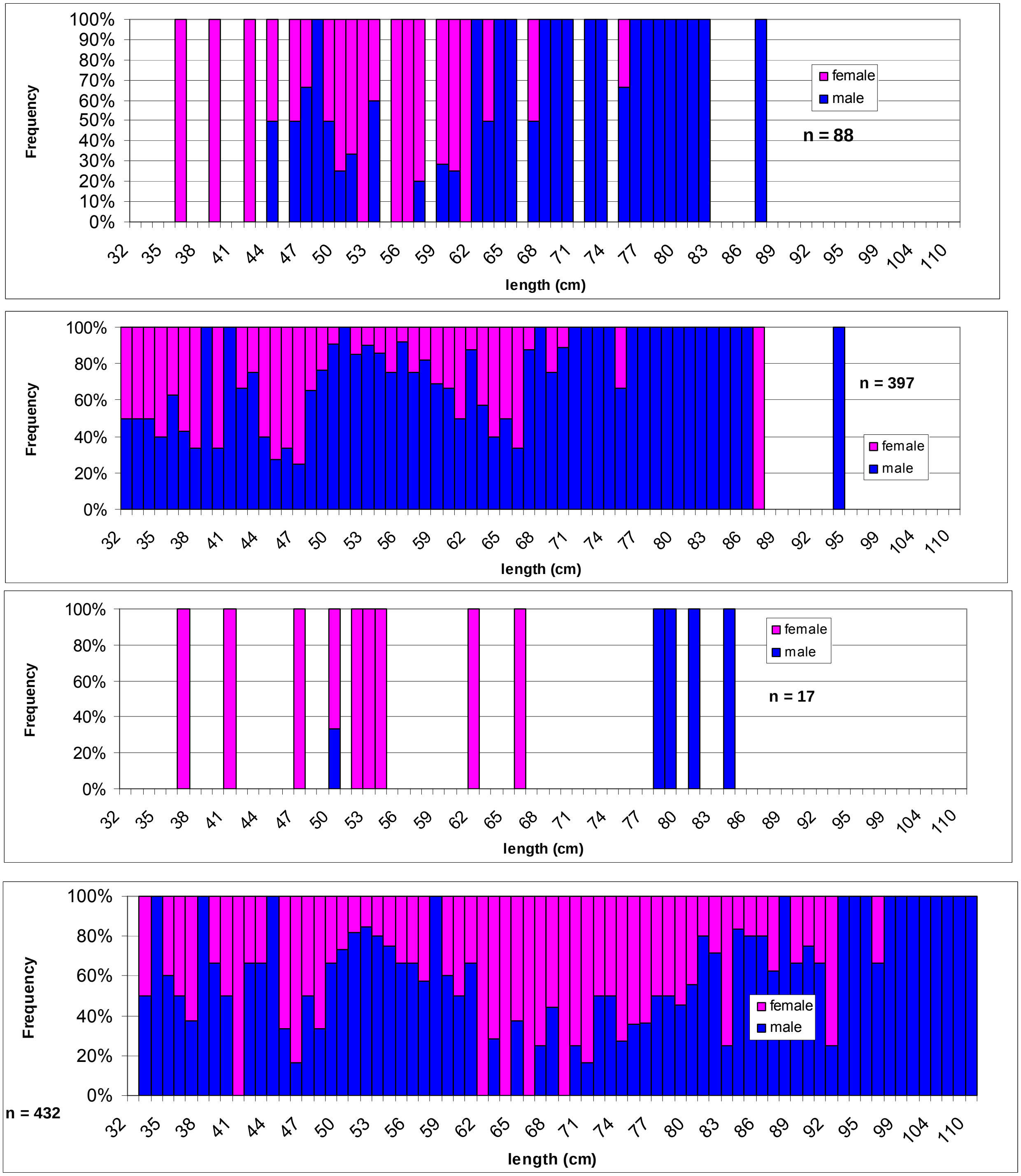
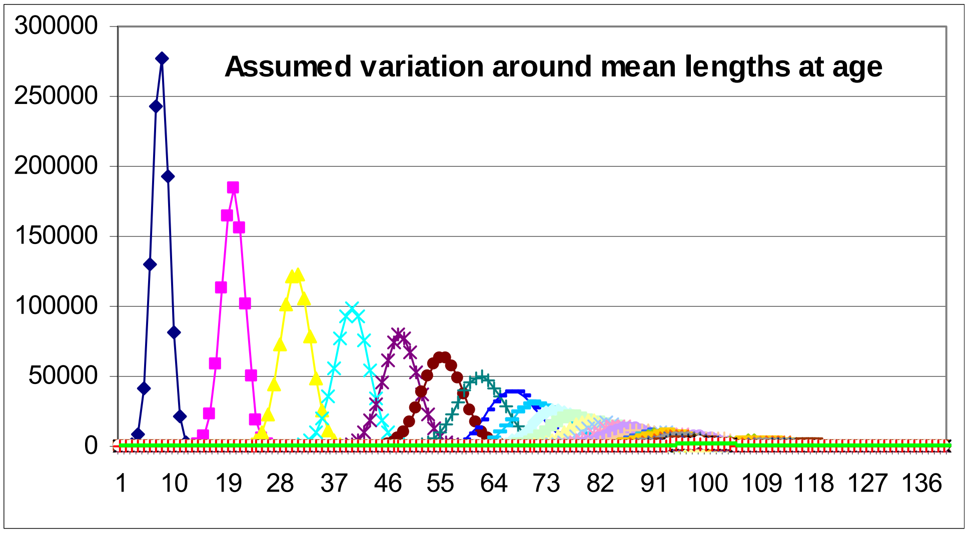


Figure A39. Study fleet sex ratio at length by trip.



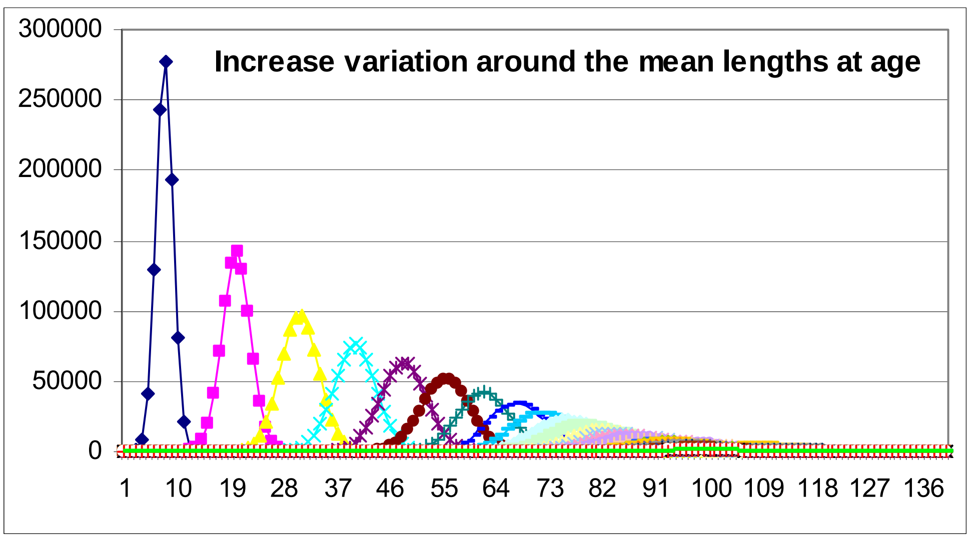


Figure A40. SCALE base run 1 assumed variation around the mean lengths at age (top) and run 5 which increased the assumed variation around the mean lengths at age (bottom).

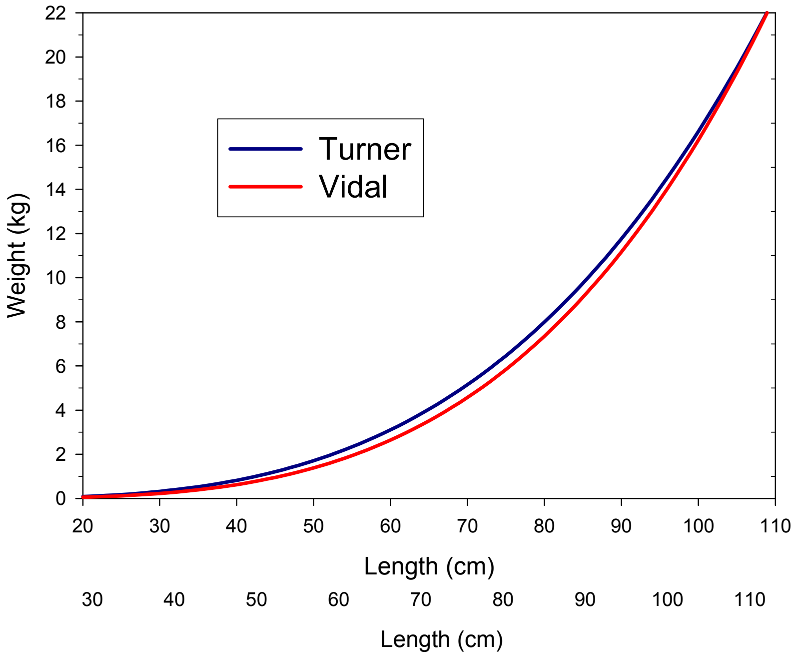


Figure A41. Top graph shows the length weight relationship calculated from the study fleet data (T Vidal 2008). Bottom graph shows the comparison between Turner's (1986) and Vidal length weight relationships.

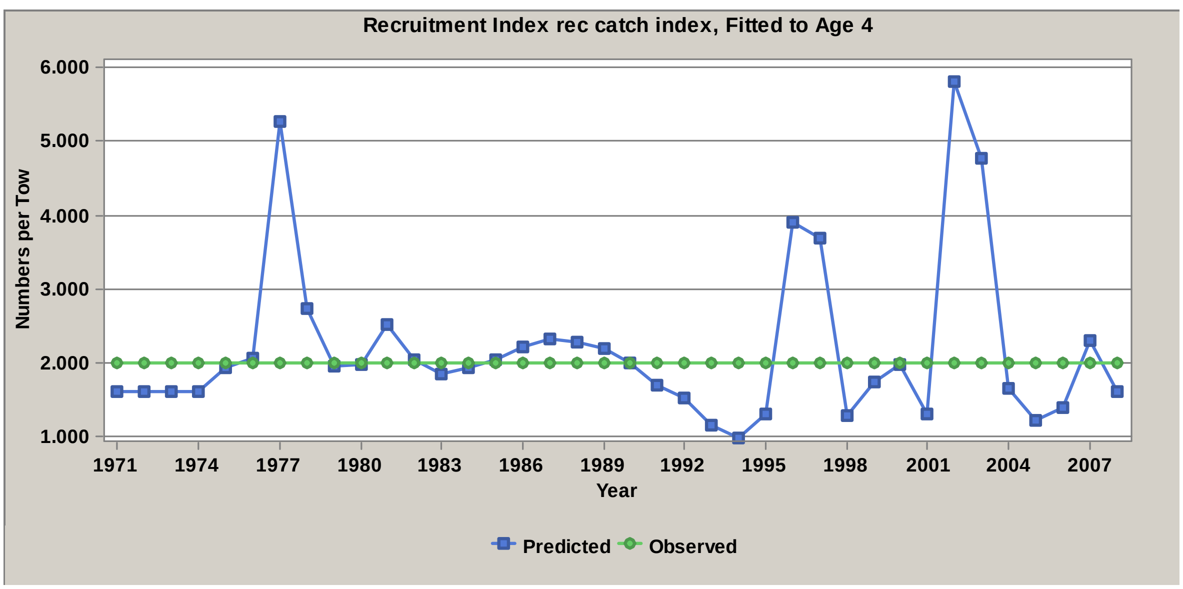


Figure A42. SCALE base run 1 Straight line recruitment index.

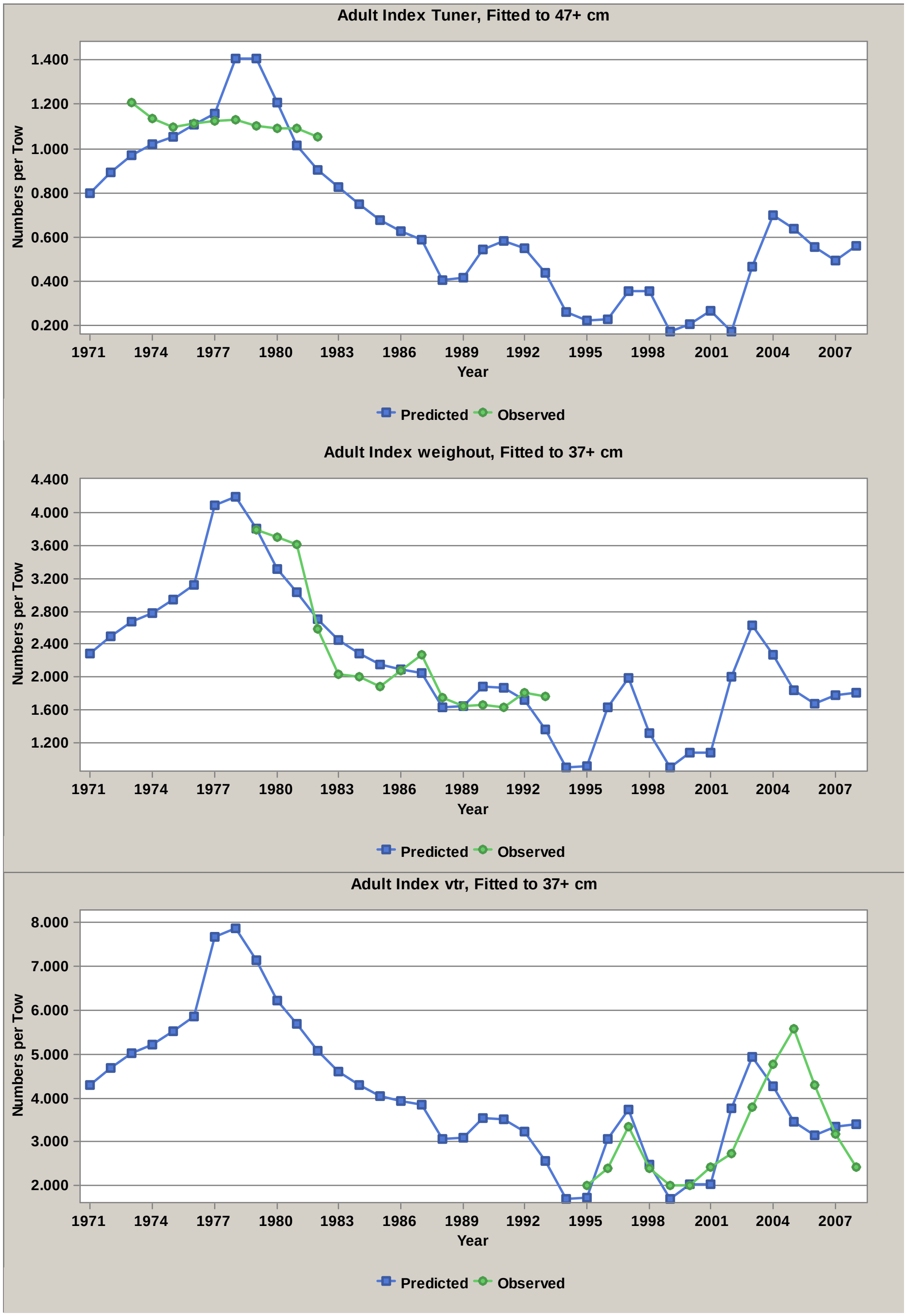


Figure A43. SCALE base run 1 fit to the three cpue indices.

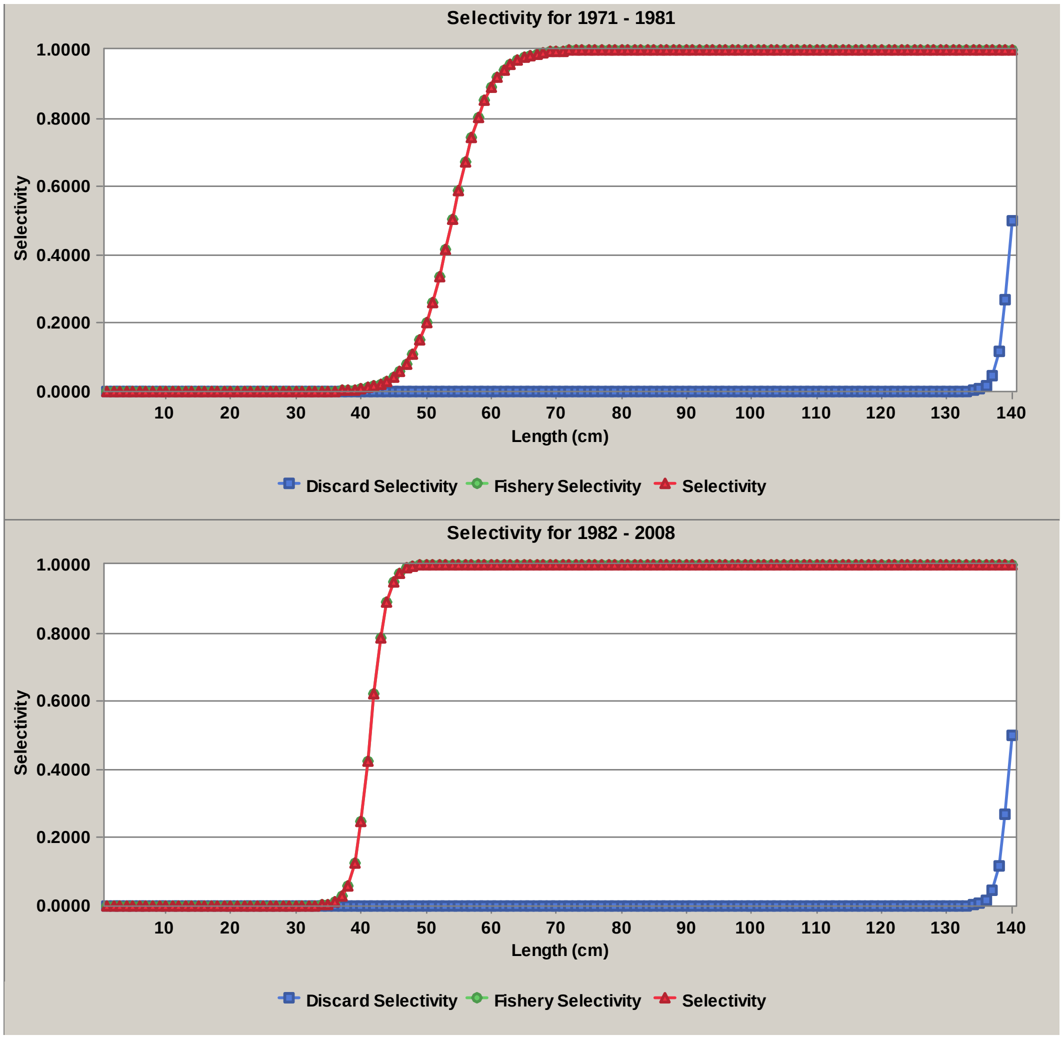


Figure A44. SCALE base run 1 estimated selectivity (block 1 is from1971-1981, block 2 is from 1984-2008).

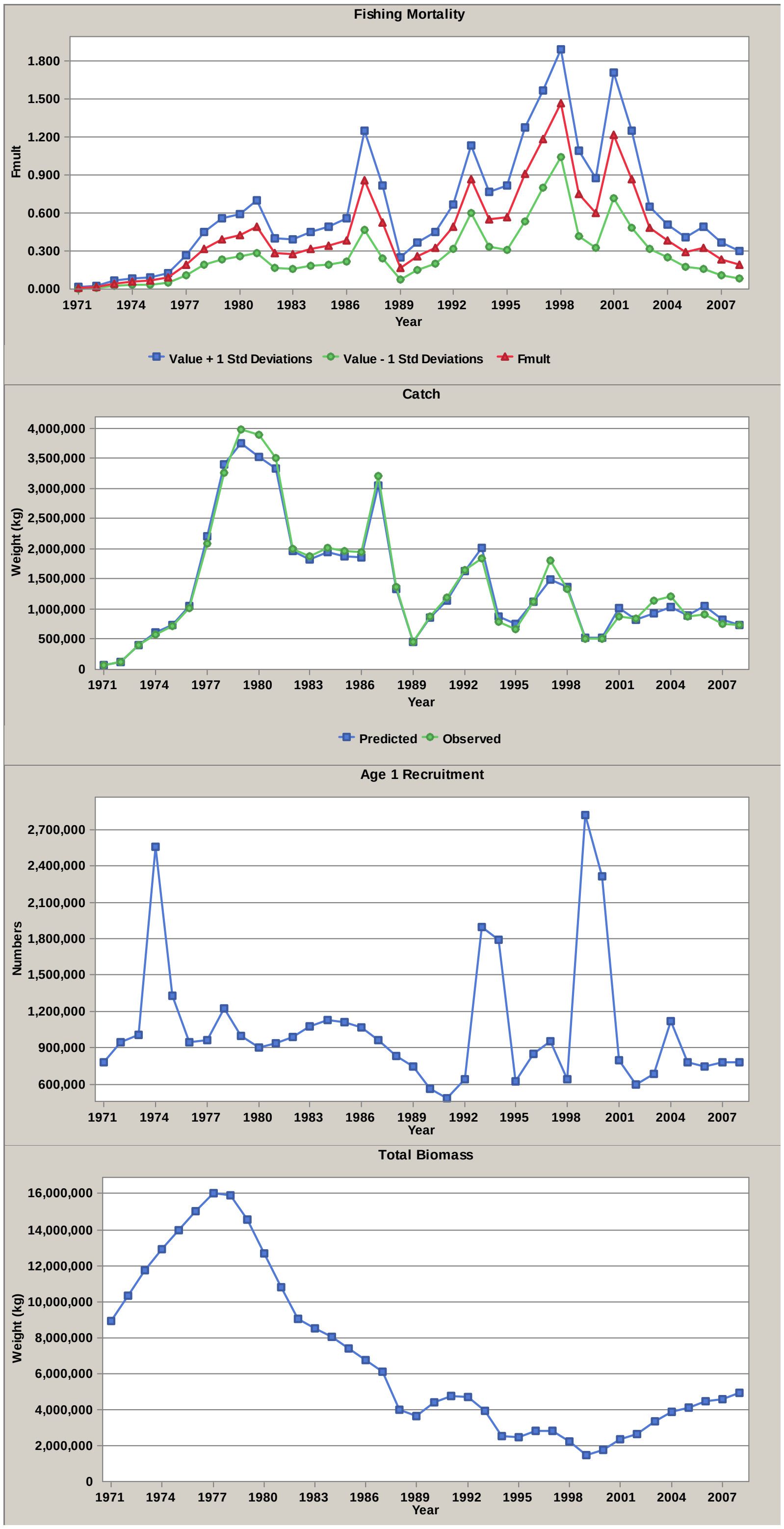
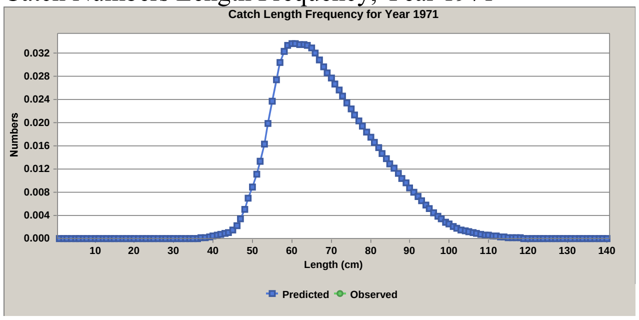
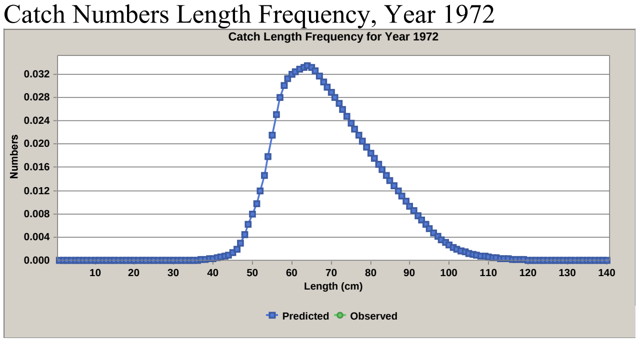


Figure A45. SCALE base run 1 estimated F, fit to the catch, estimated recruitment, and total biomass.

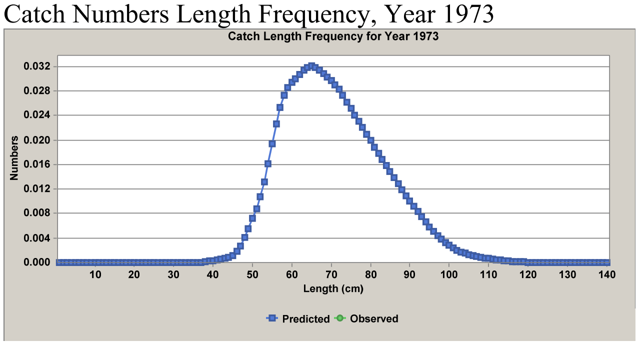
Catch Numbers Length Frequency, Year 1971



Catch Numbers Length Frequency, Year 1972



Catch Numbers Length Frequency, Year 1973



Catch Numbers Length Frequency, Year 1974

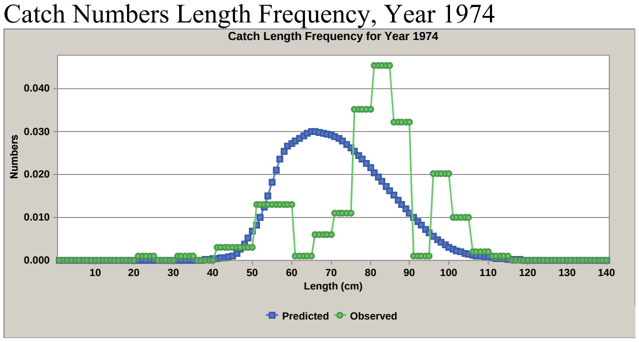
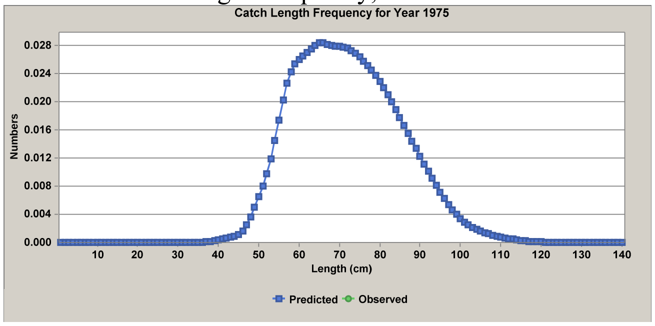
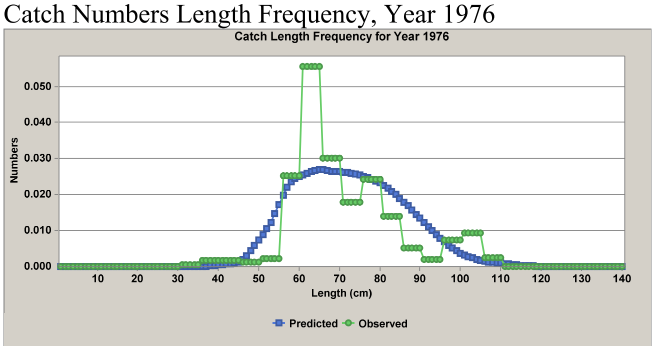


Figure A46. SCALE base run 1 predicted (blue) and observed (green) catch distributions by year. Years which do not have data are also shown.

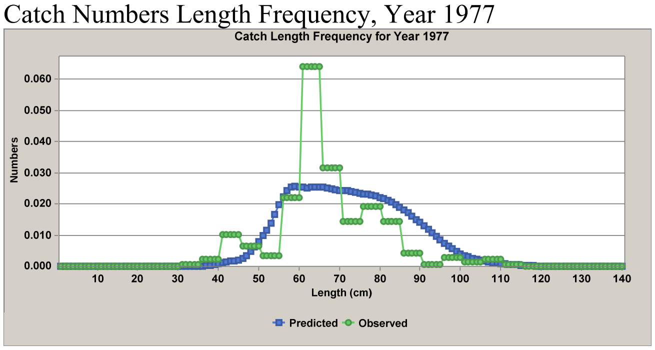
Catch Numbers Length Frequency, Year 1975



Catch Numbers Length Frequency, Year 1976



Catch Numbers Length Frequency, Year 1977



Catch Numbers Length Frequency, Year 1978

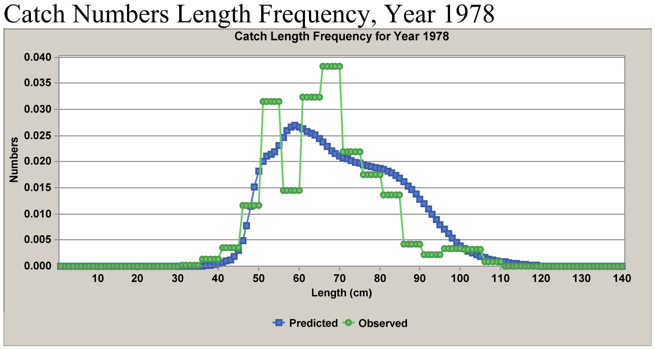
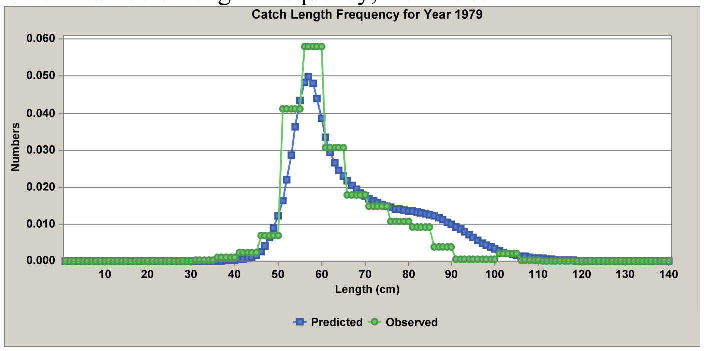
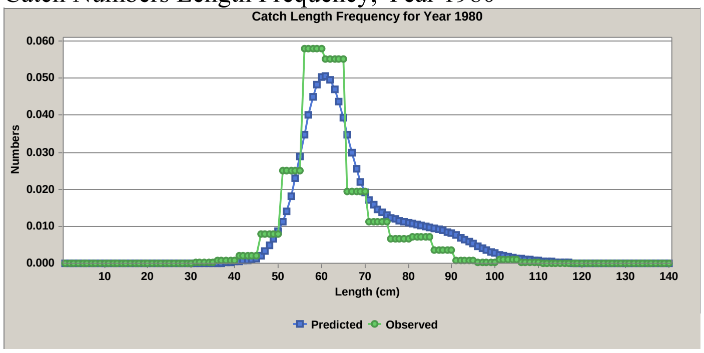


Figure A46. cont.

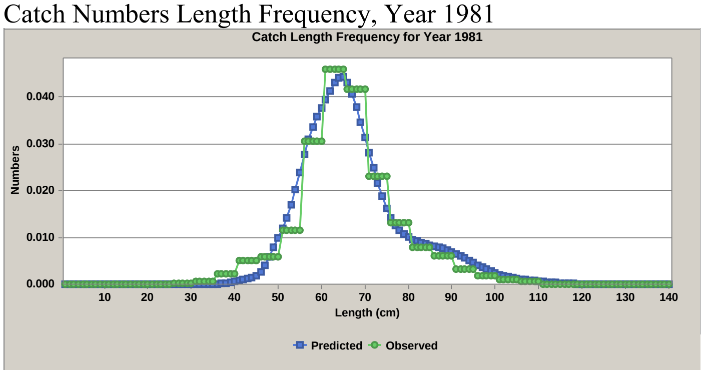
Catch Numbers Length Frequency, Year 1979



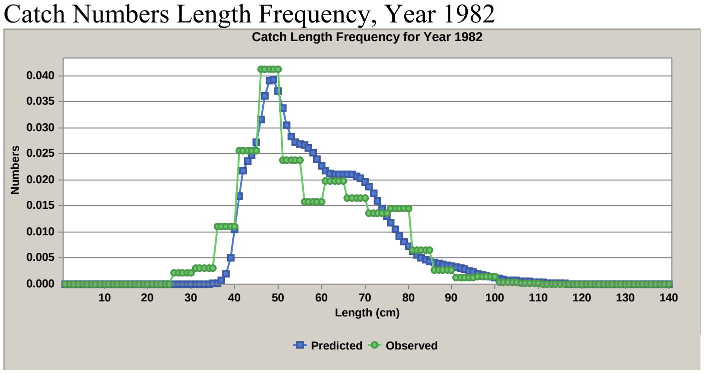
Catch Numbers Length Frequency, Year 1980



Catch Numbers Length Frequency, Year 1981



Catch Numbers Length Frequency, Year 1982



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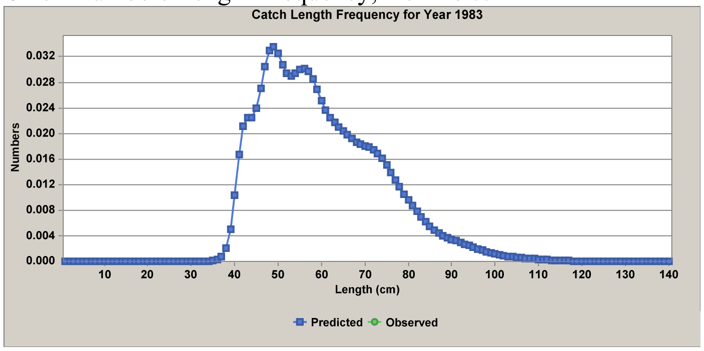
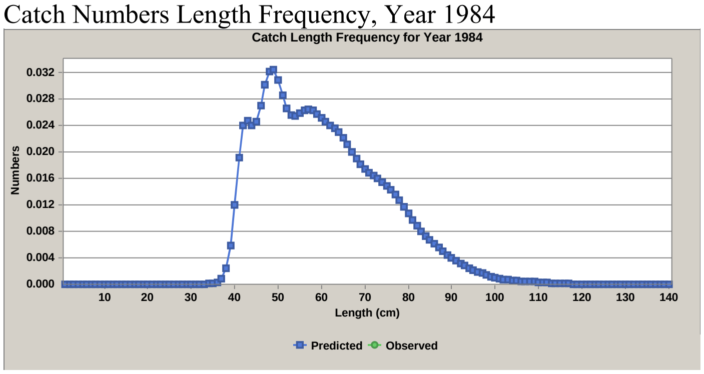
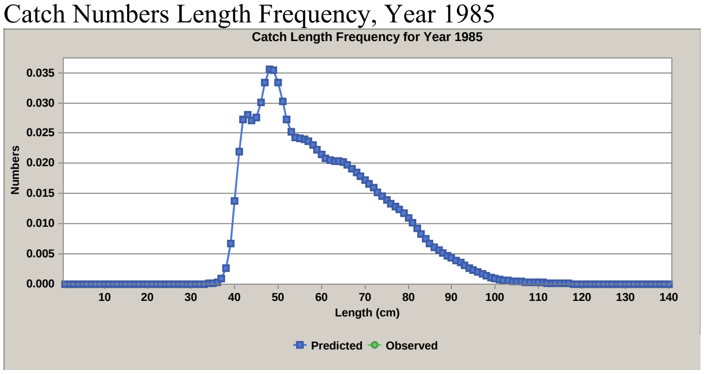
Catch Numbers Length Frequency, Year 1983



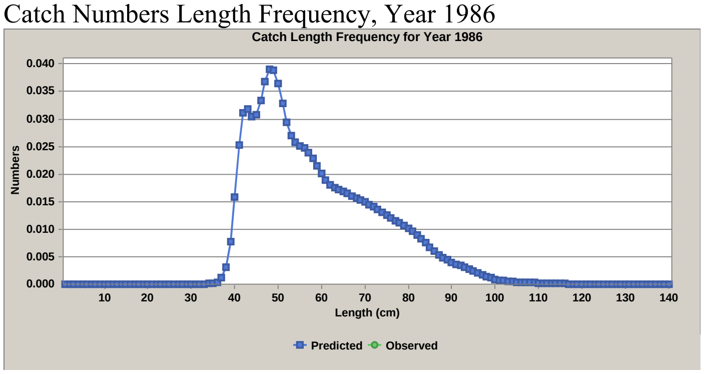
Catch Numbers Length Frequency, Year 1984



Catch Numbers Length Frequency, Year 1985



Catch Numbers Length Frequency, Year 1986



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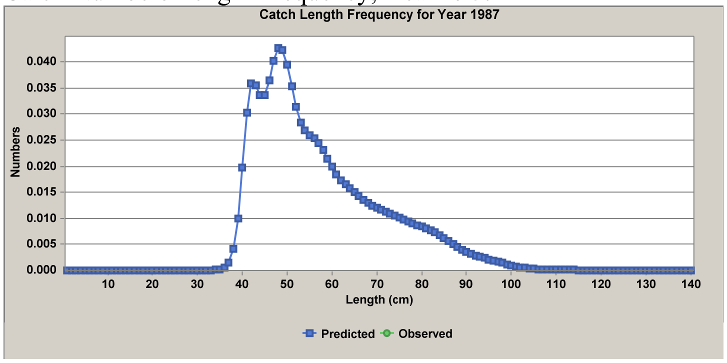
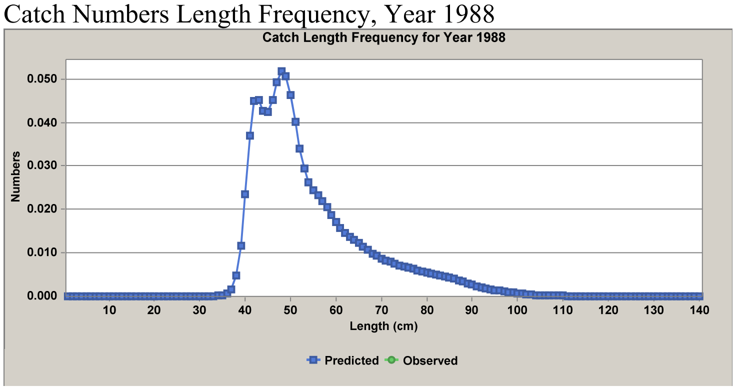
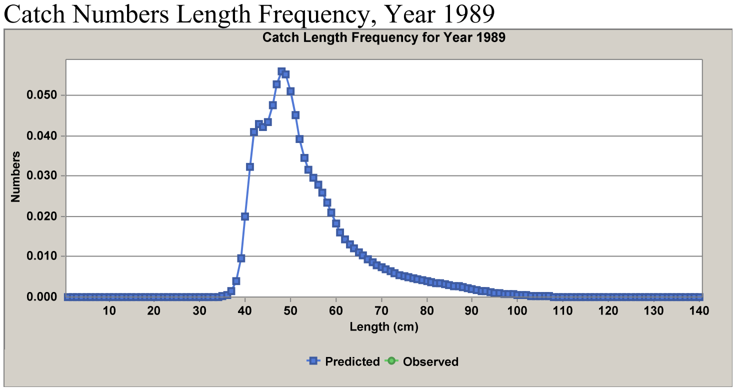
Catch Numbers Length Frequency, Year 1987



Catch Numbers Length Frequency, Year 1988



Catch Numbers Length Frequency, Year 1989



Catch Numbers Length Frequency, Year 1990

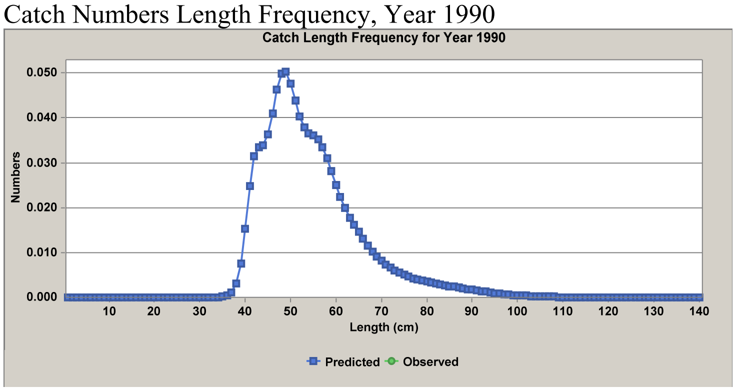
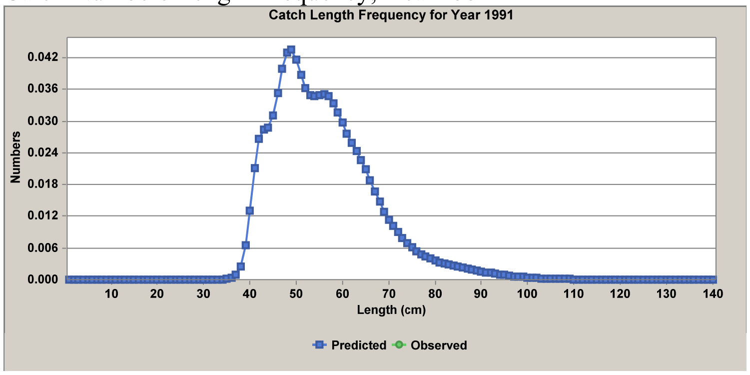
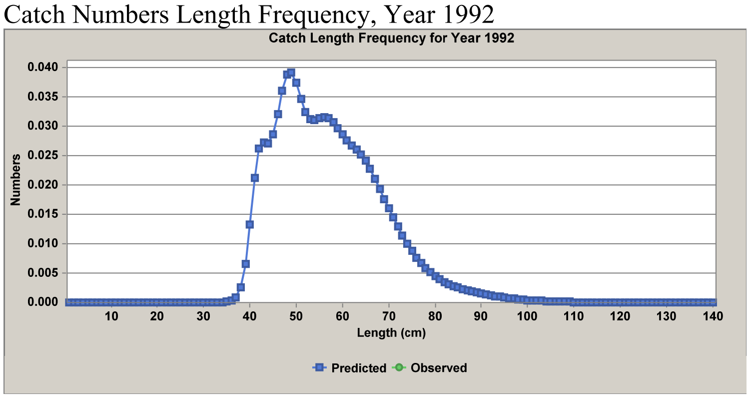


Figure A46. cont.

