Chapter 4 YELLOWFIN SOLE

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Executive Summary

The following changes have been made to this assessment relative to the November 2006 SAFE:

Changes to the input data

1) 2006 fishery age composition.
2) 2006 survey age composition.
3) 2007 trawl survey biomass point estimate and standard error.
4) Estimate of the discarded and retained portions of the 2006 catch.
5) Estimate of total catch through 8 September 2007.
6) Update of weight at age using biological data through 2006.

Assessment results

1) The projected age 2+ total biomass estimate for 2008 is 2,195,300 t.
2) The projected female spawning biomass estimate for 2008 is 550,300 t.
3) The Tier 1 2008 ABC is 247,500 t based on an $F_{\text{har mean of FMSY}}$ (0.19) harvest level.
4) The Tier 1 2008 overfishing level is 265,300 t based on an F_{MSY} (0.21) harvest level.

Summary

	2007 Assessment Values for the 2008 harvest	2006 Assessment values for the 2007 harvest
Total biomass	2,195,300 t	1,996,000 t
Female spawning biomass	550,300 t	585,100 t
Tier 1ABC	247,500 t	225,000 t
Tier 1 Overfishing yield	265,300 t	240,000 t
Tier 1 F_{ABC}	$F_{\text{har mean Fmsy}} = 0.19$	$F_{\text{har mean Fmsy}} = 0.20$
Tier 1 $F_{overfishing}$	$F_{MSY} = 0.20$	$F_{MSY} = 0.22$
B_{MSY}	302,540 t	268,000 t
$B_{40\%}$	482,800 t	402,200 t

SSC Comments from December 2006

The SSC would like to see continued exploration of MSE analysis for Tier 1 management. One example would be to attempt to actually identify when changes in productivity occur and modify management accordingly.

Although little progress was made on the MSE analysis this past year, the lead author and Dr. Ianelli plan to continue the exploration of the robustness of Tier 1 management when climate and productivity change.

The SSC notes that a more appropriate contrast between productivity regimes would be between the pre- and post-1978 datasets rather than between the full dataset and the post 1978 dataset.

The contrast between the productivity calculated from the pre- and post-1978 spawner-recruit data sets and the full data set are shown in Table 4.11 and in Figure 4.10.

While the assessment takes account of differences in weight at age between sexes when computing biomass, the SSC recommends that the assessment author consider moving to a fully split-sex model. Such a model would allow differing dynamics beyond the age of maturation to be captured more fully.

The assessment authors will work at developing a split-sex stock assessment model and modify data sources in the next assessment.

Introduction

The yellowfin sole (Limanda aspera) is one of the most abundant flatfish species in the eastern Bering Sea (EBS) and is the target of the largest flatfish fishery in the United States. They inhabit the EBS shelf and are considered one stock. Abundance in the Aleutian Islands region is negligible.

Yellowfin sole are distributed in North American waters from off British Columbia, Canada, (approx. lat. 49^o N) to the Chukchi Sea (about lat. 70^o N) and south along the Asian coast to about lat. 35^o N off the South Korean coast in the Sea of Japan. Adults exhibit a benthic lifestyle and occupy separate winter, spawning and summertime feeding distributions on the eastern Bering Sea shelf. From over-winter grounds near the shelf margins, adults begin a migration onto the inner shelf in April or early May each year for spawning and feeding. In recent years, the directed fishery has typically occurred from early spring through summer.

Catch History

Yellowfin sole have annually been caught with bottom trawls on the Bering Sea shelf since the fishery began in 1954 and were overexploited by foreign fisheries in 1959-62 when catches averaged 404,000 t annually (Fig. 4.1). As a result of reduced stock abundance, catches declined to an annual average of 117,800 t from 1963-71 and further declined to an annual average of 50,700 t from 1972-77. The lower yield in this latter period was partially due to the discontinuation of the U.S.S.R. fishery. In the early 1980s, after the stock condition had improved, catches again increased reaching a recent peak of over 227,000 t in 1985.

During the 1980s, there was also a major transition in the characteristics of the fishery. Yellowfin sole were traditionally taken exclusively by foreign fisheries and these fisheries continued to dominate through 1984. However, U.S. fisheries developed rapidly during the 1980s in the form of joint ventures, and during the last half of the decade began to dominate and then take all of the catch as the foreign fisheries were phased out of the EBS. Since 1990, only domestic harvesting and processing has occurred. Yellowfin sole are usually headed and gutted, frozen at sea, and then shipped to Asian countries for futher processing. The annual total catch (t) since implementation of the MFCMA in 1977 are shown in Table 4.1.

The 1997 catch of 181,389 t was the largest since the fishery became completely domestic but has since been at lower levels averaging 84,200 t from 1998-2007. As of 8 September, the 2007 catch totaled 116,103 t, the highest annual catch in the past 10 years. The fishery caught 2/3 of the annual total during March and April, primarily from areas 509, 513, 514 and 521. The fishing season was finished on August 6, 2007 to prevent exceeding the 2007 Pacific halibut allowance. The size composition of the 2007 catch for both males and females, from observer sampling, are shown in Figure 4.2, the catch proportions by month and area are shown in Figure 4.3, and maps of the locations where yellowfin sole were caught in 2007, by month, are shown in the Appendix figures.

Harvesting events requiring regulatory actions in 2007 included two seasonal closures. The directed fishery was closed for the entire Bering Sea on April 19 and then again on June 10 to prevent exceeding the second and third seasonal apportionments of Pacific halibut.

The time-series of catch in Table 6.1 also includes yellowfin sole that were discarded in domestic fisheries during the period 1987 to the present. Annual discard estimates were calculated from at-sea sampling (Table 4.2). The rate of discard has ranged from a low of 9% of the total catch in 2006 to 30% in 1992. The trend has been toward fuller retention of the catch in recent years Discarding primarily occurs in the yellowfin sole directed fishery, with lesser amounts in the Pacific cod, rock sole, flathead sole, and “other flatfish” fisheries (Table 4.3).

Data

The data used in this assessment include estimates of total catch, bottom trawl survey biomass estimates and their attendant 95% confidence intervals, catch-at-age from the fishery and population age composition estimates from the bottom trawl survey. Weight-at-age and proportion mature-at-age are also available from studies conducted during the bottom trawl surveys.

Fishery Catch and Catch-at-Age

This assessment uses fishery catch data from 1955- September 8, 2007 (Table 4.1) and fishery catch-at-age (numbers) from 1964-2006 (Table 4.4, 1977-2006).

Survey Biomass Estimates and Population Age Composition Estimates

Biomass estimates for yellowfin sole from the annual bottom trawl survey on the eastern Bering Sea shelf are shown in Table 4.5. Estimates are given separately for unexploited ages (less than age 7) and exploited ages (ages 7 and older) except for 2007 where age data are not yet available. The data show a doubling of exploitable biomass between 1975 and 1979 with a further increase to over 3.3 million t in 1981. Total survey abundance estimates fluctuated erratically from 1983 to 1990 with biomass ranging from as high as 3.5 million t in 1983 to as low as 1.9 million t in 1986. Biomass estimates since 1990 indicate an even trend at high levels of abundance for yellowfin sole, with the exception of the results from the 1999 and 2000 summer surveys, which were at lower levels. Surveys from 2001-2005 estimated an increase each year but the 2006 and 2007 estimates were similar at 2.13 and 2.15 million t, respectively.

Indices of relative abundance available from AFSC surveys have also shown a major increase in the abundance of yellowfin sole during the late 1970s increasing from 21 kg/ha in 1975 to 51 kg/ha in 1981 (Fig. 4.2, Bakkala and Wilderbuer 1990). These increases have also been documented through Japanese commercial pair trawl data and catch-at-age modeling in past assessments (Bakkala and Wilderbuer 1990).

Since 1981, the survey CPUEs have fluctuated widely. For example, they increased from 51 kg/ha in 1981 to 84 kg/ha in 1983 and then declined sharply to 39 kg/ha in 1986. They continued to fluctuate from 1986-90, although with less amplitude (Fig 4.4). From 1990-2006, the estimated CPUE was relatively stable but have declined the past year. Fluctuations of the magnitude shown between 1980 and 1990 and again between 1998 and 1999 are unreasonable considering the combined elements of slow growth and long life span of yellowfin sole and low exploitation rate, characteristics which should produce more gradual changes in abundance.

Variability of yellowfin sole survey abundance estimates (Fig. 4.5) is in part due to the availability of yellowfin sole to the survey area (Nichol, 1998). Yellowfin sole are known to undergo annual migrations from wintering areas off the shelf-slope break to nearshore waters where they spawn throughout the spring and summer months (Nichol, 1995; Wakabayashi, 1989; Wilderbuer et al., 1992). Exploratory survey sampling in coastal waters of the eastern Bering Sea indicate that yellowfin sole concentrations can be greater in these shallower areas not covered by the standard AFSC survey. Commercial bottom trawlers have commonly found high concentrations of yellowfin sole in areas such as near Togiak Bay (Low and Narita, 1990) and in more recent years from Kuskokwim Bay to just south of Nunivak Island. The coastline areas are sufficiently large enough to offer a substantial refuge for yellowfin sole from the current survey.

Over the past 15 years survey biomass estimates for yellowfin sole have shown a positive correlation with shelf bottom temperatures (Nichol, 1998); estimates have been low during cold years. The 1999 survey, which was conducted in exceptionally cold waters, indicated a decline in biomass that was unrealistic. The bottom temperatures during the 2000 survey were much warmer than in 1999, and the biomass increased, but still did not approach estimates from earlier years. Average bottom temperature and biomass both increased again during the period 2001 – 2003, with the 2003 value the highest temperature and biomass observed over the 22 year time series. Given that both 1999 and 2000 surveys were conducted two weeks earlier than previous surveys, it is possible that the time difference may also have affected the availability of yellowfin sole to the survey. If, for example, the timing of peak yellowfin sole spawning in nearshore waters corresponded to the time of the survey, a greater proportion of the population would be unavailable to the standard survey area. This trend was observed again in 2006 and 2007 when the temperature and the bottom trawl survey point estimate were lower.

We propose two possible reasons why survey biomass estimates are lower during years when bottom temperatures are low. First, catchability may be lower because yellowfin sole may be less active when temperatures are low. Less active fish may be less susceptible to herding, and escapement under the footrope of survey gear may increase if fish are less active. Secondly, bottom temperatures may influence the timing of the inshore spawning migrations of yellowfin sole and therefore affect their availability to the survey area. Because yellowfin sole spawning grounds include nearshore areas outside the survey area, availability of fish within the survey area can vary with the timing of this migration and the timing of the survey. In the case of 2006, a colder than average year in the Bering Sea, it is unclear from examining survey station catches along the survey border outside of Kuskowkim bay if a significant portion of the biomass lies outside this border (Fig 4.6).

Yellowfin sole population numbers-at-age estimated from the annual bottom trawl surveys are shown in Table 4.6.

Length and Weight-at-Age and Maturity-at-Age

Parameters of the von Bertalanffy growth curve for yellowfin sole from 12 years of combined data have been estimated as follows:

age range	L_{inf} (cm)	K	t_0
3-26	35.8	0.147	0.47

Mean lengths and weights at age of yellowfin sole based on 12 years (1979-90) of data from AFSC surveys and the length (cm) – weight (g) relationship (W = 0.0097217 * L ** 3.0564) have been used in past assessments. Changes in length and weight at age over time has been documented for Bering Sea northern rock sole (Walters and Wilderbuer 2000) and Bering Sea and Gulf of Alaska Pacific halibut (Clark et al 1999). In a past assessment the assumption of time invariant growth in length and weight of yellowfin sole was examined by comparing the weight and length at age from fish collected during the 1987, 1994, 1999, 2000 and 2001 surveys (Fig. 4.7). Over the age range of 4 to 14 years (fish ageing > 14 years has more error and smaller sample sizes) there are only small differences in length and weight at age from 1987 to 2001. Largest annual differences in weight at age were found in 1999 (a cold year) which were not present in the same cohorts in 2001 (a warmer year). These differences seem to be more related to annual metabolic rate than a shift in population-wide growth. Based on these findings, we concluded that use of a single weight at age vector was justified for this assessment.

In this assessment, weight at age was again examined to update the estimates to include age and weight data collected since 2001. Three different methods were used to estimate the weight at age in the yellowfin sole population. First, all length-weight data collected during trawl surveys in the Bering Sea (n=6,365 fish) were fit using the usual power function, weight (g) = a Length(cm)^b, where a and b are parameters estimated to provide the best fit to the data (Fig. 4.8). These estimates of weight at length were applied to the annual trawl survey estimates of population length at age and were then averaged over all years to calculate the weight at each age. For the second method, all trawl survey specimen data where a weight was determined for each ototlith collected, were combined into a single sample and fit with a von Bertalanffy weight at age function. The third method simply calculated the average weight for each age in the survey specimen data file (giving the average weight at age of the samples collected, not the average weight at age of the population). Results from the three methods are shown in Figure 4.8

The first method was selected to update the population weight at age because the weight at age in a population is a function of the length at age (Clark et al. 1999, Walters and Wilderbuer 2000) and this method uses the population length at age in the calculation (Table 4.7). For the 20+ group, a value of 500 g was used.

Maturity information collected from yellowfin sole females during the 1992 and 1993 eastern Bering Sea trawl surveys is used in this assessment (Table 4.8). Nichol (1994) estimated the age of 50% maturity at 10.5 years based on the histological examination of 639 ovaries. In the case of most north Pacific flatfish species, including yellowfin sole, sexual maturity occurs well after the age of entry into the fishery. Yellowfin sole are 90% selected to the fishery by age 11 but females have been found to be only 50% mature at this age.

Analytic Approach

Model Structure

The abundance, mortality, recruitment and selectivity of yellowfin sole were assessed with a stock assessment model using the AD Model builder language (Ianelli and Fournier 1998). The conceptual model is a separable catch-age analysis that uses survey estimates of biomass and age composition as auxiliary information (Fournier and Archibald 1982). The assessment model simulates the dynamics of the population and compares the expected values of the population characteristics to the characteristics observed from surveys and fishery sampling programs. This is accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the simulated values to the observable characteristics is optimized by maximizing a log(likelihood) function given some distributional assumptions about the observed data.

The suite of parameters estimated by the model are classified by three likelihood components:

Data component	**Distributional assumption**
Trawl fishery catch-at-age	Multinomial
Trawl survey population age composition	Multinomial
Trawl survey biomass estimates and S.E.	Log normal

The total log likelihood is the sum of the likelihoods for each data component (Table 4.9). The likelihood components may be weighted by an emphasis factor, however, equal emphasis was placed on fitting each likelihood component in the yellowfin sole assessment except for the catch. The AD Model Builder software fits the data components using automatic differentiation (Griewank and Corliss 1991) software developed as a set of libraries (AUTODIFF C++ library). Table 4.9 presents the key equations used to model the yellowfin sole population dynamics in the Bering Sea and Table 4.10 provides a description of the variables used in Table 4.9.