Catch Numbers Length Frequency, Year 1991



Catch Numbers Length Frequency, Year 1992



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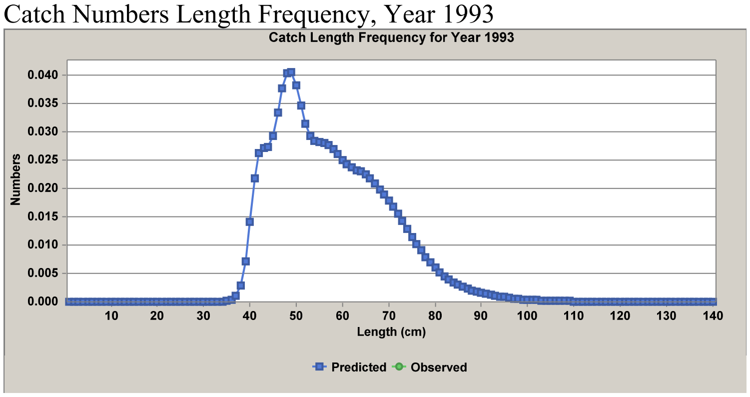


Catch Numbers Length Frequency, Year 1994

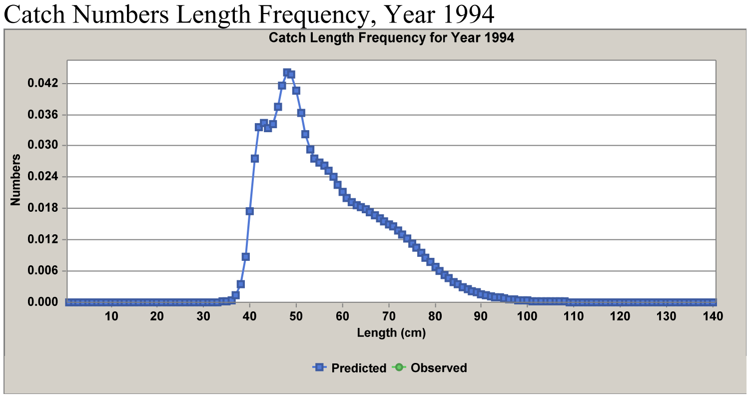
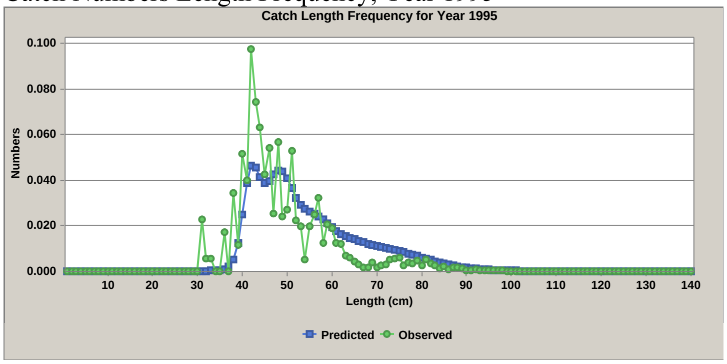
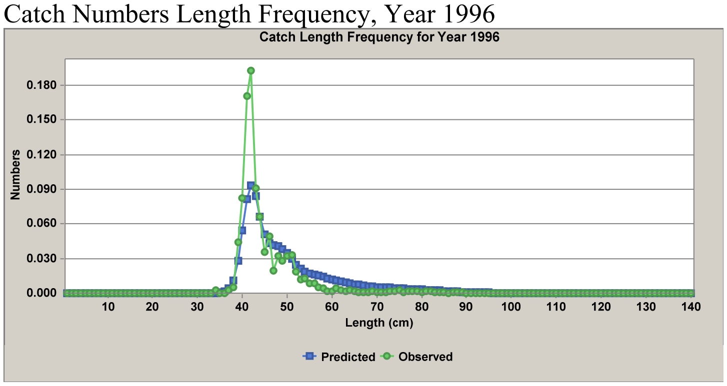


Figure A46. cont.

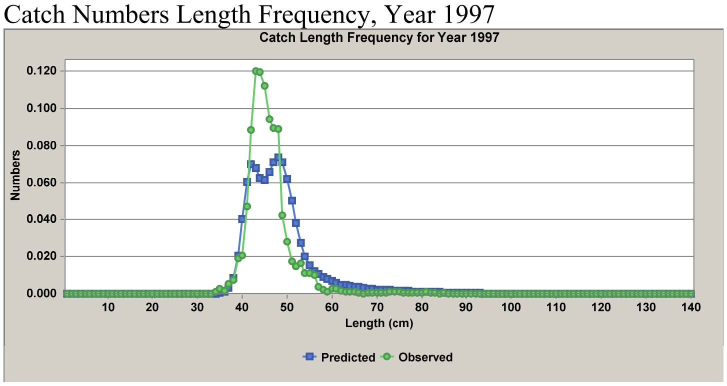
Catch Numbers Length Frequency, Year 1995



Catch Numbers Length Frequency, Year 1996



Catch Numbers Length Frequency, Year 1997



Catch Numbers Length Frequency, Year 1998

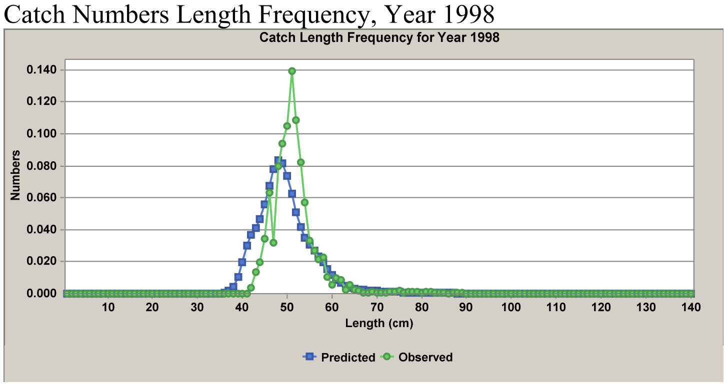
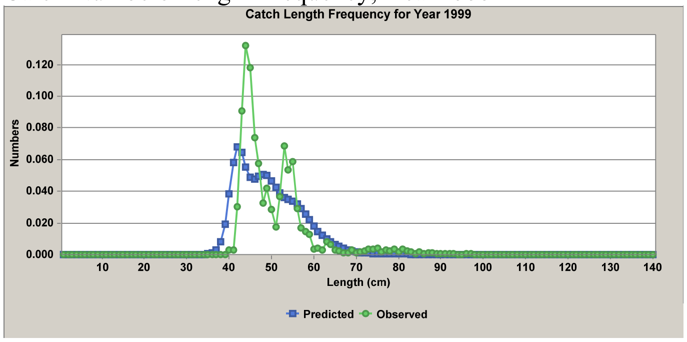
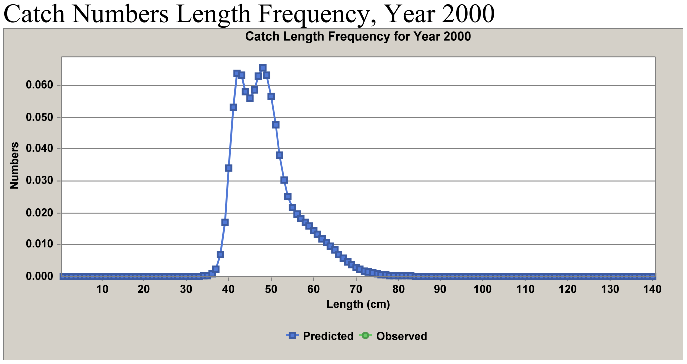


Figure A46. cont.

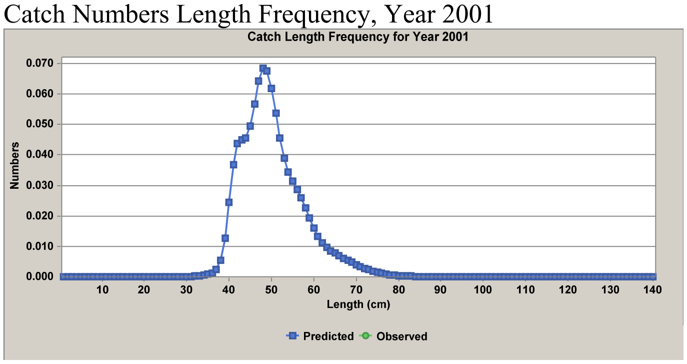
Catch Numbers Length Frequency, Year 1999



Catch Numbers Length Frequency, Year 2000



Catch Numbers Length Frequency, Year 2001



Catch Numbers Length Frequency, Year 2002

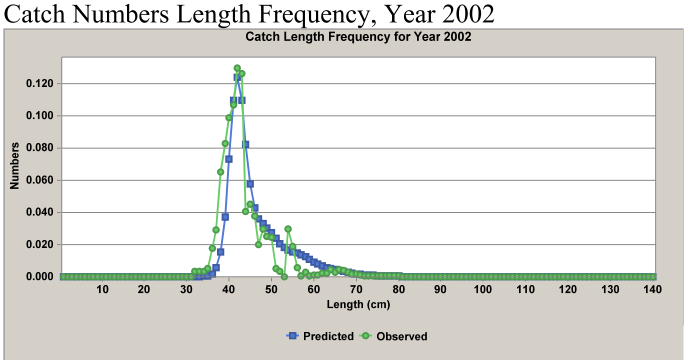
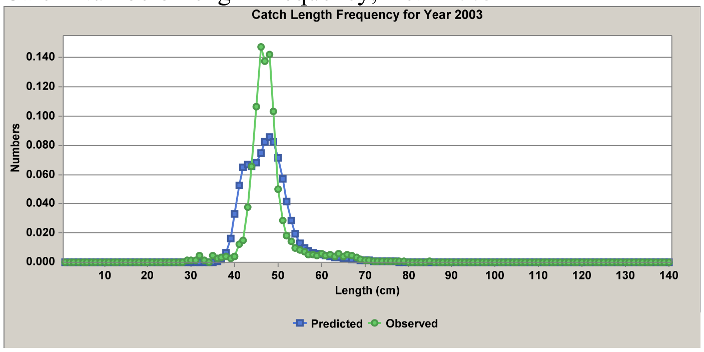
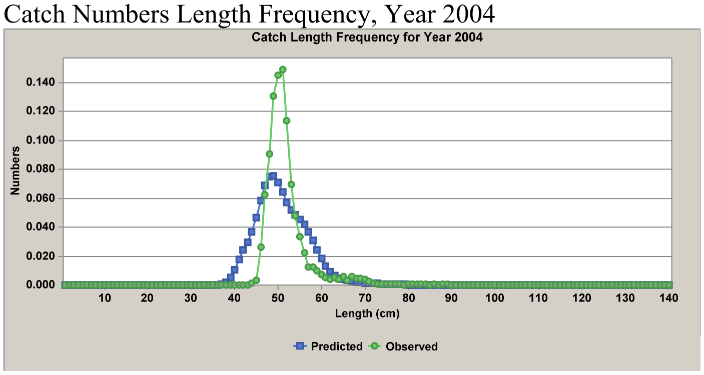


Figure A46. cont.

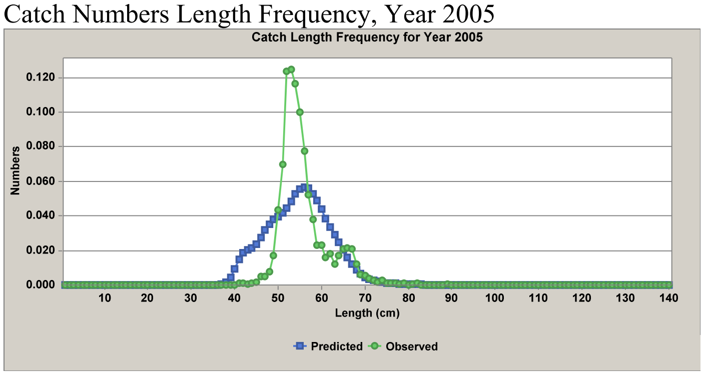
Catch Numbers Length Frequency, Year 2003



Catch Numbers Length Frequency, Year 2004



Catch Numbers Length Frequency, Year 2005



Catch Numbers Length Frequency, Year 2006

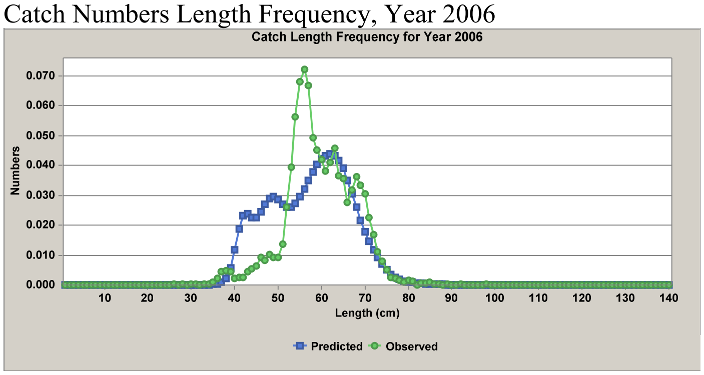
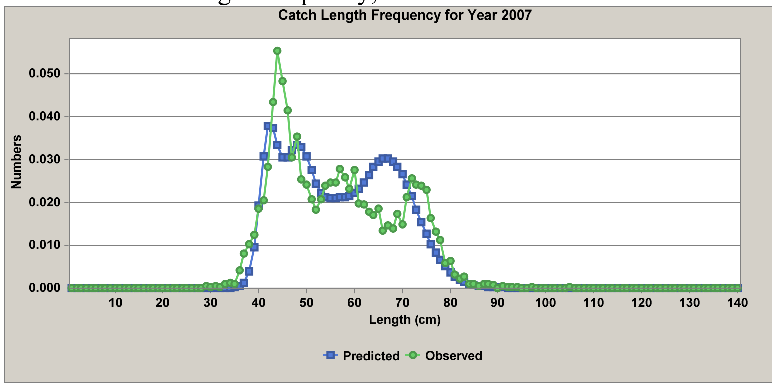
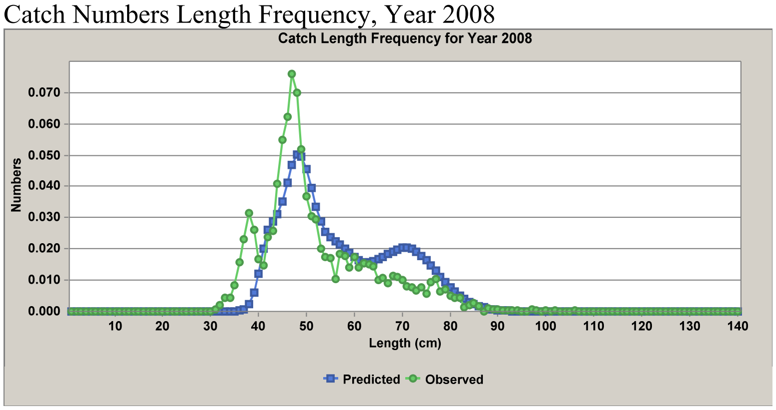


Figure A46. cont.

Catch Numbers Length Frequency, Year 2007



Catch Numbers Length Frequency, Year 2008



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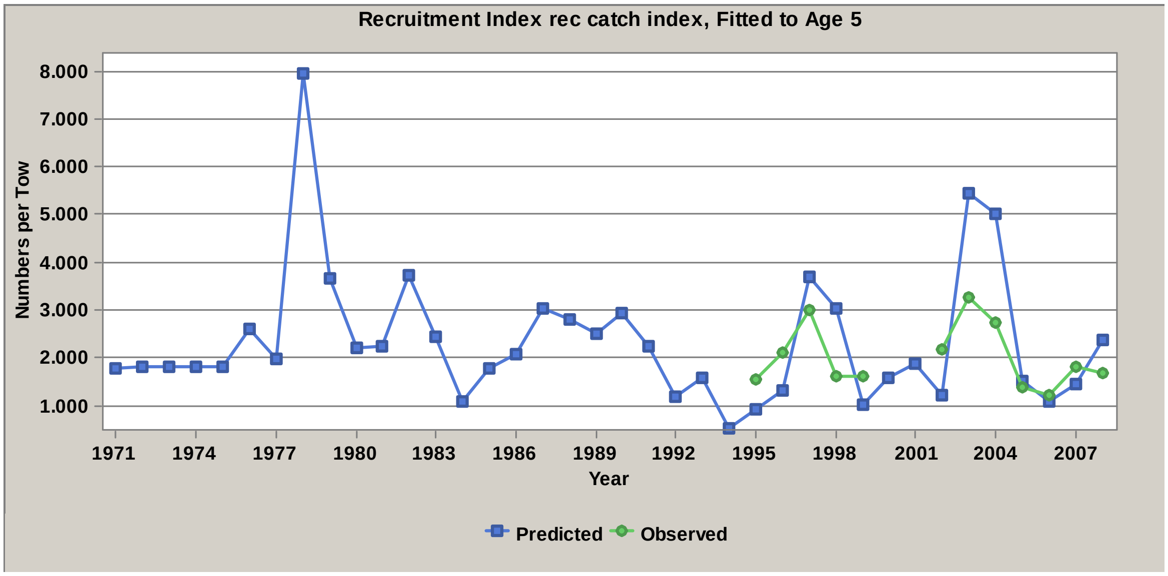


Figure A47. SCALE run 6 was fit to the recruitment index at age 5. The VTR cpue index was applied to the landings proportion at length and 40-50 cm fish were sliced from the index as age 5.

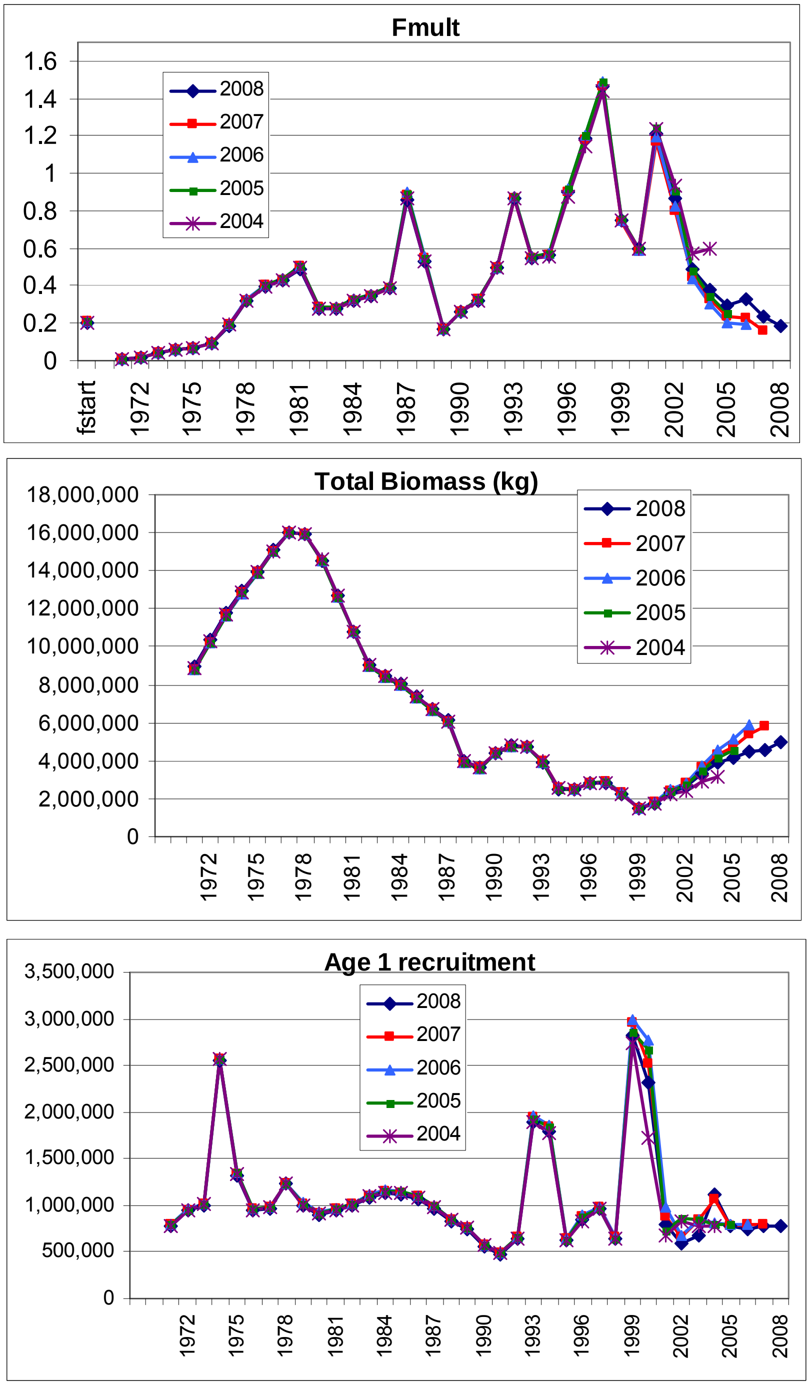


Figure A48. SCALE base run 1 retrospective pattern.

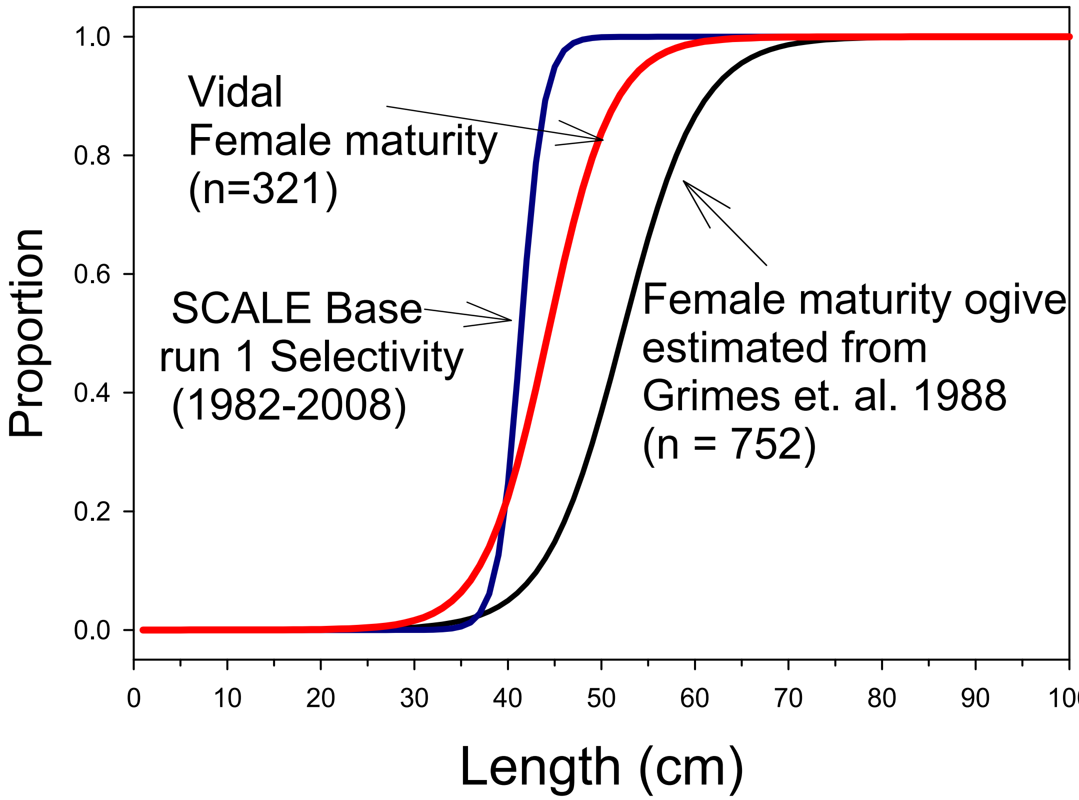


Figure A49. Comparison of SCALE base run 1 selectivity from block 2 (1984-2008), Vidal updated female maturity at length, and Grimes et al (1988) female maturity at length curves.

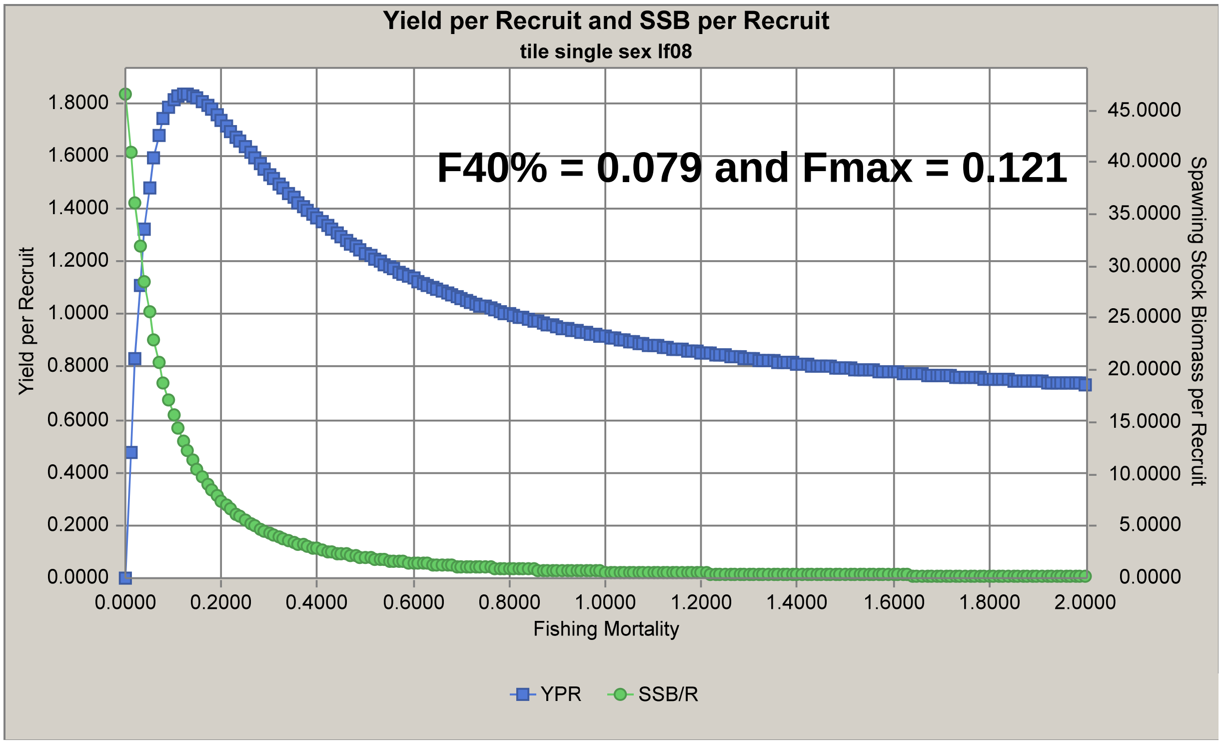


Figure A50. SCALE base run 2 age based YPR and spawners per recruit curves.

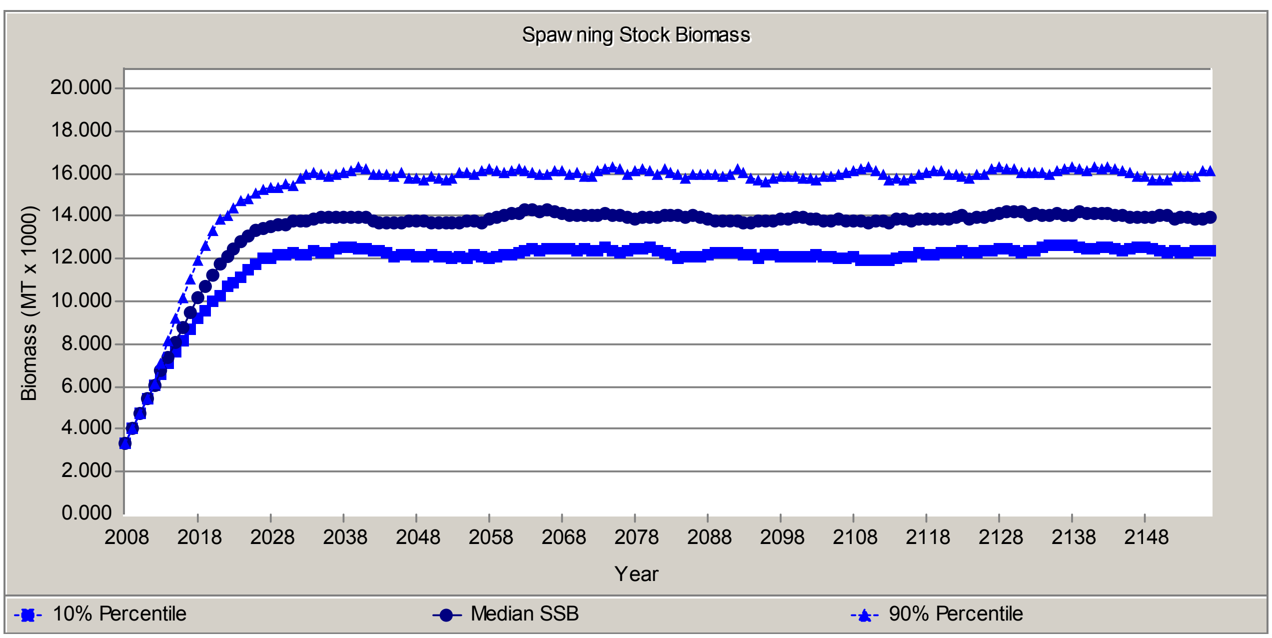


Figure A51. Long term AGEPRO projection at Fmax = 0.121 for run 2 using CDF of recruitment from 1971-2008.

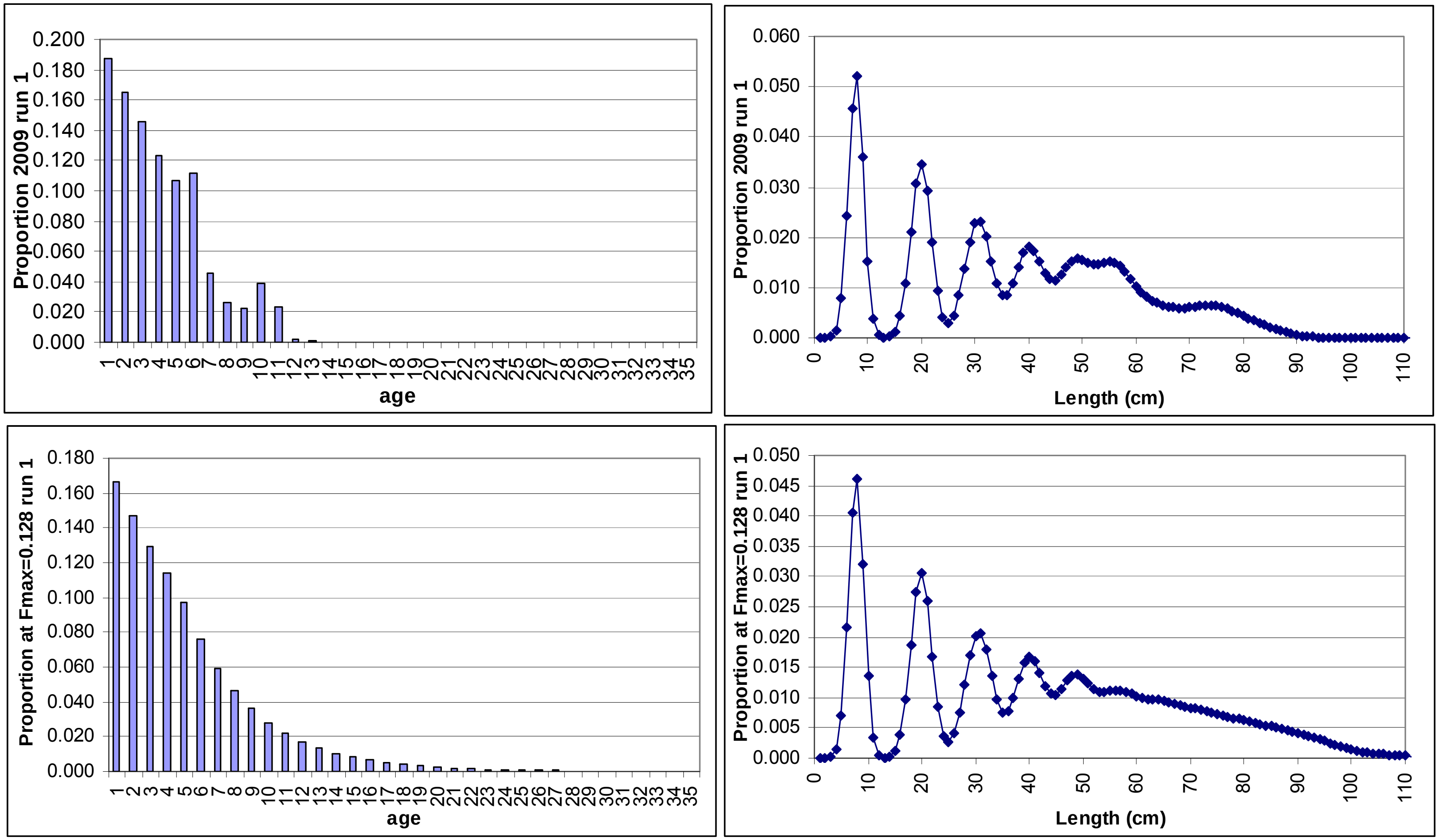


Figure A52. SCALE base run 1 comparison of proportion at length and age in 2009 to Fmax predicted length and age distributions.

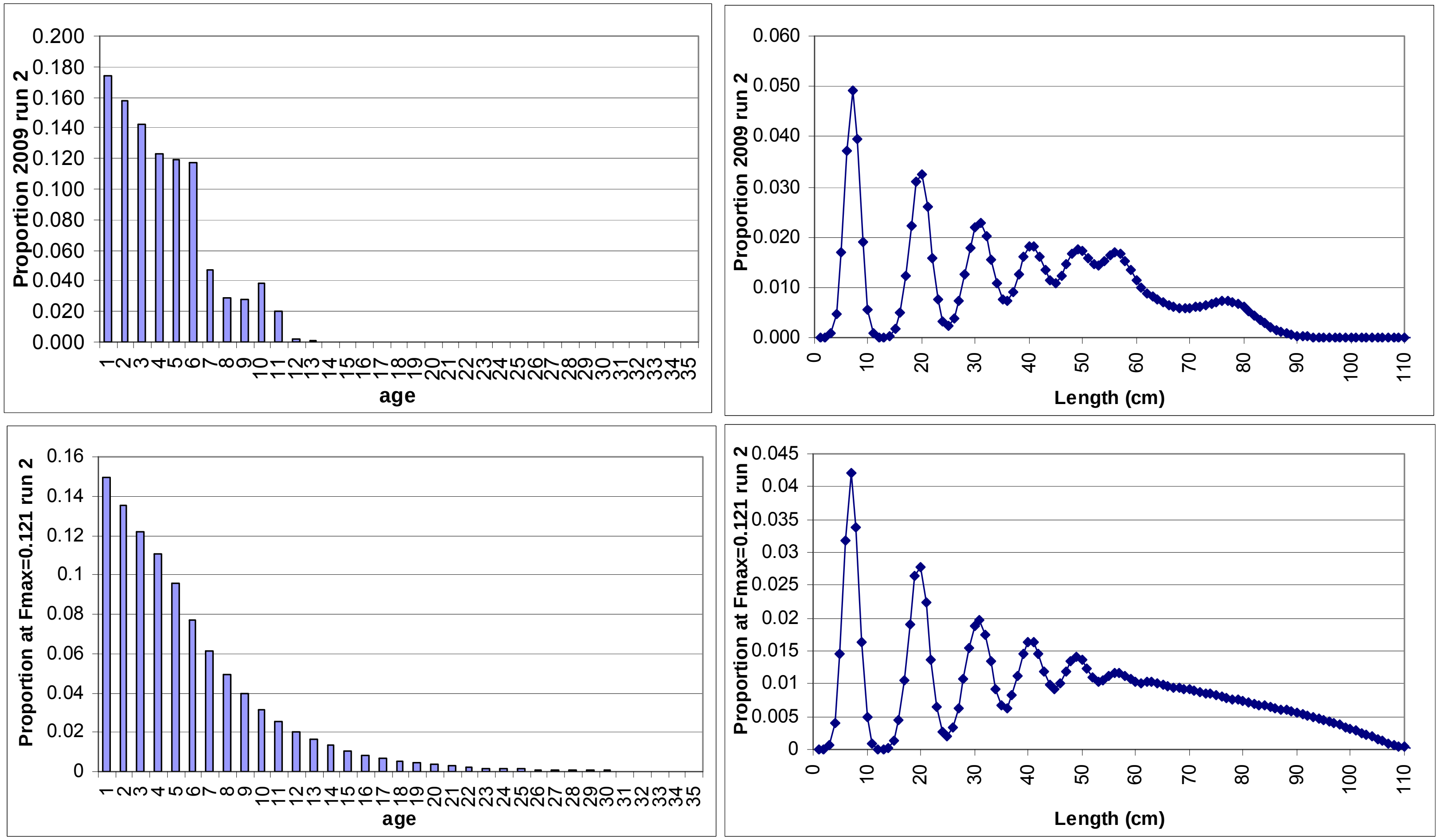


Figure A53. SCALE base run 2 comparison of proportion at length and age in 2009 to Fmax predicted length and age distributions.

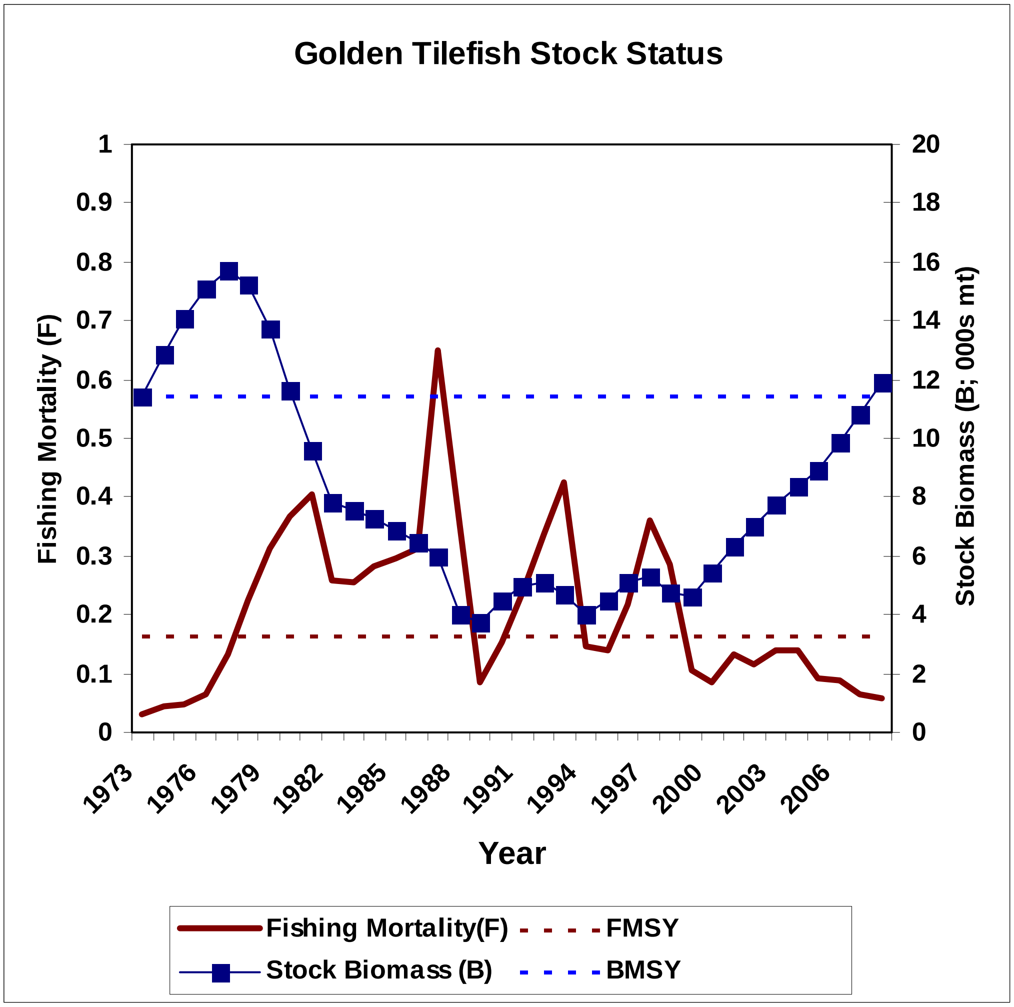


Figure A54. Stock status evaluation for Golden tilefish: 2009 BASE model run.

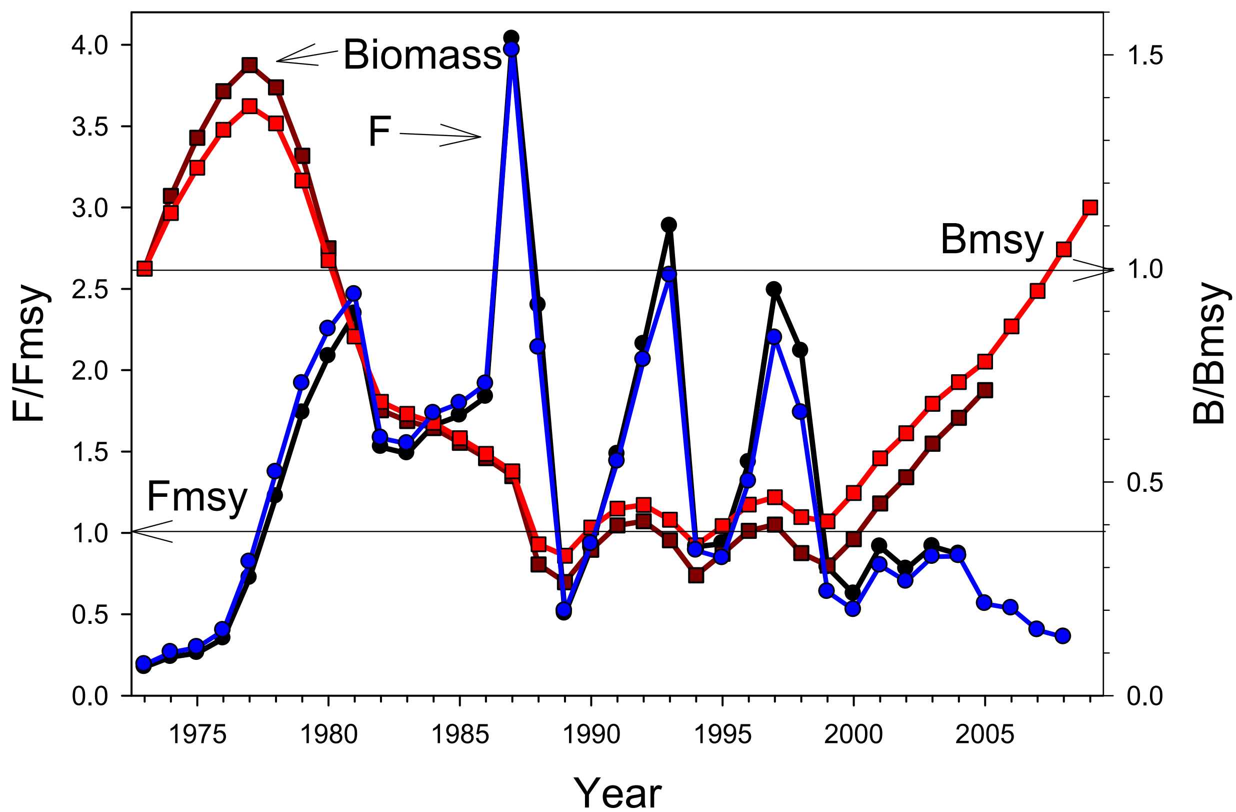


Figure A55. SARC 41 and SARC 48 trends in F/Fmsy and B/ Bmsy ratios for the base ASPIC run which fixed the B1/Bmsy ratio at 1 and used three CPUE series (Turner, Weighout, and VTR).

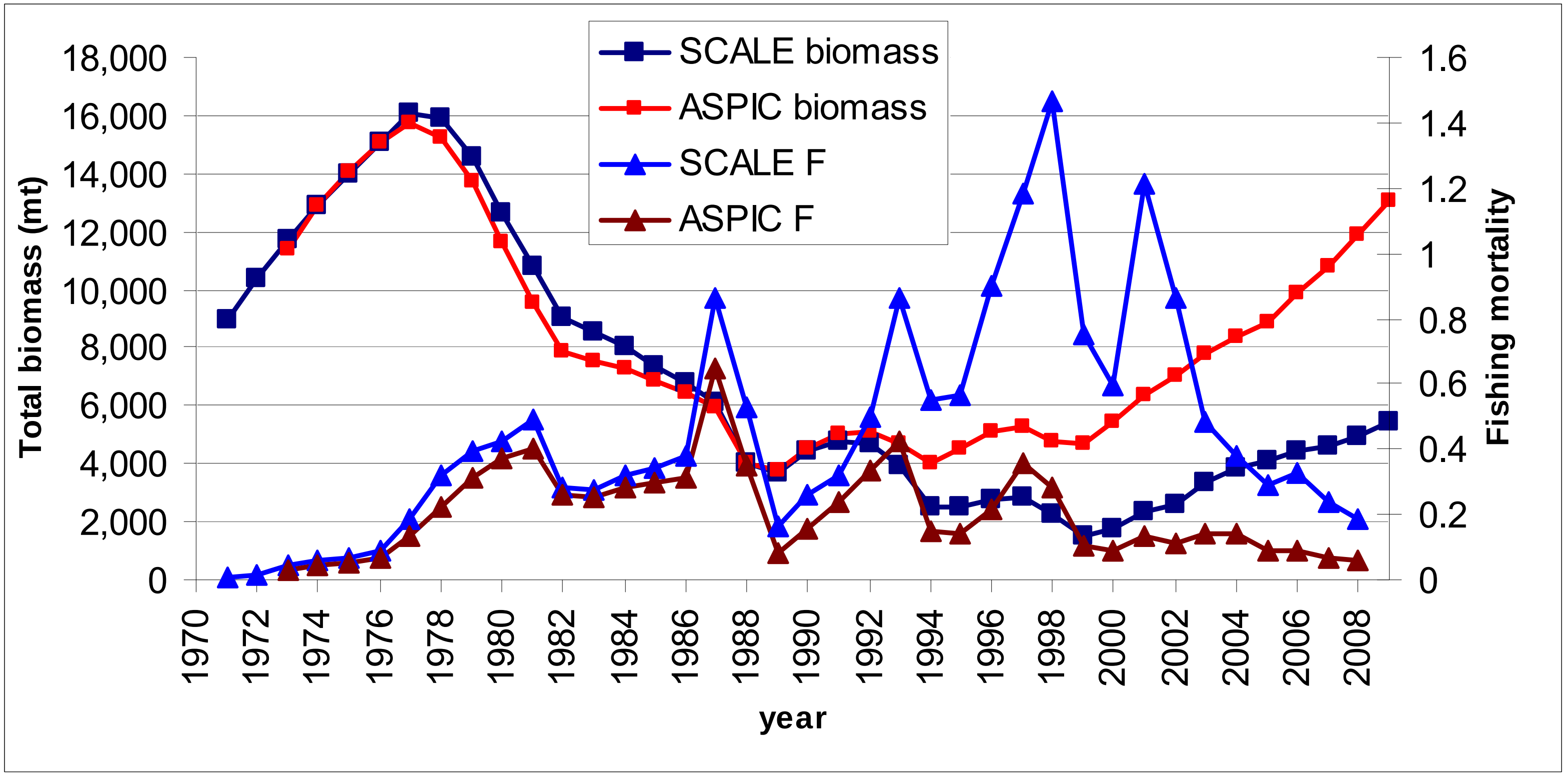


Figure A56. Comparison of F (triangles) and total biomass (squares) between the ASPIC base run 1 with the SCALE base run 1. Note ASPIC base run fixed the biomass in 1973 at Bmsy and SCALE base run estimated Fstart at 0.20.

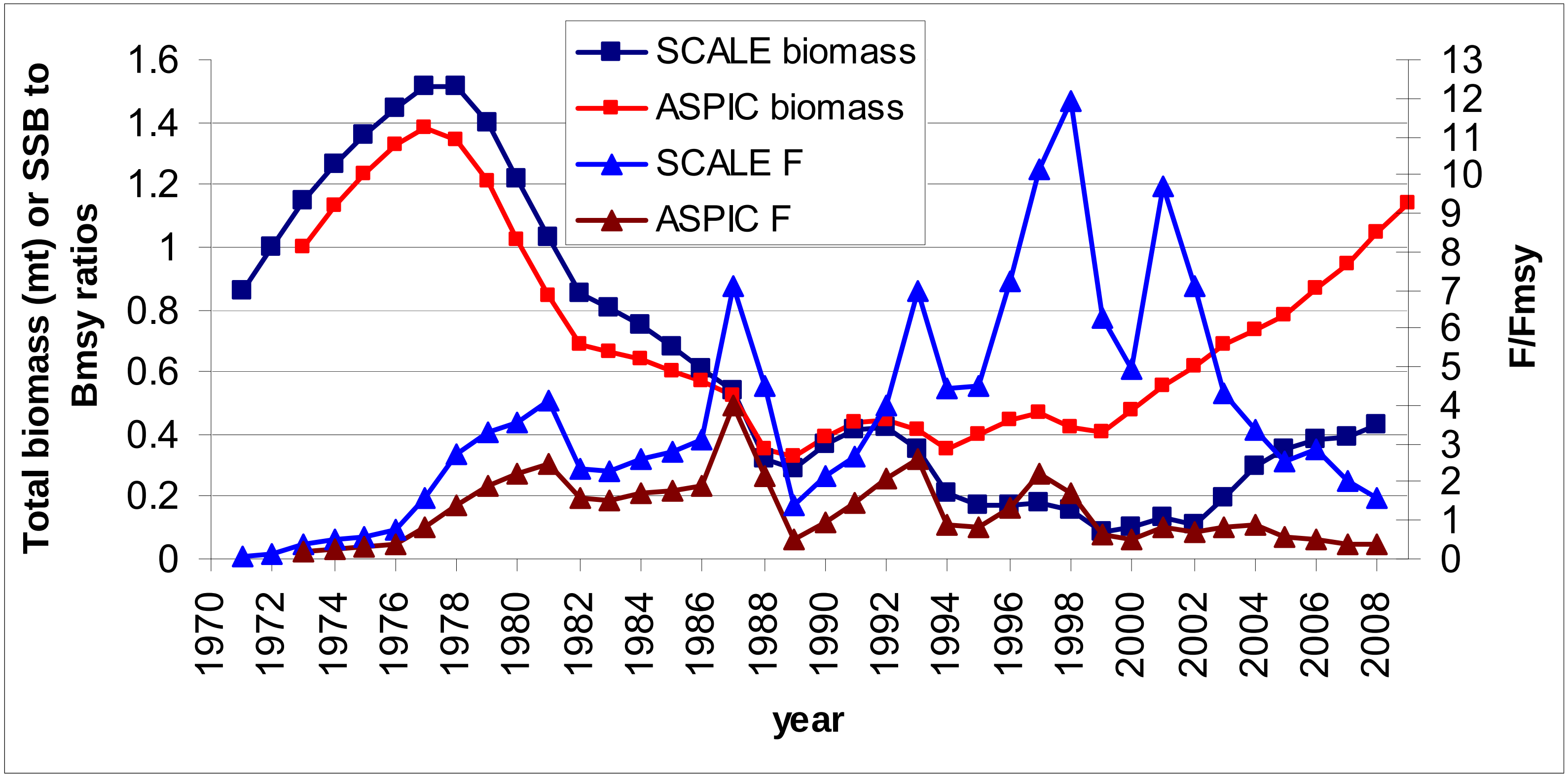


Figure A57. Comparison of F to Fmsy ratio (triangles) and total biomass or SSB to Bmsy ratios (squares) between the ASPIC base run 1 with the SCALE base run 1. Note ASPIC base run fixed the biomass in 1973 at Bmsy and SCALE base run estimated Fstart at 0.20. Fmax (0.128) is used as a proxy for Fmsy and SSBmsy (5,335 mt) is for females only in the SCALE base run 1.

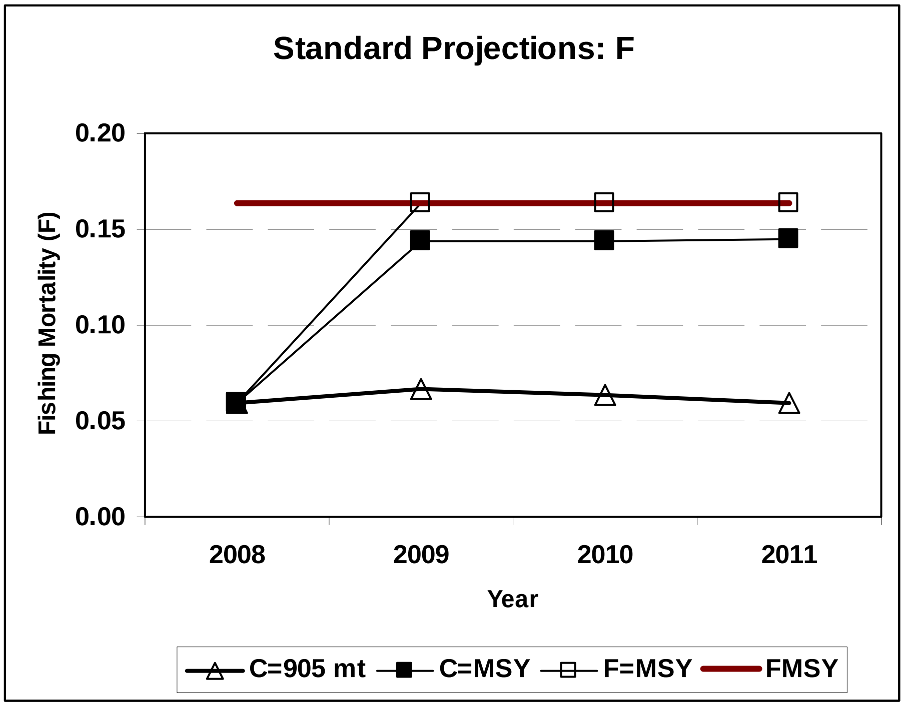


Figure A58. Standard ASPIC projections of fishing mortality (F) for 2009-2011 under alternative assumption for catch (C) or F.

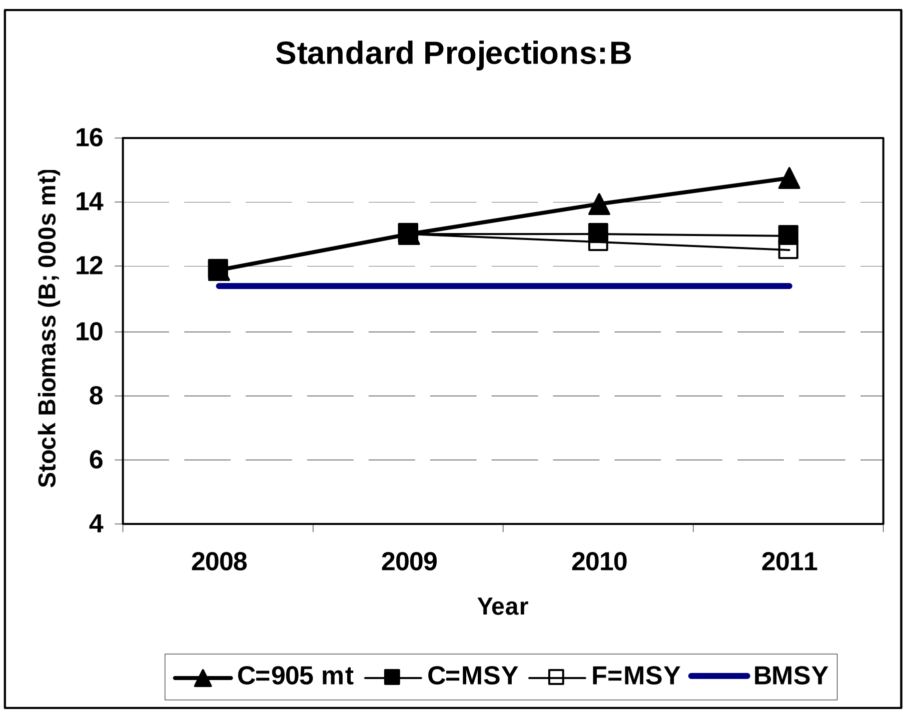


Figure A59. Standard ASPIC projections of stock biomass (B) for 2009-2011 under alternative assumption for catch or F.

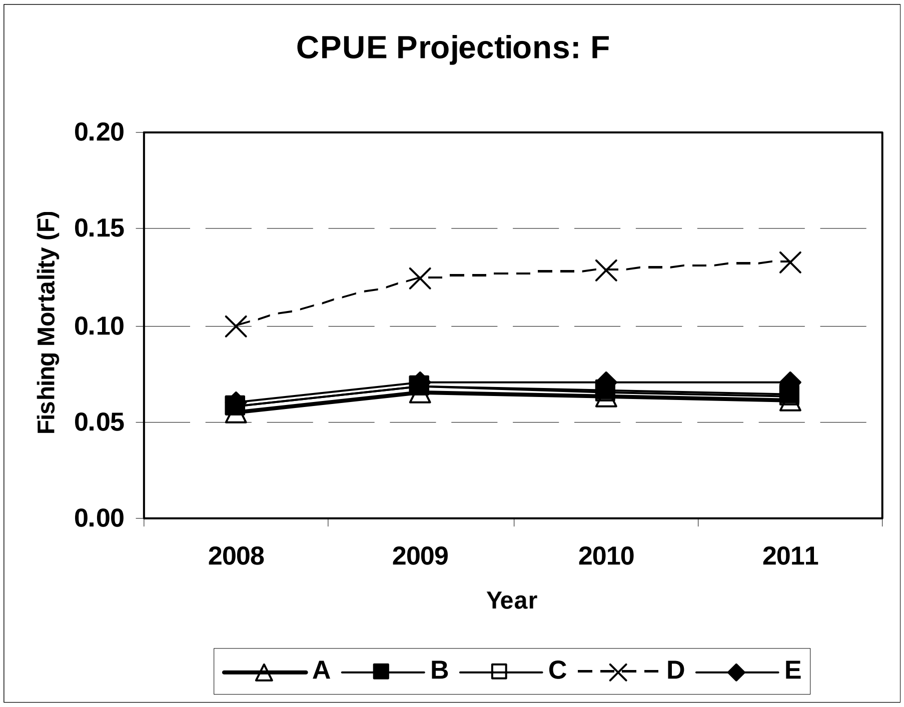


Figure A60. CPUE projections of fishing mortality (F) for 2009-2011 under alternative assumptions for the future trend in fishery VTR CPUE indices (see text).

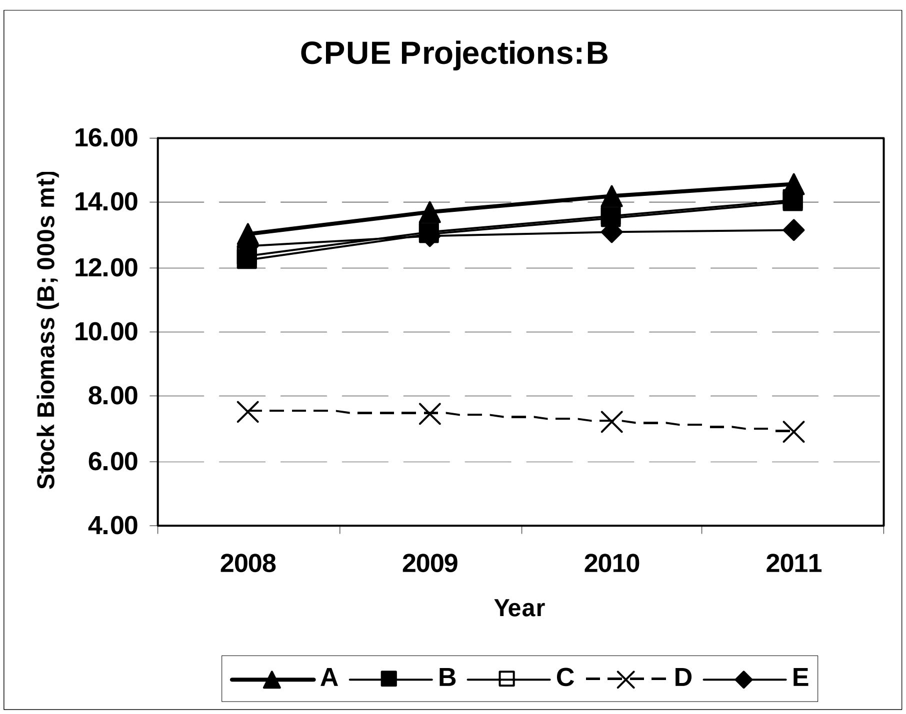


Figure A61. CPUE projections of stock biomass (B) for 2009-2011 under alternative assumptions for the future trend in fishery VTR CPUE indices (see text).

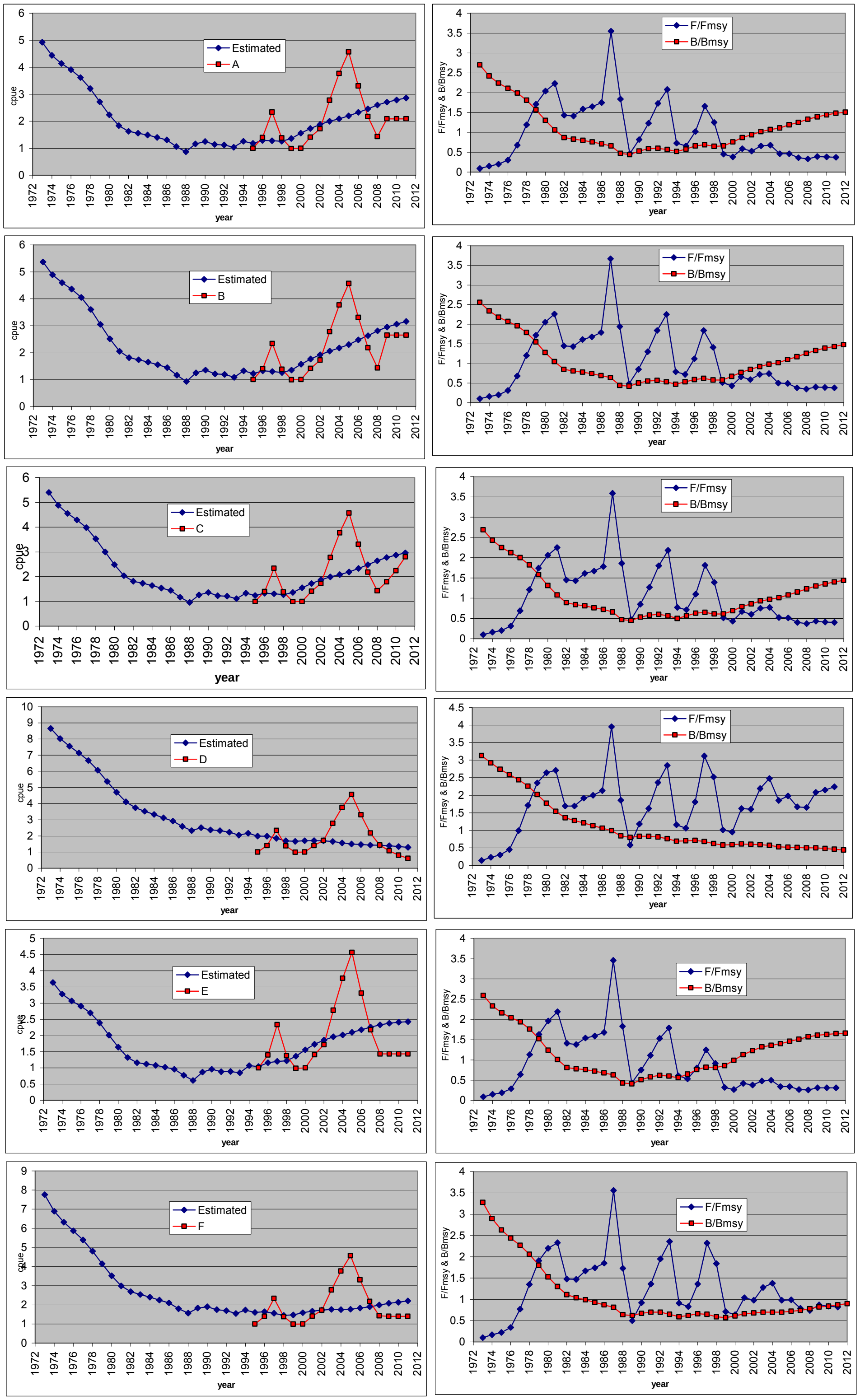


Figure A62. Sensitivity scenarios assuming a constant quota (905 mt) and different cpue estimates from 2009-2011.

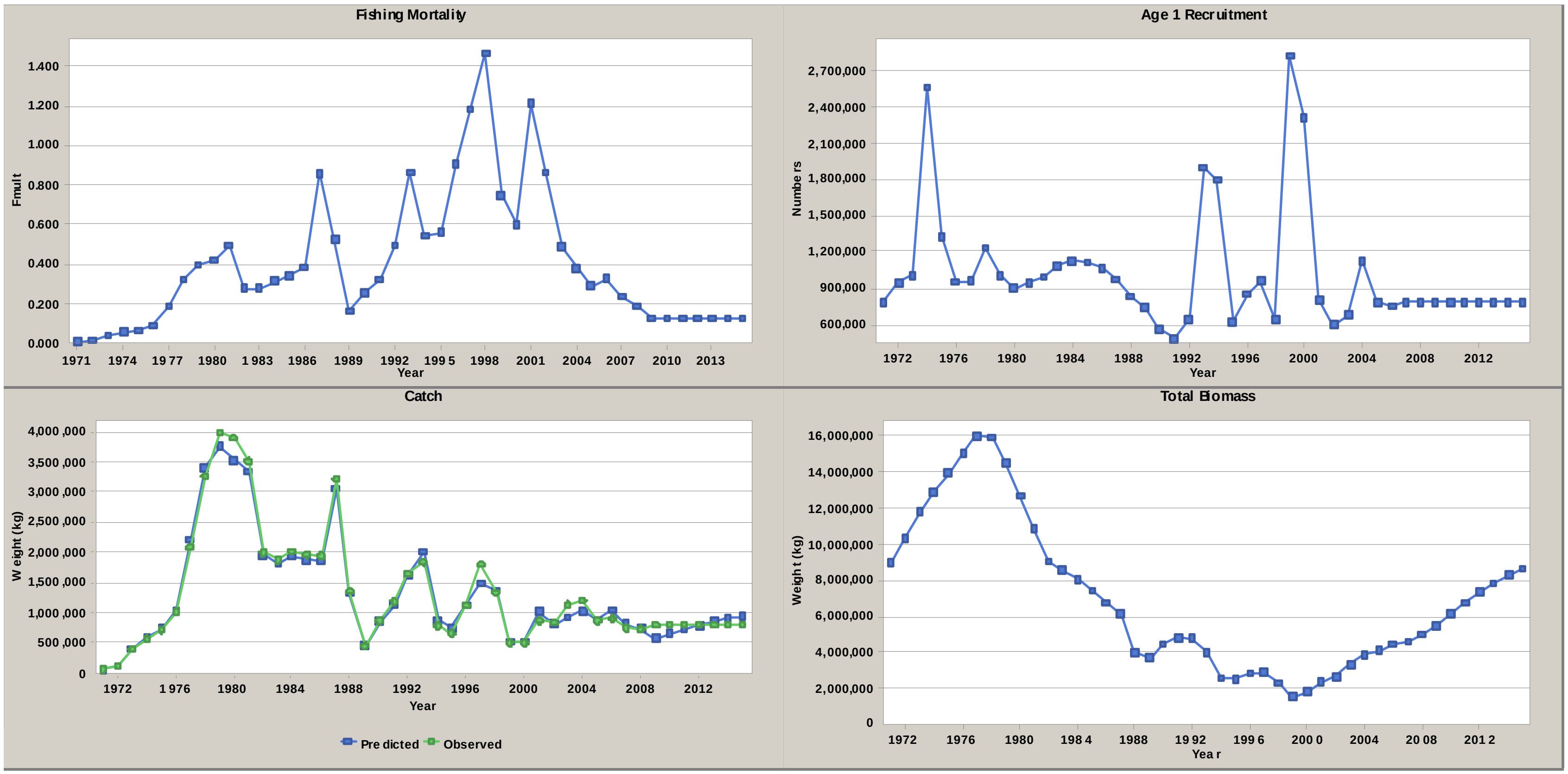


Figure A63. Example of a deterministic SCALE Projection Base run 1 assuming Fmsy=fmax=0.13 from 2009-2015.