Sharp increases in trawl survey abundance estimates for most species of Bering Sea flatfish between 1981 and 1982 indicate that the 83-112 trawl was more efficient for capturing these species than the 400-mesh eastern trawl used in 1975, and 1979-81. Allowing the model to tune to these early survey estimates would most likely underestimate the true pre-1982 biomass, thus exaggerating the degree to which biomass increased during that period. Although this underestimate would have little effect on the estimate of current yellowfin sole biomass, it would affect the spawner and recruitment estimates for the time-series. Hence, the pre-1982 survey biomass estimates were omitted from the analysis.

The model of yellowfin sole population dynamics was evaluated with respect to the observations of the time-series of survey and fishery age compositions and the survey biomass trend since 1982.

Parameters Estimated Independently

Natural mortality (M) was initially estimated by a least squares analysis where catch-at-age data were fitted to Japanese pair trawl effort data while varying the catchability coefficient (q) and M simultaneously. The best fit to the data (the point where the residual variance was minimized) produced a M value of 0.12 (Bakkala and Wespestad 1984). This was also the value which provided the best fit to the observable population characteristics when M was profiled over a range of values in the stock assessment model using data up to 1992 (Wilderbuer 1992). In addition, natural mortality is also allowed to be estimated as a free parameter in some of the stock assessment model runs which are evaluated in a latter section. A natural mortality value of 0.12 is used in the base model presented in this assessment.

Yellowfin sole maturity schedules were estimated from in situ observations as discussed in a previous section (Table 4.8).

Parameters Estimated Conditionally

The parameters estimated by the model are presented below:

Fishing mortality	Selectivity	Survey catchability	Year class strength	Spawner-recruit	Total
53	4	2	72	2	133

The increase in the number of parameters estimated in this assessment compared to last year can be accounted for by the input of another year of fishery data and the entry of another year class into the observed population.

Year class strengths

The population simulation specifies the numbers-at-age in the beginning year of the simulation, the number of recruits in each subsequent year, and the survival rate for each cohort as it moves through the population over time using the population dynamics equations given in Table 4.9.

Selectivity

Fishery and survey selectivity was modeled in this assessment using the two parameter formulation of the logistic function, as shown in Table 4.9. The model was run with an asymptotic selectivity curve for the older fish in the fishery and survey, but still was allowed to estimate the shape of the logistic curve for young fish. The oldest year classes in the surveys and fisheries were truncated at 20 and allowed to accumulate into the age category 20+ years. A single selectivity curve was fit for all years of fishery data and a single curve for all years of survey data.

Fishing Mortality

The fishing mortality rates (F) for each age and year are calculated to approximate the catch weight by solving for F while still allowing for observation error in catch measurement. A large emphasis was placed on the catch likelihood component.

Survey Catchability

A past assessment (Wilderbuer and Nichol 2001) first examined the relationship between estimates of survey biomass and bottom water temperature. To better understand how water temperature may affect the catchability of yellowfin sole to the survey trawl, catchability was estimated for each year in the stock assessment model as:

$$q = e^{\alpha + \beta T}$$

where q is catchability, T is the average annual bottom water temperature anomaly at survey stations less than 100 m, and -α and β are parameters estimated by the model. The result of the nonlinear fit to bottom temperature vs. estimated annual q is shown in Figure 4.9 (for the base model).

Spawner-Recruit Estimation
Annual recruitment estimates were constrained to fit a Ricker (1958) form of the stock recruitment relationship as follows:

$$R = \alpha S e^{-\beta S}$$

where R is age 1 recruitment, S is female spawning biomass (t) the previous year, and α and β are parameters estimated by the model. The spawner-recruit fitting is estimated in a later phase after initial estimates of survival, numbers-at-age and selectivity are obtained.

Tier 1 Considerations
The SSC determined in December 2006 that yellowfin sole would be managed under the Tier 1 harvest guidelines, and therefore future harvest recommendations would be based on MSY and F_{MSY} values calculated from a spawner-recruit relationship. MSY is an equilibrium concept and its value is dependent on both the spawner-recruit data which is assumed to represent the equilibrium stock size-recruitment relationship and the model used to fit the data. In the yellowfin sole stock assessment model, a Ricker form of the stock-recruit relationship was fit to these data and estimates of F_{MSY} and B_{MSY} were calculated, assuming that the fit to the stock-recruitment data points represent the long-term productivity of the stock.

For this assessment, 3 different stock-recruitment time-series were investigated. The full time-series 1955-2002, the pre-regime shift era of 1955-1977 and the post-regime shift era, 1978-2002 (Fig. 4.10) Very different estimates of the long-term sustainability of the stock (F_{MSY} and B_{MSY}) were obtained depending on which years of stock-recruitment data points were included in the fitting procedure (Table 4.11). When the entire time-series from 1955-2002 was fit, the large recruitments that occurred at a low spawning stock size in the 1960s and early 1970s determine that the yellowfin sole stock is most productive at a smaller stock size with the result that F_{MSY} is 3 times higher than $F_{40\%}$ (recall that $F_{40\%}$ = 0.11). Therefore, F_{MSY} is a relatively high value (0.327) and B_{MSY} is 244,000 t. If we limit the analysis to consider only recruitments which occurred after the well-documented regime shift in 1977, a much lower value of F_{MSY} is obtained (0.22) and B_{MSY} is 302,500 t.

Results from these Tier 1 calculations for yellowfin sole indicate that the harmonic mean of the F_{MSY} estimate is very close to the geometric mean value of the F_{MSY} estimate due to the low variability in the parameter estimates. This result indicates that the estimates of F_{MSY} are obtained with very little uncertainty. To better understand how uncertainty in certain parameter estimates affects the Tier 1 harvest policy calculations for yellowfin sole, the following analysis was undertaken. Selectivity, catchability, natural mortality and recruitment variability (R sigma) were selected as important parameters whose uncertainty may directly affect the pdf of the estimate of F_{MSY}. Twelve different model configurations were chosen to illustrate the effect of a range of uncertainly in these individual parameter estimates (0.4 and 0.9 for M and 0.8, 1.0, 1.2 and 1.4 for R sigma) and how they affect the estimate of the harmonic mean of F_{MSY}.

When the 1978-2001 years are fit (Model 2), the F_{MSY} value is about 60% of the full time-series value (Model 1) and half of the pre-regime shift value (Model 3). Using the estimates of recruitment and stock size from 1978-2002 as the basis for the spawner-recruit relationship (Model 2), uncertainty was introduced for the estimates of recruitment variability (Models 4-7) selectivity (Models 8), catchability (Models 9 and 10) and natural mortality (Models 10 and 11). Adding uncertainty to recruitment variability resulted in the largest difference between the geometric mean and the harmonic mean of the estimate of F_{MSY} for these Model runs, 43% reduction at the highest value considered. Placing more uncertainty on selectivity reduced the harmonic mean of the F_{MSY} by 12%. Incorporating more uncertainty in the estimation of catchability and natural mortality resulted in a 7-8% reduction for the estimate of the harmonic mean (Models 9 and 12). Thus F_{MSY} appears to be well estimated by the model. For the 2007 fishing season, the SSC chose an ABC and OFL based on the 1978-2002 data set, which is also considered here as the base model for stock assessment model evaluation.

Model Evaluation

Model evaluation for this assessment entails the use of a single structural model (Model 2 in Table 4.11) to consider the uncertainty in the key parameters M and catchability. Model 2 (from above) is the base model which has been used in past assessments and operates by fixing M at 0.12 and then estimates q using the relationship between survey catchability and the annual average water temperature at the sea floor (from survey stations at less than 100 m). Alternative Models 1 and 2 fix q at 1.17 (the value resulting from the base Model) but estimate M as a free parameter with different amounts of uncertainty in the parameter estimate ($sigma_M$ values of 0.2 and 0.5 for Alternative Models 1 and 2, respectively). Alternative Models 3 and 4 fix M at 0.12 but estimate q as a free parameter (without consideration of the relationship with annual bottom water temperature) with different amounts of uncertainty in the parameter estimate ($sigma_q$ values of 0.2 and 0.5 for Alternative Models 3 and 4, respectively). Alternative Models 5 and 6 estimate both M and q as free parameters, again with varying amounts of uncertainty ($sigma_M$ and $sigma_q$ values of 0.2 and 0.5 for Alternative Models 5 and 6, respectively).

Results from these runs indicate that fixing either M or q at values estimated from the base Model (Model 2) and then estimating the other parameter give similar estimates of 2008 female spawning biomass, total biomass, $F_{40\%}$ and 2008 tier 3 ABC (Alternative Models 1-4, Table 4.12). When M and q are both estimated as free parameters with no constraint on either, the best fit to the observable population characteristics occur at high values of q and low values of M (Alternative Models 5 and 6). These Models result in low estimates of female spawning biomass, total biomass and ABC, which are not credible.

Alternative Model runs 1-4 indicate that, even with a high level of uncertainty, M and q are fairly well estimated within a narrow range, as long as one of the parameters are constrained at the level present in the base model. The values of M estimated in Alternative Models 5 and 6 (0.07 and 0.05) seem unrealistic given the maximum age of yellowfin sole observed from 43 years of data collection and age determination and the resulting low biomass estimates.

Modeling survey catchability as a nonlinear function of bottom water temperature at stations less than 100 m produces an estimate of survey catchability greater than 1. This value is consistent with supporting evidence from experiments examining the bridle efficiency of the Bering Sea survey trawl which indicate that yellowfin sole are herded into the trawl path from an area between the wing tips of the net and the point where the bridles contact the seafloor (Somerton and Munro 2001) and also our hypothesis of the timing of the survey relative to the temperature dependent timing of the annual spawning migration to nearshore areas which are outside of the survey area. The herding experiments suggest that the survey trawl catchability is greater than 1.0. The likelihood profile of q from the model indicated a small variance with a narrow range of likely values with a low probability of q being equal to the value of 1.0 in a past assessment (Wilderbuer and Nichol 2003).

Thus, the model configuration which utilizes the relationship between annual seafloor temperature and survey catchability with M fixed at 0.12 (base model), will be used to base our assessment of the condition of the Bering Sea yellowfin sole resource for the 2008 fishing season.

Model Results

Fishing Mortality and Selectivity

The assessment model estimates of the annual fishing mortality on fully selected ages are given in Table 4.13. The full-selection F has averaged 0.08 over the period of 1978-2006 with a maximum of 0.16 in 1978 and a minimum in 2001 at 0.05. Selectivities estimated by the model (Table 4.14, Figure 4.11) indicate that yellowfin sole are 50% selected by the fishery at age 9 and nearly fully selected by age 13.

Abundance Trend

The model estimates q at an average value of 1.17 for the period 1982-2007 which results in the model estimate of the 2007 total biomass at 2,155,670 t (Table 4.15). Model results indicate that yellowfin sole total biomass (age 2+) was at low levels during most of the 1960s and early 1970s (700,000-800,000 t) after a period of high exploitation (Table 4.15, Figure 4.11, bottom left panel). Sustained above average recruitment from 1967-76 combined with light exploitation resulted in a biomass increase to a peak of 2.8 million t by 1984. The population biomass has since been in a slow decline as the strong 1981 and 1983 year-classes have passed through the population with only the 1991 and 1995 year classes at levels observed during the 1970s. Although the stock biomass has declined since the peak values in the mid-1980s, it has remained at high and stable levels in recent years and is currently estimated at 77% of the peak level.

The female spawning biomass has also declined since the peak in 1985, with a 2007 estimate of 602,400 t (25% decline). The spawning biomass has been stable for the past 7 years and is about 125% of the $B_{40\%}$ level (Fig. 4.12). The model estimate of yellowfin sole population numbers at age for all years is shown in Table 4.16 and the resulting fit to the observed fishery and survey age compositions input into the model are shown in the Appendix. The fit to the trawl survey biomass estimates are shown in Figure 4.13. Allowing q to be correlated with annual bottom temperature provides a better fit to the bottom trawl survey estimates.

Both the trawl survey and the stock assessment model indicate that the yellowfin sole resource slowly increased during the 1970s and early 1980s to a peak level during the mid-1980s after which the resource experienced a slow, consistent decline until about the past 9 years where the trend has been transitioning from stable to increasing (Figure 4.10). Above average recruitment from the 1995 and 1999 year-classes is expected to maintain the abundance of yellowfin sole at a level above B_{40} in the near future. The stock assessment projection model (later section) indicates a slow increase in female spawning biomass in the near future if the fishing mortality rate continues at the same level as the average of the past 5 years.

Recruitment Trends

The primary reason for the sustained increase in abundance of yellowfin sole during the 1970s and early 1980s was the recruitment of a series of stronger than average year classes spawned in 1967-76 (Figure 4.14 and Table 4.17). The 1981 year class was the strongest observed (and estimated) during the 46 year period analyzed and the 1983 year class was also very strong. Survey age composition estimates and the assessment model also estimate that the 1987 and 1988 year classes were average and the 1991, 1995, 1999 and 2001 year classes are above average. With the exception of these 6 year classes, recruitment from 12 of the last 18 years estimated (since the strong 1983 year-class) has been below the 48 year average, which has caused the population to gradually decline. The 1995 year-class were at the maximum of their cohort biomass in 2005 and but should contribute to the mature adult reservoir of spawners in future years. The recruitment contribution to the stock biomass in the near future may be indicated by the 1999 and 2001 year classes, which are estimated at average strength.

Historical Exploitation Rates

Based on results from the stock assessment model, annual exploitation rates of yellowfin sole ranged from 3 to 8% of the total biomass since 1977, and have averaged 5% (Table 4.13).

Acceptable Biological Catch

After increasing during the 1970s and early 1980s, estimates from the stock assessment model indicate the total biomass has been at a slow decline from high levels of stock biomass since the peak in 1985. The estimate of total biomass for 2008 is 2,195,300 t.

The SSC has determined that yellowfin sole qualify as a Tier 1 stock and therefore the 2008 ABC is calculated using Tier 1 methodology. It is critical for the Tier 1 calculations to identify which subset of the stock recruitment data is used. Using the full time series to fit the spawner recruit curve estimates that the stock is most productive at a small stock size. Thus MSY and F_{MSY} are high values and B_{MSY} is a low value. If the stock was productive in the past at a small stock size because of non density dependent factors (environment), then reducing the stock size to low levels could be detrimental to the long-term sustainability of the stock if the environment, and thus productivity, had changed from the earlier period. Since observations of yellowfin sole recruitment at low stock sizes are not available from multiple time periods, it is uncertain if future recruitment events at low stock conditions would be as productive as during the late 1960s-early 1970s. In 2006 the SSC used a conservative approach and selected the 1978-2001 data set for the Tier 1 harvest recommendation. Using this approach again for the 2008 harvest recommendation (Model 2 in Table 4.11), the $F_{ABC} = F_{\text{harmonic mean}} = 0.19$.

The Tier 1 harvest level is calculated as the product of the harmonic mean of F_{MSY} and the geometric mean of the 2008 biomass estimate, as follows:

$B_{gm} = e^{\ln \hat{B} - \frac{cv^2}{2}}$, where B_{gm} is the geometric mean of the 2008 biomass estimate, $\hat{B}$ is the point estimate of the 2008 biomass from the stock assessment model and cv^2 is the coefficient of variation of the point estimate;

and

$\bar{F}_{har} = e^{\ln \hat{F}_{msy} - \frac{\ln sd^2}{2}}$, where $\bar{F}_{har}$ is the harmonic mean, $\hat{F}_{msy}$ is the peak mode of the F_{MSY} distribution and sd^2 is the square of the standard deviation of the F_{MSY} distribution. This calculation gives a Tier 1 ABC harvest recommendation of **247,500 t** and an OFL of 265,300 t for 2008.