Grouped Fmult, Age 1 Recruitment, Observed vs. Predicted Catch Weight, and Total Biomass

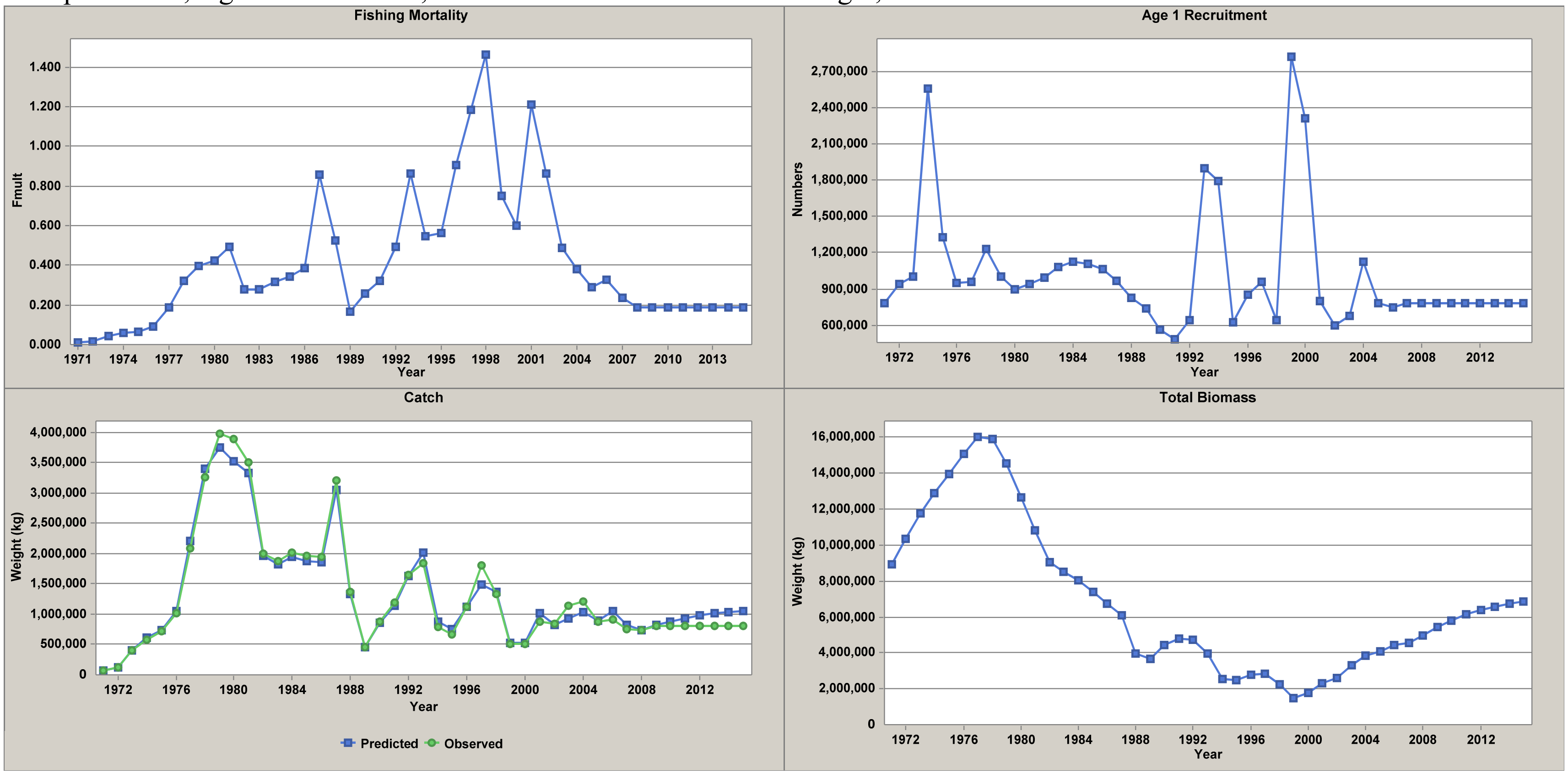
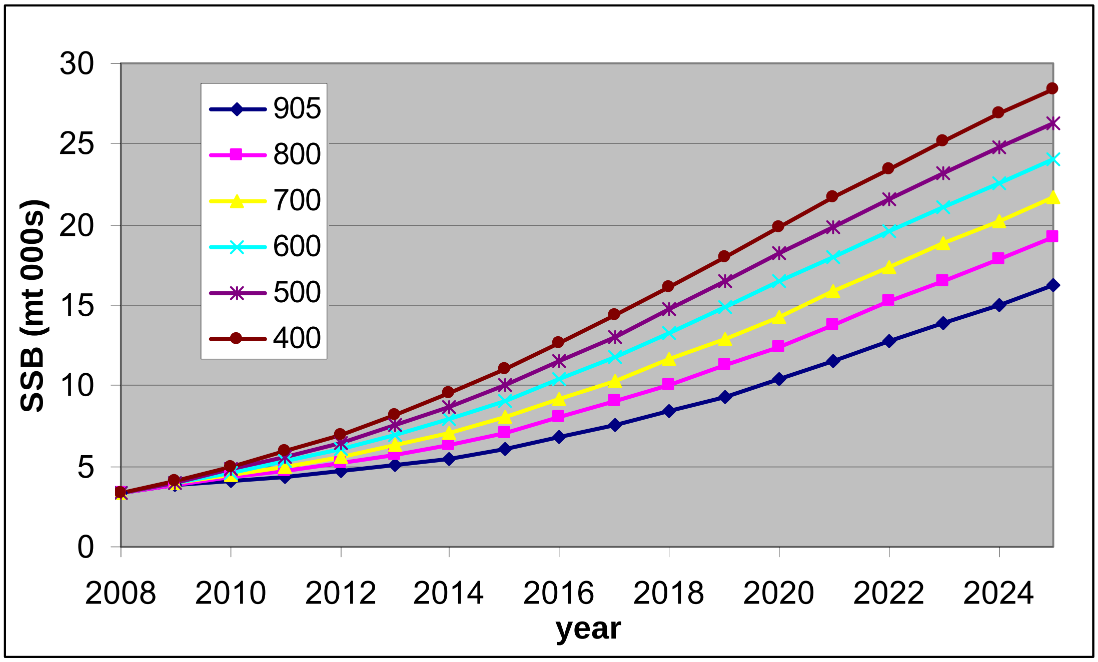


Figure A64. Example of a deterministic SCALE Projection Base run 1 assuming F2008 = 0.19 from 2009-2015.



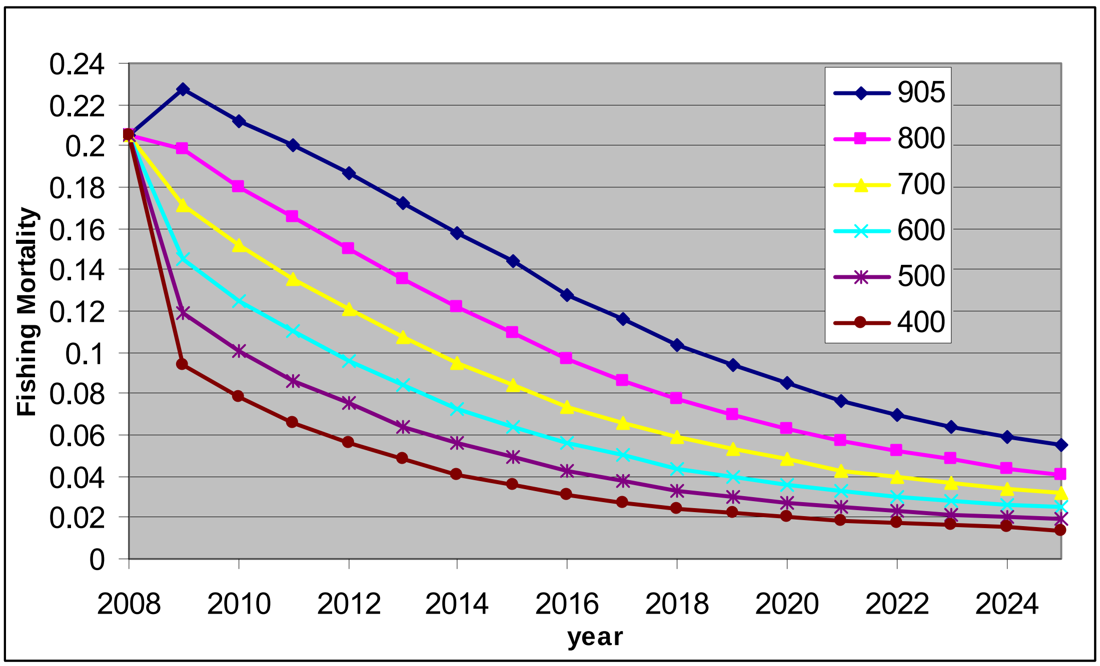


Figure A65. Comparison of SSB and F from Agepro projections for run 2 assuming different constant quotas using the CDF of recruitment from 1971-2008. Note a constant quota no higher than 500 mt is needed to reduce F to Fmax (0.12) in 2009.

Tilefish Appendixes

Working Paper Appendix A.1
June 1, 2009

An overview of the tilefish data collected through the Northeast Fisheries Science Center's Study Fleet project

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A Working Paper in Support of SAW 48 Terms of Reference A.1

Abstract

The last assessment of golden tilefish, *Lopholatilus chamaeleonticeps*, was based on a surplus production model which utilized a commercial catch per unit effort (CPUE) derived from fishing vessel trip reports (VTRs) as an index of abundance. The 2005 Stock Assessment Review Committee (41st SAW, 2005) concluded that "the effort metric (days absent) in the Weighout and VTR CPUE is a crude measure of effort and could be improved by collecting information (number and size of hooks, length of main line, soak time, time of day, depth fished and area fished) on a haul by haul basis and not by a trip basis." In 2007, the Northeast Fisheries Science Center began a cooperative Study Fleet project with the tilefish industry specifically to address the concerns of the 41st SAW. A brief overview of the program and the data collection protocols is presented along with a general overview of the quality of the data collected by the project to date and a cursory examination of the relationships between haul-based effort metrics and catch. The information is intended to inform the 48th Stock Assessment Review Committee on the types of data available from self-reported haul-by-haul data collection programs. Because of the short time series of these data and data quality concerns, their utility to the current assessment is largely limited to informing the assessment (e.g., accuracy of the days absent effort metric and codification of fishing practices). However, this review serves an important first step in determining whether these types of data can be used in future assessments and whether this, or similar studies, should be extended.

Introduction

The golden tilefish, *Lopholatilus chamaeleonticeps* (hereafter referred to as tilefish), fishery in the Mid-Atlantic region is primarily targeted by a small (< 10 vessels) demersal longline fleet with virtually no observer coverage (Appendix Table A.1.1). Furthermore, this stock lacks a fishery independent index of abundance such that the surplus production model used to assess this stock relies entirely on commercial catch per unit effort (CPUE) derived from fishing vessel trip reports (VTRs) as an index of abundance. The 2005 Stock Assessment Review Committee (41st SAW, 2005) concluded that "…the effort metric (days absent) in the Weighout and VTR CPUE is a crude measure of effort and could be improved by collecting information (number and size of hooks, length of main line, soak time, time of day, depth fished and area fished) on a haul by haul basis and not by a trip basis." Beginning in 2007, the NEFSC began a cooperative Study Fleet project with the tilefish industry specifically to address the concerns of the 41st SAW.

The Northeast Fisheries Science Center (NEFSC) has been operating a Study Fleet Program since 2002. The overall objective of the Study Fleet Program is to assemble a fleet of vessels that are "…capable of providing high resolution (haul-by-haul) self-reported data on catch, effort and environmental conditions while conducting "normal" fishing operations" (Palmer et al. 2007). The Program has been involved in numerous fisheries since 2002 including the groundfish, scallop, hagfish, squid and fluke fisheries. In 2007, four longline vessels which target tilefish for all or part of the year were contracted by the NEFSC to collect fine-scale information on fishing effort and catch. Of the four vessels, two held category A permits (full time) and two held category B permits (part time). The small size of the contracted fleet does restrict how much information can be publically released due to the NEFSC's responsibility to protect vessel confidentiality. The first trip recorded by a tilefish vessel occurred in December 2007 and data collections are currently ongoing. In 2008, the first year of full coverage, 42 trips and 642 hauls were recorded. The trips recorded in 2008 accounted for 237.6 mt of landings, representing 32% of the total annual tilefish landings (736 mt; SAW 48 Working Paper A.1.1). Overall, 52 trips and 702 hauls have been recorded through the Study Fleet Program (*through March 1, 2009*).

Data collection protocols

Electronic logbook

Participating tilefish vessels were equipped with the electronic logbook (ELB) software, Fisheries Logbook Data Recording Software (FLDRS). FLDRS collects all of the information currently collected on paper VTRs, but allows fishermen to record effort and catch information for each haul, rather than aggregated to the subtrip level (i.e., one summary report per gear and area fished). FLDRS can be connected to the vessel's global positioning system (GPS) and depth sounder so vessel captains can capture the date, time, position, statistical area and bottom depth of each haul with the click of the mouse button rather than having to enter this information manually. In addition to basic trip information (vessel, captain, date of sailing, port, etc.) captains were asked to estimate the total length of line and number of hooks hauled (Appendix Figure A.1.1). Because of the complexity associated with the setting behavior of tilefish gear (Appendix Figure A.1.2), captains were asked only to record the hauling activity. For each haul recorded, captains had to provide catch estimates (both retained and discarded). During planning meetings with the industry they had commented that hook competition with other species can negatively impact tilefish catch. In an effort to capture this information captains were also asked to estimate the total number of hooks occupied by non-tilefish species (Appendix Figure A.1.3). On review, the hook competition information appeared incomplete, and was therefore not included in this analysis (in 2008 the number of non-tilefish occupied hooks was only recorded for 331 of 642 hauls). On completion of a trip, captains entered the landings information (date landed port landed, species, amount offloaded, dealer, date sold). Captains were allowed to adjust the landings to reflect the true amount of offloaded catch, such that landings were not affected by hailing errors at the haul-level or by missed hauls during the trip.

GPS polling observations

In addition to the self-reported information, FLDRS was configured to poll the vessel's GPS and depth sounder once every 20 seconds to record fine scale information on vessel cruise paths and bottom topography. These data were stored in a file separate from the trip file and were manually collected by Study Fleet field scientists approximately once per month. By using the ELB entered haul times, it was determined that > 90% of the hauling activity occurs between 3.1 km/hr and 10.2 km/hr, whereas only 12% of non-hauling activity occurs in this speed window (Appendix Figure A.1.4). Plotting fishing tracks in a Geographic Information System (GIS), the hauling vs. non-hauling activity could be differentiated with manual post-processing and used to validate the ELB recorded information (Appendix Figure A.1.5). Of the 42 trips recorded in the ELB in 2008, 36 had GPS polling coverage. Failure of the ELB to communicate with the GPS was the primary reason why GPS polling data were unavailable for a particular trip.

Field scientist observations

NEFSC field scientists were present on four of the ELB-recorded trips (total of 51 hauls). The objectives of the field scientists were to: a) provide independent estimates of tilefish catch; and, b) collect biological samples (e.g., length, weight and age) from the tilefish catch. Field scientists did not observe all hauls during a trip nor did they record observations on the amount of fishing effort (e.g., mainline length, number of hooks, bottom depth). Field scientist information can only be used to assess the accuracy of catch estimates and provide biological information on the resulting catch.

Data quality

Overview

The ELB data collected by the tilefish vessels have not previously been analyzed. This analysis represents the first assessment of the quality and utility of these data. It is a critical first step to determine the overall quality of these data and understand how the quality of both the self-reported and electronically recorded (i.e., by GPS and depth sounder) impact their utility for future tilefish stock assessments. Because of the short time series of these data, their utility to the current assessment is largely limited to informing the assessment (e.g., accuracy of the days absent effort metric and codification of fishing practices). However, this review serves an important first step in determining whether these types of data can be used in future assessments and whether this, or similar studies, should be extended. Data quality analyses focused on the quality of the self reported effort metrics (number of hauls, mainline length, number of hooks, soak duration, and fishing depth) and catch estimates.

Effort metrics were primarily validated by comparing the self-reported estimates to estimates obtained from post-processing of the GPS polling information. The post-processing step is an extremely time consuming process taking approximately 4-8 staff hours per trip file depending on the length of the trip and spatial density of the fishing patterns. Due to the time intensive nature of this activity, only 23 of the 36 trips with GPS polling information were post-processed. Unfortunately, all of these trips were from a single vessel so the results of the data quality analysis should not be overly interpreted as indicative of all of the self-reported data. Because of the limited applicability of these data, no statistical tests were performed.

Number of hauls per trip

During preliminary review of the tilefish data it was observed that the sum of individual catches was often much less than the total landings (Appendix Figure A.1.6). This could indicate that either the individual haul hail estimates were consistently low, or not all hauls were recorded in the ELB. Follow-up conversations with vessel captains suggested that the greatest contributor to these discrepancies was missing hauls. Comparison of the number of self-reported hauls per trip to the number estimated from the GPS indicated that hauls do occasionally go unreported in the logbook (Appendix Figure A.1.7). Of the 23 trips examined there was complete agreement in the haul counts on eight trips and no instances of the ELB recording more hauls compared to the GPS analysis. The degree of underestimation in the ELB was variably, but generally less than 5 hauls per trip.

Mainline length hauled

Mainline length was determined from the GPS polling data by calculating the cumulative haversine distance (Sinnott 1984) of all points between the start and ending points of a haul. In general, the ELB estimated mainline length hauled agreed reasonably well with the GPS calculated mainline length, though there was considerable variability and the numerous outliers (Appendix Figure A.1.8).

Number of hooks hauled

There was no way to directly validate the number of hooks self-reported on the ELB, however by comparing these estimates to the GPS calculated mainline length a general understanding of the accuracy of these estimates can be obtained. However, the variability observed in the relationship will be contingent on the accuracy of the self-reported data and the setting hook density (number of hooks per km of line set). There is general agreement between ELB hooks hauled and the GPS calculated mainline length (Appendix Figure A.1.9); however, there is greater spread in the relationship compared to the ELB mainline to GPS mainline comparisons.

Soak duration

GPS soak duration was calculated as the average of the soak durations (time difference between when a particular section of gear was set and when the same section was hauled) from five observations taken along the length of the haul. The soak duration associated with the start haul and end haul was always taken and the intent was that the remaining three observations would be equally spaced out across the haul. The average soak duration and standard deviation were calculated for each haul. The ELB estimates of soak duration were generally higher than those calculated from the GPS polling files (Appendix Figure A.1.10). In conversations with the vessel owners, it could be that this difference is partly attributable to the fact that vessel captains calculate soak duration differently (difference between when the last piece of gear was set and when the last piece of gear was hauled).

There was an interesting trend in the relationship of the standard deviation to the average soak duration (Appendix Figure A.1.11). Two different trends are present, one representing efforts where the gear was hauled in the same direction it was set in (lower ratio of variability to average soak duration), and the other when gear were hauled in the opposite direction from which they were set (higher ratio of variability to average soak duration).

Fishing depth

Because tilefish are caught with bottom tending gear, the fishing depth is the bottom depth. Average fishing depth was calculated from the GPS polling file by calculating the average bottom depth between the start of the haul and the end of the haul. The ELB estimates of bottom depth agreed well with the GPS calculated values, though several outliers exist (Appendix Figure A.1.12).

Catch estimates

ELB-reported catch estimates were compared to the catch estimates recorded by the Study Fleet field scientists. The haul-by-haul difference in reported tilefish catch was generally similar with the median centered near 0 and the spread uniform about the median (Appendix Figure A.1.13). There were three hauls where the ELB estimates were considerably higher than the estimates of the field scientists.

Data quality conclusions

Overall, the self-reported ELB data examined did track the general trends derived from alternate sources (GPS/depth sounder or field scientists). While these conclusions are based on a small subset that was generally limited to a single vessel, they do suggest that the overall quality of the self-reported data are sufficient for use in making general inferences about catch relationships and trends.

Use of VTR days absent as a proxy for fishing effort

The 41st SAW (2005) characterized days absent as calculated from the VTR as a "…a crude measure of effort". The availability of more precise and more accurate (particularly when derived from GPS observations) allows the inaccuracy of VTR days absent to be assessed. There are two fundamental questions: 1) does VTR days absent minus one accurately reflect the amount of time spent on the fishing grounds?; and, 2) does this metric track well with alternate effort metrics such as the amount of mainline length fished?

To evaluate the first question, the GPS data were used to determine the total amount of days the vessel spent on the fishing grounds and compare this to the VTR days absent minus one metric. The agreement between the two was highly significant (Appendix Figure A.1.14; $n = 23$, $r = 0.937$, $p < 0.0001$) indicating that the VTR days absent minus one metric accurately reflects the true time spent fishing. When comparing these two metrics to the GPS estimated mainline length fished, the GPS days fished explains a greater degree of the variability in the mainline length hauled ($r^2 = 0.73$) compared to the VTR days absent minus one metric ($r^2 = 0.52$). These results suggests that while the VTR days absent metric accurately reflects the time spent on the fishing grounds and explains some of the variability in mainline length hauled, more precise metrics may offer improvements over the current metric used in the surplus production model.

Catch relationships as a basis for alternate CPUE estimates

SAW 41 (2005) stated that "…the effort metric [used in calculating CPUE]…could be improved by collecting information (number and size of hooks, length of main line, soak time, time of day, depth fished and area fished) on a haul by haul basis." We've taken an exploratory look at the relationship between these alternate haul-based determinants of tilefish catch. Based on the relative accuracy of the self-reported ELB data all recorded haul records (702 hauls recorded between December 1, 2007 and March 1, 2009) were used in these comparisons. The effort metrics examined here are: mainline length, number of hooks, hook density (hooks/km), soak duration, depth and latitude fished. There is a high degree of multicollinearity among these variables which is expected, particularly among those effort metrics that are closely related such as mainline length and number of hooks (Appendix Table A.1.2).

Catch appears most closely related to the number of hooks fished (Appendix Figure A.1.16), with a weaker relationship to the mainline length (Appendix Figure A.1.17), though because of the collinearity between number of hooks and mainline length, it is unclear if this is direct relationship. Interestingly, there is no linear relationship between catch and hook density (Appendix Figure A.1.18); the highest catch rates occur between 200 and 300 hooks/km, but catch rates are lower at densities outside this range. There a weak linear relationship of catch to soak duration (Appendix Figure A.1.19), but again, because of the collinearity of soak duration to both number of hooks and mainline length it is impossible to determine if soak duration is a determinant of catch. There is no linear relationship between catch and depth (Appendix Figure A.1. 20) or latitude (Appendix Figure A.1.21), however catches do appear to be lower at greater depths and lower latitudes. The interpretation of these results is difficult because vessel tended to fish in shallower depths at higher latitudes (Appendix Figure A.1.22).

The length frequency information collected by the field scientists was cursorily examined for trends with respect to depth (Appendix Figure A.1.23) and latitude (Appendix Figure A.1.24). There were significant relationships of size to both of these variables, with latitude explaining a greater degree of the variability in tilefish fork length.

Catch trends over time

Based on the relative strength of the relationship between catch and the number of hooks fished, a CPUE metric was constructed as the catch (live wt. kg) per hook hauled. CPUEs observed in this time series ranged from 0.0 to 1.0 kg/hook. Three different CPUEs trends were examined; 1) using all data across the time series fit with a loess smoother (Appendix Figure A.1.25); 2) using only hauls occurring within a 40 minute square region in the vicinity of Hudson Canyon (Appendix Figure A.1.26); and, 3) using only hauls occurring within a 40 minute square region in the vicinity of Block Canyon (Appendix Figure A.1.26). The area in the vicinity of Hudson Canyon was the most heavily fished area for the duration of the time series, with the Block Canyon region being the second most heavily exploited area. While there is some evidence of declining CPUE in each of the time series, the data are insufficient to draw any conclusions, as the trends are driven by high catches early in the time series and may associated with seasonal effects or some other unknown effect.

Conclusions

The information presented in this working paper is intended to inform the 48th Stock Assessment Review Committee on the types of data available from Study Fleet-like projects focusing on the collection of self-reported haul-by-haul information. The data quality is sufficient to detect relationships and perhaps general trends, but the overall quality of the data can be improved. It should be noted that many of the vessels in the tilefish fleet utilize multiple captains, which increases the time period necessary to familiarize one self with the electronic logbook and data collection protocols. Through closer collaboration with the tilefish industry the quality of these data are likely to improve. Because of the quality of these data, more in depth analyses were not performed, however the results do indicate that the current VTR days absent effort metric does provide a reasonable measure of fishing effort, but that it could be improved on by collecting information at a finer scale.

Acknowledgements

Funding for this project was provided by the NEFSC's Cooperative Research Partners Program. Administrative support was provided by Dr. John Hoey and Carolyn Woodhead. Lauren Marcinkiewicz and Tiffany Vidal provided valuable assistance in the field. This project relied heavily on the NEFSC's information technologies capabilities; a debt of gratitude is owed to Heidi Maraotta, Holly McBride, David Hiltz, Bobbi North and Joan Palmer. Most importantly the success of the project was predicated on the participation and cooperative of the owners, captains and crews of the participating tilefish vessels.

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Tables

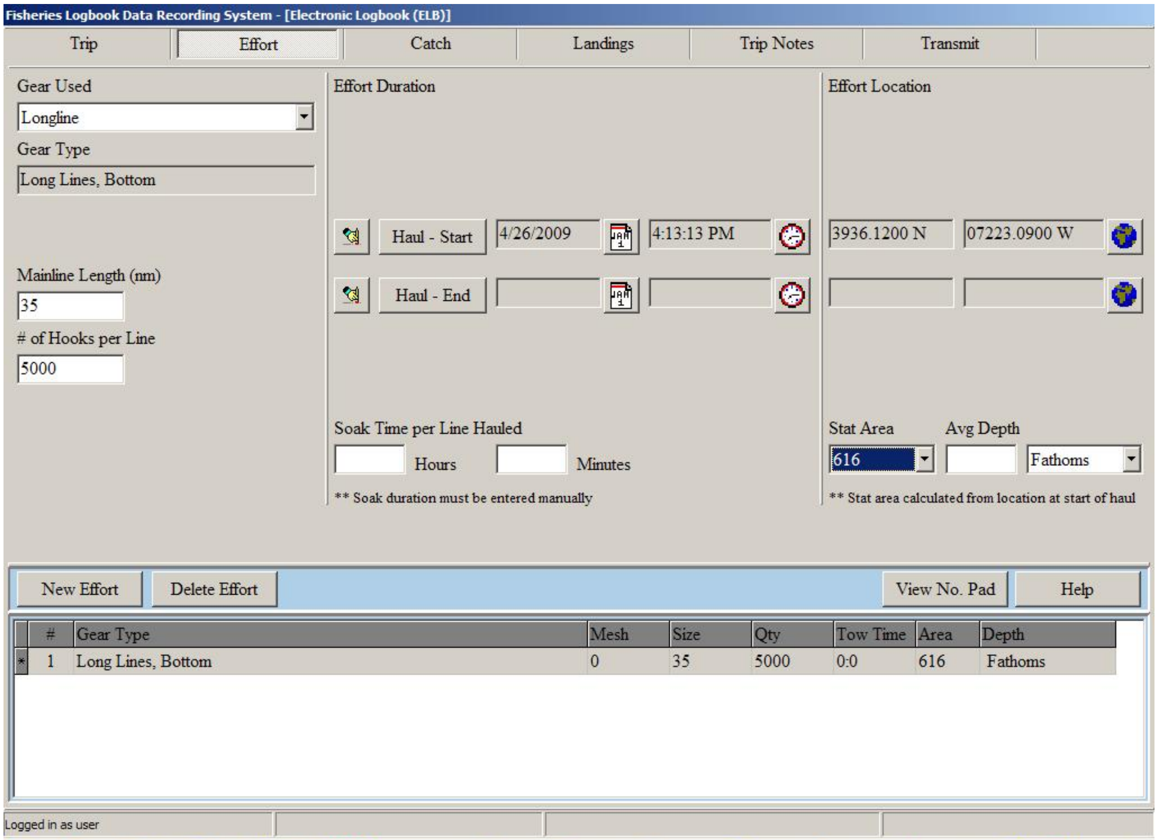
Appendix Table A.1.1. Number of directed tilefish trips (longline gear only) observed by the Northeast Fisheries Observer Program by year.

Year	Number of directed tilefish trips observed (*longline gear only*)
1992	1
2004	1
2005	4
2006	4
2007	2
2008	1

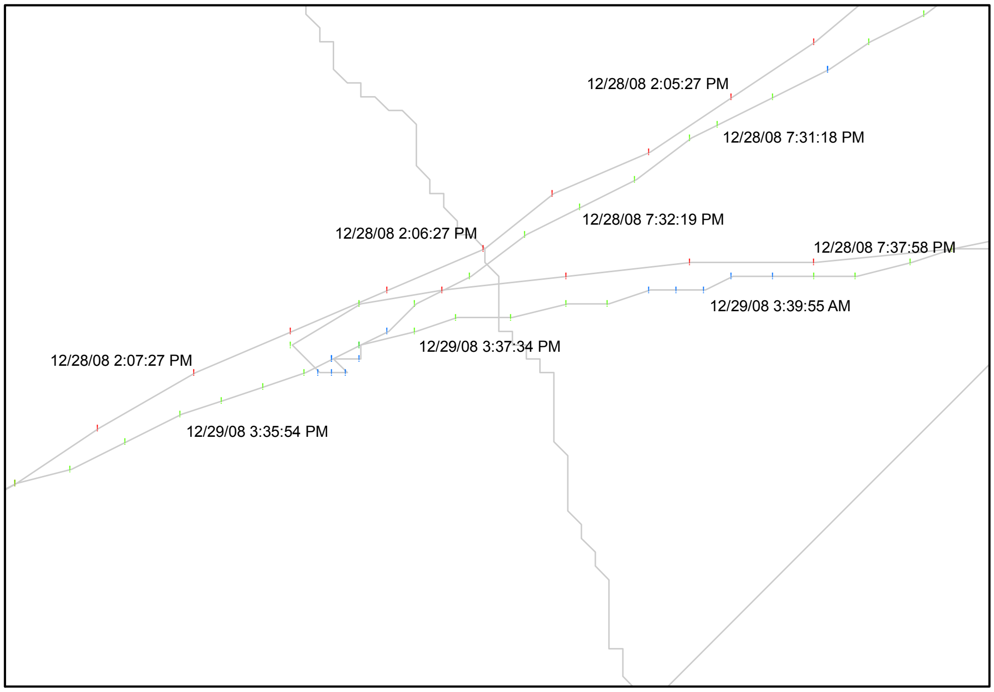
Appendix Table A.1.2. Correlation matrix of tilefish catch and effort metrics from data reported by captains using the electronic logbook. Relationships significant at the p < 0.05 are shown in bold.

	Tilefish catch (live wt. kg)	Mainline length (km)	Number of hooks	Hook density (hooks/km)	Soak duration (hours)	Bottom depth (m)
Mainline length (km)	**0.589** ***(<0.0001)***					
Number of hooks	**0.607** ***(<0.0001)***	**0.819** ***(<0.0001)***				
Hook density (hooks/km)	-0.053 *(0.158)*	**-0.308** ***(<0.0001)***	**0.208** ***(<0.0001)***			
Soak duration (hours)	**0.447** ***(<0.0001)***	**0.638** ***(<0.0001)***	**0.604** ***(<0.0001)***	0.017 (0.654)		
Bottom depth (m)	-0.060 *(0.115)*	-0.061 *(0.107)*	-0.066 *(0.083)*	0.008 *(0.832)*	-0.011 *(0.772)*	
Latitude (dd)	-0.049 *(0.1972)*	0.008 *(0.8229)*	**0.094** ***(0.0123)***	**0.123** ***(0.0011)***	**-0.189** ***(<0.0001)***	**-0.361** ***(<0.0001)***

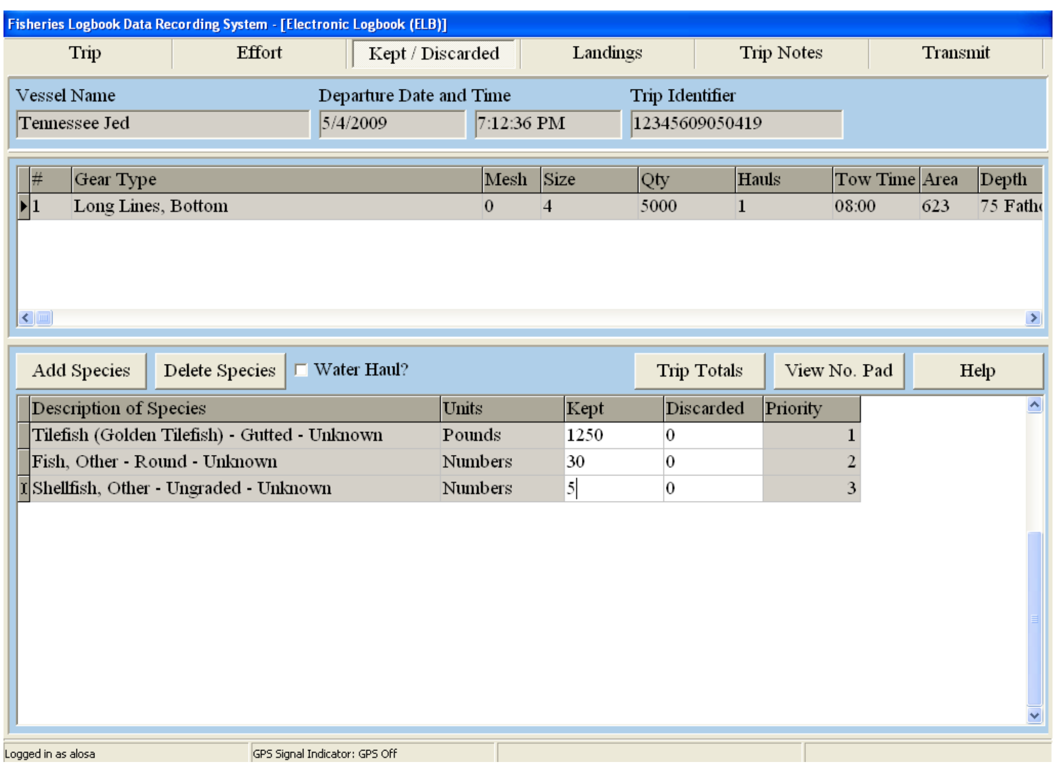
Figures



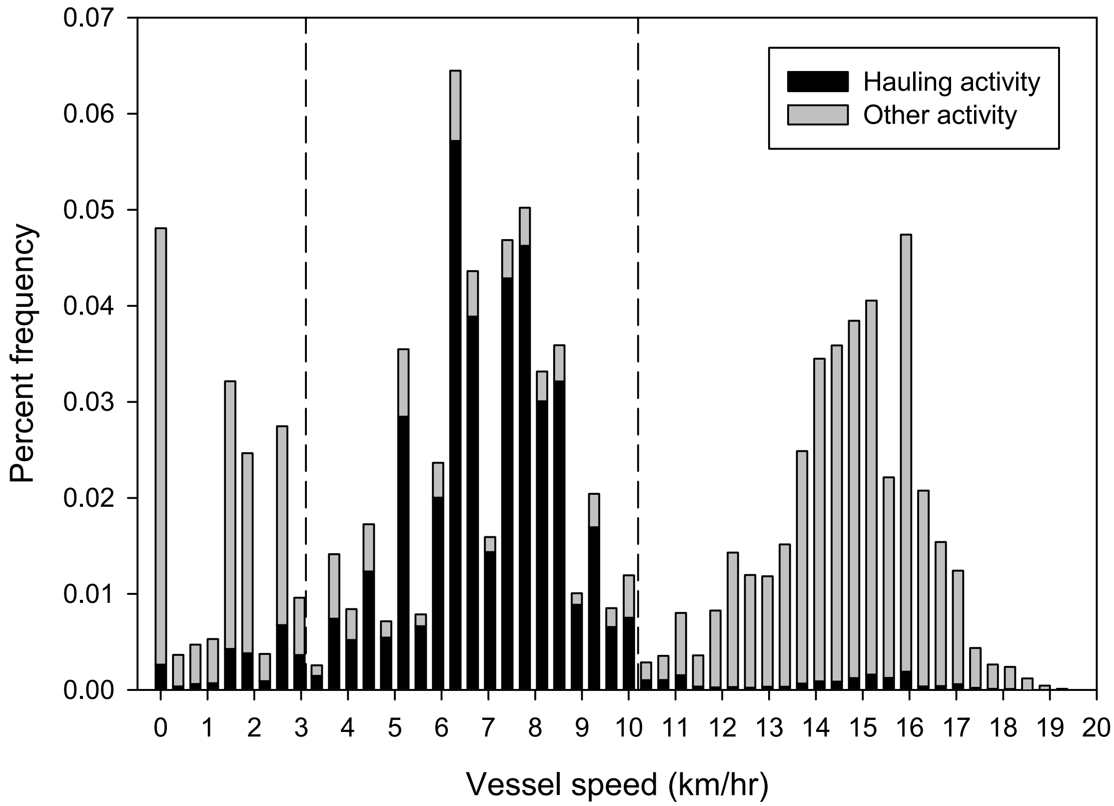
Appendix Figure A.1.1. A screen shot of the Fisheries Logbook Data Recording Software (FLDRS) effort data entry screen. This screen shot is similar to that used by tilefish vessel captains to record information on the gear hauled.



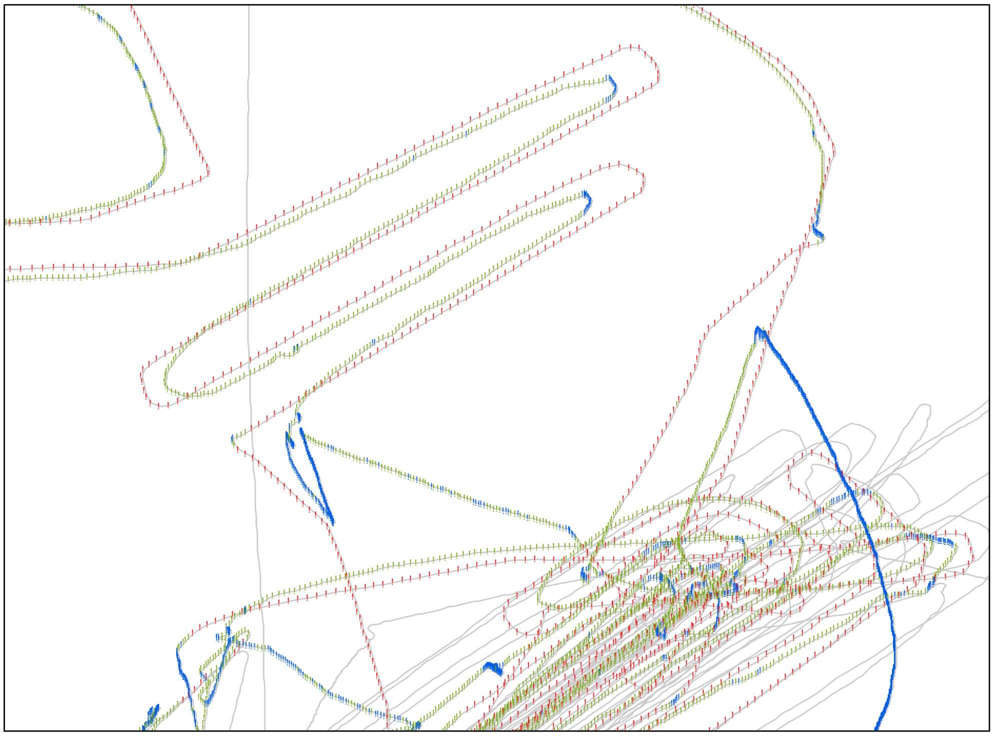
Appendix Figure A.1.2. Example of a tilefish haul where line is hauled from two separate setting events. The 12/29 haul includes gear set on 12/28 around 2:00 PM and also gear set around 7:30 PM. Spatial reference information is intentionally not shown to protect the confidentiality of the vessel data.



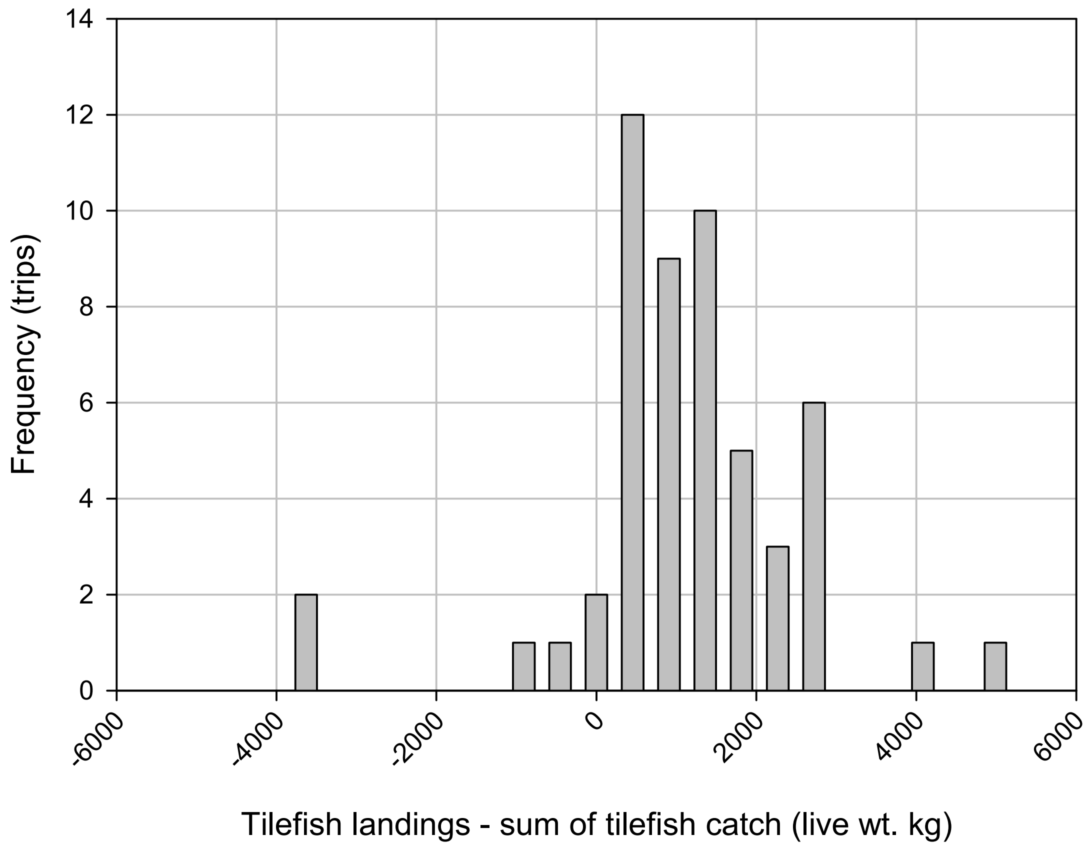
Appendix Figure A.1.3. A screen shot of the Fisheries Logbook Data Recording Software (FLDRS) catch data entry screen. This screen shot is similar to that used by tilefish vessel captains to record information on the fish caught for each haul.



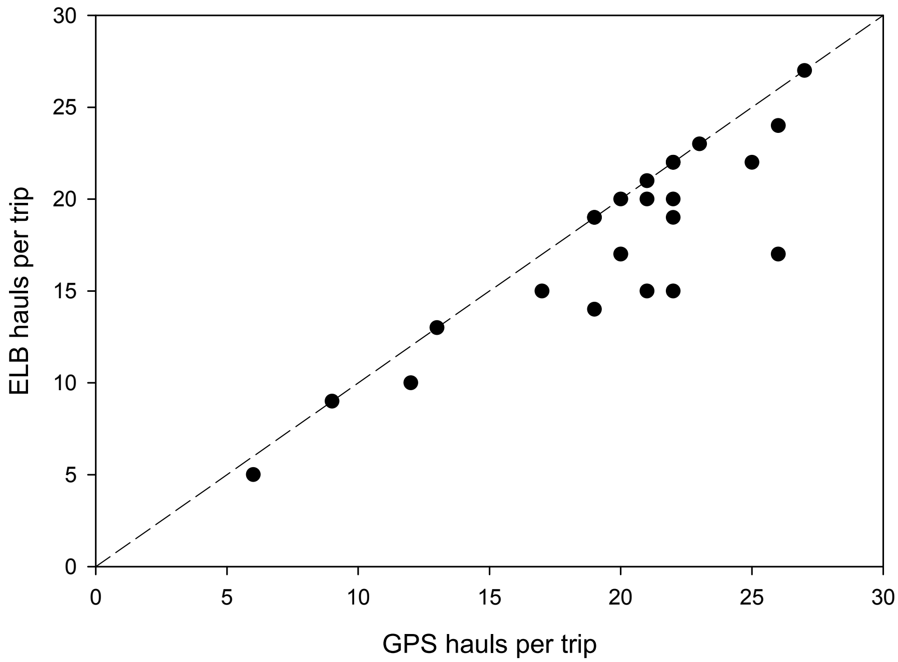
Appendix Figure A.1.4. Percent frequency distribution of recorded tilefish vessel speeds divided into hauling and other activity. The dashed lines (3.1 km/hr and 10.2 km/hr) indicate the speed window where >90% of the hauling activity occurs.



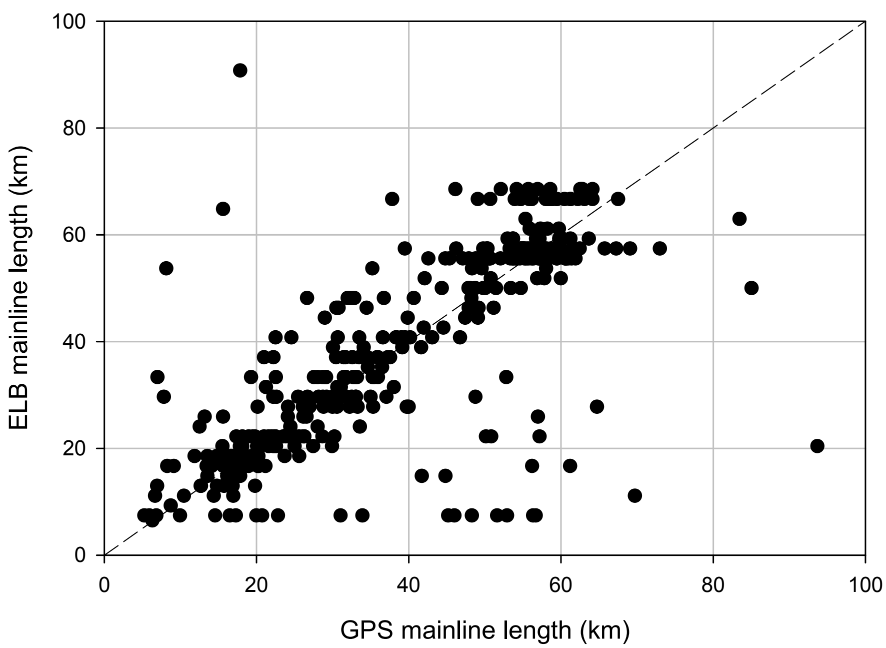
Appendix Figure A.1.5. Example of a global positioning system (GPS) polling file collected from a tilefish vessel. The cruise track is color coded based on vessel speed (blue < 1.7 knots, 1.7 ≥ green ≤ 5.5 knots, red > 5.5 knots). Spatial reference information is intentionally not shown to protect the confidentiality of the vessel data.



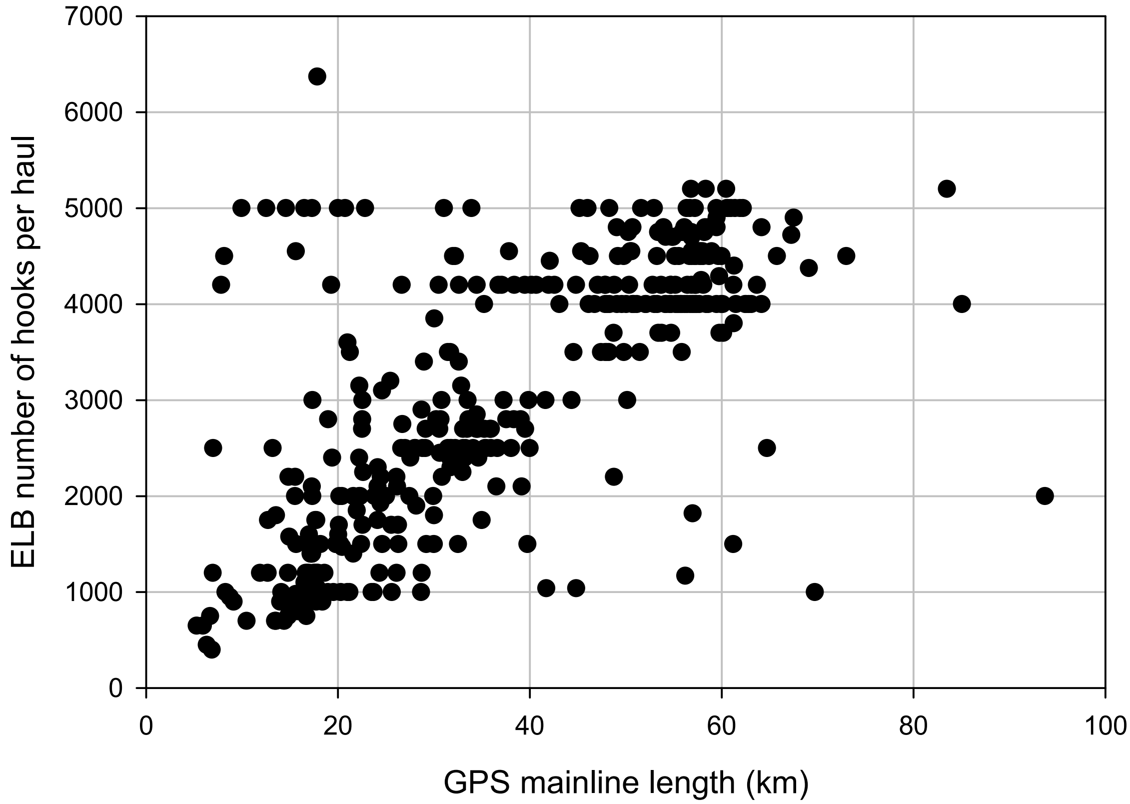
Appendix Figure A.1.6. Frequency distribution of the difference between the amount of landed tilefish and the sum of the individual haul hail weights for a trip. Positive values indicate more landed catch than recorded for the individual hauls, negative values indicates that there was more catch hailed than actually landed.



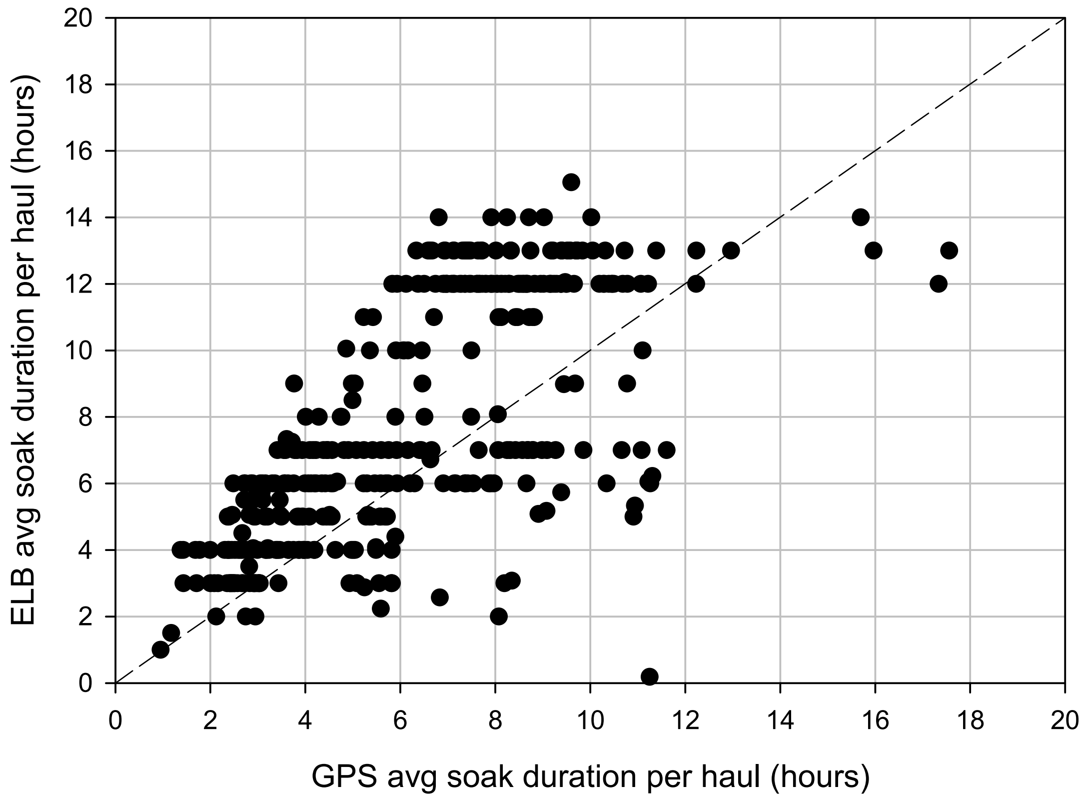
Appendix Figure A.1.7. The number of hauls recorded by the captain in the electronic logbook (ELB) compared to the number of hauls estimated from analysis of the global positioning system (GPS) polling file. The dashed line indicates the 1:1 identity line.



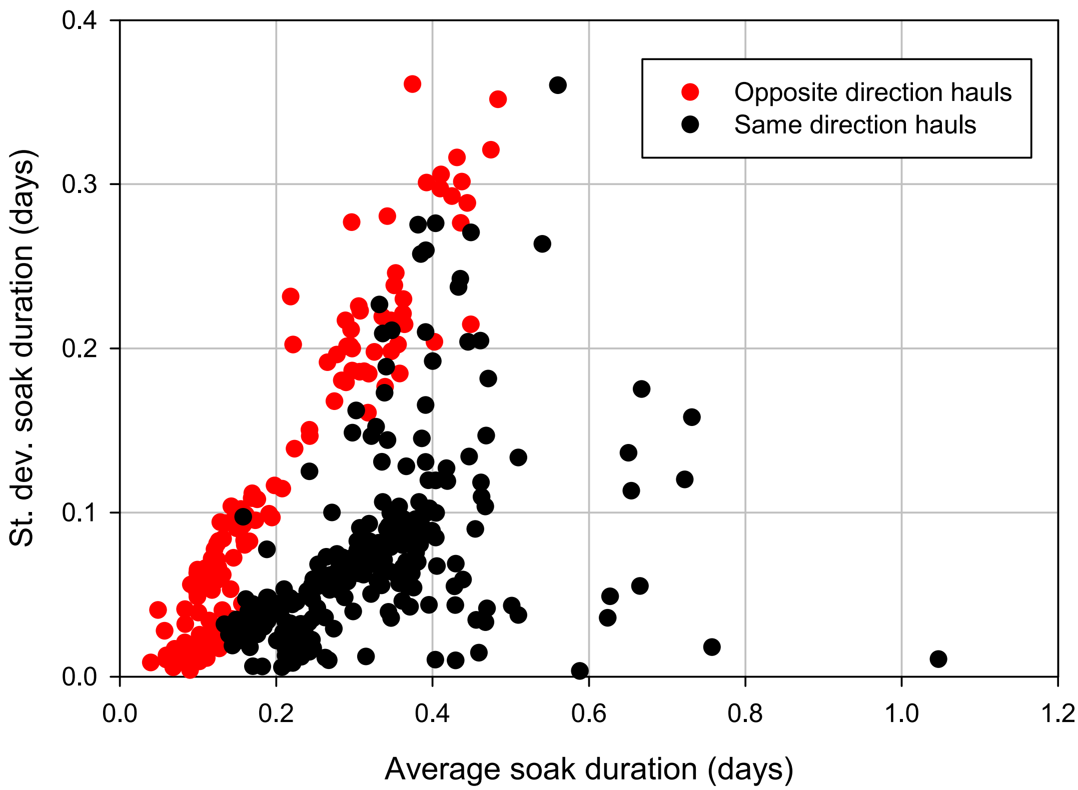
Appendix Figure A.1.8. The captain's estimate of mainline length hauled recorded in the electronic logbook (ELB) compared to the mainline length estimated from analysis of the global positioning system (GPS) polling file. The dashed line indicates the 1:1 identity line.



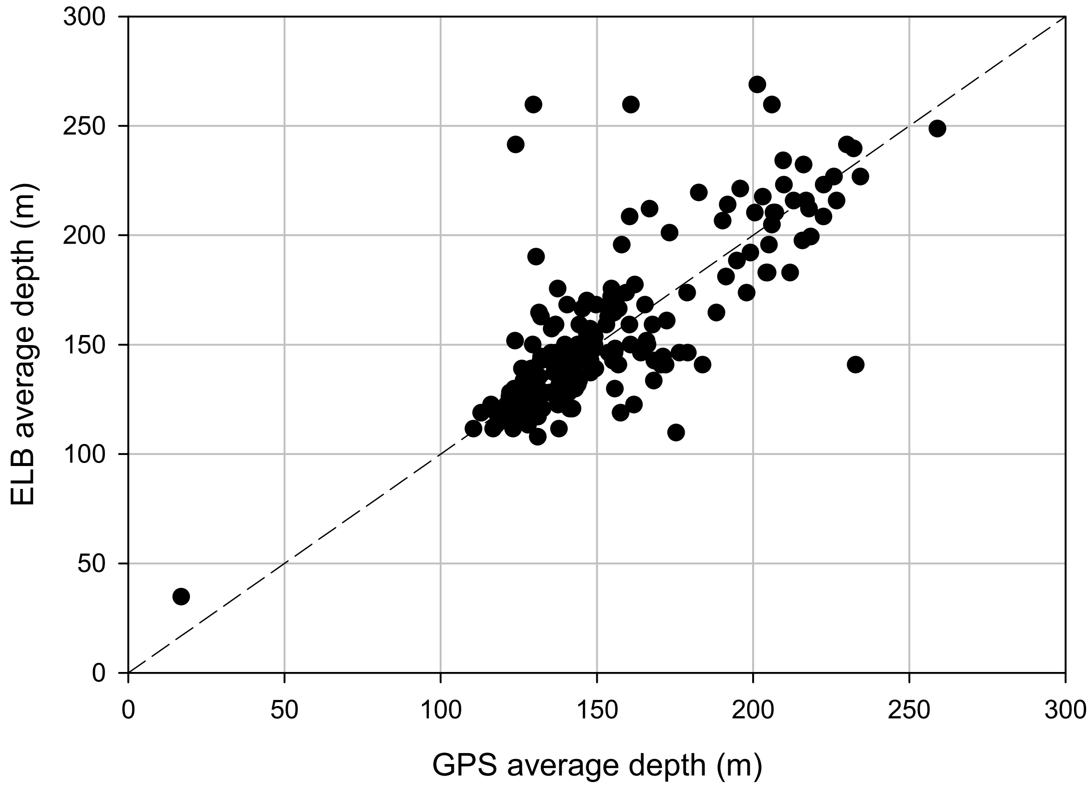
Appendix Figure A.1.9. The captain's estimate of the number of hooks hauled as recorded in the electronic logbook (ELB) compared to the mainline length estimated from analysis of the global positioning system (GPS) polling file.



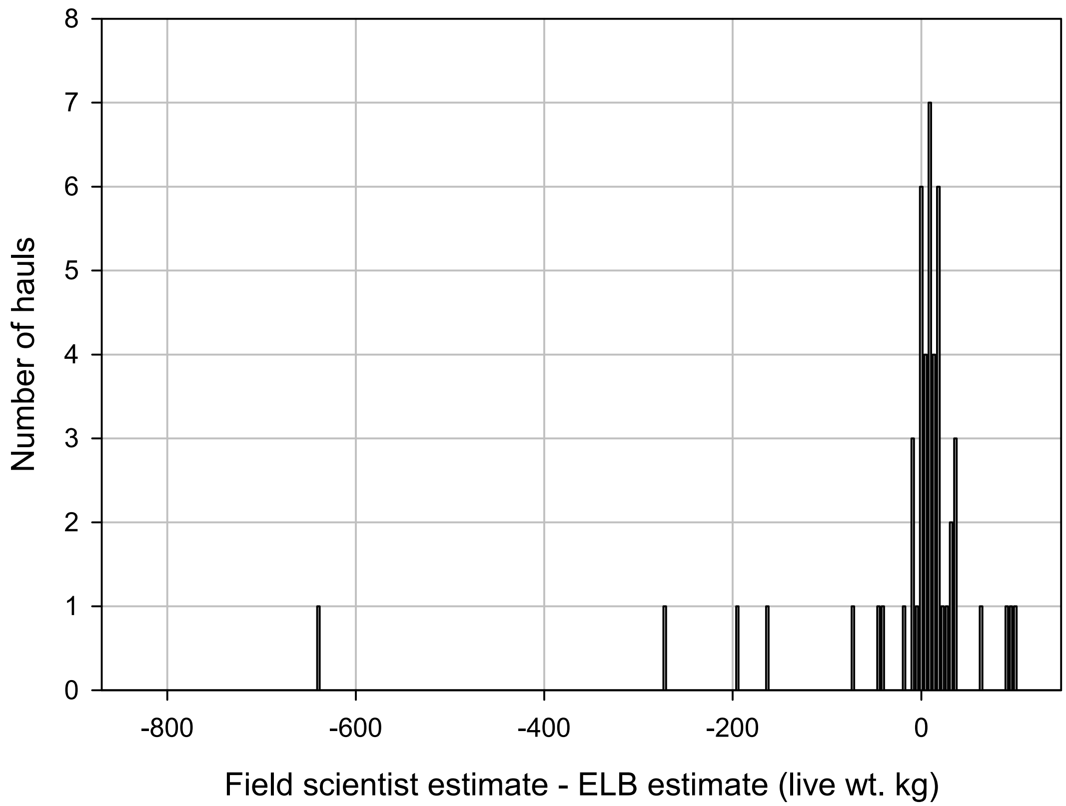
Appendix Figure A.1.10. The captain's estimate of the average soak duration of each haul recorded in the electronic logbook (ELB) compared to the average soak duration estimated from analysis of the global positioning system (GPS) polling file. The dashed line indicates the 1:1 identity line.



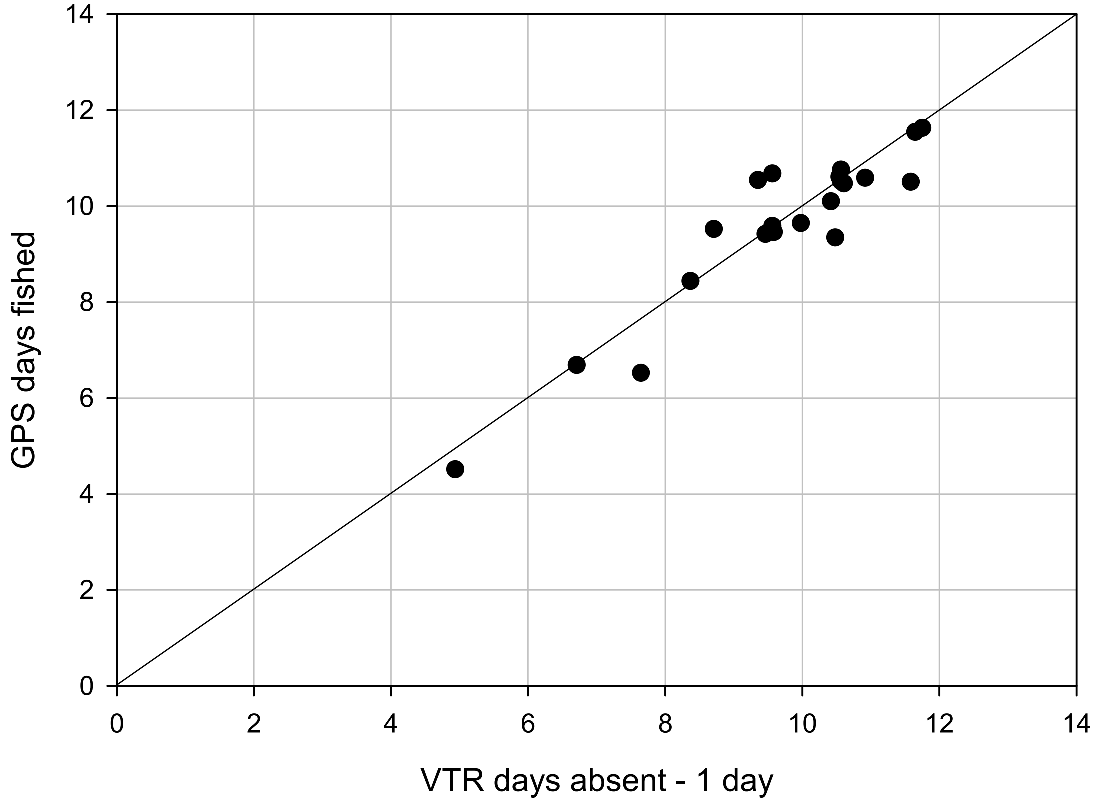
Appendix Figure A.1.11. Comparison of the amount of variability in haul soak times to the overall average soak time for the individual haul. Data points in red represent hauls that were hauled in the opposite direction from which they were set and the points in black represent hauls that were hauled in the same direction they were set.



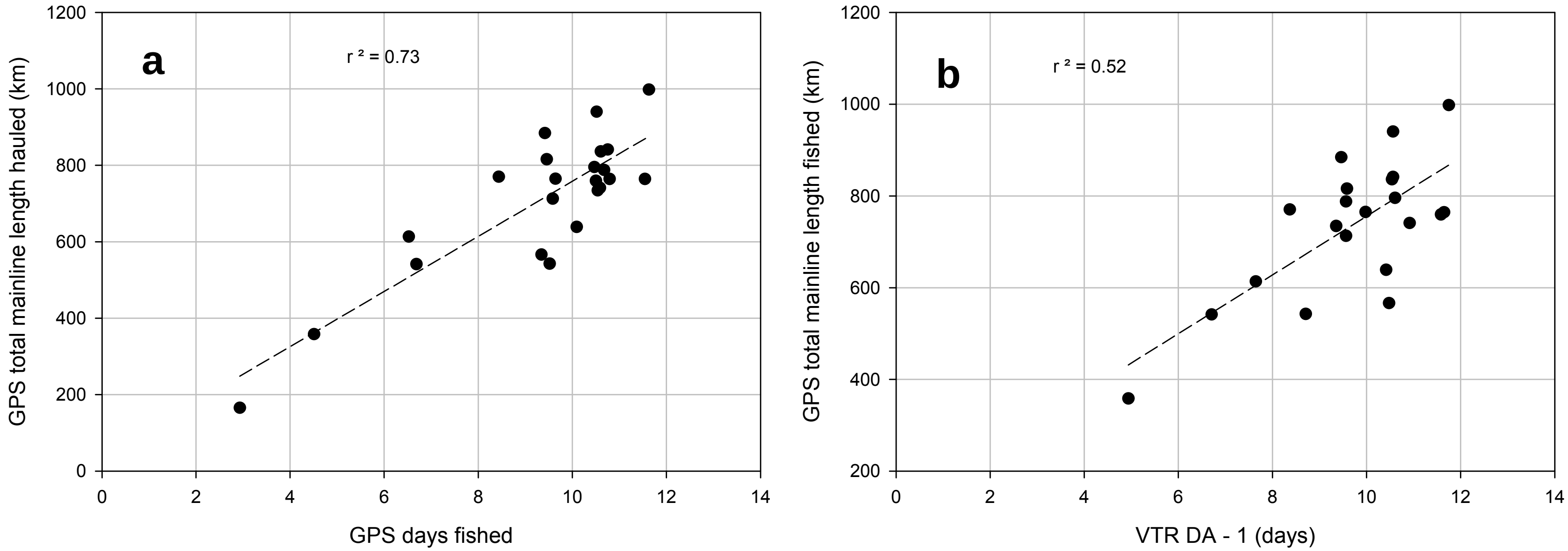
Appendix Figure A.1.12. The captain's estimate of the fishing depth of each haul recorded in the electronic logbook (ELB) compared to the average haul depth (m) estimated from analysis of the global positioning system (GPS) polling file.



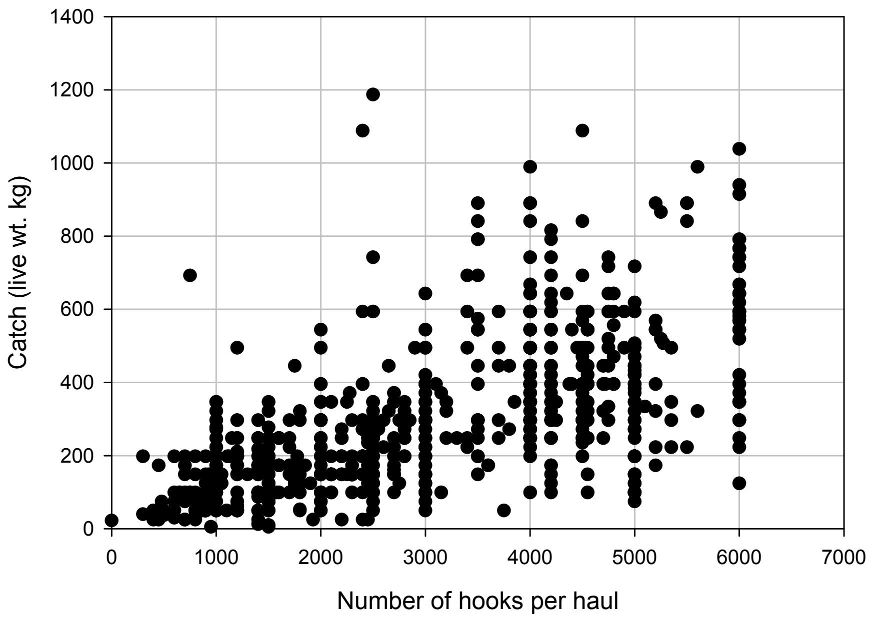
Appendix Figure A.1.13. Frequency distribution of the difference between the captain's haul-level hail weights and those estimated by Study Fleet field scientists. The compared weights span three different trips on three different vessels.



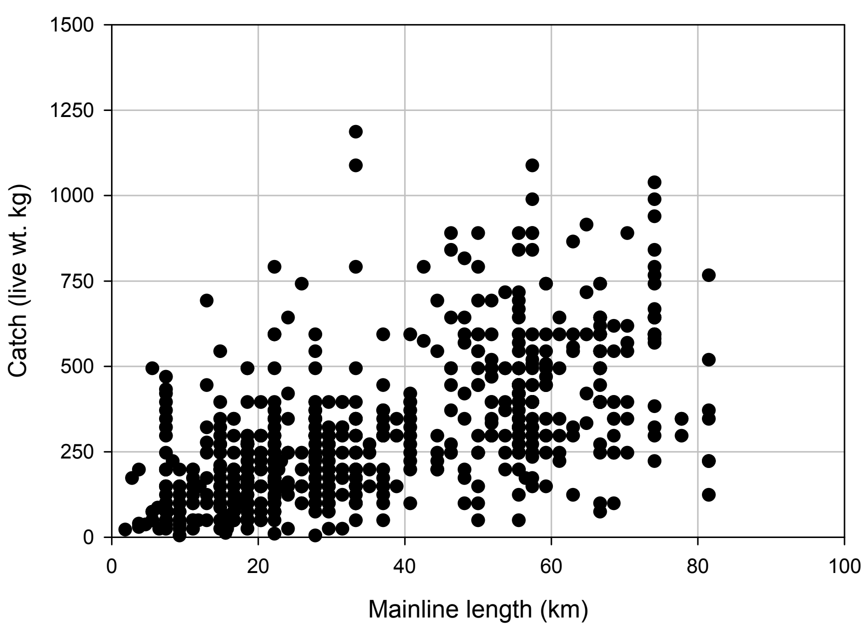
Appendix Figure A.1.14. Relationship between the total number of days fished as determined from analysis of global positioning system (GPS) data and the effort metric used is the surplus production model, the total days absent minus one calculated from the vessel trip reports (VTR).