Overfishing

The stock assessment analysis must also consider harvest limits, usually described as overfishing fishing mortality levels with corresponding yield amounts. Amendment 56 to the BSAI FMP sets the Tier 1 harvest limit at the F_{MSY} fishing mortality value. The overfishing fishing mortality values, ABC fishing mortality values and their corresponding yields are given as follows (Tier 3a values are also included:

Harvest level	F value	2008 Yield
Tier 3 F_{OFL} = $F_{0.35}$	0.13	162,400 t
Tier 3 F_{ABC} = $F_{0.40}$	0.11	137,200 t
Tier 1 F_{OFL} = F_{MSY}	**0.22**	**265,300 t**
Tier 1 F_{ABC} = $F_{harmonic\ mean}$	**0.19**	**247,500 t**

Biomass Projections

Status Determination

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2007 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2008, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2008 recommended in the assessment to the *max* F_{ABC} for 2008. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *Scenario 3*: In all future years, F is set equal to 75% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2003-2007 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2008 and above its MSY level in 2018 under this scenario, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2020 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results shown in Table 4.18 and Figure 4.15 indicate that yellowfin sole are not currently overfished and are not approaching an overfished condition.

Scenario Projections and Two-Year Ahead Overfishing Level

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. The 2008 numbers at age from the stock assessment model are projected to 2009 given the 2008 catch and then the 2008 OFL harvest rate is applied to the projected 2009 population biomass to obtain the 2009 OFL.

	Tier 1		
Year	Catch	**ABC**	**OFL**
2008	116,100	**247,500**	**265,300**
2009	116,100	**275,800**	**295,700**

Ecosystem Considerations

Ecosystem Effects on the stock

1) Prey availability/abundance trends
Yellowfin sole diet by life stage varies as follows: Larvae consume plankton and algae, early juveniles consume zooplankton, late juvenile stage and adults prey includes bivalves, polychaetes, amphipods, mollusks, euphausids, shrimps, brittle stars, sculpins and miscellaneous crustaceans. Information is not available to assess the abundance trends of the benthic infauna of the Bering Sea shelf. The original description of infaunal distribution and abundance by Haflinger (1981) resulted from sampling conducted in 1975 and 1976 and has not been re-sampled since. The large populations of flatfish which have occupied the middle shelf of the Bering Sea over the past twenty years for summertime feeding do not appear food-limited. These populations have fluctuated due to the variability in recruitment success which suggests that the primary infaunal food source has been at an adequate level to sustain the yellowfin sole resource.

2) Predator population trends

As juveniles, it is well-documented from studies in other parts of the world that flatfish are prey for shrimp species in near shore areas. This has not been reported for Bering Sea yellowfn sole due to a lack of juvenile sampling and collections in near shore areas, but is thought to occur. As late juveniles they have been found in stomachs of Pacific cod and Pacific halibut; mostly on small yellowfin sole ranging from 7 to 25 cm standard length..

Past, present and projected future population trends of these predator species can be found in their respective SAFE chapters in this volume and also from Annual reports compiled by the International Pacific Halibut Commission. Encounters between yellowfin sole and their predators may be limited since their distributions do not completely overlap in space and time.

3) Changes in habitat quality

Changes in the physical environment which may affect yellowfin sole distribution patterns, recruitment success ,and migration timing patterns are catalogued in the Ecosystem Considerations Appendix of this SAFE report. Habitat quality may be enhanced during years of favorable cross-shelf advection (juvenile survival) and warmer bottom water temperatures with reduced ice cover (higher metabolism with more active feeding).

Fishery Effects on the ecosystem

1) The yellowfin sole target fishery contribution to the total bycatch of other non-prohibited species is shown for 1991-2005 in Table 4.19. The yellowfin sole target fishery contribution to the total bycatch of prohibited species is shown for 2004 and 2005 in Table 13 of the Economic SAFE (Appendix C) and is summarized for 2005 as follows:

Prohibited species	Yellowfin sole fishery % of total bycatch
Halibut mortality	12.0
Herring	7.0
Red King crab	39.0
C. bairdi	30.0
Other Tanner crab	71.3
Salmon	< 1

2) Relative to the predator needs in space and time, the yellowfin sole target fishery has a low selectivity for fish between 7-25 cm and therefore has minimal overlap with removals from predation.

3) The target fishery is not perceived to have an effect on the amount of large size target fish in the population due to its history of light exploitation (6%) over the past 30 years.

4) Yellowfin sole fishery discards are presented in the Catch History section.

5) It is unknown what effect the fishery has had on yellowfin sole maturity-at-age and fecundity.

6) Analysis of the benthic disturbance from the yellowfin sole fishery is available in the Preliminary draft of the Essential Fish Habitat environmental Impact Statement.

Ecosystem effects on yellowfin sole			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Benthic infauna	Stomach contents	Stable, data limited	Unknown
Predator population trends			
Fish (Pacific cod, halibut, skates)	Stable	Possible increases to rock sole mortality	
Changes in habitat quality			
Temperature regime	Cold years yellowfin sole catchability and herding may decrease, timing of migration may be prolonged	Likely to affect surveyed stock	No concern (dealt with in model)
Winter-spring environmental conditions	Affects pre-recruit survival	Probably a number of factors	Causes natural variability

***Yellowfin sole* effects on ecosystem**			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Low bycatch levels of (spp)	Bycatch levels small relative to HAPC biota	No concern
Marine mammals and birds	Very minor direct-take	Safe	No concern
Sensitive non-target species	Likely minor impact	Data limited, likely to be safe	No concern
Fishery concentration in space and time	Low exploitation rate	Little detrimental effect	No concern
Fishery effects on amount of large size target fish	Low exploitation rate	Natural fluctuation	No concern
Fishery contribution to discards and offal production	Stable trend	Improving, but data limited	Possible concern
Fishery effects on age-at-maturity and fecundity	Unknown	NA	Possible concern

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Tables

Table 4.1--Catch (t) of yellowfin sole 1977-2007. Catch for 2007 is the total through September 8, 2007.

		Domestic		
Year	Foreign	JVP	DAP	Total
1977	58,373			58,373
1978	138,433			138,433
1979	99,019			99,019
1980	77,768	9,623		87,391
1981	81,255	16,046		97,301
1982	78,331	17,381		95,712
1983	85,874	22,511		108,385
1984	126,762	32,764		159,526
1985	100,706	126,401		227,107
1986	57,197	151,400		208,597
1987	1,811	179,613	4	181,428
1988		213,323	9,833	223,156
1989		151,501	1,664	153,165
1990		69,677	14,293	83,970
1991			115,842	115,842
1992			149,569	149,569
1993			106,101	106,101
1994			144,544	144,544
1995			124,740	124,740
1996			129,659	129,659
1997			181,389	181,389
1998			101,201	101,201
1999			67,320	67,320
2000			83,850	83,850
2001			63,395	63,395
2002			73,000	73,000
2003			74,418	74,418
2004			69,046	69,046
2005			94,383	94,383
2006			99,068	99,068
2007			116,107	116,103

Table 4.2 Estimates of retained and discarded (t) yellowfin sole caught in Bering Sea fisheries.

Year	Retained	Discarded
1987	3	1
1988	7,559	2,274
1989	1,279	385
1990	10,093	4,200
1991	89,054	26,788
1992	103,989	45,580
1993	76,798	26,838
1994	107,629	36,948
1995	96,718	28,022
1996	101,324	28,334
1997	149,570	31,818
1998	80,365	20,836
1999	55,202	12,118
2000	69,788	14,062
2001	54,759	8,635
2002	62,050	10,950
2003	63,732	10,686
2004	57,378	11,668
2005	85,321	9,062
2006	90,570	8,498

Table 4.3. Discarded and retained catch of yellowfin sole, by fishery, in 2005 and 2006.

2005

Target Fishery	Discard	Retained	Grand Total
Atka mackerel	4	22	26.1
Bottom pollock	42	4	46
Pacific cod	1,675	375	2,049
Mid-water pollock	11	6	17
Sablefish	0	0	0
Rockfish	0	0	0
Arrowtooth flounder	1	15	16
Flathead sole	470	1,729	2,199
Rock sole	1,300	6,280	7,580
Yellowfin sole	5,544	76,885	82,429
Greenland turbot	0	0	0
Other flatfish	15	6	21
Other species	0	0	0
			0
Total	9,062	85,321	94,383

2006

Target Fishery	Discard	Retained	Grand Total
Atka mackerel	1	1	1.9
Bottom pollock	52	56	108
Pacific cod	1,109	795	1,904
Mid-water pollock	126	22	148
Sablefish	0	0	0
Rockfish	0	0	0
Arrowtooth flounder	38	32	70
Flathead sole	358	2,244	2,602
Rock sole	1,007	8,886	9,893
Yellowfin sole	5,743	78,436	84,178
Alaska plaice	0	0	
Greenland turbot	63	93	156
Other flatfish	1	5	6
Other species	0	0	1
			0
Total	8,498	90,570	99,068

Table 4.4. Yellowfin sole fishery catch-at-age numbers (millions), 1977-2006.

year/age	7	8	9	10	11	12	13	14	15	16	17+
1977	31.62	52.75	57.54	72.78	40.64	14.37	8.98	3.79	2.20	2.26	2.56
1978	44.56	102.00	132.59	110.87	116.56	59.31	20.18	12.32	5.20	3.02	6.63
1979	17.99	46.09	82.36	81.93	56.75	54.24	26.52	8.82	5.39	2.27	4.22
1980	19.42	26.32	53.09	73.40	61.01	38.60	35.52	16.99	5.65	3.45	4.16
1981	26.78	42.97	45.87	71.67	82.91	63.01	38.40	34.57	16.53	5.50	7.40
1982	15.08	40.43	51.13	42.28	55.25	58.41	42.75	25.49	22.95	10.97	8.56
1983	19.56	31.25	66.09	64.83	44.90	53.67	54.67	39.14	23.34	21.01	17.89
1984	17.41	49.78	62.51	102.18	83.76	53.00	61.01	60.79	43.53	25.95	43.26
1985	16.52	47.52	105.97	102.05	138.65	103.56	63.03	70.96	70.71	50.63	80.50
1986	27.32	26.58	59.49	101.33	80.79	99.77	71.60	42.60	47.96	47.79	88.63
1987	17.45	45.92	34.88	59.84	84.61	61.41	72.91	51.16	30.44	34.27	97.48
1988	60.92	41.26	84.54	49.15	69.97	90.05	62.83	72.96	51.19	30.46	131.82
1989	7.45	80.04	42.29	66.33	31.96	41.38	51.18	34.91	40.53	28.44	90.16
1990	16.93	6.60	55.91	22.86	29.94	13.17	16.42	19.86	13.55	15.73	46.02
1991	6.00	34.11	10.53	69.47	23.85	28.63	12.14	14.81	17.91	12.22	55.69
1992	8.81	19.99	89.62	21.45	118.54	37.25	43.07	17.87	21.80	26.37	99.96
1993	8.00	11.06	19.77	68.59	13.72	69.24	20.95	23.69	9.83	11.99	69.49
1994	15.14	20.86	22.72	31.47	91.39	16.72	81.28	24.06	27.21	11.29	93.58
1995	13.16	25.43	27.57	23.22	26.87	71.28	12.55	59.70	17.67	19.98	77.03
1996	5.92	25.33	38.54	32.34	22.77	24.08	61.51	10.60	50.40	14.92	81.90
1997	10.29	16.86	56.54	66.26	46.37	29.80	30.34	75.82	13.06	62.12	119.33
1998	15.71	12.72	16.35	42.18	41.13	26.24	16.22	16.14	40.34	6.95	96.55
1999	5.51	19.00	12.15	12.11	26.15	23.32	14.33	8.66	8.62	21.55	55.28
2000	5.65	12.36	33.67	16.75	14.01	27.70	23.81	14.31	8.66	8.62	76.76
2001	4.28	8.34	14.44	30.60	12.77	9.78	18.64	15.67	9.42	5.70	56.19
2002	12.68	8.62	13.31	17.95	31.95	12.21	9.01	16.81	14.14	8.50	55.84
2003	4.83	23.52	12.67	15.22	17.24	28.11	10.36	7.48	13.96	11.74	53.40
2004	4.32	8.27	31.90	13.39	13.52	14.02	22.04	7.95	5.74	10.71	49.97
2005	10.55	12.74	19.28	57.82	20.36	18.83	18.83	28.96	10.44	7.54	79.73
2006	14.63	18.59	17.71	20.78	52.17	16.80	14.96	14.64	22.52	8.12	67.86

Table 4.5—Yellowfin sole biomass estimates (t) from the annual Bering Sea shelf bottom trawl survey and upper and lower 95% confidence intervals.

	Age				
Year	0-6	7 +	Total	Lower CI	Upper CI
1975	169,500	803,000	972,500	812,300	1,132,700
1979	211,500	1,655,000	1,866,500	1,586,000	2,147,100
1980	235,900	1,606,500	1,842,400	1,553,200	2,131,700
1981	343,200	2,051,500	2,394,700	2,072,900	2,716,500
1982	685,700	2,692,100	3,377,800	2,571,000	4,184,600
1983	198,000	3,337,300	3,535,300	2,958,100	4,112,400
1984	172,800	2,968,400	3,141,200	2,636,800	3,645,600
1985	166,200	2,277,500	2,443,700	1,563,400	3,324,000
1986	80,200	1,829,700	1,909,900	1,480,700	2,339,000
1987	125,500	2,487,600	2,613,100	2,051,800	3,174,400
1988	45,600	2,356,800	2,402,400	1,808,400	2,996,300
1989	196,900	2,119,400	2,316,300	1,836,700	2,795,800
1990	69,600	2,114,200	2,183,800	1,886,200	2,479,400
1991	60,000	2,333,300	2,393,300	2,116,000	2,670,700
1992	145,900	2,027,000	2,172,900		
1993	188,200	2,277,200	2,465,400	2,151,500	2,779,300
1994	142,000	2,468,500	2,610,500	2,266,800	2,954,100
1995	213,000	1,796,700	2,009,700	1,724,800	2,294,600
1996	161,600	2,137,000	2,298,600	1,749,900	2,847,300
1997	239,330	1,924,070	2,163,400	1,907,900	2,418,900
1998	150,756	2,178,844	2,329,600	2,033,130	2,626,070
1999	57,700	1,246,770	1,306,470	1,118,800	1,494,150
2000	73,200	1,508,700	1,581,900	1,382,000	1,781,800
2001	135,900	1,727,800	1,863,700	1,605,000	2,122,300
2002	83,200	1,933,500	2,016,700	1,740,700	2,292,700
2003	2,900	2,236,700	2,239,600	1,822,700	2,656,600
2004	191,800	2,338,800	2,530,600	2,147,900	2,913,300
2005	158,865	2,664,635	2,823,500	2,035,800	3,499,800
2006	141,053	1,992,017	2,133,070	1,818,253	2,447,932
2007			2,152,738	1,775,191	2,530,285

Table 4.6. Yellowfin sole population numbers-at-age (millions) estimated from the annual bottom trawl surveys, 1982-2006.

YEAR AGE	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17+
1982	124	363	743	2882	3156	2408	3194	1445	1557	1258	1141	864	532	164	74	90
1983	0	7	142	379	1659	3495	1836	2388	1786	1597	2080	1577	772	751	154	114
1984	0	116	494	577	958	1555	1766	1833	1982	1759	953	1019	723	580	311	251
1985	0	43	242	762	1040	619	1206	1353	787	905	847	568	519	448	295	178
1986	0	35	67	311	698	1298	535	888	788	693	483	508	302	450	212	496
1987	0	6	102	211	1555	933	1478	682	650	819	535	553	319	381	392	1199
1988	1	4	32	783	134	2997	1524	1272	319	501	447	465	822	548	291	2
1989	0	17	46	337	1848	504	3245	1351	979	255	280	503	352	541	267	1296
1990	0	29	117	221	638	1947	387	2400	726	746	142	138	175	102	286	1004
1991	0	13	229	594	256	719	1933	207	2423	536	765	143	197	138	165	1221
1992	0	13	282	670	854	387	437	1522	183	1526	232	467	128	134	204	1150
1993	0	53	181	610	1300	828	548	472	2419	148	1725	226	223	120	68	1060
1994	4	75	166	389	945	1857	1211	789	475	1992	26	1138	90	406	153	434
1995	0	19	322	408	451	1556	1192	369	314	100	1111	34	1163	153	105	930
1996	0	92	249	1650	537	513	878	879	555	295	300	1026	181	1116	180	1151
1997	0	38	542	928	1523	437	423	952	474	308	391	292	1014	123	578	949
1998	0	59	153	829	989	1732	419	430	574	685	715	321	334	453	180	1974
1999	0	9	169	344	403	430	1307	251	202	555	461	262	126	131	296	1974
2000	0	24	135	527	417	594	791	1021	269	384	320	344	279	264	233	1314
2001	0	1	146	377	1159	637	751	789	1175	493	282	406	217	228	302	1038
2002	0	70	202	327	591	1500	689	603	474	906	391	226	555	251	297	1269
2003	0	0	0	5	44	217	1784	387	774	256	1198	426	304	436	364	4525
2004	0	97	303	861	991	643	651	1830	508	326	418	515	189	58	374	1525
2005	0	102	333	381	1076	909	417	775	1806	319	286	312	456	239	146	1981
2006	9	175	481	727	609	1141	864	464	624	1122	249	288	160	195	187	1141

Table 4.7—Mean length and weight at age for yellowfin sole.

age	mean length (cm)	mean wt (g)
1	0.7	0
2	1.7	2
3	12.1	17
4	14.4	30
5	17.2	52
6	19.7	81
7	22.2	119
8	24.3	157
9	26.2	201
10	27.8	242
11	28.9	275
12	30.0	312
13	30.8	339
14	31.5	366
15	31.9	379
16	32.5	402
17	32.7	412
18	33.1	429
19	32.0	419
20	33.8	458

Table 4.8. Female yellowfin sole proportion mature at age from Nichol (1994).

Age	Proportion mature
1	0.00
2	0.00
3	.001
4	.004
5	*.008*
6	.020
7	.046
8	.104
9	.217
10	.397
11	.612
12	.790
13	.899
14	.955
15	.981
16	.992
17	.997
18	1.000
19	1.000
20	1.000

Table 4.9. Key equations used in the population dynamics model.

$N_{t,1} = R_t = R_0 e^{\tau_t}$, $\tau_t \sim N(0,\delta^2{}_R)$	Recruitment 1956-75
$N_{t,1} = R_t = R_\gamma e^{\tau_t}$, $\tau_t \sim N(0,\delta^2{}_R)$	Recruitment 1976-96
$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}}\left(1 - e^{-Z_{t,a}}\right)N_{t,a}$	Catch in year *t* for age *a* fish
$N_{t+1,a+1} = N_{t,a}e^{-Z_{t,a}}$	Numbers of fish in year *t+1* at age *a*
$N_{t+1,A} = N_{t,A-1}e^{-Z_{t,A-1}} + N_{t,A}e^{-Z_{t,A}}$	Numbers of fish in the “plus group”
$S_t = \sum N_{t,a}W_{t,a}\phi_a$	Spawning biomass
$Z_{t,a} = F_{t,a} + M$	Total mortality in year *t* at age *a*
$F_{t,a} = s_a \mu^F \exp^{\varepsilon^F{}_t}$, $\varepsilon^F{}_t \sim N(o,\sigma^{2_F})$	Fishing mortality
$s_a = \frac{1}{1+\left(e^{-\alpha+\beta a}\right)}$	Age-specific fishing selectivity
$C_t = \sum C_{t,a}$	Total catch in numbers
$P_{t,a} = {C_{t,a}}/{C_t}$	Proportion at age in catch
$SurB_t = q\sum N_{t,a}W_{t,a}v_a$	Survey biomass

$$qlike = \lambda \frac{0.5(\ln q_{est} - \ln q_{prior})^2}{\sigma_q^2}$$ survey catchability likelihood (when estimated)

$$mlike = \lambda \frac{0.5(\ln m_{est} - \ln m_{prior})^2}{\sigma_m^2}$$ natural mortality likelihood (when estimated)

$$reclike = \lambda\left(\sum_{i=1965}^{endyear} (\bar{R} - R_i)^2 + \sum_{a=1}^{20} (\bar{R}_{init} - R_{init,a})^2 + \frac{1}{2\left(\left(\sum_{i=1965}^{endyear} \bar{R} - R_i\right)\frac{1}{n+1}\right)}\right)$$ recruitment likelihood

$$catchlike = \lambda \sum_{i=startyear}^{endyear} (\ln C_{obs,i} - \ln C_{est,i})^2$$ catch likelihood

$$surveylike = \lambda \frac{(\ln B - \ln \hat{B})^2}{2\sigma^2}$$ survey likelihood

$$SurvAgelike = \sum_{i,t} m_t P_{t,a} \ln \frac{\hat{P}_{t,a}}{P_{t,a}}$$ survey age composition likelihood

$$FishAgelike = \sum_{i,t} m_t P_{t,a} \ln \frac{\hat{P}_{t,a}}{P_{t,a}}$$ fishery age composition likelihood

Table 4.10. Variables used in the population dynamics model.

Variables	
R_t	Age 1 recruitment in year *t*
R_0	Geometric mean value of age 1 recruitment, 1956-75
R_γ	Geometric mean value of age 1 recruitment, 1976-96
τ_t	Recruitment deviation in year *t*
$N_{t,a}$	Number of fish in year *t* at age *a*
$C_{t,a}$	Catch numbers of fish in year *t* at age *a*
$P_{t,a}$	Proportion of the numbers of fish age *a* in year *t*
C_t	Total catch numbers in year *t*
$W_{t,a}$	Mean body weight (kg) of fish age *a* in year *t*
ϕ_a	Proportion of mature females at age *a*
$F_{t,a}$	Instantaneous annual fishing mortality of age *a* fish in year *t*
M	Instantaneous natural mortality, assumed constant over all ages and years
$Z_{t,a}$	Instantaneous total mortality for age *a* fish in year *t*
s_a	Age-specific fishing gear selectivity
μ^F	Median year-effect of fishing mortality
ε_t^F	The residual year-effect of fishing mortality
ν_a	Age-specific survey selectivity
α	Slope parameter in the logistic selectivity equation
β	Age at 50% selectivity parameter in the logistic selectivity equation
σ_t	Standard error of the survey biomass in year *t*

Table 4.11- Models used to evaluate the effect of uncertainty on the estimate of the harmonic mean of F_{MSY}. The highlighted values are those which change between models.

	Years used in S/R fit	Selectivity CV	R sigma	q sigma	M sigma	F_{MSY}	Harmonic mean of F_{MSY} (% of F_{msy})
Model 1	1955-2002	0.4	0.6	q not estimated	M not estimated	0.327	0.321 (98%)
Model 2	1978-2002	0.4	0.6	q not estimated	M not estimated	0.211	0.191 (91%)
Model 3	1955-1978	0.4	0.6	q not estimated	M not estimated	0.396	0.388 (98%)
Model 4	1978-2002	0.4	0.8	q not estimated	M not estimated	0.209	0.178 (85%)
Model 5	1978-2002	0.4	1.0	q not estimated	M not estimated	0.209	0.1628 (78%)
Model 6	1978-2002	0.4	1.2	q not estimated	M not estimated	0.209	0.1463 (70%)
Model 7	1978-2002	0.4	1.5	q not estimated	M not estimated	0.209	0.12 (57%)
Model 8	1978-2002	0.9	0.6	q not estimated	M not estimated	0.209	0.185 (88%)
Model 9	1978-2002	0.4	0.6	0.9	M not estimated	0.208	0.189 (91%)
Model 10	1978-2002	0.4	0.6	0.4	M not estimated	0.208	0.189 (91%)
Model 11	1978-2002	0.4	0.6	q not estimated	0.9	0.237	0.221 (93%)
Model 12	1978-2002	0.4	0.6	q not estimated	0.4	0.233	0.217 (93%)

Table 4.12. Models evaluated for the 2007 stock assessment of yellowfin sole. $Sigma_M$ and $Sigma_q$ are the level of uncertainty placed on the parameter estimates of natural mortality and catchability, respectively. Biomass is in 1,000s t.

		Model 2	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
model	**2006 model**	**BASE model**	**M estimated with $sigma_M$ = 0.2**	**M estimated with $sigma_M$ = 0.5**	**q estimated with $sigma_q$ = 0.2**	**q estimated with $sigma_q$ = 0.5**	**M and q estimated with sigma = 0.2**	**M and q estimated with sigma = 0.5**
ending FSB	598.748	602.431	628.676	629.118	607.104	607.239	429.18	372.406
ending total biomass	1995.96	2155.67	2170.41	2171.07	2145.77	2146.18	1427.83	1208.35
M	0.12	0.12	0.11	0.11	0.12	0.12	0.07	0.048
q	1.16	1.17	1.17	1.17	1.16	1.16	1.82	2.19
F40%	0.109	0.109	0.103	0.103	0.109	0.109	0.073	0.05
Tier 3 ABC	135.463	144.415	140.987	140.971	142.818	142.849	70.0	45.03
survey, catch, age and recruit likelihood	1272.36	1337.0	1354.51	1354.503	1357.16	1357.16	1335.4	1331.09

Table 4.13. Model estimates of yellowfin sole fishing mortality and exploitation rate (catch/total biomass).

Year	Full selection F	Exploitation Rate
1964	0.48	0.16
1965	0.19	0.07
1966	0.30	0.13
1967	0.48	0.21
1968	0.26	0.12
1969	0.56	0.23
1970	0.54	0.20
1971	0.85	0.24
1972	0.29	0.07
1973	0.41	0.09
1974	0.16	0.04
1975	0.15	0.05
1976	0.12	0.04
1977	0.09	0.03
1978	0.16	0.07
1979	0.09	0.04
1980	0.07	0.04
1981	0.08	0.04
1982	0.06	0.04
1983	0.07	0.04
1984	0.10	0.06
1985	0.14	0.08
1986	0.12	0.08
1987	0.11	0.07
1988	0.14	0.09
1989	0.10	0.06
1990	0.05	0.03
1991	0.05	0.04
1992	0.09	0.06
1993	0.06	0.04
1994	0.08	0.06
1995	0.08	0.05
1996	0.08	0.06
1997	0.12	0.09
1998	0.08	0.05
1999	0.05	0.03
2000	0.06	0.04
2001	0.05	0.03
2002	0.05	0.04
2003	0.05	0.04
2004	0.05	0.03
2005	0.07	0.05
2006	0.07	0.05
2007	0.09	0.05

Table 4.14. Model estimates of yellowfin sole age-specific selectivities for the survey and fishery.

Age	Fishery (1964-2006)	Survey (1982-2006)
1	0.00	0.00
2	0.00	0.01
3	0.00	0.03
4	0.01	0.13
5	0.02	0.41
6	0.06	0.77
7	0.16	0.94
8	0.34	0.99
9	0.59	1.00
10	0.80	1.00
11	0.91	1.00
12	0.97	1.00
13	0.99	1.00
14	0.99	1.00
15	0.99	1.00
16	0.99	1.00
17	0.99	1.00
18	0.99	1.00
19	0.99	1.00
20	0.99	1.00

Table 4.15. Model estimates of yellowfin sole age 2+ total biomass (t) and begin-year female spawning biomass (t) from the 2006 and 2007 stock assessments.

	2007 Assessment		2006 Assessment	
Year	Female Spawning Biomass	Age 2+ Total Biomass	Female Spawning Biomass	Age 2+ Total Biomass
1964	65,407	711,918	75,802	751,570
1965	74,806	717,847	80,474	754,941
1966	95,853	776,175	106,392	808,050
1967	105,745	770,668	124,093	799,107
1968	107,887	695,412	118,894	721,658
1969	107,128	713,163	129,491	738,735
1970	87,790	661,973	105,379	686,580
1971	66,661	669,499	87,490	706,195
1972	52,430	691,397	58,433	737,696
1973	57,059	877,659	65,835	929,017
1974	67,401	1,058,160	72,675	1,113,000
1975	95,251	1,300,760	101,108	1,353,500
1976	139,084	1,557,710	142,311	1,580,460
1977	202,170	1,813,790	205,787	1,820,570
1978	277,358	2,056,540	287,797	2,056,710
1979	353,146	2,209,920	357,796	2,196,480
1980	442,917	2,386,040	443,284	2,357,860
1981	530,673	2,541,310	532,240	2,506,810
1982	604,824	2,646,370	610,891	2,617,810
1983	672,456	2,739,390	683,757	2,717,900
1984	721,476	2,811,830	747,124	2,794,130
1985	736,855	2,781,790	782,118	2,813,890
1986	723,475	2,698,870	776,046	2,760,430
1987	708,248	2,630,040	759,970	2,716,430
1988	682,446	2,590,450	743,986	2,682,530
1989	651,743	2,491,030	705,115	2,586,800
1990	659,078	2,470,660	703,937	2,551,580
1991	694,005	2,505,500	741,134	2,576,460
1992	718,947	2,499,170	775,997	2,564,670
1993	730,248	2,415,630	779,120	2,476,360
1994	735,074	2,376,670	791,623	2,433,940
1995	719,222	2,288,120	771,891	2,344,140
1996	694,757	2,205,540	749,297	2,268,960
1997	662,308	2,130,310	720,089	2,188,600
1998	618,422	2,003,580	668,910	2,061,660
1999	603,433	1,948,750	650,042	2,020,170
2000	590,615	1,934,200	642,645	2,011,090
2001	587,255	1,935,110	630,890	1,990,910
2002	578,963	1,943,390	626,952	1,986,270
2003	579,664	1,964,560	621,447	1,983,570
2004	576,871	1,997,590	612,852	1,983,340
2005	574,888	2,059,450	609,868	1,998,940
2006	568,079	2,098,380	598,748	1,995,960
2007	562,879	2,155,670		