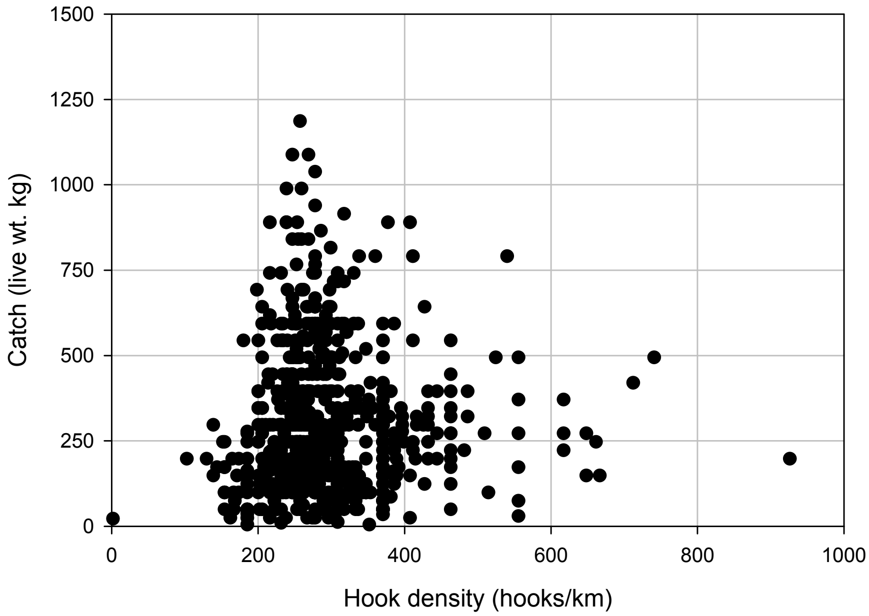
Appendix Figure A.1.15. Relationship between the total mainline length fished per trip as calculated from analysis of global positioning system (GPS) data and the total number of days fished (a) and the total days absent minus one calculated from the vessel trip reports (VTR; b).



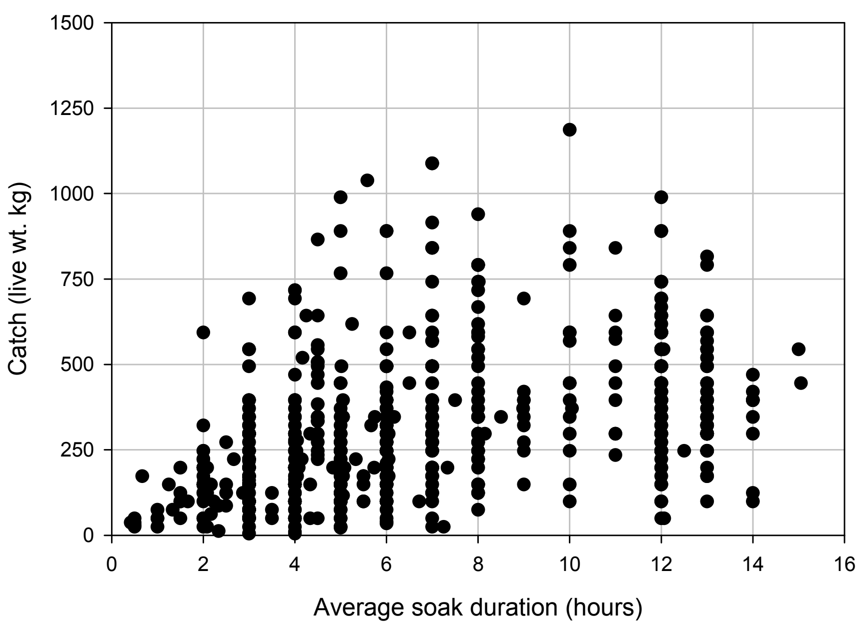
Appendix Figure A.1.16. Tilefish catch (kg live wt.) as a function of the number of hooks fished per haul. Tilefish catches are reported at the haul level by the vessel captains in the electronic logbook.



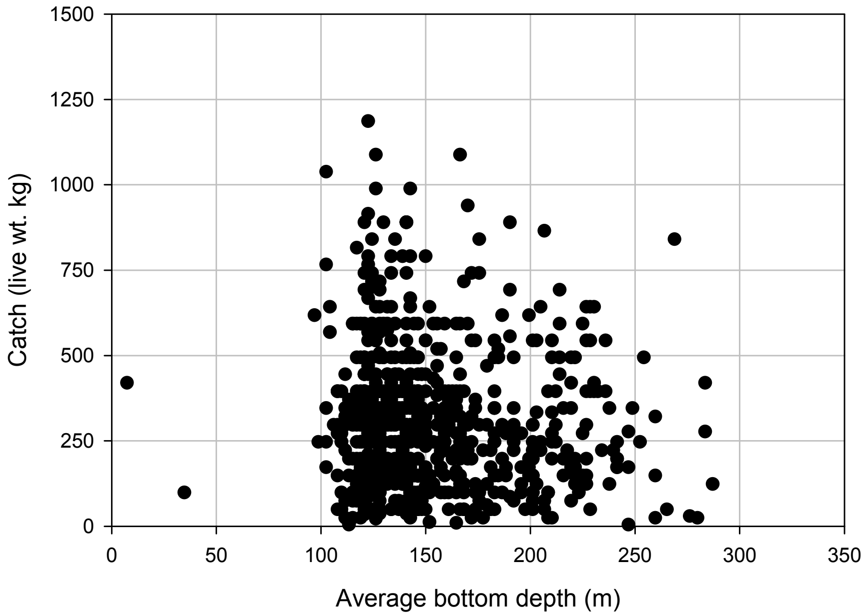
Appendix Figure A.1.17. Tilefish catch (kg live wt.) as a function of mainline length (km). Tilefish catches are reported at the haul level by the vessel captains in the electronic logbook.



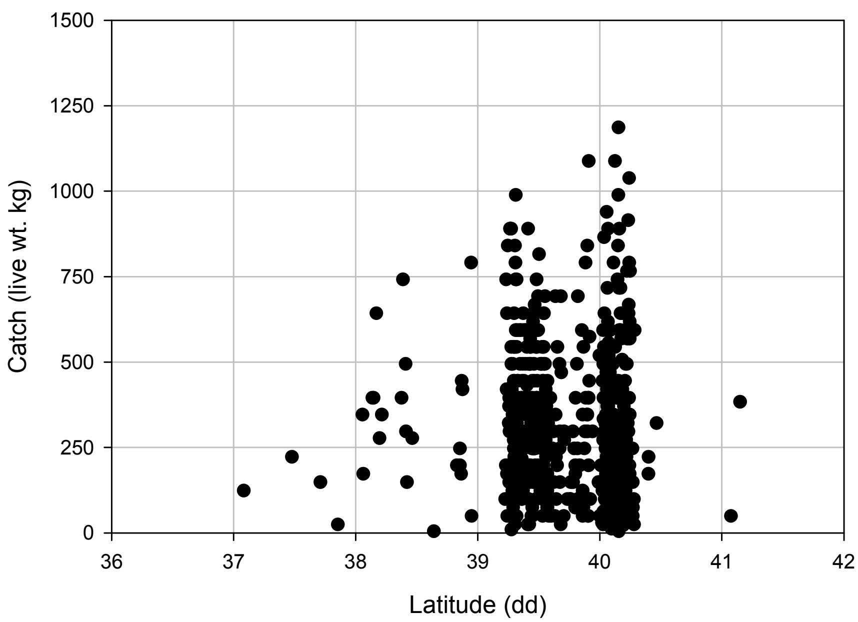
Appendix Figure A.1.18. Tilefish catch (kg live wt.) as a function of hook density (hooks/km). Tilefish catches are reported at the haul level by the vessel captains in the electronic logbook.



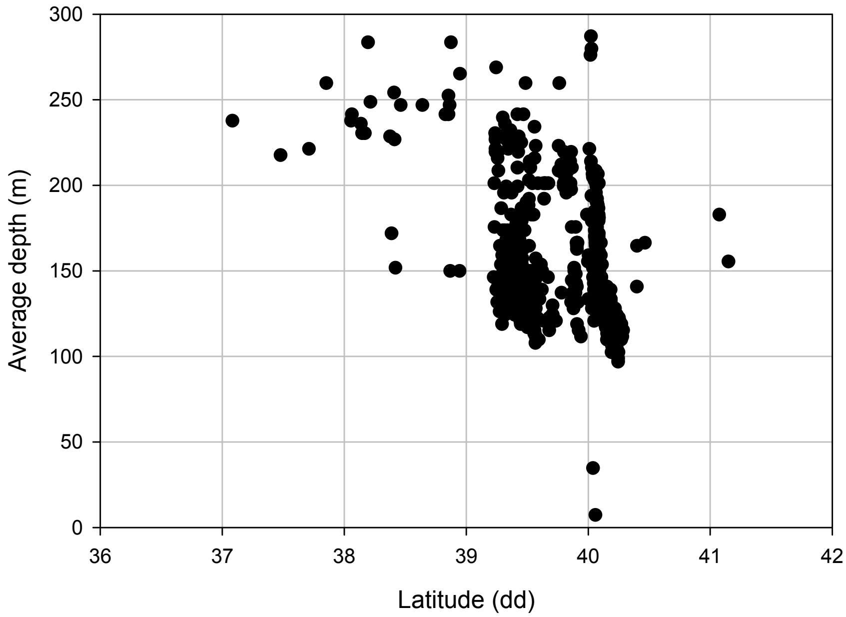
Appendix Figure A.1.19. Tilefish catch (kg live wt.) as a function of average soak duration (hours). Tilefish catches are reported at the haul level by the vessel captains in the electronic logbook.



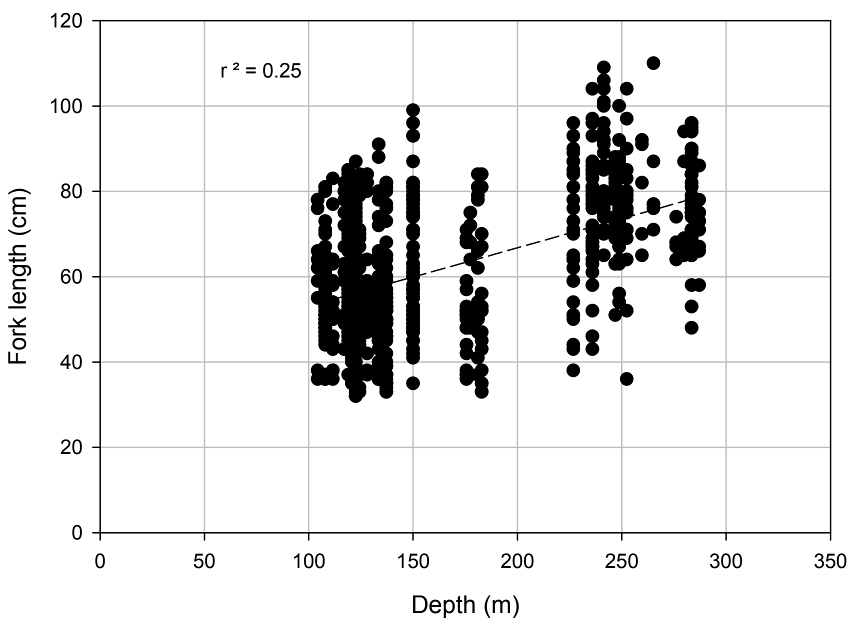
Appendix Figure A.1.20. Tilefish catch (kg live wt.) as a function of bottom depth (m). Tilefish catches are reported at the haul level by the vessel captains in the electronic logbook.



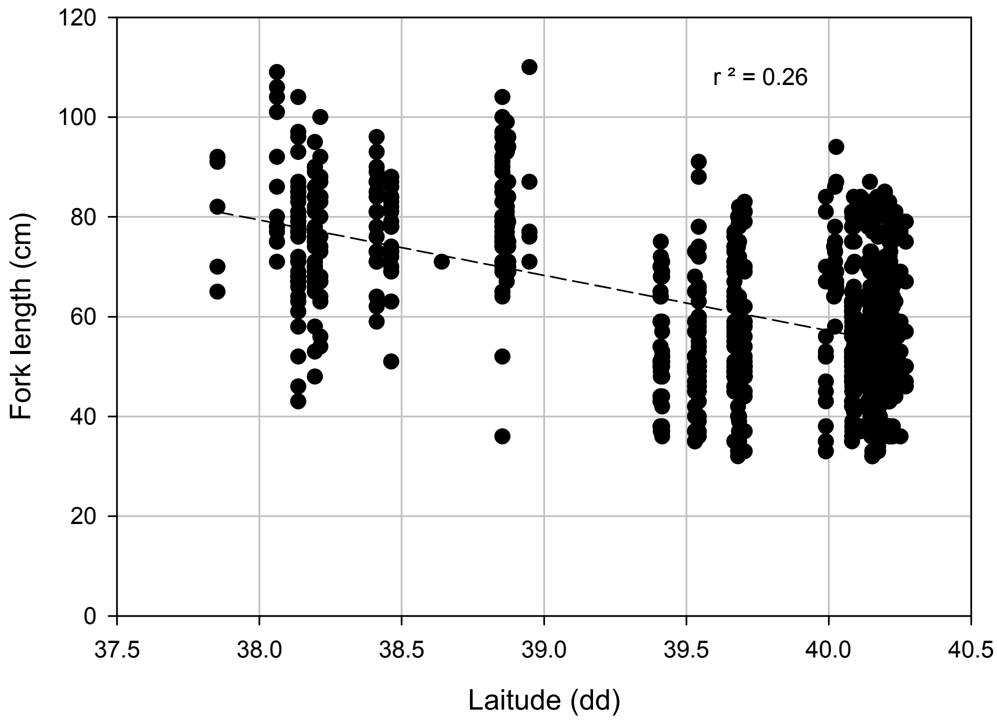
Appendix Figure A.1.21. Tilefish catch (kg live wt.) as a function of latitude (decimal degrees, dd). Tilefish catches are reported at the haul level by the vessel captains in the electronic logbook.



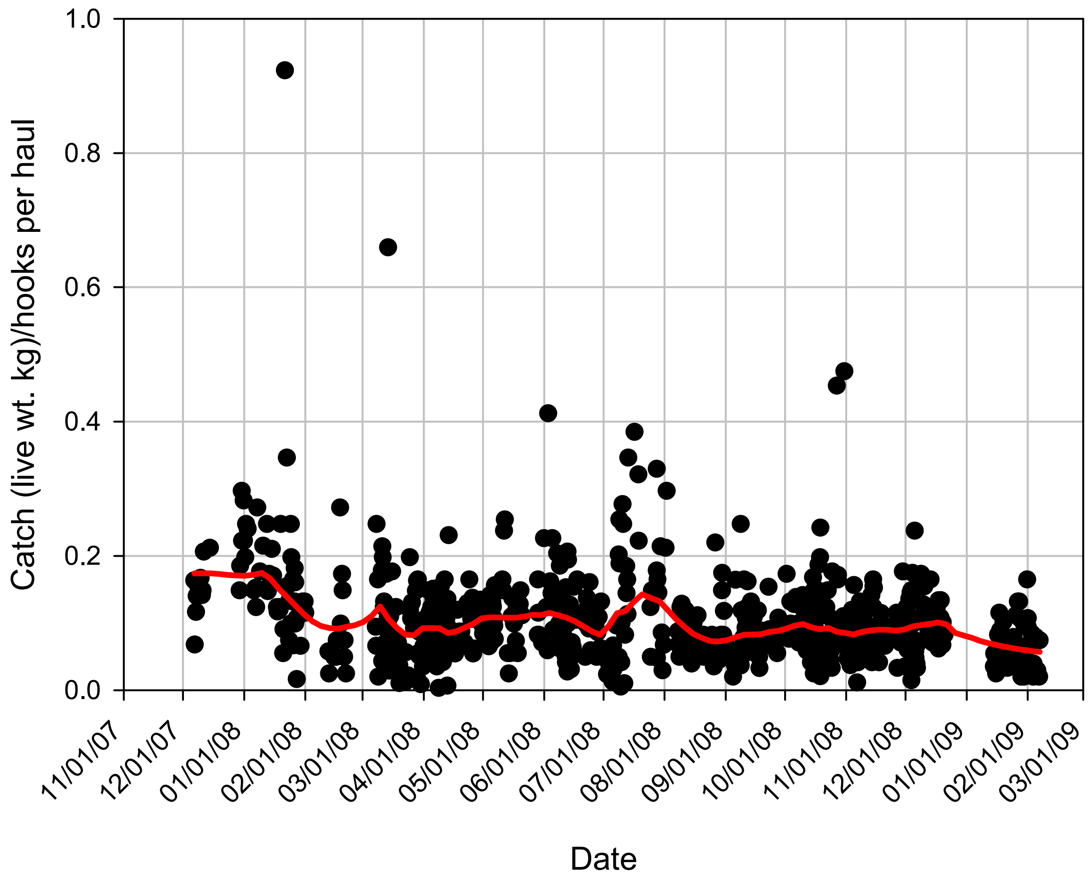
Appendix Figure A.1.22. Bottom depth fished (m) as a function of latitude (decimal degrees, dd).



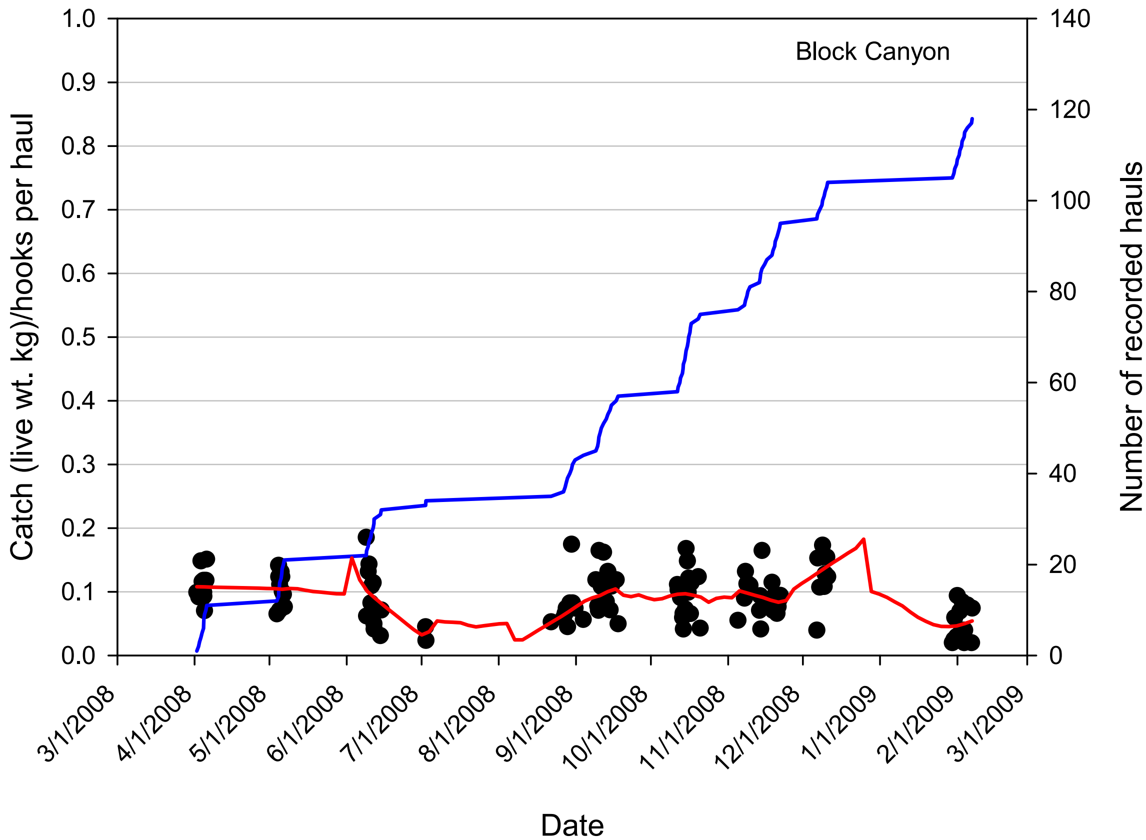
Appendix Figure A.1.23. Tilefish fork length (cm) as a function of bottom depth fished (m).



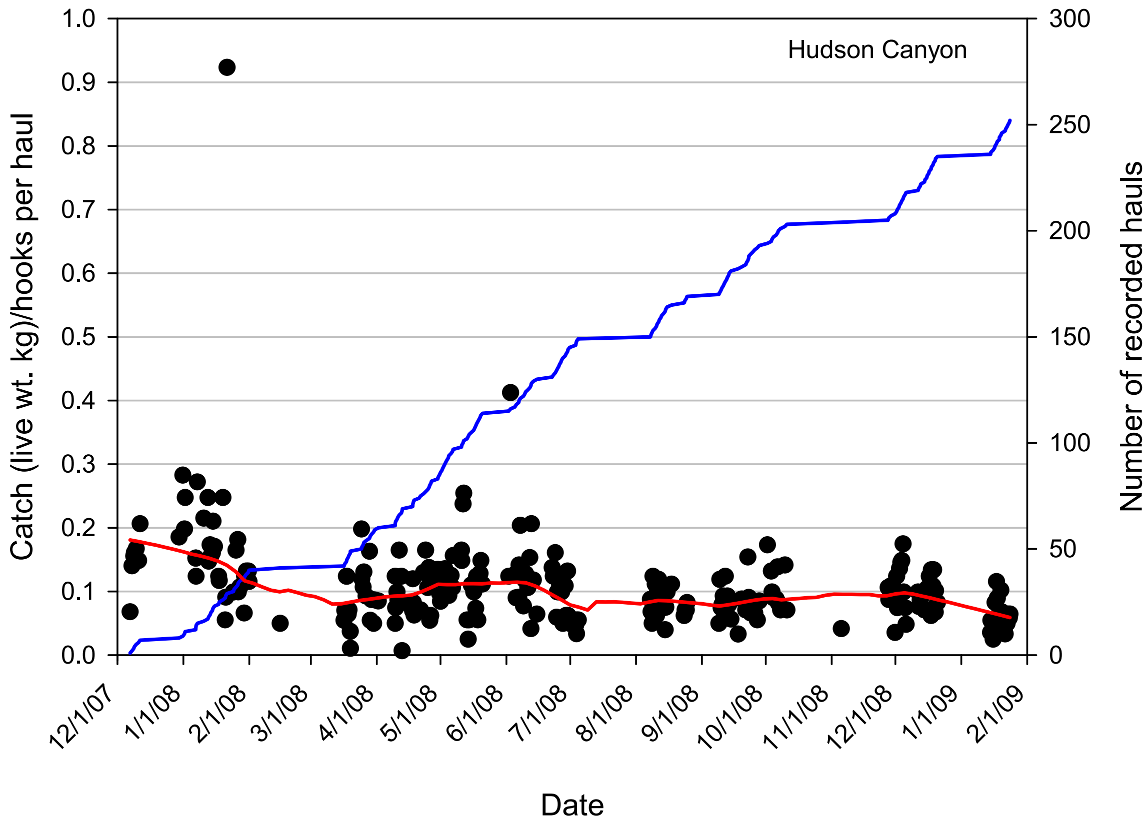
Appendix Figure A.1.24. Tilefish fork length (cm) as a function of the latitude fished (decimal degrees, dd).



Appendix Figure A.1.25. Tilefish haul-level catch (kg live wt.) over time (all data). The red line represents a loess smoothed trend of the time series.



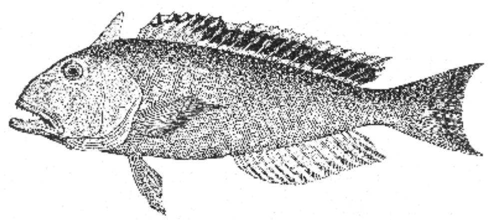
Appendix Figure A.1.26. Tilefish haul-level catch (kg live wt.) over time in the vicinity of Block Canyon. The red line represents a loess smoothed trend of the time series.



Appendix Figure A.1.27. Tilefish haul-level catch (kg live wt.) over time in the vicinity of Hudson Canyon. The red line represents a loess smoothed trend of the time series.

Evaluating shifts in size and age at maturity of Golden tilefish from the Mid-Atlantic Bight

Tiffany Vidal
NOAA/UMass Cooperative Marine Education & Research Program
Northeast Fisheries Science Center



Summary
Macroscopic and histological analysis of golden tilefish sampled from the 2008 fishery indicates smaller size at maturity and younger age at maturity than similar analysis of samples from the 1982 fishery. Histology results from analysis of 2008 data indicate that size at 50% maturity was 46cm for females and 48cm for males. Size at age observations also suggest changes in growth rates since the 1980s.

Introduction

The objective of this research was to evaluate size and age at maturation for male and female tilefish, *Lopholatilus chamaeleonticeps*, from the Mid-Atlantic stock. This analysis used macroscopic maturity class data from at-sea sampling on commercial longline vessels combined with histological analysis. The size at maturation for the 2008 stock was then compared to the 1982 stock, to determine if the proportion mature, as a function of size, has shifted towards maturation at smaller sizes. A shift towards maturation at smaller sizes could be an indication that the population size has decreased (Grift et al. 2003; Ernande et al. 2004; Anderson et al. 2007). An ageing study was performed to evaluate changes in the growth curves since 1982 and to determine age at length and maturation and to assess whether or not size at maturity has shifted from 1982, the last time the reproductive biology was evaluated (Grimes et al. 1988). Understanding and evaluating changes in size and age at maturation are important in understanding the broader population dynamics of this stock.

Methods

Sampling Design

Tilefish were sampled from commercial longline catches using a systematic sampling design stratified by fish length and gender; sampling one fish per cm interval per sex. The systematic sampling design was to ensure that the entire size distribution of the fish encountered was sampled, and that the sizes more and less frequently encountered, were not over or under-sampled, respectively. Two commercial trips, for sample collection, were made during the spawning season; June and July. Additional samples, approximately 10 fish bimonthly, were collected portside from commercial trips to obtain samples throughout the year. These fish were selected randomly from market categories: kitten, medium, and large, from the last haul of the trip.

Macroscopic staging

Tilefish are gonochoristic (i.e., they have separate sexes) and are indeterminate serial spawners (i.e., they spawn in multiple batches). Tilefish gonads are paired organs located posteriorly in the body cavity below the swim bladder, with the ovaries suspended by thin mesovaria; testis by mesorchia (Idelberger 1985). Gonads were classified to six macroscopic classes: immature, developing, ripe, ripe and running, spent, and resting; the criteria to classify individuals to a given class were based on Idelberger's (1985) classification criteria. All classes, except immature (and fish of unknown sex and/or class) were considered to be mature. Fish developing to spawn for the first time were not differentiated from repeat spawners.

One ovarian lobe or testis was removed and preserved in 10% buffered formalin; alternatively a transverse section of the medial portion of one ovary or testis was preserved for histology. In the laboratory, the gonad tissue samples were dehydrated through a series of increasing ethanol concentrations, cleared with Clear Rite™, and embedded into paraffin. The paraffin blocks were allowed to harden, trimmed around the edges using a razor blade to remove excess paraffin, sectioned at a thickness of 4μm using a microtome, mounted on glass slides, stained with hematoxylin, counterstained with eosin and coverslipped. The hematoxylin and eosin (H&E) staining method used was based on H&E procedures detailed by Luna (1968).

Microscopic staging

Microscopic criteria for staging gonadal cells were based on maturity classifications described for the following species: tilefish (Grimes et al. 1988, Erickson et al. 1985), round scad (McBride et al. 2002), tilapia (Hyder 1969), and common snook (Grier et al. 1998). Females were considered immature if the perinucleolar stage was the most advanced stage of oocyte development observed. An individual was considered to be mature if cortical alveolar, vitellogenic, or hydrated oocytes were observed. The presence of postovulatory follicles was also an indication of prior spawning. For males, the presence of spermatozoa in the spermatogenic crypts and/or lobules was the criterion for maturity.

Ageing

The fish sampled for histology were also aged. The sagittal otoliths were extracted at sea, mounted on a wax pillow atop a paper tab with crosshairs for alignment with a low-speed diamond blade Isomet® saw, completely embedded in wax, and thin sectioned through the core. The right sagittae was used unless it was broken or unavailable. Annular rings were counted to determine fish age. Each annulus, or ring, represents one year of growth; with the annuli typically laid down by June of each year (Turner 1986). Confirmation of this aging method has been done through marginal increment analysis. Otoliths from Turner's (1986) aging study were used as a reference collection to maintain consistency in the aging method.

Statistical Analysis

Logistic regression was used predict the maturity ogives for males and females from the 2008 population using the GLM function with a logit link, in the R statistical software program.

$$P_i = \frac{e^{\beta_0 + \beta_1 X_i}}{1 + e^{\beta_0 + \beta_1 X_i}} \tag{1}$$

P_i: proportion mature at size or age i
B_0: intercept of logistic model
B_1: logistic regression coefficient for explanatory variable X1
X_i: the ith observation of the explanatory variable (size or age)

The 95% confidence bands were calculated as +/- 1.96 times the standard error of the estimate of proportion mature at a given size.

The maturity ogives, for males and females, based on macroscopic and histological data were compared, and precision estimates between the two methods were determined. The macroscopic results were compared to the Grimes et al. (1988) data. The raw data were not available from the Grimes et al. (1988) study, so the binned data were expanded out and treated as raw data. This is not an ideal method for comparison, but should provide a general idea as to whether or not there have been shifts in the ogives.

To quantitatively determine whether the proportion mature as a function of length was significantly different between the macroscopic and histological methods logistic regression models were used. Logistic regression was also used to test difference in length and age at maturation between 1982 and 2008. The p-values associate with the z-statistics from the model output, in addition to the Bayesian information Criterion (BIC)

$$BIC = z - statistic^2 - \ln(n) \tag{2}$$

were used to test the significance of the regression parameters (Pampel 2000).

Growth curves were computed for the sampled 2008 population using a von Bertalanffy (1938) growth model,

$$L_t = L_\infty [1 - e^{-k(t-t_0)}] \tag{3}$$

Lt: length at age *t*
$L\infty$: asymptotic length
k: Brody growth coefficient
t_0: age at length=0

and a von Bertalanffy growth model with equally weighted mean length at age values. Growth model parameters were estimated using the SAS nlin procedure using Turner's (1986) parameter estimates as the initial values for L_∞, k, and t_0. Age at length was calculated and used to asses shifts in age at maturation, ignoring growth variation and overlapping length distributions, but associating each length with an age using the estimated von Bertalanffy parameter estimates (Hilborn and Walters 1992).

$$\hat{t} = t_0 - \left(\frac{1}{k}\right)\log\left[1 - \left(\frac{L_t}{L_\infty}\right)\right] \tag{4}$$

Growth curves were estimated for both sexes combined as well as males and females separately.

Results

Females – macroscopic

The logistic regression model predicted the proportion of fish mature at length with 95% confidence bands around the estimates. The macroscopic data analyzed were for fish sampled for histology as well; the results indicate that female tilefish begin maturing around 40 cm and are almost 100% mature by 50 cm (Figure 1). The regression cannot fully predict to the lower tails due to a lack of small fish. There is some size selectivity based on the hook size, which selects against the smallest fish in the population. As a result there is limited data for the small sizes, however the ogive fits the data fairly well. Fifty percent maturity (M_{50}) is achieved at approximately 45 cm (n=66; Table 1) and 5 years (Table 2).

Females – histological

Histological evaluation indicated that M_{50} is 46 cm (n=70; Table 3; Figure 2) and 5 years (Table 2). There was strong agreement between the two staging methods for females, with 92% precision. Eighty percent of the disagreement was due to immature fish between 42 and 50 cm being classified as developing macroscopically.

Males – macroscopic

The macroscopic maturity ogive for the 2008 males (Figure 3) shows that they begin maturing around 48 cm and are almost 100% mature at about 73 cm. The length range over which maturation occurs is much wider for the males than for the females. M_{50} is approximately 56 cm (n=149; Table 4; Figure 4) and 6 years (Table 2).

Males – histological

Agreement between the two staging methods for males was less than for the females with 85% precision. Ninety one percent of the disagreement was due to developing fish classified as immature in the field. Fifty percent maturity based on histological evaluation was predicted to be 48 cm (n=151; Table 5) and 5 years (Table 2).

All macroscopic staging

Additional macroscopic observations were made beyond those that were paired with histology. Figures 5 and 6 show all macroscopic staging data for females and males respectively from 2008. Length at 50% maturity (L_{50}) for females is predicted at 44 cm (n=321) and L_{50} for males predicted at 57 cm (n=479; Tables 6 and 7); ages 5 and 6 respectively.

Comparison to 1982 stock

The 1982 data were macroscopic observations expanded out based on the sample sizes noted on the logistic regression plots in the Grimes et al. (1988) study. The data represented proportion mature at each 5 cm length bin; the raw data were not available. Both the macroscopic and histological results were compared to the 1982 macroscopic data. Figures 7 and 8 are qualitative ways to visualize the shifts in maturity ogives from 1982 to the present. The blue line represents the 2008 data and the green line is the 1982 data from Grimes et al. (1988). Each of these plots indicates a shift toward maturation at smaller sizes in 2008 as compared to observations in 1982.

The full regression models, sexes combined, indicated that maturity schedules were significantly different between sexes; sexes were therefore analyzed separately. For all models, year was significant ($p<<0.05$; BIC>10; Tables 8-13), indicating a significant shift in size and age at maturation between 1982 and 2008. M_{50} in 1982 for females was approximately 52 cm (Table 14) and 6 years; 8 cm larger than the combined macroscopic results in 2008 and 6 cm larger than the histology results. M_{50} for males in 1982 was approximately 63 cm (Table 15) and 8 years; 6 cm larger than the combined macroscopic results in 2008 and 16 cm larger than the histology results.

Age at Length

The age-length keys developed from the two growth models: von Bertalanffy using raw data and the von Bertalanffy growth model using equally weighted mean length-at-age values are shown in Tables 16 and 2.

Growth models

Von Bertalanffy growth model results based on individual observations are displayed in Tables 17-19; Figures 9-11. Asymptotic length was substantially larger than previous estimates, due to few old fish in the sample and relatively high frequency of fish ages 5-10. To address this uneven sample distribution, alternative von Bertalanffy growth models were fit to mean length-at-age, which weights each age equally (Tables 20-22; Figures 12-14).

Discussion

These results show a significant decrease in size and age at maturation since the last evaluation of this stock in the early 1980's (Grimes et al. 1986). An environment in which survival rates are low for potentially reproducing individuals, often favors selection of individuals that are able to reproduce at smaller sizes and younger ages (Hutchings 1993; Reznick et al. 1990). In a hook fishery, it is assumed that the smallest fish in the population are less vulnerable to the gear depending on the hook size. In this fishery, hook size has been intentionally increased to avoid catch of the smallest fish in the population. The fact that such dramatic changes have manifested in this stock may suggest a density-dependent effect of decreased population size. It is uncertain at this point in time, whether these changes are consequences of phenotypic plasticity or selection towards genotypes with lower size and age at maturation.