Table 4.16—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2007.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1954	3.39	4.43	2.18	0.85	0.4	0.34	0.32	0.31	0.3	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28
1955	1.6	3.01	3.93	1.94	0.75	0.36	0.3	0.28	0.28	0.27	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.5
1956	0.96	1.42	2.67	3.49	1.72	0.67	0.32	0.27	0.25	0.24	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.65
1957	3.23	0.85	1.26	2.37	3.09	1.52	0.59	0.28	0.23	0.22	0.21	0.2	0.2	0.19	0.19	0.19	0.19	0.19	0.19	0.76
1958	2.3	2.87	0.76	1.12	2.1	2.74	1.35	0.52	0.25	0.2	0.19	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.16	0.82
1959	1.71	2.04	2.54	0.67	0.99	1.86	2.42	1.19	0.46	0.21	0.18	0.16	0.16	0.15	0.14	0.14	0.14	0.14	0.14	0.84
1960	1.77	1.52	1.81	2.25	0.59	0.87	1.63	2.09	0.99	0.36	0.16	0.13	0.12	0.11	0.11	0.11	0.1	0.1	0.1	0.72
1961	1.03	1.57	1.35	1.6	1.99	0.52	0.75	1.32	1.53	0.63	0.2	0.09	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.42
1962	1.79	0.91	1.39	1.19	1.41	1.72	0.43	0.56	0.83	0.74	0.25	0.07	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.15
1963	0.92	1.59	0.81	1.23	1.04	1.2	1.39	0.31	0.31	0.32	0.21	0.06	0.02	0.01	0	0	0	0	0	0.04
1964	0.85	0.81	1.41	0.71	1.09	0.92	1.04	1.16	0.24	0.21	0.2	0.13	0.04	0.01	0	0	0	0	0	0.02
1965	1.17	0.75	0.72	1.25	0.63	0.95	0.79	0.86	0.87	0.16	0.13	0.12	0.07	0.02	0.01	0	0	0	0	0.01
1966	1.23	1.04	0.67	0.64	1.11	0.56	0.83	0.68	0.71	0.69	0.12	0.1	0.09	0.05	0.01	0	0	0	0	0.01
1967	2.57	1.09	0.92	0.59	0.56	0.97	0.48	0.71	0.54	0.53	0.48	0.08	0.06	0.06	0.03	0.01	0	0	0	0.01
1968	3.99	2.28	0.96	0.81	0.52	0.49	0.84	0.4	0.53	0.36	0.32	0.27	0.04	0.04	0.03	0.02	0.01	0	0	0
1969	3.41	3.54	2.02	0.85	0.72	0.46	0.43	0.71	0.32	0.41	0.26	0.22	0.19	0.03	0.02	0.02	0.01	0	0	0
1970	4.49	3.03	3.14	1.79	0.75	0.63	0.39	0.35	0.52	0.21	0.23	0.14	0.12	0.1	0.02	0.01	0.01	0.01	0	0
1971	4.99	3.98	2.68	2.78	1.58	0.66	0.54	0.32	0.26	0.34	0.12	0.12	0.07	0.06	0.05	0.01	0.01	0.01	0	0
1972	4.03	4.42	3.53	2.37	2.44	1.37	0.55	0.42	0.21	0.14	0.15	0.05	0.05	0.03	0.02	0.02	0	0	0	0
1973	2.92	3.57	3.92	3.13	2.1	2.15	1.2	0.47	0.34	0.16	0.1	0.1	0.03	0.03	0.02	0.02	0.01	0	0	0
1974	4.02	2.59	3.17	3.47	2.76	1.84	1.86	0.99	0.36	0.23	0.1	0.06	0.06	0.02	0.02	0.01	0.01	0.01	0	0
1975	4.69	3.57	2.29	2.81	3.07	2.44	1.62	1.61	0.83	0.29	0.18	0.08	0.05	0.05	0.01	0.01	0.01	0.01	0.01	0
1976	3.28	4.16	3.16	2.03	2.49	2.72	2.15	1.4	1.36	0.68	0.23	0.14	0.06	0.03	0.04	0.01	0.01	0.01	0.01	0.01
1977	3.86	2.91	3.69	2.8	1.8	2.2	2.39	1.87	1.19	1.12	0.55	0.18	0.11	0.05	0.03	0.03	0.01	0.01	0.01	0.01
1978	2.52	3.42	2.58	3.27	2.48	1.6	1.94	2.09	1.61	1.01	0.93	0.45	0.15	0.09	0.04	0.02	0.02	0.01	0.01	0.01
1979	1.63	2.24	3.03	2.29	2.9	2.19	1.4	1.68	1.76	1.3	0.79	0.71	0.34	0.11	0.07	0.03	0.02	0.02	0.01	0.01

Table 4.16—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2007 (continued).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	3.11	1.45	1.99	2.69	2.03	2.56	1.94	1.23	1.45	1.48	1.08	0.64	0.58	0.28	0.09	0.06	0.02	0.01	0.01	0.02
1981	2.19	2.76	1.28	1.76	2.38	1.8	2.26	1.7	1.06	1.23	1.25	0.9	0.54	0.48	0.23	0.08	0.05	0.02	0.01	0.03
1982	6	1.95	2.45	1.14	1.56	2.11	1.58	1.98	1.47	0.9	1.03	1.03	0.74	0.44	0.4	0.19	0.06	0.04	0.02	0.03
1983	1.03	5.32	1.73	2.17	1.01	1.38	1.86	1.39	1.72	1.25	0.76	0.86	0.86	0.61	0.37	0.33	0.16	0.05	0.03	0.04
1984	4.96	0.92	4.72	1.53	1.92	0.89	1.22	1.63	1.2	1.46	1.05	0.63	0.71	0.71	0.51	0.3	0.27	0.13	0.04	0.06
1985	1.64	4.4	0.81	4.18	1.36	1.7	0.79	1.07	1.4	1.01	1.2	0.85	0.51	0.57	0.57	0.41	0.24	0.22	0.1	0.08
1986	1.35	1.45	3.9	0.72	3.7	1.2	1.5	0.68	0.9	1.14	0.8	0.94	0.66	0.39	0.44	0.44	0.31	0.19	0.17	0.14
1987	1.84	1.2	1.29	3.46	0.64	3.28	1.05	1.3	0.58	0.74	0.92	0.63	0.74	0.52	0.31	0.35	0.34	0.25	0.15	0.25
1988	2.5	1.63	1.07	1.14	3.06	0.57	2.88	0.92	1.11	0.48	0.6	0.74	0.5	0.58	0.41	0.24	0.27	0.27	0.2	0.31
1989	2.43	2.22	1.45	0.94	1.01	2.71	0.5	2.5	0.78	0.91	0.38	0.47	0.57	0.39	0.45	0.32	0.19	0.21	0.21	0.39
1990	1.06	2.15	1.97	1.28	0.84	0.89	2.39	0.43	2.14	0.65	0.74	0.31	0.38	0.46	0.31	0.36	0.25	0.15	0.17	0.48
1991	1.21	0.94	1.91	1.75	1.14	0.74	0.79	2.1	0.38	1.85	0.55	0.63	0.26	0.32	0.39	0.26	0.31	0.21	0.13	0.55
1992	2.79	1.07	0.84	1.69	1.55	1.01	0.66	0.7	1.83	0.33	1.57	0.47	0.53	0.22	0.27	0.33	0.22	0.26	0.18	0.57
1993	1.52	2.48	0.95	0.74	1.5	1.37	0.89	0.57	0.6	1.54	0.27	1.28	0.38	0.43	0.18	0.22	0.26	0.18	0.21	0.61
1994	1.31	1.35	2.2	0.84	0.66	1.33	1.21	0.78	0.5	0.51	1.3	0.23	1.07	0.32	0.36	0.15	0.18	0.22	0.15	0.68
1995	1.26	1.16	1.2	1.95	0.75	0.58	1.17	1.06	0.67	0.42	0.42	1.07	0.18	0.88	0.26	0.29	0.12	0.15	0.18	0.68
1996	3.5	1.12	1.03	1.06	1.73	0.66	0.51	1.03	0.92	0.57	0.35	0.35	0.88	0.15	0.72	0.21	0.24	0.1	0.12	0.71
1997	1.36	3.1	0.99	0.91	0.94	1.53	0.58	0.45	0.89	0.78	0.48	0.29	0.29	0.72	0.12	0.59	0.18	0.2	0.08	0.68
1998	1.34	1.2	2.75	0.88	0.81	0.83	1.34	0.51	0.38	0.73	0.63	0.38	0.23	0.23	0.57	0.1	0.47	0.14	0.16	0.6
1999	2.09	1.19	1.07	2.44	0.78	0.71	0.73	1.18	0.44	0.32	0.61	0.52	0.31	0.19	0.19	0.47	0.08	0.38	0.11	0.62
2000	3.09	1.85	1.05	0.95	2.16	0.69	0.63	0.65	1.03	0.38	0.28	0.52	0.44	0.26	0.16	0.16	0.39	0.07	0.32	0.62
2001	1.91	2.74	1.64	0.93	0.84	1.92	0.61	0.55	0.56	0.88	0.32	0.23	0.43	0.36	0.22	0.13	0.13	0.33	0.06	0.79
2002	2.94	1.69	2.43	1.45	0.83	0.74	1.69	0.54	0.48	0.48	0.75	0.27	0.2	0.37	0.31	0.19	0.11	0.11	0.28	0.71
2003	4.25	2.6	1.5	2.15	1.29	0.73	0.66	1.49	0.47	0.42	0.41	0.64	0.23	0.17	0.31	0.26	0.16	0.09	0.09	0.84
2004	3.85	3.77	2.31	1.33	1.91	1.14	0.65	0.58	1.3	0.4	0.36	0.35	0.54	0.19	0.14	0.26	0.22	0.13	0.08	0.79
2005	1.98	3.41	3.34	2.05	1.18	1.69	1.01	0.57	0.5	1.12	0.35	0.3	0.3	0.46	0.16	0.12	0.22	0.19	0.11	0.74
2006	2.16	1.76	3.03	2.97	1.81	1.05	1.49	0.89	0.49	0.43	0.94	0.29	0.25	0.25	0.38	0.14	0.1	0.18	0.15	0.7
2007	2.19	1.92	1.56	2.69	2.63	1.61	0.92	1.31	0.77	0.42	0.36	0.79	0.24	0.21	0.2	0.31	0.11	0.08	0.15	0.71

Table 4.17. Model estimates of yellowfin sole age 5 recruitment (millions) from the 2006 and 2007 stock assessments.

Year class	2007 Assessment	2006 Assessment
1959	1,086	1,126
1960	630	664
1961	1,106	1,141
1962	564	591
1963	522	540
1964	720	736
1965	754	767
1966	1,580	1,583
1967	2,445	2,425
1968	2,099	2,072
1969	2,763	2,719
1970	3,074	3,019
1971	2,488	2,447
1972	1,802	1,776
1973	2,484	2,458
1974	2,897	2,885
1975	2,027	2,043
1976	2,383	2,428
1977	1,561	1,615
1978	1,010	1,053
1979	1,924	2,010
1980	1,356	1,417
1981	3,705	3,872
1982	639	667
1983	3,063	3,194
1984	1,011	1,051
1985	837	868
1986	1,137	1,181
1987	1,548	1,595
1988	1,501	1,562
1989	657	676
1990	749	774
1991	1,726	1,818
1992	939	991
1993	807	857
1994	780	811
1995	2,164	2,144
1996	839	773
1997	827	805
1998	1,290	1,112
1999	1,909	1,547
2000	1,181	1,132
2001	1,815	1,776

Table 4.18. Projections of yellowfin sole female spawning biomass (1,000s t), catch (1,000s t) and full selection fishing mortality rate for seven future harvest scenarios. 2007 ABC is highlighted.

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2007	562.440	116.10	0.09
2008	547.341	137.20	0.11
2009	533.422	136.79	0.11
2010	527.942	139.11	0.11
2011	537.037	143.53	0.11
2012	550.000	146.98	0.11
2013	564.858	147.47	0.11
2014	570.977	145.45	0.11
2015	571.033	142.73	0.11
2016	559.651	139.95	0.11
2017	547.111	137.81	0.11
2018	536.762	136.20	0.11
2019	530.889	134.37	0.11
2020	524.550	132.27	0.11

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2007	562.440	116.10	0.09
2008	556.962	68.60	0.05
2009	569.857	75.34	0.06
2010	588.492	79.41	0.06
2011	621.381	84.45	0.06
2012	656.959	88.89	0.06
2013	694.268	91.62	0.06
2014	721.085	92.75	0.06
2015	740.851	93.18	0.06
2016	743.609	93.15	0.06
2017	741.665	93.16	0.06
2018	739.586	93.29	0.06
2019	741.364	93.41	0.06
2020	739.546	93.34	0.06

Scenario 4
Harvest at average F over the past 5 years

Year	Female spawning biomass	catch	F
2007	562.440	116.10	0.09
2008	553.035	96.84	0.08
2009	558.907	70.72	0.05
2010	579.367	74.85	0.05
2011	614.190	79.92	0.05
2012	651.988	84.42	0.05
2013	691.654	87.30	0.05
2014	720.858	88.63	0.05
2015	742.819	89.26	0.05
2016	747.547	89.43	0.05
2017	747.293	89.62	0.05
2018	746.655	89.88	0.05
2019	749.719	90.13	0.05
2020	748.975	90.18	0.05

Scenario 5
No fishing

Year	Female spawning biomass	catch	F
2007	562.440	116.10	0.09
2008	566.305	0	0
2009	608.134	0	0
2010	657.721	0	0
2011	723.892	0	0
2012	793.751	0	0
2013	867.275	0	0
2014	930.019	0	0
2015	986.699	0	0
2016	1020.150	0	0
2017	1044.830	0	0
2018	1066.500	0	0
2019	1091.650	0	0
2020	1108.240	0	0

Table 4.18—continued.

Scenario 6
Determination of whether yellowfin sole are currently overfished **B35=422.500**

Year	Female spawning biomass	catch	F
2007	562.440	116.10	0.09
2008	543.731	162.41	0.13
2009	520.047	159.24	0.13
2010	506.054	159.66	0.13
2011	507.263	162.82	0.13
2012	513.143	164.99	0.13
2013	521.276	163.86	0.13
2014	521.532	160.06	0.13
2015	516.366	155.76	0.13
2016	501.779	151.55	0.13
2017	487.711	145.63	0.13
2018	477.673	140.81	0.12
2019	472.967	137.98	0.12
2020	468.570	135.74	0.12

Scenario 7
Determination of whether the stock is approaching an overfished condition **B35=422.500**

Year	Female spawning biomass	catch	F
2007	562.440	116.10	0.09
2008	547.341	137.20	0.11
2009	533.421	136.79	0.11
2010	524.513	164.71	0.13
2011	523.846	167.21	0.13
2012	527.602	168.73	0.13
2013	533.628	166.98	0.13
2014	531.818	162.62	0.13
2015	524.932	157.85	0.13
2016	508.696	153.42	0.13
2017	493.082	147.89	0.13
2018	481.605	142.53	0.12
2019	475.809	139.19	0.12
2020	470.561	136.56	0.12

Table 4-19. Yellowfin catch and bycatch from 1992-2006 estimated from a combination of regional office reported catch and observer sampling of the catch.

Species	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Pollock	13,100	15,253	33,200	27,041	22,254	24,100	15,335	8,701	13,425	16,502	14,489	11,396	10,382	10,312	6,084
Arrowtooth Flounder	366	1,017	1,595	346	820	386	2,382	1,627	1,998	1,845	998	1,125	279	645	352
Pacific Cod	8,700	8,723	16,415	13,181	8,684	12,825	10,224	4,380	5,192	6,531	6,259	4,621	3,606	3,767	2,588
Groundfish, General	7,990	3,847	3,983	2,904	2,565	4,755	3,580	2,524	3,541	3,936	2,678	3,133	1,612	2,134	2,333
Rock Sole	14,646	7,301	8,097	7,486	12,903	16,693	9,825	10,773	7,345	5,810	10,665	8,419	10,068	10,086	8,113
Flathead Sole		1,198	2,491	3,929	3,166	3,896	5,328	2,303	2,644	3,231	2,190	2,899	1,102	1,246	2,039
Sablefish	0	0		0	0	0	0	4	0	0				1	
Atka Mackerel	1	0			0	0	1	33	0	0	0	17		110	17
Pacific ocean Perch	0	5		0		0	1	12	1	1	1	11		15	
Rex Sole			1	1		0	20	36	1	2	0				
Flounder, General	16,826	6,615	7,080	11,092	10,372	10,743	6,362	8,812	7,913	4,854	378	214	434	654	877
Squid	0		5	0	11	0	2	1	0	0	0	1			
Dover Sole			35												
Thornyhead					0		1								
Shortraker/Rougheye	0				1	0	1	15		1					
Butter Sole			0			3	3		2		7				
Eulachon smelt								0							
Starry Flounder		227	106	16	37	124	35	48	71	82	133				
Northern Rockfish						1	0	0			1			3	
Dusky Rockfish								0			0				
Yellowfin Sole	136,804	91,931	126,163	108,493	112,818	169,661	90,062	62,941	71,479	54,722	66,178	68,954	65,604	82,420	84,178
English Sole		1									1				
Unsp.demersal rockfish						12	0								
Greenland Turbot	1	5	5	67	8	4	103	70	24	32	2		1	7	8
Alaska Plaice		1,579	2,709	1,130	553	6,351	2,758	2,530	2,299	1,905	10,396	365	5,891	8,707	14,043
Sculpin, General								215	97	12	1,226				
Skate, General								26	4	21	1,042				
Sharpchin Rockfish								1							
Bocaccio	0														
Rockfish, General	0		0	3	23	0	1	3	4	1		1	3	1	1
Octopus								0							
Smelt, general								0	0	0					
Chilipepper		1													
Eels								1	1	0	0				
Lingcod										2					
Jellyfish (unspecified)									127	173	161				
Snails								12	4	0	4				
Sea cucumber								0	56		0				
Korean horsehair crab								0	0	0					
Greenling, General									0						
Shrimp, general								0	0	0	0				

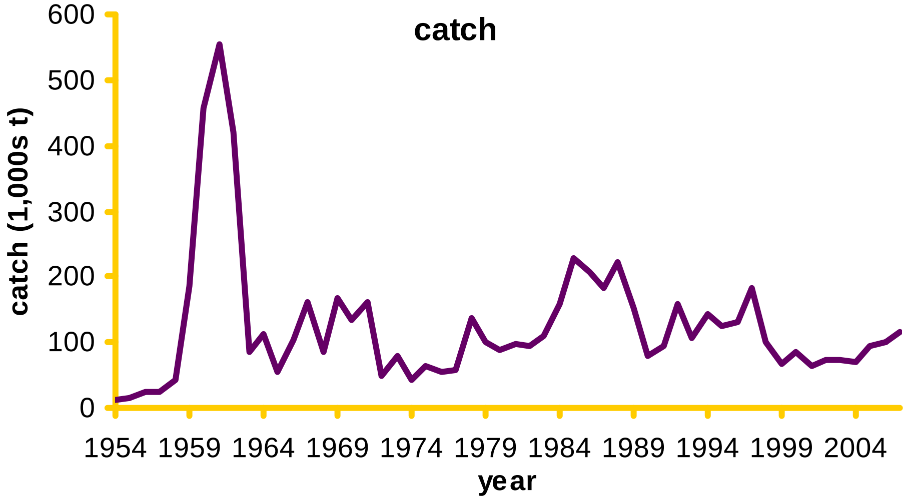


Figure 4.1—Yellowfin sole catch (1,000s t) in the Eastern Bering Sea from 1954-2007.

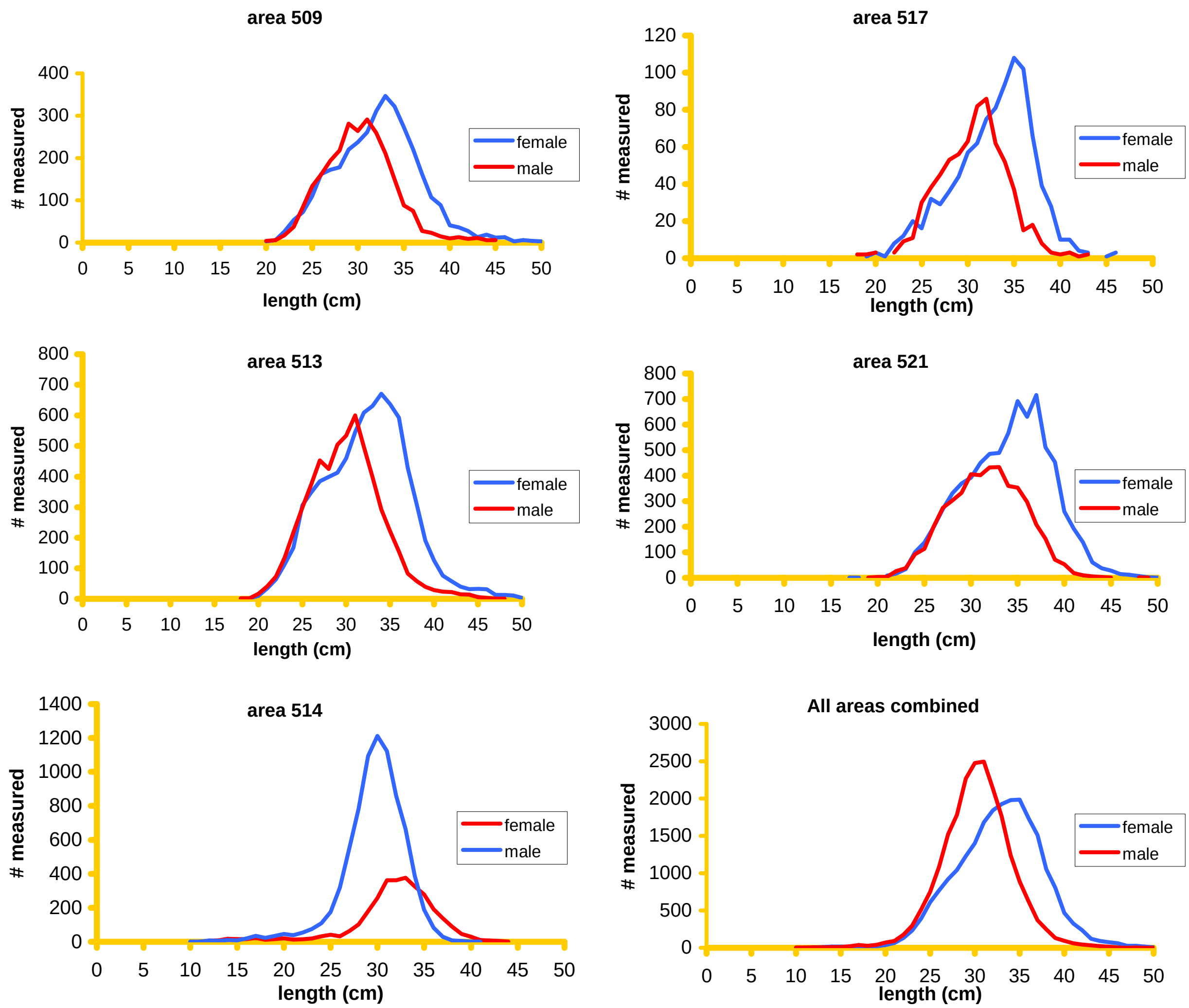
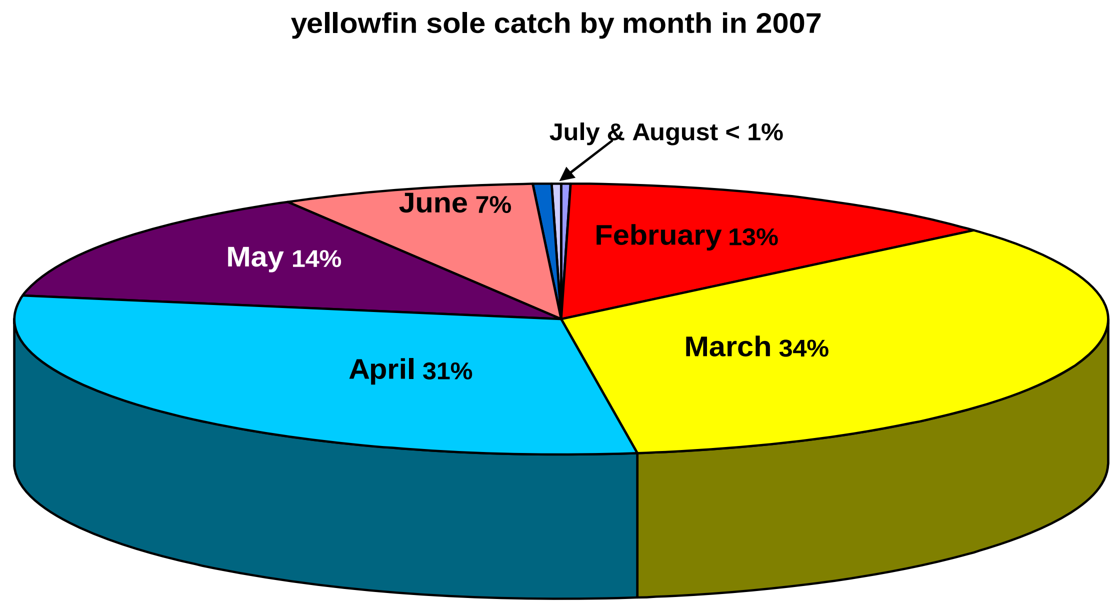


Figure 4.2—Size composition of the yellowfin sole catch in 2007, by subarea and total.



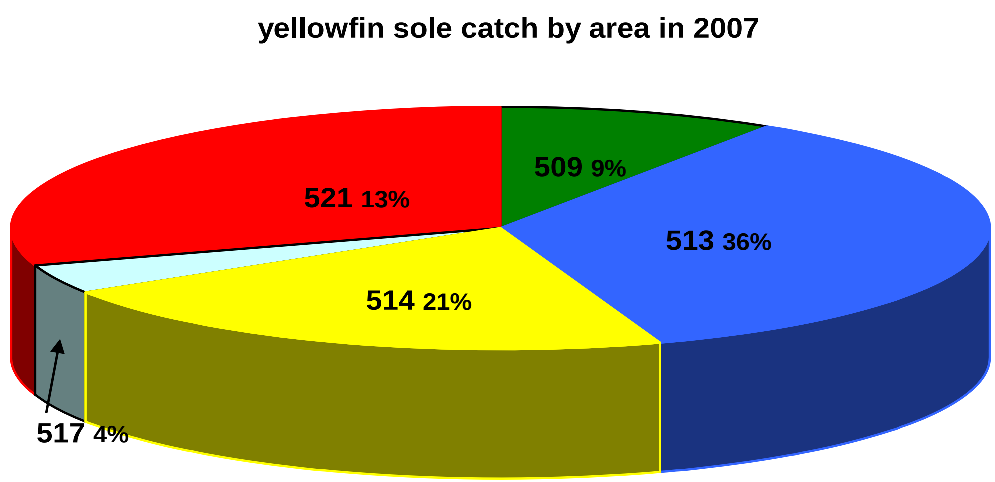


Figure 4.3—Yellowfin sole catch by month and area in the Eastern Bering Sea in 2007.

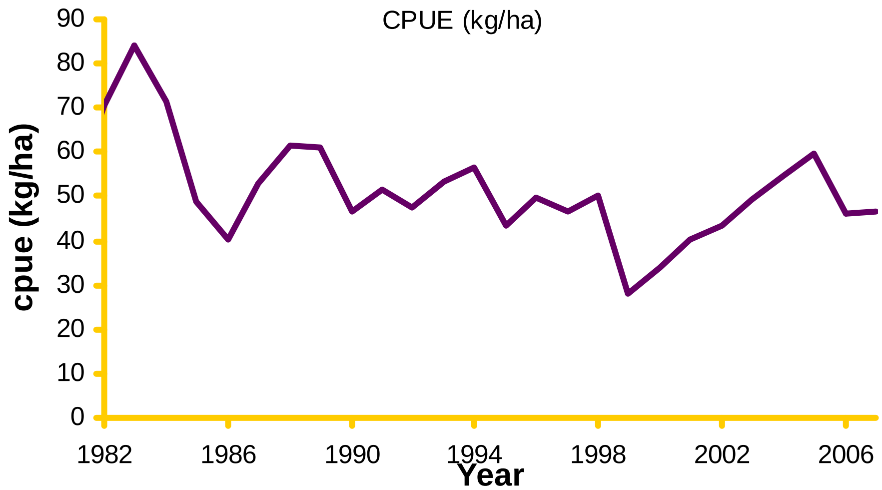


Figure 4.4. Yellowfn sole CPUE (catch per unit effort in kg/ha) from the annual Bering Sea shelf trawl surveys, 1982-2007.

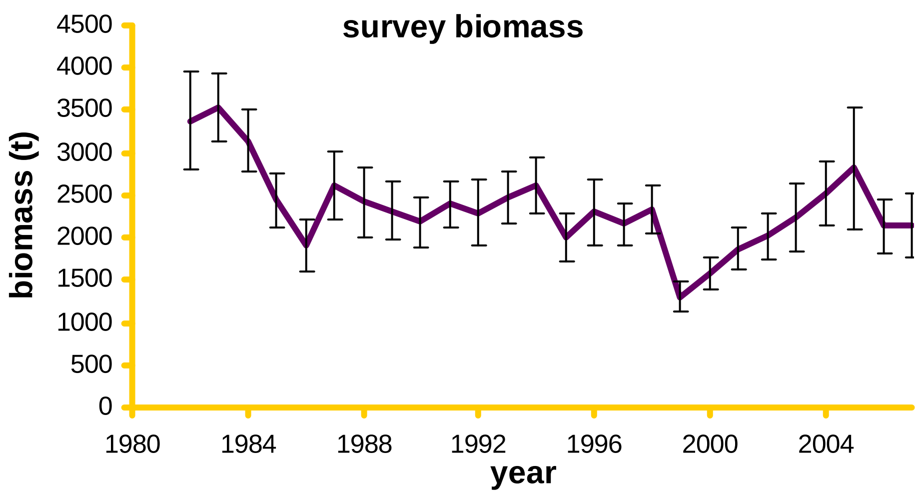


Figure 4.5. Annual bottom trawl survey biomass point-estimates and 95% confidence intervals for yellowfin sole, 1982-2007.