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Table 1. Proportion mature at length for 2008 females (macroscopic)

Proportion	Length	SE
p = 0.025	36.35355	3.005000
p = 0.250	42.22186	1.487536
p = 0.500	44.73536	1.115889
p = 0.750	47.24885	1.203578
p = 0.975	53.11716	2.545929

Table 2. Age-length keys from von Bertalanffy growth model using mean length at age (sexes combined)

Age at Length		Length at Age	
Length (cm)	Age (years)	Length (cm)	Age (years)
10	1	7	1
11	1	20	2
12	1	31	3
13	1	40	4
14	2	49	5
15	2	56	6
16	2	63	7
17	2	68	8
18	2	73	9
19	2	78	10
20	2	81	11
21	2	85	12
22	2	88	13
23	2	90	14
24	2	92	15
25	2	94	16
26	3	96	17
27	3	98	18
28	3	99	19
29	3	100	20
30	3	101	21
31	3	102	22
32	3	103	23
33	3	103	24
34	3	104	25
35	3	104	26
36	4	105	27
37	4	105	28
38	4	106	29
39	4	106	30
40	4	106	31
41	4	106	32
42	4	107	33
43	4	107	34

44	4	107	35
45	5	107	36
46	5	107	37
47	5	107	38
48	5	107	39
49	5	107	40
50	5	107	41
51	5	107	42
52	5	108	43
53	6	108	44
54	6	108	45
55	6	108	46
56	6	108	47
57	6	108	48
58	6	108	49
59	6	108	50
60	7		
61	7		
62	7		
63	7		
64	7		
65	7		
66	8		
67	8		
68	8		
69	8		
70	8		
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77	10		
78	10		
79	10		
80	11		
81	11		
82	11		
83	11		
84	12		
85	12		
86	12		
87	13		
88	13		
89	14		
90	14		
91	14		
92	15		
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95	16
96	17
97	18
98	18
99	19
100	20
101	21
102	22
103	24
104	25
105	28
106	31
107	36

Table 3. Proportion mature at length for 2008 females (histological)

Proportion	Length	SE
p = 0.025	36.62657	3.160495
p = 0.250	43.10680	1.433769
p = 0.500	45.88239	1.043394
p = 0.750	48.65799	1.256798
p = 0.975	55.13821	2.898430

Table 4. Proportion mature at length for 2008 males (macroscopic)

Proportion	Length	SE
p = 0.025	39.32151	3.381805
p = 0.250	51.07196	1.644096
p = 0.500	56.10488	1.289149
p = 0.750	61.13780	1.496608
p = 0.975	72.88825	3.145142

Table 5. Proportion mature at length for 2008 males (histological)

Proportion	Length	SE
p = 0.025	38.14695	2.954953
p = 0.250	45.13220	1.528347
p = 0.500	48.12411	1.142997
p = 0.750	51.11601	1.141340
p = 0.975	58.10127	2.299208

Table 6. Proportion mature at length for 2008 females (all macroscopic observations)

Proportion	Length	SE
p = 0.025	31.60688	2.2969273
p = 0.250	40.49261	1.1497262
p = 0.500	44.29852	0.8305603
p = 0.750	48.10443	0.8333328
p = 0.975	56.99016	1.7842602

Table 7. Proportion mature at length for 2008 males (all macroscopic observations)

Proportion	Length	SE
p = 0.025	38.11876	1.8763305
p = 0.250	51.60568	0.8664657
p = 0.500	57.38236	0.7582732
p = 0.750	63.15904	1.0026450
p = 0.975	76.64596	2.0903147

Table 8. Logistic regression model output for length at maturation (females - macro)

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-12.91363	0.74598	-17.311	< 2e-16 ***
length	0.24692	0.01372	17.994	< 2e-16 ***
year2008	2.05630	0.25472	8.073	6.87e-16 ***

Table 9. Logistic regression model output for length at maturation (males - macro)

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-8.787480	0.443466	-19.815	< 2e-16 ***
year2008	0.741363	0.159973	4.634	3.58e-06 ***
length	0.139662	0.007022	19.889	< 2e-16 ***

Table 10. Logistic regression model output for length at maturation (females – histo 2008; macro 1982)

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-12.8166	0.7826	-16.376	< 2e-16 ***
length	0.2451	0.0144	17.017	< 2e-16 ***
year2008	1.5979	0.3856	4.144	3.41e-05 ***

Table 11. Logistic regression model output for length at maturation (males – histo 2008; macro 1982)

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-8.310188	0.485691	-17.110	< 2e-16 ***
year2008	2.445288	0.298275	8.198	2.44e-16 ***
length	0.131946	0.007707	17.120	< 2e-16 ***

Table 12. Logistic regression model output for age at maturation (females)

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-8.88270	0.58353	-15.22	<2e-16 ***
age	1.49627	0.09428	15.87	<2e-16 ***
year2008	2.26650	0.24190	9.37	<2e-16 ***

Table 13. Logistic regression model output for age at maturation (males)

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-5.23012	0.27635	-18.926	< 2e-16 ***
age	0.62969	0.03419	18.415	< 2e-16 ***
year2008	1.20293	0.15711	7.657	1.91e-14 ***

Table 14. Proportion mature at length for 1982 females (Grimes et al. 1988)

Proportion	Length	SE
p = 0.025	37.05423	1.0855842
p = 0.250	47.69894	0.5337725
p = 0.500	52.25825	0.3908343
p = 0.750	56.81757	0.4133665
p = 0.975	67.46228	0.8934191

Table 15. Proportion mature at length for 1982 males (Grimes et al. 1988)

Proportion	Length	SE
p = 0.025	33.76355	1.8815446
p = 0.250	54.25703	0.8505181
p = 0.500	63.03475	0.7033085
p = 0.750	71.81246	0.9232099
p = 0.975	92.30595	1.9925294

Table 16. Age-length keys from von Bertalanffy growth model (sexes combined)

Age at Length		**Length at Age**	
Length (cm)	Age (years)	Length (cm)	Age (years)
10	1	12	1
11	1	23	2
12	1	32	3
13	1	40	4
14	1	48	5
15	1	55	6
16	1	61	7
17	1	67	8
18	2	72	9
19	2	77	10
20	2	81	11
21	2	85	12
22	2	89	13
23	2	92	14
24	2	95	15
25	2	98	16
26	2	100	17
27	2	102	18
28	3	104	19
29	3	106	20
30	3	108	21
31	3	109	22
32	3	111	23
33	3	112	24
34	3	113	25
35	3	114	26
36	3	115	27
37	4	116	28
38	4	116	29
39	4	117	30
40	4	118	31
41	4	118	32
42	4	119	33
43	4	119	34
44	4	120	35
45	5	120	36
46	5	120	37
47	5	121	38
48	5	121	39

49	5	121	40
50	5	121	41
51	5	122	42
52	6	122	43
53	6	122	44
54	6	122	45
55	6	122	46
56	6	123	47
57	6	123	48
58	6	123	49
59	7	123	50
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115	27
116	28
117	30
118	32
119	33
120	36
121	39
122	44
123	52

Table 17. von Bertalanffy growth model parameter estimates (sexes combined)

Parameter	Estimate	Std Error	Approximate 95% Confidence Limits	
li	123.8	7.7452	108.5	139.1
k	0.0969	0.0127	0.0719	0.1219
t0	-0.0778	0.2908	-0.6519	0.4962

Table 18. von Bertalanffy growth model parameter estimates (females)

Parameter	Estimate	Std Error	Approximate 95% Confidence Limits	
li	112.0	9.1182	93.8035	130.2
k	0.0964	0.0175	0.0614	0.1313
t0	-0.5450	0.4590	-1.4618	0.3717

Table 19. von Bertalanffy growth model parameter estimates (males)

Parameter	Estimate	Std Error	Approximate 95% Confidence Limits	
li	141.5	12.1959	117.3	165.7
k	0.0833	0.0136	0.0564	0.1102
t0	-0.0920	0.3331	-0.7527	0.5687

Table 20. von Bertalanffy growth model parameter estimates using mean length at age (sexes combined)

Parameter	Estimate	Std Error	Approximate 95% Confidence Limits	
li	107.9	5.7375	95.9875	119.8
k	0.1338	0.0226	0.0869	0.1807
t0	0.4944	0.5182	-0.5802	1.5690

Table 21. von Bertalanffy growth model parameter estimates using mean length at age (females)

Parameter	Estimate	Std Error	Approximate 95% Confidence Limits	
li	100.1	7.1457	84.1627	116.0
k	0.1393	0.0337	0.0643	0.2142
t0	0.4136	0.7551	-1.2688	2.0961

Table 22. von Bertalanffy growth model parameter estimates using mean length at age (males)

Parameter	Estimate	Std Error	Approximate 95% Confidence Limits	
li	122.2	7.6163	105.0	139.5
k	0.1134	0.0196	0.0691	0.1577
t0	0.4276	0.5271	-0.7649	1.6200

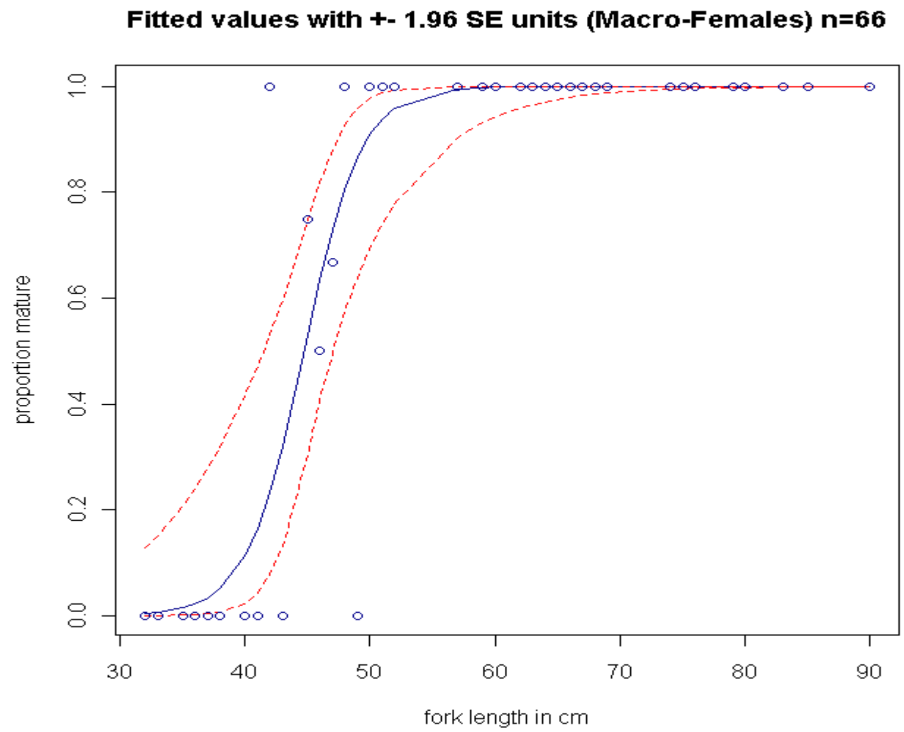

Figure 1. Maturity ogive for females based on macroscopic data (2008)

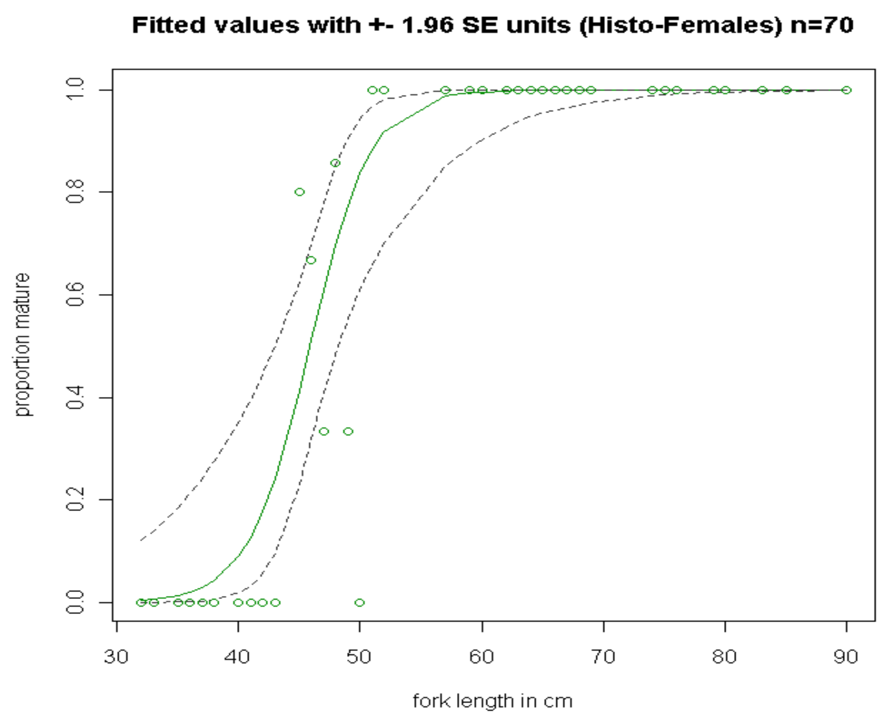

Figure 2. Maturity ogive for females based on histological data (2008)

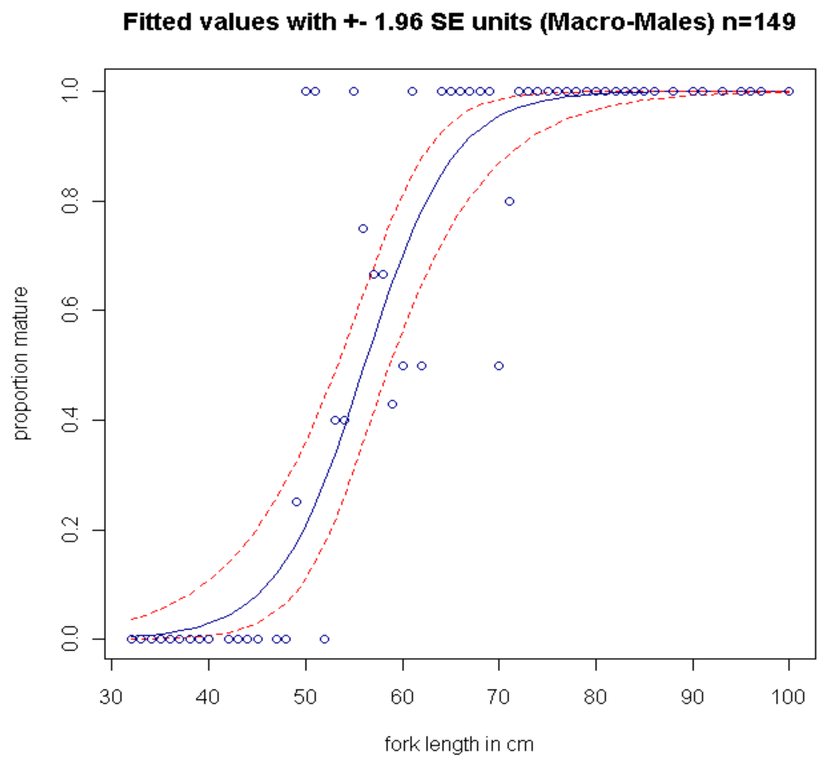

Figure 3. Maturity ogive for males based on macroscopic data (2008)

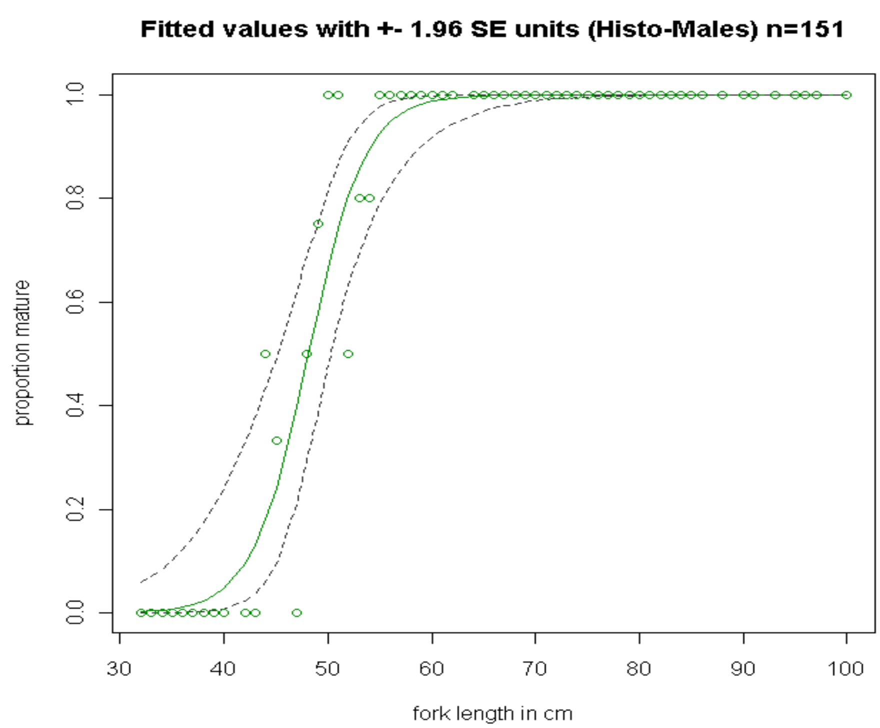

Figure 4. Maturity ogive for males based on histological data (2008)

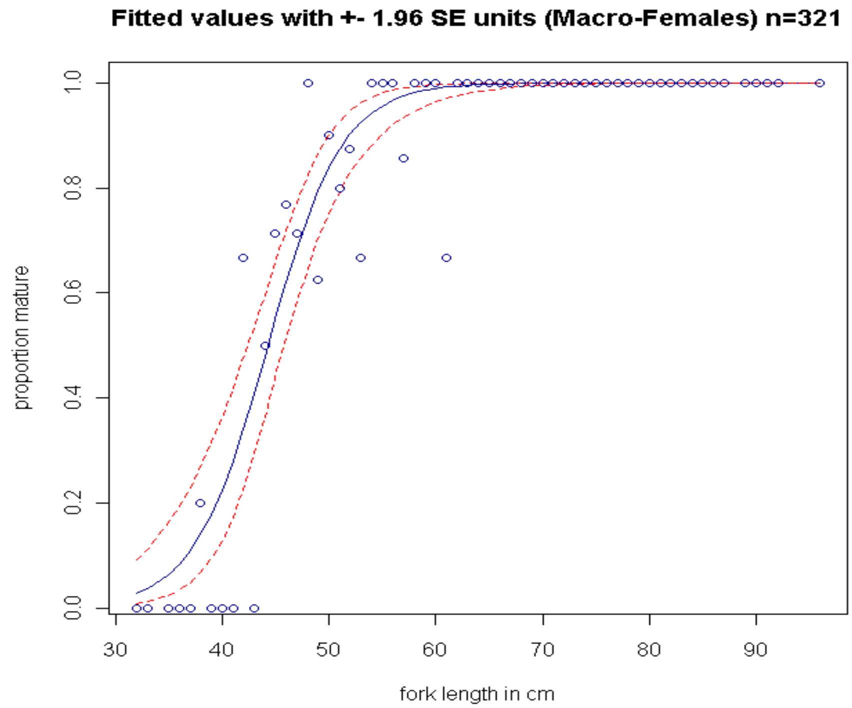

Figure 5. All macroscopic observations for females (2008)

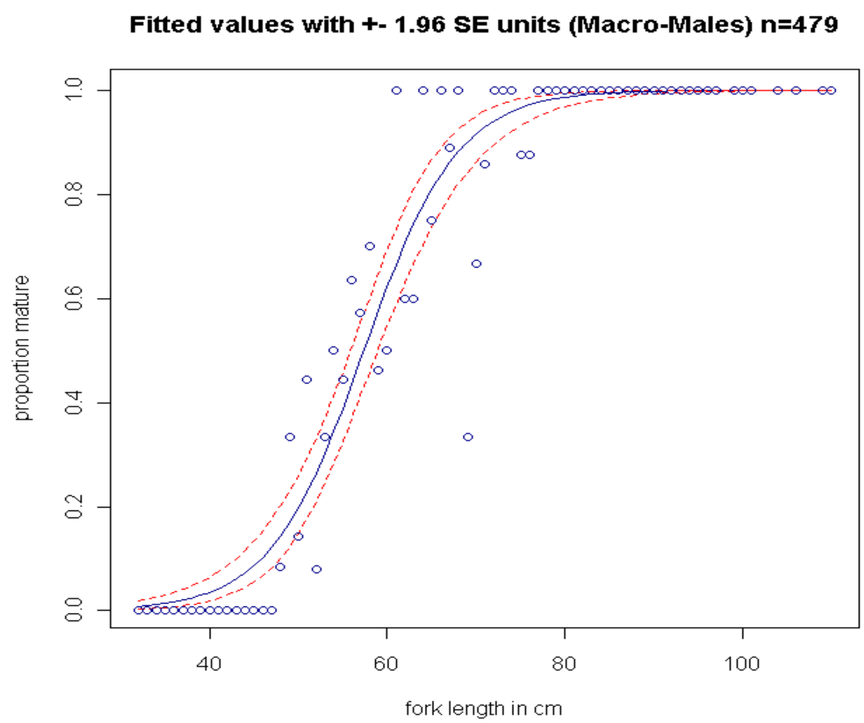

Figure 6. All macroscopic observations for males (2008)

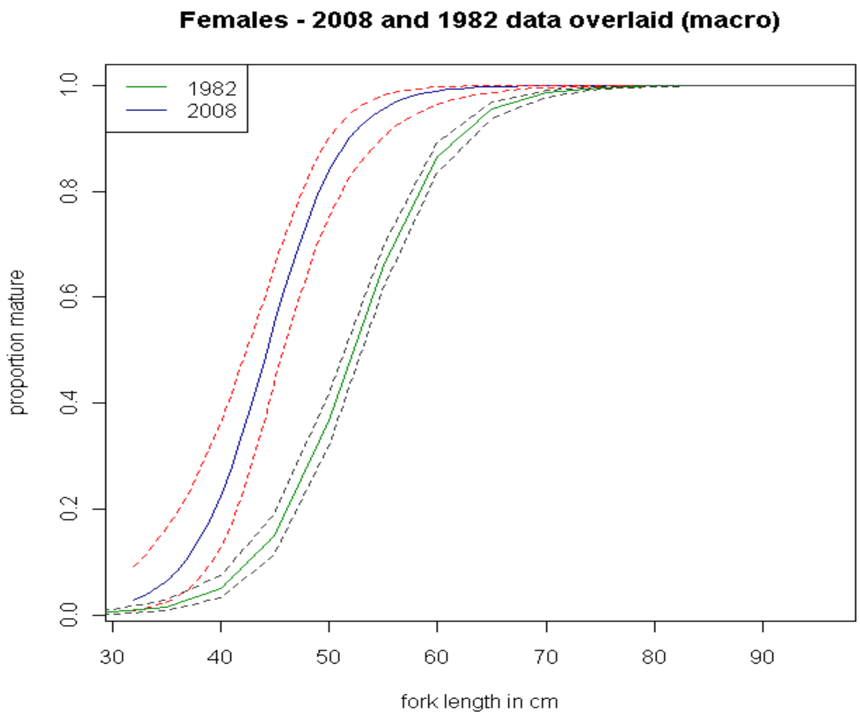

Figure 7. Maturity ogives, with 95% confidence limits, for the 1982 and 2008 females: green line=1982; blue line=2008. The 2008 data is based on all macroscopic observations..

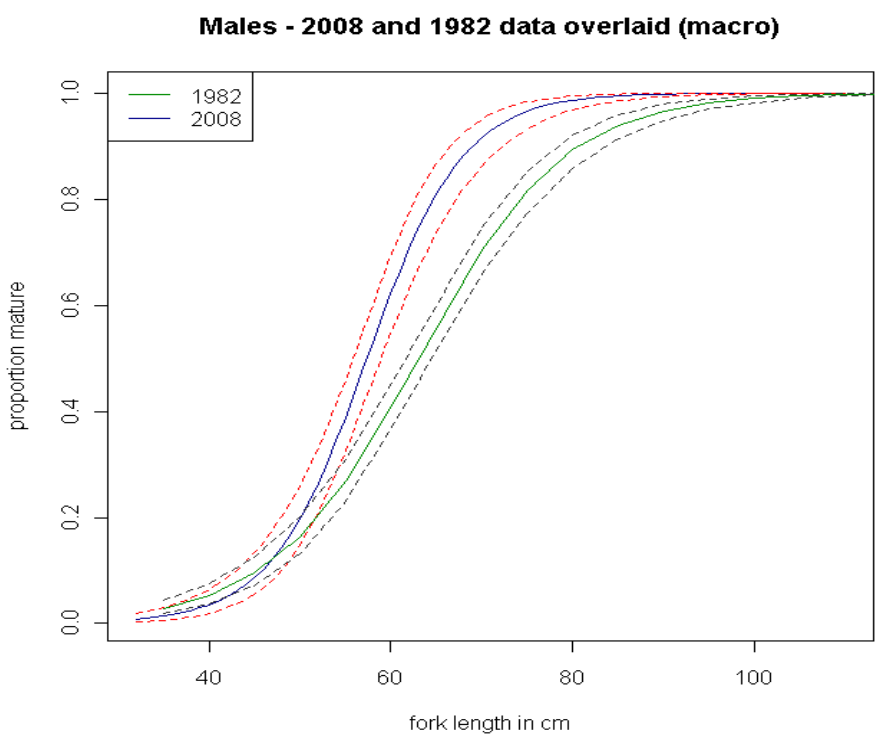

Figure 8. Maturity ogives, with 95% confidence limits, for the 1982 and 2008 males: green line=1982; blue line=2008. The 2008 data is based on all macroscopic observations

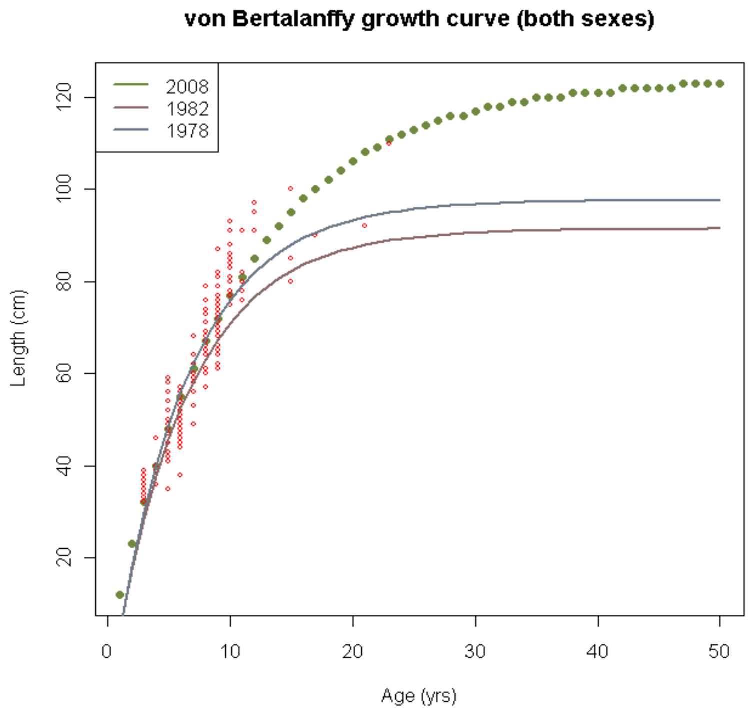

Figure 9. von Bertalanffy growth curve fit to observations of length at age (sexes combined)

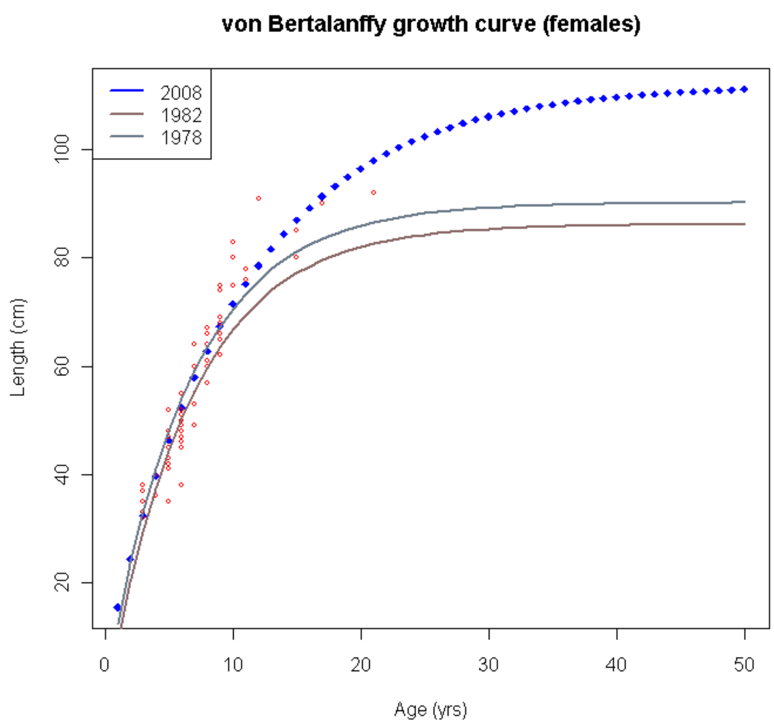

Figure 10. von Bertalanffy growth curve fit to observations of length at age (females)

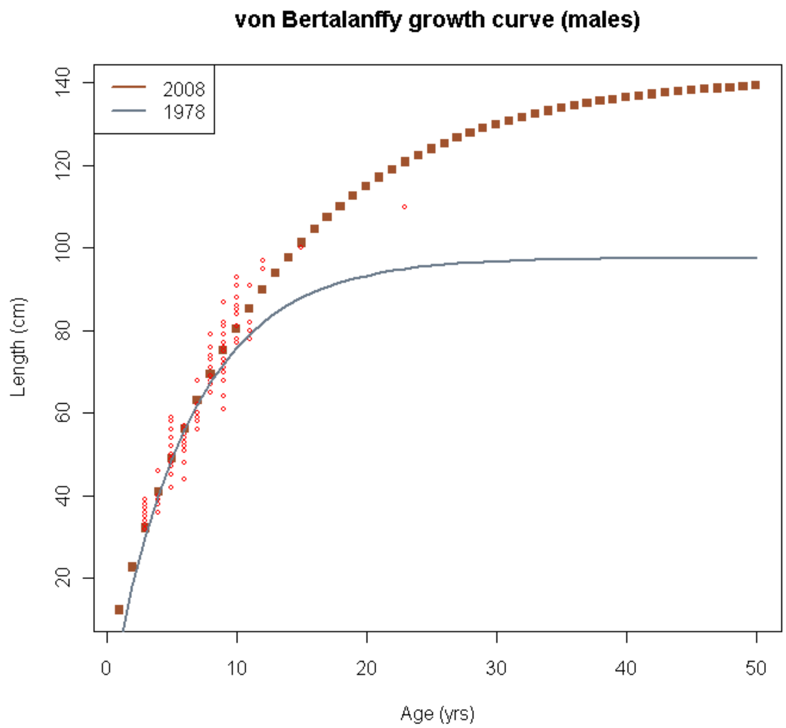

Figure 11. von Bertalanffy growth curve fit to observations of length at age (males)

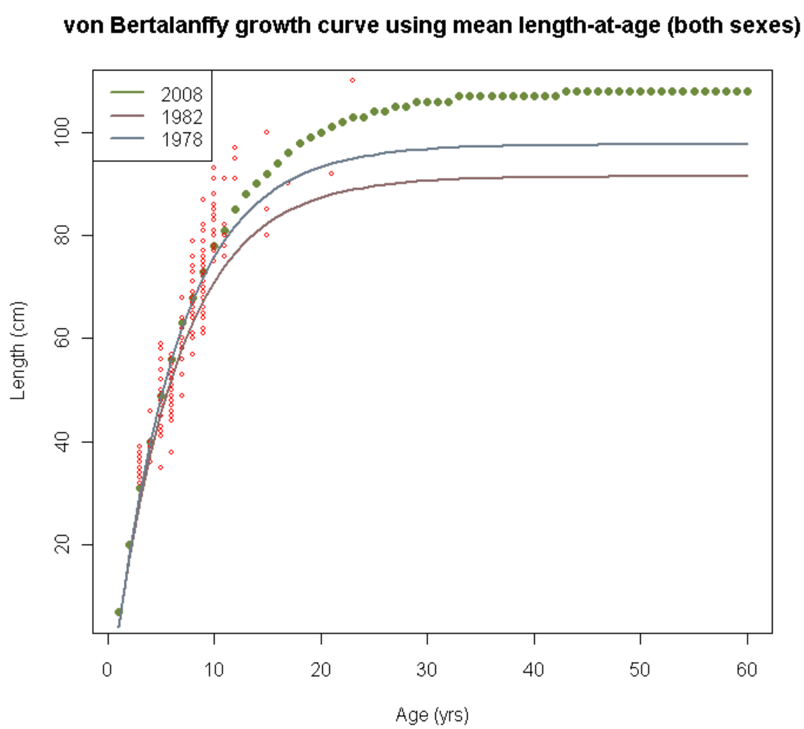

Figure 12. von Bertalanffy growth curve fit to mean length at age (sexes combined)

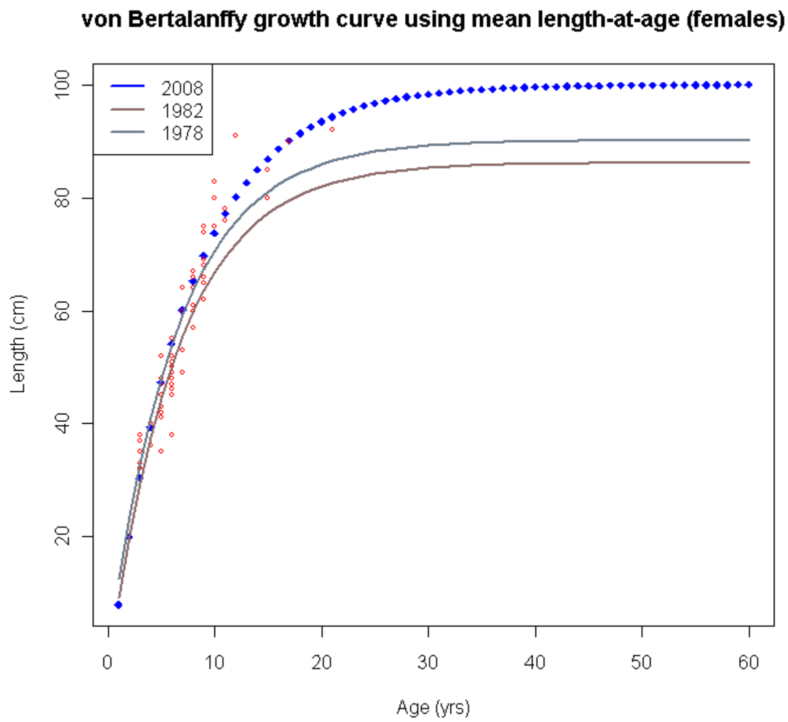

Figure 13. von Bertalanffy growth curve fit to mean length at age (females)

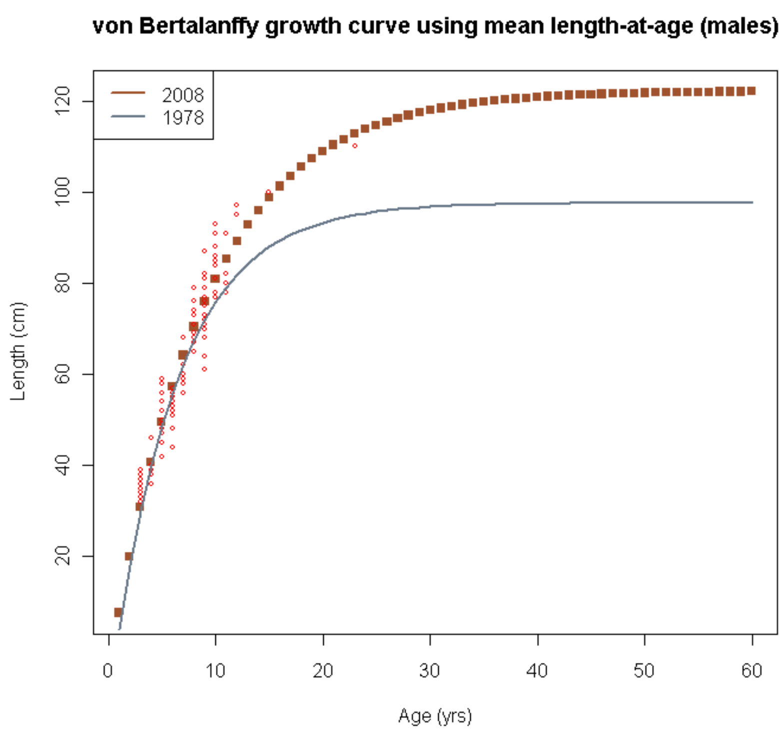

Figure 14. von Bertalanffy growth curve fit to mean length at age (males)