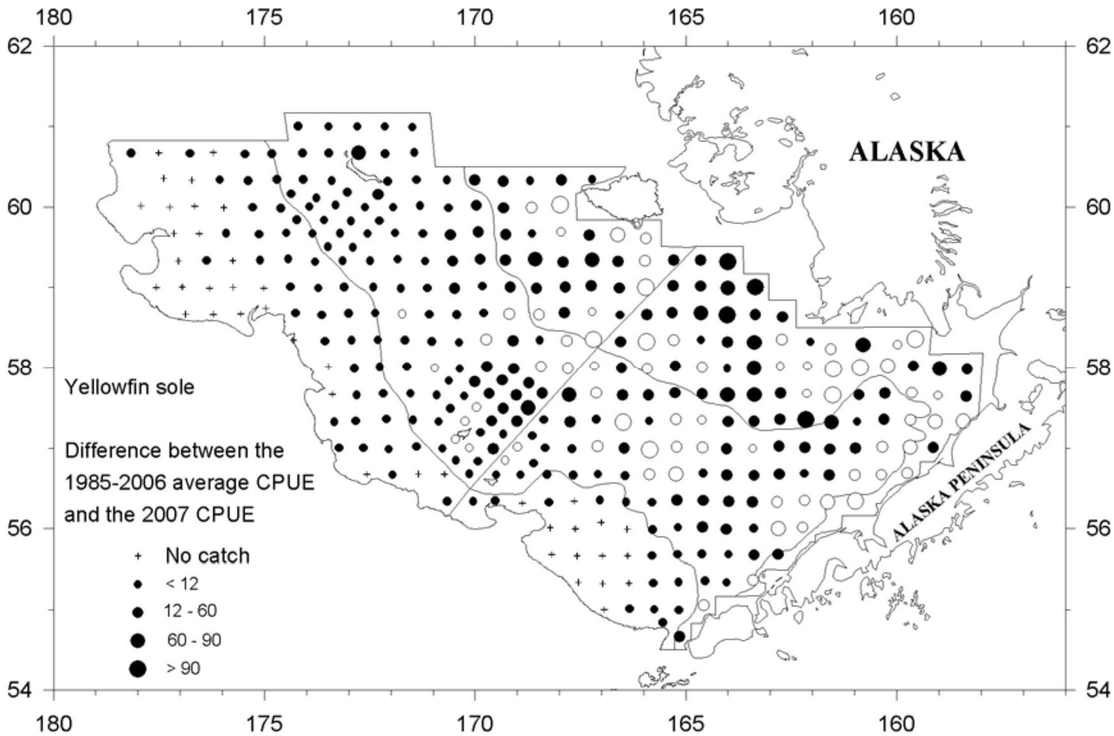


Figure 4.6. Difference between the 1985-2006 average trawl survey CPUE for yellowfin sole and the 2007 survey CPUE. Open circles indicate that the magnitude of the catch was greater in 2007 than the long-term average, closed circles indicate the catch was greater in the long-term average than in 2007.

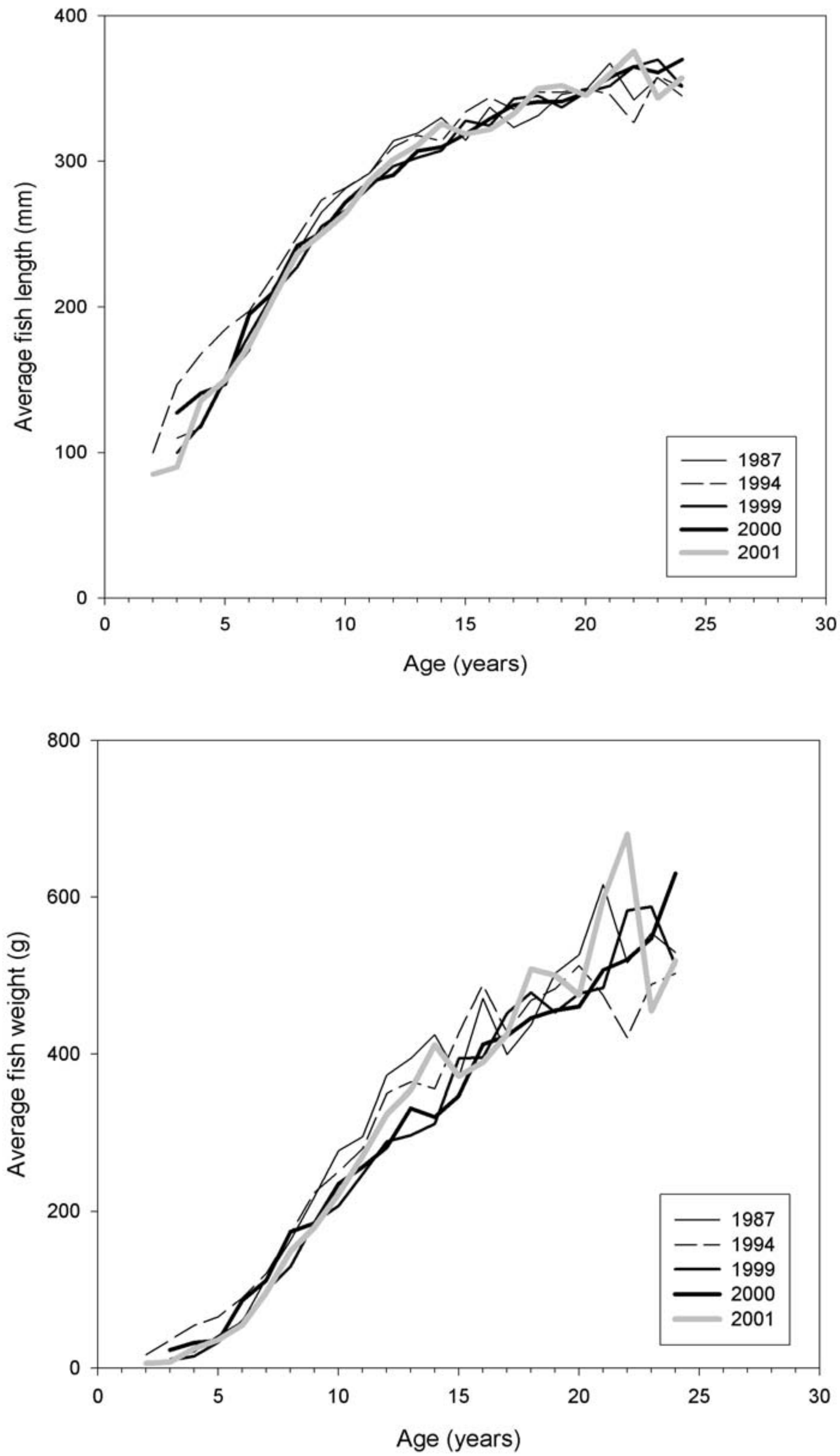


Figure 4.7. Comparison of yellowfin sole length at age (top panel) and weight at age (bottom panel) from biological samples collected in 1987, 1994, 1999, 2000 and 2001.

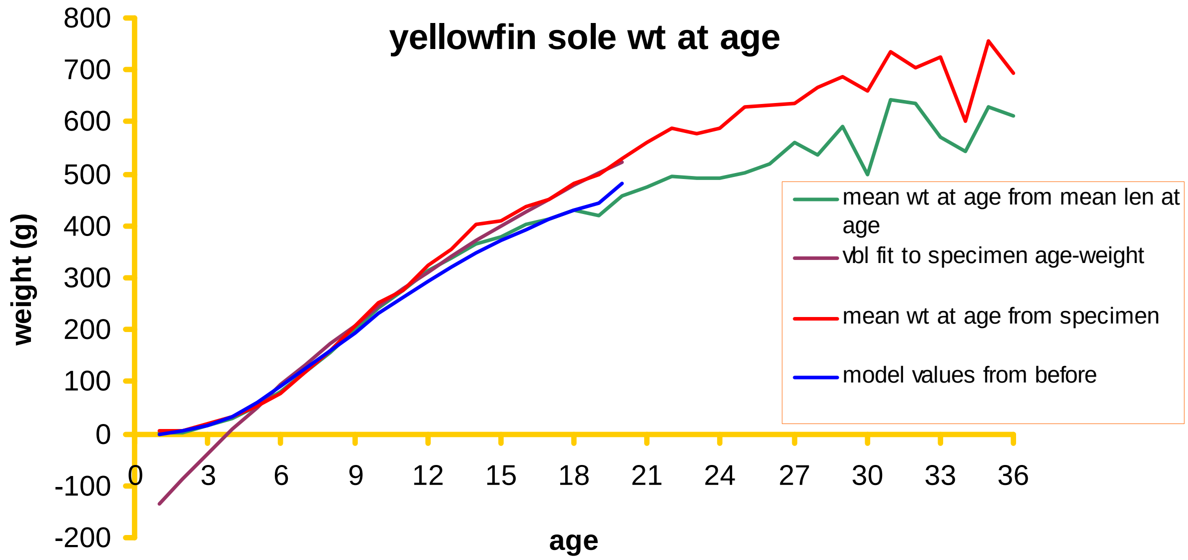


Figure 4.8--Estimates of yellowfin sole weight-at-age (g) from 4 methods.

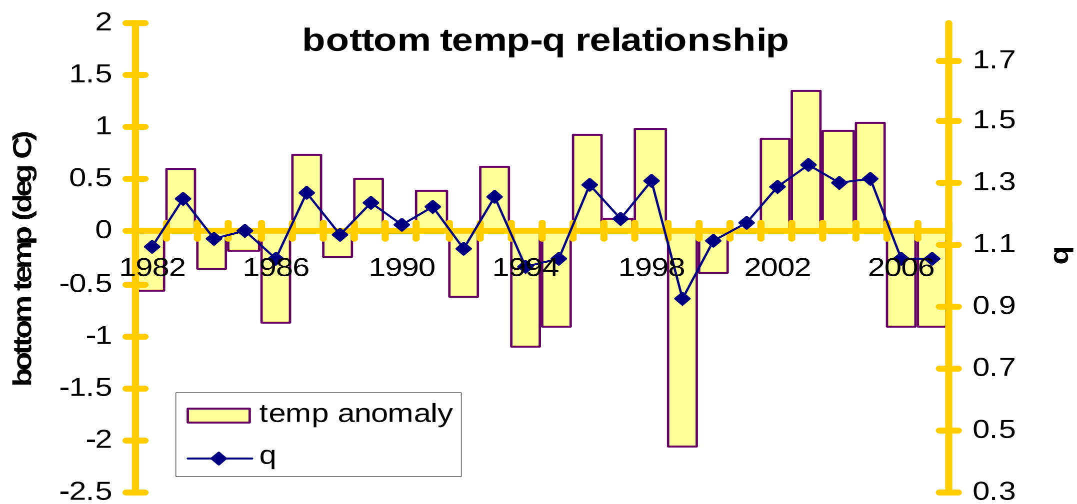


Figure 4.9.--Average bottom water temperature from stations less than or equal to 100 m in the Bering Sea trawl survey and the stock assessment model estimate of q for each year 1982-2007.

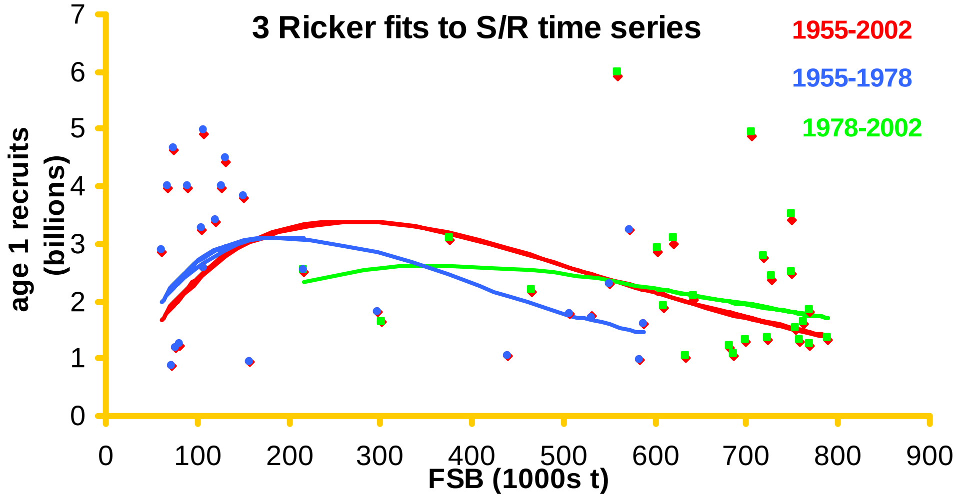


Figure 4.10--Fit of the Ricker (1958) stock recruitment model to three distinct stock recruitment time-series data sets, and the associated annual stock-recruitment point estimates.

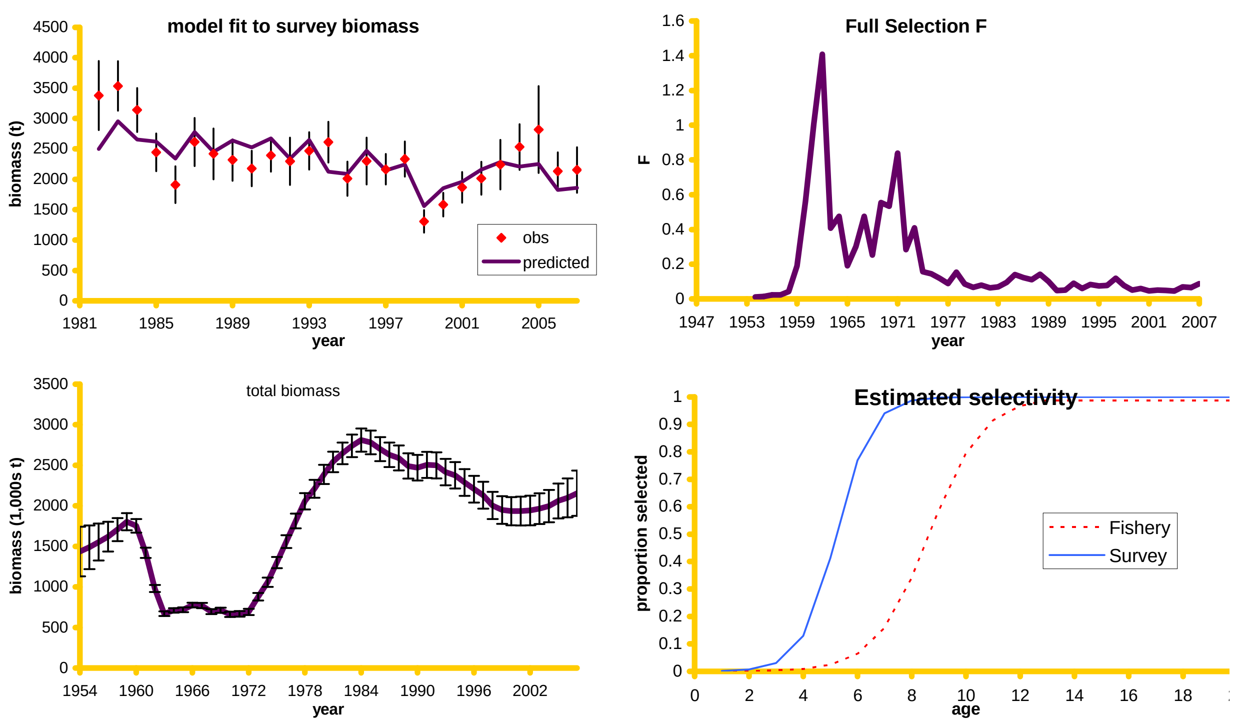


Figure 4.11. Model fit to the survey biomass estimates (top left panel), model estimate of the full selection fishing mortality rate throughout the time-series (top right panel), model estimate of total biomass (bottom left panel) and the model estimate of fishery and survey selectivity (bottom right panel).