NEFSC Weighout CPUE GLM model

```
The SAS System
14:00 Thursday, March 31, 2005   1

The GLM Procedure
                                                      Class Level Information
Class        Levels  Values

lndyear         15  1979 1980 1981 1982 1983 1985 1986 1987 1988 1989 1990 1991 1992 1993 9999


permit          92        delete permit numbers
Number of observations    1897
The SAS System
 14:00 Thursday, March 31, 2005   2

The GLM Procedure
 Dependent Variable: LNCPUE

                                          Sum of
Source                       DF          Squares     Mean Square    F Value    Pr > F
Model                       105      743.569869        7.081618      23.67    <.0001
Error                      1791      535.787323        0.299155

Corrected Total            1896     1279.357192

R-Square     Coeff Var      Root MSE    LNCPUE Mean
0.581206      8.116663      0.546951       6.738619

Source                       DF       Type I SS     Mean Square    F Value    Pr > F
lndyear                      14     566.9637531      40.4974109     135.37    <.0001
permit                       91     176.6061156       1.9407265       6.49    <.0001

Source                       DF     Type III SS     Mean Square    F Value    Pr > F
lndyear                      14     281.1521083      20.0822934      67.13    <.0001
permit                       91     176.6061156       1.9407265       6.49    <.0001

                                                 Standard
Parameter              Estimate                 Error    t Value    Pr > |t|

Intercept          6.232567267 B      0.11429828      54.53      <.0001
lndyear   1979     1.022878443 B      0.07430951      13.77      <.0001
lndyear   1980     0.991305758 B      0.07181247      13.80      <.0001
lndyear   1981     0.957632235 B      0.07168379      13.36      <.0001
lndyear   1982     0.461931590 B      0.07359297       6.28      <.0001
lndyear   1983     0.036989477 B      0.07511938       0.49      0.6225
lndyear   1985    -0.116577906 B      0.07301030      -1.60      0.1105
lndyear   1986     0.078237855 B      0.07992860       0.98      0.3278
lndyear   1987     0.235247667 B      0.07689409       3.06      0.0023
lndyear   1988    -0.290869711 B      0.08580020      -3.39      0.0007
lndyear   1989    -0.437414680 B      0.11355219      -3.85      0.0001
lndyear   1990    -0.412418009 B      0.10524248      -3.92      <.0001
lndyear   1991    -0.462210977 B      0.09637704      -4.80      <.0001
lndyear   1992    -0.213720208 B      0.09349023      -2.29      0.0224
lndyear   1993    -0.277906028 B      0.09113548      -3.05      0.0023
lndyear   9999     0.000000000 B       .               .          .
permit    -        0.053877941 B      0.39953947       0.13      0.8927
permit    -        0.290799259 B      0.40217631       0.72      0.4697
permit    -        2.200653904 B      0.55660933       3.95      <.0001
permit    -       -0.720065816 B      0.33062733      -2.18      0.0295
permit    -        1.204048080 B      0.23673422       5.09      <.0001
permit    -       -0.918838210 B      0.55660933      -1.65      0.0990
permit    -        0.884977111 B      0.55660933       1.59      0.1120
permit    -        0.089186369 B      0.13030426       0.68      0.4938
permit    -        0.351073875 B      0.55660933       0.63      0.5283
permit    -       -0.474685588 B      0.40127024      -1.18      0.2370
permit    -       -1.051239079 B      0.55796370      -1.88      0.0597
permit    -        0.883791874 B      0.55876605       1.58      0.1139
permit    -        0.042036558 B      0.15197217       0.28      0.7821
```

permit	-	-2.501448583	B	0.55827964	-4.48	<.0001
permit	-	0.450272193	B	0.12822212	3.51	0.0005
permit	-	0.471191134	B	0.55809344	0.84	0.3986
permit	-	-0.050060896	B	0.14723604	-0.34	0.7339
permit	-	-0.138317903	B	0.24734699	-0.56	0.5761
permit	-	0.288864363	B	0.40301160	0.72	0.4736
permit	-	-0.719753788	B	0.55856606	-1.29	0.1977
permit	-	0.539895149	B	0.20257954	2.67	0.0078
permit	-	0.200325406	B	0.14810284	1.35	0.1764
permit	-	0.166798650	B	0.13012707	1.28	0.2001
permit	-	0.171959971	B	0.11302093	1.52	0.1283
permit	-	0.231976547	B	0.12244851	1.89	0.0583
permit	-	0.024125664	B	0.13432034	0.18	0.8575
permit	-	0.094051267	B	0.16446785	0.57	0.5675
permit	-	0.371090946	B	0.17507191	2.12	0.0342
permit	-	0.068525060	B	0.15621988	0.44	0.6610
permit	-	0.291237884	B	0.55606608	0.52	0.6005
permit	-	0.250774748	B	0.19444954	1.29	0.1973
permit	-	-1.365464039	B	0.19254217	-7.09	<.0001
permit	-	0.202892095	B	0.11692497	1.74	0.0829
permit	-	-0.150565146	B	0.55660933	-0.27	0.7868
permit	-	-1.227887492	B	0.55827964	-2.20	0.0280
permit	-	-1.316984788	B	0.55796370	-2.36	0.0184
permit	-	0.055682092	B	0.55606608	0.10	0.9202
permit	-	0.476788308	B	0.56089822	0.85	0.3954
permit	-	-1.513147475	B	0.22407363	-6.75	<.0001
permit	-	0.925030445	B	0.56089822	1.65	0.0993
permit	-	-0.260880622	B	0.40623775	-0.64	0.5208
permit	-	0.277147040	B	0.11033921	2.51	0.0121
permit	-	-0.894403775	B	0.26894018	-3.33	0.0009
permit	-	-0.087797738	B	0.21953680	-0.40	0.6893
permit	-	0.002668324	B	0.19877790	0.01	0.9893
permit	-	0.496364007	B	0.10872728	4.57	<.0001
permit	-	-0.163600190	B	0.55796370	-0.29	0.7694
permit	-	0.467983305	B	0.12033347	3.89	0.0001
permit	-	0.024708856	B	0.13276574	0.19	0.8524
permit	-	-1.665756882	B	0.40275435	-4.14	<.0001
permit	-	-0.008289609	B	0.21203679	-0.04	0.9688
permit	-	0.422212817	B	0.56253472	0.75	0.4530
permit	-	-0.994541917	B	0.41068120	-2.42	0.0155
permit	-	0.640814312	B	0.17122800	3.74	0.0002
permit	-	0.289229697	B	0.11245469	2.57	0.0102
permit	-	0.232020794	B	0.11406216	2.03	0.0421
permit	-	0.435287696	B	0.23285239	1.87	0.0617
permit	-	-0.093362255	B	0.55876605	-0.17	0.8673
permit	-	0.565119319	B	0.29382393	1.92	0.0546
permit	-	0.185883996	B	0.10864670	1.71	0.0873
permit	-	0.383628924	B	0.26777330	1.43	0.1521
permit	-	-0.429338431	B	0.15476255	-2.77	0.0056
permit	-	0.941153790	B	0.26751142	3.52	0.0004
permit	-	-0.144900138	B	0.55876605	-0.26	0.7954
permit	-	-0.018365360	B	0.39831869	-0.05	0.9632
permit	-	0.233109656	B	0.24325318	0.96	0.3380
permit	-	0.579583698	B	0.55656992	1.04	0.2979
permit	-	0.280357477	B	0.14815327	1.89	0.0586
permit	-	-0.220190021	B	0.33549831	-0.66	0.5117
permit	-	0.477244382	B	0.17126647	2.79	0.0054
permit	-	0.586558492	B	0.29544304	1.99	0.0473
permit	-	1.003951166	B	0.55606608	1.81	0.0712
permit	-	0.882877530	B	0.33498687	2.64	0.0085
permit	-	0.191509700	B	0.24286878	0.79	0.4305
permit	-	0.297364159	B	0.29099874	1.02	0.3070
permit	-	0.283495433	B	0.12957609	2.19	0.0288
permit	-	1.042813481	B	0.56089822	1.86	0.0632
permit	-	-0.065468315	B	0.19188028	-0.34	0.7330
permit	-	-0.153684912	B	0.40328873	-0.38	0.7032
permit	-	0.036432483	B	0.15621610	0.23	0.8156
permit	-	0.099929826	B	0.29223882	0.34	0.7324
permit	-	0.224377910	B	0.11753056	1.91	0.0564
permit	-	0.334472400	B	0.29263852	1.14	0.2532
permit	-	0.346528767	B	0.39933585	0.87	0.3856
permit	-	0.131354900	B	0.17613902	0.75	0.4559
permit	-	0.056859718	B	0.15272950	0.37	0.7097
permit	-	-1.420176111	B	0.55660933	-2.55	0.0108
permit	-	-1.054505031	B	0.33062733	-3.19	0.0015
permit	-	1.290671749	B	0.56253472	2.29	0.0219

permit	-	-0.545675103 B	0.55660933	-0.98	0.3270
permit	-	0.722755358 B	0.12789264	5.65	<.0001
permit	-	0.000000000 B	.	.	.

NEFSC VTR CPUE GLM model

The SAS System
14:33 Monday, March 9, 2009

The GLM Procedure
Class Level Information

Class	Levels	Values
lndyear	14	1995 1996 1997 1998 1999 2001 2002 2003 2004 2005 2006 2007 2008 9999
permit	28	delete permit numbers

Number of observations 1644

The SAS System
14:33 Monday, March 9, 2009

The GLM Procedure

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	40	486.8316755	12.1707919	56.67	<.0001
Error	1603	344.2626234	0.2147615		
Corrected Total	1643	831.0942989			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.585772	6.982976	0.463424	6.636478

Source	DF	Type I SS	Mean Square	F Value	Pr > F
lndyear	13	349.5367440	26.8874418	125.20	<.0001
permit	27	137.2949315	5.0849975	23.68	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
lndyear	13	300.7498197	23.1346015	107.72	<.0001
permit	27	137.2949315	5.0849975	23.68	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		5.105961941 B	0.27514746	18.56	<.0001
lndyear	1995	-0.000311337 B	0.06567651	-0.00	0.9962
lndyear	1996	0.333314839 B	0.06159706	5.41	<.0001
lndyear	1997	0.849015959 B	0.06047455	14.04	<.0001
lndyear	1998	0.322043216 B	0.05885335	5.47	<.0001
lndyear	1999	-0.010958858 B	0.06068052	-0.18	0.8567
lndyear	2001	0.340009452 B	0.06244886	5.44	<.0001
lndyear	2002	0.541877218 B	0.06287945	8.62	<.0001
lndyear	2003	1.021480120 B	0.06520389	15.67	<.0001
lndyear	2004	1.324952771 B	0.06417921	20.64	<.0001
lndyear	2005	1.517578755 B	0.06802508	22.31	<.0001
lndyear	2006	1.193859874 B	0.06813050	17.52	<.0001
lndyear	2007	0.778697695 B	0.06658842	11.69	<.0001
lndyear	2008	0.358006552 B	0.06567768	5.45	<.0001
lndyear	9999	0.000000000 B	.	.	.
permit	-	0.971373595 B	0.53879108	1.80	0.0716
permit	-	-1.049233248 B	0.34106397	-3.08	0.0021

```
   permit    -     -0.211985376 B      0.42788650      -0.50      0.6204
   permit    -      0.637114469 B      0.29088986       2.19      0.0287
   permit    -      1.043620837 B      0.53836635       1.94      0.0527
   permit    -     -0.207701079 B      0.32349487      -0.64      0.5209
   permit    -      0.199074689 B      0.29734291       0.67      0.5033
   permit    -      0.795214347 B      0.33240705       2.39      0.0169
   permit    -      0.631300722 B      0.29044120       2.17      0.0299
   permit    -      0.056104033 B      0.28182625       0.20      0.8422
   permit    -      0.900218135 B      0.27302248       3.30      0.0010
   permit    -     -0.029499084 B      0.29005518      -0.10      0.9190
   permit    -      0.710693173 B      0.28013526       2.54      0.0113
   permit    -      0.490335540 B      0.31508786       1.56      0.1199
   permit    -      0.841245620 B      0.28298212       2.97      0.0030
   permit    -      1.922829272 B      0.53861803       3.57      0.0004
   permit    -      0.967713437 B      0.27304640       3.54      0.0004
   permit    -      0.370539541 B      0.30374715       1.22      0.2227
   permit    -     -1.091964427 B      0.53895045      -2.03      0.0429
   permit    -     -0.084261747 B      0.35851162      -0.24      0.8142
   permit    -      0.953641916 B      0.27327679       3.49      0.0005
   permit    -      0.929799416 B      0.28667927       3.24      0.0012
   permit    -      1.158830352 B      0.27203468       4.26      <.0001
   permit    -      0.552623254 B      0.35951185       1.54      0.1245
   permit    -     -1.584154615 B      0.53917468      -2.94      0.0033
   permit    -      0.944499945 B      0.28519020       3.31      0.0009
   permit    -      1.066086228 B      0.27210354       3.92      <.0001
   permit    -      0.000000000 B       .                .          .

NOTE: The X'X matrix has been found to be singular, and a generalized inverse
      was used to solve the normal equations.  Terms whose estimates are
      followed by the letter 'B' are not uniquely estimable.
```

ASPIC Base Boostrap run 1

```
TILEFISH 2009 BASE Bootstrap

    Wednesday, 11 Mar 2009 at 11:09:35
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.33)

      BOT program mode
Author:         Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research
                            LOGISTIC model mode   101 Pivers Island Road; Beaufort, North
Carolina  28516  USA                               YLD conditioning
Mike.Prager@noaa.gov
SSE optimization

Reference:  Prager, M. H. 1994. A suite of extensions to a nonequilibrium             ASPIC
User's Manual is available surplus-production model.  Fishery Bulletin 92: 374-389.
              gratis from the author.

CONTROL  PARAMETERS  (FROM  INPUT  FILE)                                        Input  file:
c:\tile2009\aspic\f73fix1_v5_2008_base_boot.inp
-------------------------------------------------------------------------------------------------
-------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization with bootstrap.
Number of years analyzed:        36         Number of bootstrap trials:     1000
Number of data series:            3         Bounds on MSY (min, max): 3.750E-02 3.000E+02
Objective function:      Least squares      Bounds on K (min, max):  8.000E-01  2.000E+03
Relative conv. criterion (simplex):       1.000E-08
Monte Carlo search mode, trials:          1         50000
Relative     conv.     criterion     (restart):                                      3.000E-08
Random number seed:                       973142085
Relative conv. criterion (effort):        1.000E-04
Identical convergences required in fitting:       6
Maximum F allowed in fitting:                 5.000

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)
        error code   0
-------------------------------------------------------------------------------------
Normal convergence

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
-------------------------------------------------------------------------------------
                                       |
 1  weighout cpue                      |   1.000
```

```
                                          |      15
                                          |
 2  turner                                |   0.994   1.000
                                          |       4      10
                                          |
 3  vtr                                   |   0.000   0.000   1.000
                                          |       0       0      14
                                          --------------------------------------------------
                                                  1       2       3


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
-----------------------------------------------------------------------------------------

                                    Weighted      Weighted     Current    Inv. var.    R-squared
Loss component number and title       SSE     N      MSE        weight      weight      in CPUE

Loss(-1)  SSE in yield           0.000E+00
Loss(0)   Penalty for B1 > K     0.000E+00   1      N/A        0.000E+00       N/A
Loss(1)   weighout cpue          1.255E+00   15    9.653E-02    1.000E+00    1.141E+00   0.652
Loss(2)   turner                 6.429E-01   10    8.037E-02    1.000E+00    1.370E+00   0.224
Loss(3)   vtr                    2.258E+00   14    1.881E-01    1.000E+00    5.852E-01   0.201
.........................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:          4.15554979E+00          1.222E-01    3.496E-01
Estimated contrast index (ideal = 1.0):               0.5261         C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):               1.0000         N* = 1 - |min(B-Bmsy)|/K
TILEFISH                        2009                       BASE                        Bootstrap

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-------------------------------------------------------------------------------------------------
Parameter                                 Estimate User/pgm guess 2nd guess  Estimated User guess

B1/K Starting relative biomass (in 1973)  5.000E-01  5.000E-01    9.000E-01     0           1
MSY  Maximum sustainable yield            1.868E+00  3.000E+00    1.271E+00     1           1
K    Maximum population size              2.279E+01  4.000E+01    7.629E+00     1           1
phi  Shape of production curve (Bmsy/K)   0.5000     0.5000           ----      0           1

--------- Catchability Coefficients by Data Series ---------------
q(1)      weighout cpue                 1.754E-01   3.000E-02    4.750E-01      1           1
q(2)      turner                        8.791E-03   3.000E-02    4.750E-01      1           1
q(3)      vtr                           2.604E-01   3.000E-02    4.750E-01      1           1

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-------------------------------------------------------------------------------------------------
Parameter                               Estimate         Logistic formula          General formula

MSY   Maximum sustainable yield          1.868E+00            ----                       ----
Bmsy  Stock biomass giving MSY           1.140E+01            K/2               K*n**(1/(1-n))
Fmsy  Fishing mortality rate at MSY      1.639E-01          MSY/Bmsy                 MSY/Bmsy

n     Exponent in production function      2.0000             ----                       ----
g     Fletcher's gamma                   4.000E+00            ----      [n**(n/(n-1))]/[n-1]

B./Bmsy Ratio: B(2009)/Bmsy              1.143E+00            ----                       ----
F./Fmsy Ratio: F(2008)/Fmsy              3.598E-01            ----                       ----
Fmsy/F. Ratio: Fmsy/F(2008)              2.779E+00            ----                       ----

Y.(Fmsy) Approx. yield available at Fmsy in 2009   2.136E+00   MSY*B./Bmsy         MSY*B./Bmsy
          ...as proportion of MSY         1.143E+00            ----                       ----
Ye.  Equilibrium yield available in 2009  1.830E+00     4*MSY*(B/K-(B/K)**2) g*MSY*(B/K-(B/K)**n)
          ...as proportion of MSY         9.795E-01            ----                       ----

--------- Fishing effort rate at MSY in units of each CE or CC series ---------
fmsy(1)   weighout cpue                  9.349E-01          Fmsy/q( 1)              Fmsy/q( 1)
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TILEFISH 2009 BASE Bootstrap

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1973	0.031	1.140E+01	1.259E+01	3.940E-01	3.940E-01	1.872E+00	1.908E-01	9.999E-01
2	1974	0.043	1.287E+01	1.349E+01	5.860E-01	5.860E-01	1.803E+00	2.649E-01	1.130E+00
3	1975	0.049	1.409E+01	1.461E+01	7.100E-01	7.100E-01	1.719E+00	2.965E-01	1.236E+00
4	1976	0.065	1.510E+01	1.542E+01	1.010E+00	1.010E+00	1.635E+00	3.995E-01	1.325E+00
5	1977	0.134	1.573E+01	1.549E+01	2.082E+00	2.082E+00	1.627E+00	8.200E-01	1.380E+00
6	1978	0.225	1.527E+01	1.447E+01	3.257E+00	3.257E+00	1.730E+00	1.373E+00	1.340E+00
7	1979	0.314	1.374E+01	1.262E+01	3.968E+00	3.968E+00	1.842E+00	1.918E+00	1.206E+00
8	1980	0.369	1.162E+01	1.054E+01	3.889E+00	3.889E+00	1.853E+00	2.251E+00	1.019E+00
9	1981	0.404	9.581E+00	8.663E+00	3.499E+00	3.499E+00	1.757E+00	2.464E+00	8.407E-01
10	1982	0.259	7.839E+00	7.675E+00	1.990E+00	1.990E+00	1.669E+00	1.582E+00	6.878E-01
11	1983	0.254	7.518E+00	7.396E+00	1.877E+00	1.877E+00	1.638E+00	1.548E+00	6.597E-01
12	1984	0.284	7.279E+00	7.069E+00	2.009E+00	2.009E+00	1.599E+00	1.734E+00	6.387E-01
13	1985	0.295	6.869E+00	6.656E+00	1.961E+00	1.961E+00	1.545E+00	1.797E+00	6.027E-01
14	1986	0.314	6.453E+00	6.212E+00	1.950E+00	1.950E+00	1.482E+00	1.915E+00	5.662E-01
15	1987	0.650	5.984E+00	4.936E+00	3.210E+00	3.210E+00	1.264E+00	3.967E+00	5.251E-01
16	1988	0.351	4.038E+00	3.882E+00	1.361E+00	1.361E+00	1.056E+00	2.139E+00	3.543E-01
17	1989	0.085	3.733E+00	5.323E+00	4.540E-01	4.540E-01	1.206E+00	5.203E-01	3.275E-01
18	1990	0.153	4.485E+00	5.717E+00	8.740E-01	8.740E-01	1.380E+00	9.325E-01	3.936E-01
19	1991	0.236	4.991E+00	5.041E+00	1.189E+00	1.189E+00	1.287E+00	1.439E+00	4.380E-01
20	1992	0.338	5.090E+00	4.888E+00	1.653E+00	1.653E+00	1.259E+00	2.063E+00	4.466E-01
21	1993	0.424	4.696E+00	4.340E+00	1.838E+00	1.838E+00	1.152E+00	2.583E+00	4.120E-01
22	1994	0.146	4.009E+00	5.374E+00	7.860E-01	7.860E-01	1.299E+00	8.922E-01	3.518E-01
23	1995	0.139	4.522E+00	4.808E+00	6.660E-01	6.660E-01	1.244E+00	8.450E-01	3.967E-01
24	1996	0.216	5.099E+00	5.197E+00	1.121E+00	1.121E+00	1.315E+00	1.316E+00	4.474E-01
25	1997	0.360	5.294E+00	5.023E+00	1.810E+00	1.810E+00	1.284E+00	2.198E+00	4.645E-01
26	1998	0.285	4.767E+00	4.708E+00	1.342E+00	1.342E+00	1.225E+00	1.739E+00	4.183E-01
27	1999	0.104	4.650E+00	5.024E+00	5.250E-01	5.250E-01	1.284E+00	6.374E-01	4.080E-01
28	2000	0.086	5.409E+00	5.864E+00	5.060E-01	5.060E-01	1.427E+00	5.264E-01	4.746E-01
29	2001	0.131	6.330E+00	6.665E+00	8.740E-01	8.740E-01	1.546E+00	7.998E-01	5.554E-01
30	2002	0.115	7.002E+00	7.395E+00	8.510E-01	8.510E-01	1.637E+00	7.020E-01	6.144E-01
31	2003	0.140	7.788E+00	8.080E+00	1.130E+00	1.130E+00	1.710E+00	8.531E-01	6.834E-01
32	2004	0.141	8.368E+00	8.643E+00	1.215E+00	1.215E+00	1.759E+00	8.575E-01	7.342E-01
33	2005	0.092	8.912E+00	9.385E+00	8.680E-01	8.680E-01	1.809E+00	5.642E-01	7.820E-01
34	2006	0.088	9.853E+00	1.033E+01	9.070E-01	9.070E-01	1.851E+00	5.356E-01	8.645E-01
35	2007	0.066	1.080E+01	1.136E+01	7.510E-01	7.510E-01	1.867E+00	4.032E-01	9.474E-01
36	2008	0.059	1.191E+01	1.248E+01	7.360E-01	7.360E-01	1.850E+00	3.598E-01	1.045E+00
37	2009		1.303E+01						1.143E+00

TILEFISH 2009 BASE Bootstrap

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED)
weighout cpue

Data type CC: CPUE-catch series
Series weight: 1.000

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Statist weight
1	1973	*	2.209E+00	0.0313	3.940E-01	3.940E-01	0.00000	1.000E+00
2	1974	*	2.366E+00	0.0434	5.860E-01	5.860E-01	0.00000	1.000E+00
3	1975	*	2.562E+00	0.0486	7.100E-01	7.100E-01	0.00000	1.000E+00
4	1976	*	2.705E+00	0.0655	1.010E+00	1.010E+00	0.00000	1.000E+00
5	1977	*	2.716E+00	0.1344	2.082E+00	2.082E+00	0.00000	1.000E+00
6	1978	*	2.537E+00	0.2251	3.257E+00	3.257E+00	0.00000	1.000E+00
7	1979	2.789E+00	2.213E+00	0.3145	3.968E+00	3.968E+00	-0.23140	1.000E+00
8	1980	2.702E+00	1.848E+00	0.3690	3.889E+00	3.889E+00	-0.37962	1.000E+00
9	1981	2.612E+00	1.519E+00	0.4039	3.499E+00	3.499E+00	-0.54194	1.000E+00
10	1982	1.591E+00	1.346E+00	0.2593	1.990E+00	1.990E+00	-0.16731	1.000E+00
11	1983	1.041E+00	1.297E+00	0.2538	1.877E+00	1.877E+00	0.21989	1.000E+00
12	1984	1.000E+00	1.240E+00	0.2842	2.009E+00	2.009E+00	0.21482	1.000E+00
13	1985	8.920E-01	1.167E+00	0.2946	1.961E+00	1.961E+00	0.26888	1.000E+00
14	1986	1.085E+00	1.089E+00	0.3139	1.950E+00	1.950E+00	0.00409	1.000E+00
15	1987	1.269E+00	8.656E-01	0.6503	3.210E+00	3.210E+00	-0.38250	1.000E+00
16	1988	7.500E-01	6.808E-01	0.3506	1.361E+00	1.361E+00	-0.09680	1.000E+00
17	1989	6.500E-01	9.335E-01	0.0853	4.540E-01	4.540E-01	0.36198	1.000E+00
18	1990	6.660E-01	1.003E+00	0.1529	8.740E-01	8.740E-01	0.40913	1.000E+00
19	1991	6.330E-01	8.840E-01	0.2359	1.189E+00	1.189E+00	0.33403	1.000E+00
20	1992	8.110E-01	8.572E-01	0.3382	1.653E+00	1.653E+00	0.05536	1.000E+00
21	1993	7.610E-01	7.611E-01	0.4235	1.838E+00	1.838E+00	0.00008	1.000E+00
22	1994	*	9.424E-01	0.1463	7.860E-01	7.860E-01	0.00000	1.000E+00
23	1995	*	8.432E-01	0.1385	6.660E-01	6.660E-01	0.00000	1.000E+00
24	1996	*	9.114E-01	0.2157	1.121E+00	1.121E+00	0.00000	1.000E+00
25	1997	*	8.808E-01	0.3604	1.810E+00	1.810E+00	0.00000	1.000E+00
26	1998	*	8.256E-01	0.2851	1.342E+00	1.342E+00	0.00000	1.000E+00
27	1999	*	8.811E-01	0.1045	5.250E-01	5.250E-01	0.00000	1.000E+00
28	2000	*	1.028E+00	0.0863	5.060E-01	5.060E-01	0.00000	1.000E+00
29	2001	*	1.169E+00	0.1311	8.740E-01	8.740E-01	0.00000	1.000E+00
30	2002	*	1.297E+00	0.1151	8.510E-01	8.510E-01	0.00000	1.000E+00
31	2003	*	1.417E+00	0.1398	1.130E+00	1.130E+00	0.00000	1.000E+00
32	2004	*	1.516E+00	0.1406	1.215E+00	1.215E+00	0.00000	1.000E+00
33	2005	*	1.646E+00	0.0925	8.680E-01	8.680E-01	0.00000	1.000E+00
34	2006	*	1.811E+00	0.0878	9.070E-01	9.070E-01	0.00000	1.000E+00
35	2007	*	1.992E+00	0.0661	7.510E-01	7.510E-01	0.00000	1.000E+00
36	2008	*	2.188E+00	0.0590	7.360E-01	7.360E-01	0.00000	1.000E+00

* Asterisk indicates missing value(s).

TILEFISH 2009 BASE Bootstrap

RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED)
turner

Data type I1: Abundance index (annual average)
Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1973	1.000E+00	1.000E+00	--	2.060E-01	1.107E-01	0.62086	1.000E+00
2	1974	1.000E+00	1.000E+00	--	1.350E-01	1.186E-01	0.12930	1.000E+00
3	1975	1.000E+00	1.000E+00	--	9.600E-02	1.284E-01	-0.29099	1.000E+00
4	1976	1.000E+00	1.000E+00	--	1.140E-01	1.356E-01	-0.17339	1.000E+00
5	1977	1.000E+00	1.000E+00	--	1.250E-01	1.362E-01	-0.08555	1.000E+00
6	1978	1.000E+00	1.000E+00	--	1.320E-01	1.272E-01	0.03715	1.000E+00
7	1979	1.000E+00	1.000E+00	--	1.000E-01	1.109E-01	-0.10375	1.000E+00
8	1980	1.000E+00	1.000E+00	--	9.100E-02	9.267E-02	-0.01815	1.000E+00
9	1981	1.000E+00	1.000E+00	--	9.000E-02	7.616E-02	0.16699	1.000E+00
10	1982	1.000E+00	1.000E+00	--	5.100E-02	6.747E-02	-0.27987	1.000E+00
11	1983	0.000E+00	0.000E+00	--	*	6.502E-02	0.00000	1.000E+00
12	1984	0.000E+00	0.000E+00	--	*	6.214E-02	0.00000	1.000E+00
13	1985	0.000E+00	0.000E+00	--	*	5.851E-02	0.00000	1.000E+00
14	1986	0.000E+00	0.000E+00	--	*	5.462E-02	0.00000	1.000E+00
15	1987	0.000E+00	0.000E+00	--	*	4.340E-02	0.00000	1.000E+00
16	1988	0.000E+00	0.000E+00	--	*	3.413E-02	0.00000	1.000E+00
17	1989	0.000E+00	0.000E+00	--	*	4.680E-02	0.00000	1.000E+00
18	1990	0.000E+00	0.000E+00	--	*	5.027E-02	0.00000	1.000E+00
19	1991	0.000E+00	0.000E+00	--	*	4.432E-02	0.00000	1.000E+00
20	1992	0.000E+00	0.000E+00	--	*	4.297E-02	0.00000	1.000E+00
21	1993	0.000E+00	0.000E+00	--	*	3.815E-02	0.00000	1.000E+00
22	1994	0.000E+00	0.000E+00	--	*	4.724E-02	0.00000	1.000E+00
23	1995	0.000E+00	0.000E+00	--	*	4.227E-02	0.00000	1.000E+00
24	1996	0.000E+00	0.000E+00	--	*	4.569E-02	0.00000	1.000E+00
25	1997	0.000E+00	0.000E+00	--	*	4.416E-02	0.00000	1.000E+00
26	1998	0.000E+00	0.000E+00	--	*	4.139E-02	0.00000	1.000E+00
27	1999	0.000E+00	0.000E+00	--	*	4.417E-02	0.00000	1.000E+00
28	2000	0.000E+00	0.000E+00	--	*	5.155E-02	0.00000	1.000E+00
29	2001	0.000E+00	0.000E+00	--	*	5.860E-02	0.00000	1.000E+00
30	2002	0.000E+00	0.000E+00	--	*	6.501E-02	0.00000	1.000E+00
31	2003	0.000E+00	0.000E+00	--	*	7.104E-02	0.00000	1.000E+00
32	2004	0.000E+00	0.000E+00	--	*	7.598E-02	0.00000	1.000E+00
33	2005	0.000E+00	0.000E+00	--	*	8.251E-02	0.00000	1.000E+00
34	2006	0.000E+00	0.000E+00	--	*	9.081E-02	0.00000	1.000E+00
35	2007	0.000E+00	0.000E+00	--	*	9.988E-02	0.00000	1.000E+00
36	2008	0.000E+00	0.000E+00	--	*	1.097E-01	0.00000	1.000E+00

* Asterisk indicates missing value(s).

TILEFISH 2009 BASE Bootstrap

RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED)
vtr

-----Data Series

type I1: Abundance index (annual average)
weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1973	0.000E+00	0.000E+00	--	*	3.279E+00	0.00000	1.000E+00
2	1974	0.000E+00	0.000E+00	--	*	3.513E+00	0.00000	1.000E+00
3	1975	0.000E+00	0.000E+00	--	*	3.803E+00	0.00000	1.000E+00
4	1976	0.000E+00	0.000E+00	--	*	4.015E+00	0.00000	1.000E+00
5	1977	0.000E+00	0.000E+00	--	*	4.032E+00	0.00000	1.000E+00
6	1978	0.000E+00	0.000E+00	--	*	3.767E+00	0.00000	1.000E+00
7	1979	0.000E+00	0.000E+00	--	*	3.285E+00	0.00000	1.000E+00
8	1980	0.000E+00	0.000E+00	--	*	2.744E+00	0.00000	1.000E+00
9	1981	0.000E+00	0.000E+00	--	*	2.255E+00	0.00000	1.000E+00
10	1982	0.000E+00	0.000E+00	--	*	1.998E+00	0.00000	1.000E+00
11	1983	0.000E+00	0.000E+00	--	*	1.926E+00	0.00000	1.000E+00
12	1984	0.000E+00	0.000E+00	--	*	1.840E+00	0.00000	1.000E+00
13	1985	0.000E+00	0.000E+00	--	*	1.733E+00	0.00000	1.000E+00
14	1986	0.000E+00	0.000E+00	--	*	1.617E+00	0.00000	1.000E+00
15	1987	0.000E+00	0.000E+00	--	*	1.285E+00	0.00000	1.000E+00
16	1988	0.000E+00	0.000E+00	--	*	1.011E+00	0.00000	1.000E+00
17	1989	0.000E+00	0.000E+00	--	*	1.386E+00	0.00000	1.000E+00
18	1990	0.000E+00	0.000E+00	--	*	1.489E+00	0.00000	1.000E+00
19	1991	0.000E+00	0.000E+00	--	*	1.312E+00	0.00000	1.000E+00
20	1992	0.000E+00	0.000E+00	--	*	1.273E+00	0.00000	1.000E+00
21	1993	0.000E+00	0.000E+00	--	*	1.130E+00	0.00000	1.000E+00
22	1994	0.000E+00	0.000E+00	--	*	1.399E+00	0.00000	1.000E+00
23	1995	1.000E+00	1.000E+00	--	1.002E+00	1.252E+00	-0.22256	1.000E+00
24	1996	1.000E+00	1.000E+00	--	1.398E+00	1.353E+00	0.03267	1.000E+00
25	1997	1.000E+00	1.000E+00	--	2.342E+00	1.308E+00	0.58275	1.000E+00
26	1998	1.000E+00	1.000E+00	--	1.382E+00	1.226E+00	0.12002	1.000E+00
27	1999	1.000E+00	1.000E+00	--	9.910E-01	1.308E+00	-0.27765	1.000E+00
28	2000	1.000E+00	1.000E+00	--	1.000E+00	1.527E+00	-0.42307	1.000E+00
29	2001	1.000E+00	1.000E+00	--	1.408E+00	1.735E+00	-0.20906	1.000E+00
30	2002	1.000E+00	1.000E+00	--	1.723E+00	1.925E+00	-0.11101	1.000E+00
31	2003	1.000E+00	1.000E+00	--	2.783E+00	2.104E+00	0.27984	1.000E+00
32	2004	1.000E+00	1.000E+00	--	3.770E+00	2.250E+00	0.51608	1.000E+00
33	2005	1.000E+00	1.000E+00	--	4.572E+00	2.443E+00	0.62654	1.000E+00
34	2006	1.000E+00	1.000E+00	--	3.307E+00	2.689E+00	0.20676	1.000E+00
35	2007	1.000E+00	1.000E+00	--	2.183E+00	2.958E+00	-0.30376	1.000E+00
36	2008	1.000E+00	1.000E+00	--	1.434E+00	3.249E+00	-0.81780	1.000E+00

* Asterisk indicates missing value(s)

TILEFISH 2009 BASE Bootstrap
ESTIMATES FROM BOOTSTRAPPED ANALYSIS

Param name	Point estimate	Estimated bias in pt estimate	Estimated relative bias	Bias-corrected approximate confidence limits: 80% lower	80% upper	50% lower	50% upper	Inter-quartile range	Relative IQ range
B1/K	5.000E-01	1.223E-09	0.00%	5.000E-01	5.000E-01	5.000E-01	5.000E-01	6.215E-11	0.000
K	2.279E+01	-2.125E+00	-9.32%	2.037E+01	3.705E+01	2.275E+01	3.026E+01	7.509E+00	0.329
q(1)	1.754E-01	2.847E-02	16.23%	9.546E-02	2.078E-01	1.194E-01	1.797E-01	6.030E-02	0.344
q(2)	8.791E-03	1.139E-03	12.95%	6.002E-03	1.012E-02	6.967E-03	9.109E-03	2.142E-03	0.244
q(3)	2.604E-01	2.603E-02	10.00%	1.629E-01	3.851E-01	1.931E-01	3.145E-01	1.214E-01	0.466
MSY	1.868E+00	8.060E-02	4.31%	1.577E+00	1.927E+00	1.699E+00	1.869E+00	1.699E-01	0.091
Ye(2009)	1.830E+00	-2.391E-01	-13.06%	1.640E+00	2.010E+00	1.806E+00	1.973E+00	1.670E-01	0.091
Y.@Fmsy	2.136E+00	3.323E-01	15.56%	1.190E+00	3.115E+00	1.514E+00	2.518E+00	1.004E+00	0.470
Bmsy	1.140E+01	-1.062E+00	-9.32%	1.019E+01	1.853E+01	1.138E+01	1.513E+01	3.755E+00	0.329
Fmsy	1.639E-01	3.430E-02	20.92%	8.329E-02	1.899E-01	1.130E-01	1.653E-01	5.230E-02	0.319
fmsy(1)	9.349E-01	5.018E-02	5.37%	8.046E-01	1.060E+00	8.588E-01	9.864E-01	1.276E-01	0.136
fmsy(2)	1.865E+01	1.288E+00	6.90%	1.459E+01	2.134E+01	1.609E+01	1.954E+01	3.450E+00	0.185
fmsy(3)	6.296E-01	1.366E-01	21.69%	4.375E-01	1.150E+00	5.026E-01	8.316E-01	3.291E-01	0.523
B./Bmsy	1.143E+00	1.063E-01	9.30%	6.972E-01	1.597E+00	8.432E-01	1.317E+00	4.743E-01	0.415
F./Fmsy	3.598E-01	-1.037E-02	-2.88%	2.404E-01	6.314E-01	3.019E-01	5.095E-01	2.076E-01	0.577
Ye./MSY	9.795E-01	-1.528E-01	-15.60%	9.078E-01	1.000E+00	9.768E-01	9.999E-01	2.303E-02	0.024
q2/q1	5.013E-02	-3.456E-04	-0.69%	4.188E-02	6.291E-02	4.625E-02	5.674E-02	1.050E-02	0.209
q3/q1	1.485E+00	-3.899E-02	-2.63%	8.846E-01	2.096E+00	1.145E+00	1.827E+00	6.825E-01	0.460

INFORMATION FOR REPAST (Prager, Porch, Shertzer, & Caddy. 2003. NAJFM 23: 349-361)

Unitless limit reference point in F (Fmsy/F.): 2.779
CV of above (from bootstrap distribution): 0.4376

NOTES ON BOOTSTRAPPED ESTIMATES:

- Bootstrap results were computed from 1000 trials.
- Results are conditional on bounds set on MSY and K in the input file.
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The default 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- Bias estimates are typically of high variance and therefore may be misleading.

Trials replaced for lack of convergence: 0
Trials replaced for MSY out of bounds: 0
Trials replaced for q out-of-bounds: 139
Trials replaced for K out-of-bounds: 0
Residual-adjustment factor: 1.0710
Elapsed time: 0 hours, 8 minutes, 23 seconds.