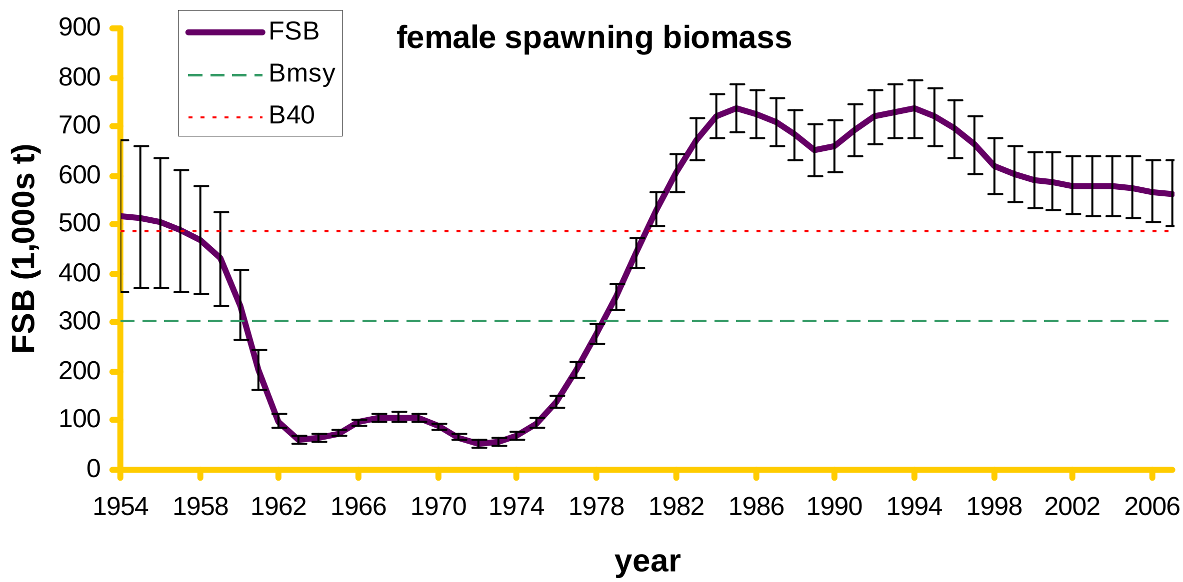


Figure 4.12--Model estimate of yellowfin sole female spawning biomass from 1955-2007 with B40 and Bmsy levels indicated.

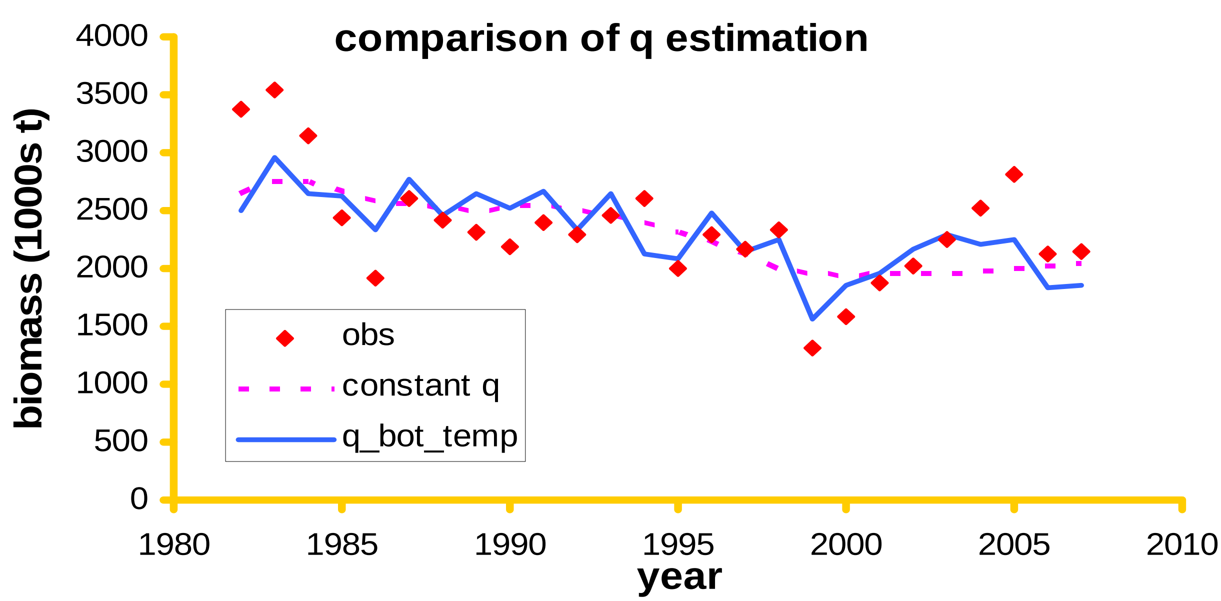


Figure 4.13--Comparison of the fit to the survey biomass using a fixed q and the q-bottom temperature

relationship.

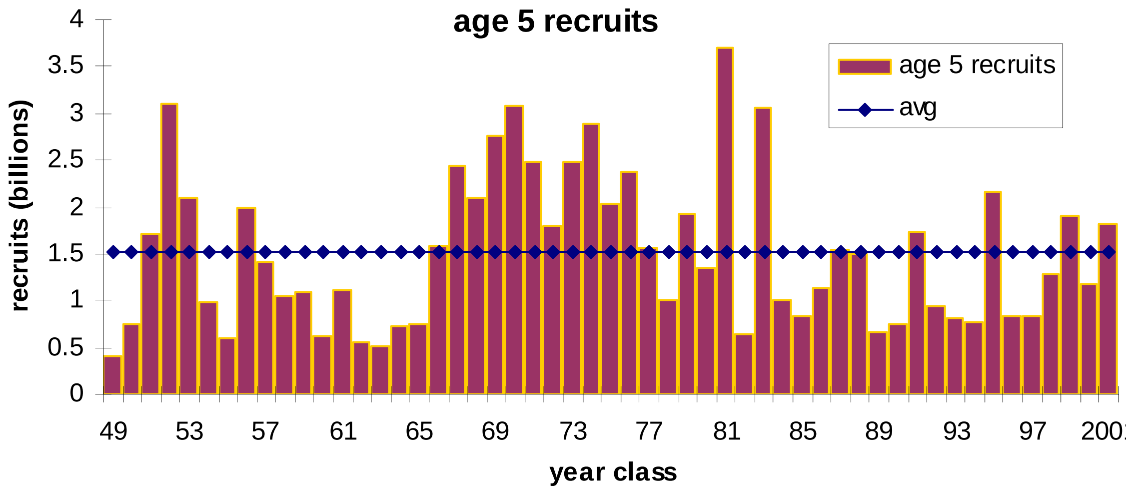


Figure 4.14 Year class strength of age 5 yellowfin sole estimated by the stock assessment model. The dotted line is the average of the estimates from 49 years of recruitment.

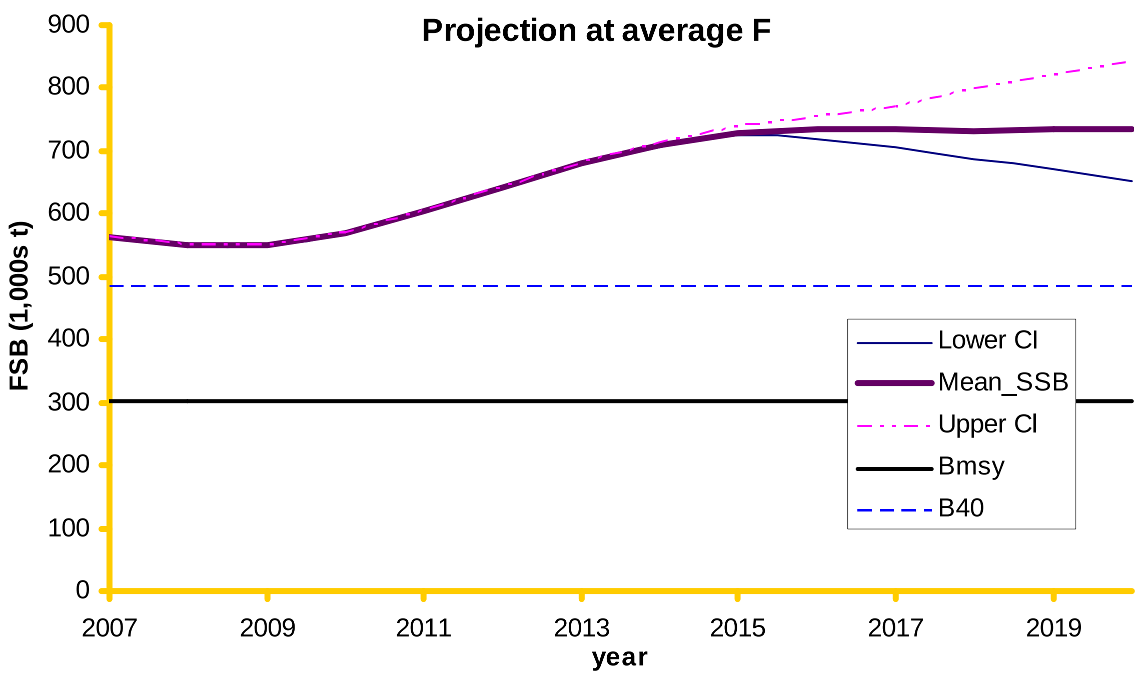


Figure 4.15. Projection of yellowfin sole female spawning biomass (1,000s t) at the average F from the past 5 years (0.055) through 2019 with $B_{40\%}$ and $B_{35\%}$ levels indicated.

Appendix

List of figures and tables

1) 2006 fishery locations by month.

2) Figures showing the fit of the stock assessment model to the time-series of fishery and trawl survey age compositions (survey and fishery observations are the solid lines).

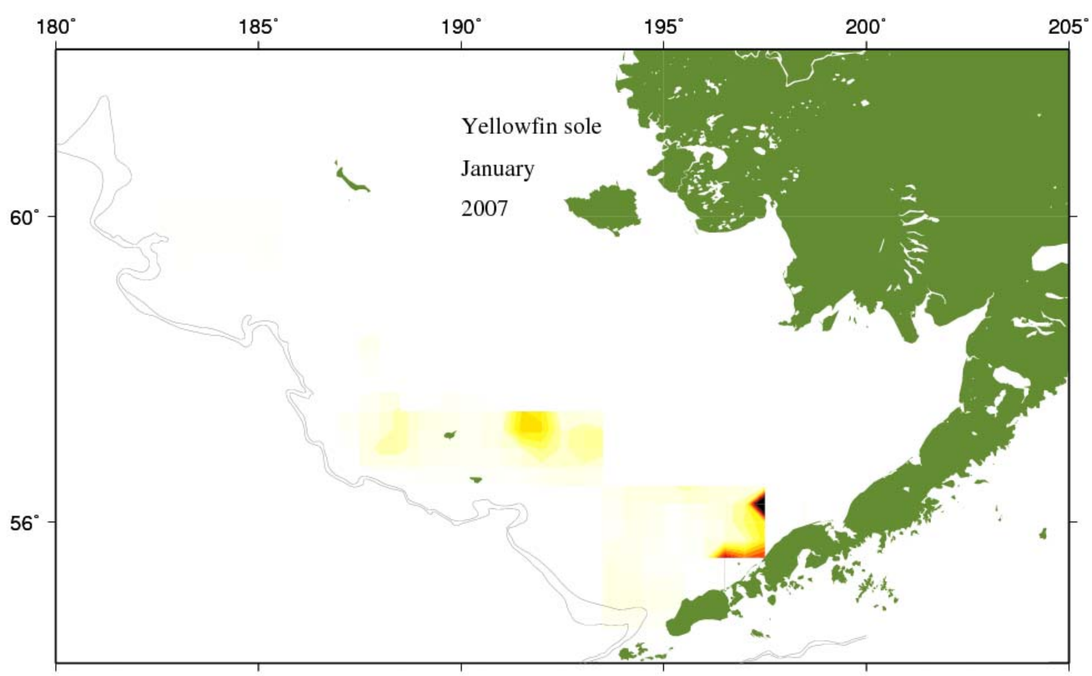
3) Table of yellowfin sole catch (t) from surveys conducted in the eastern Bering Sea and Aleutian Islands area, 1977-2006.

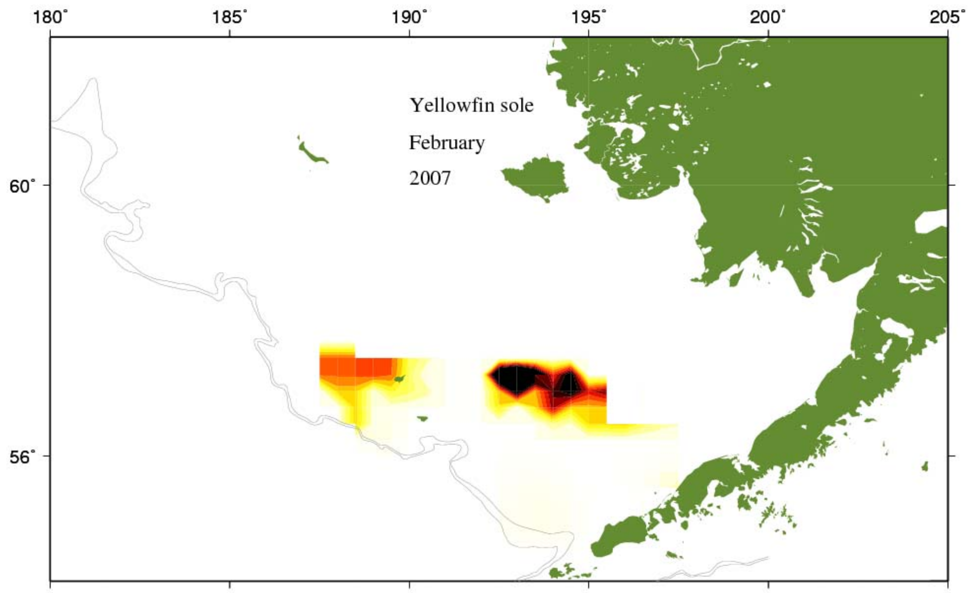
4) Table of number of female spawners (millions) estimated by the stock assessment model for each year.

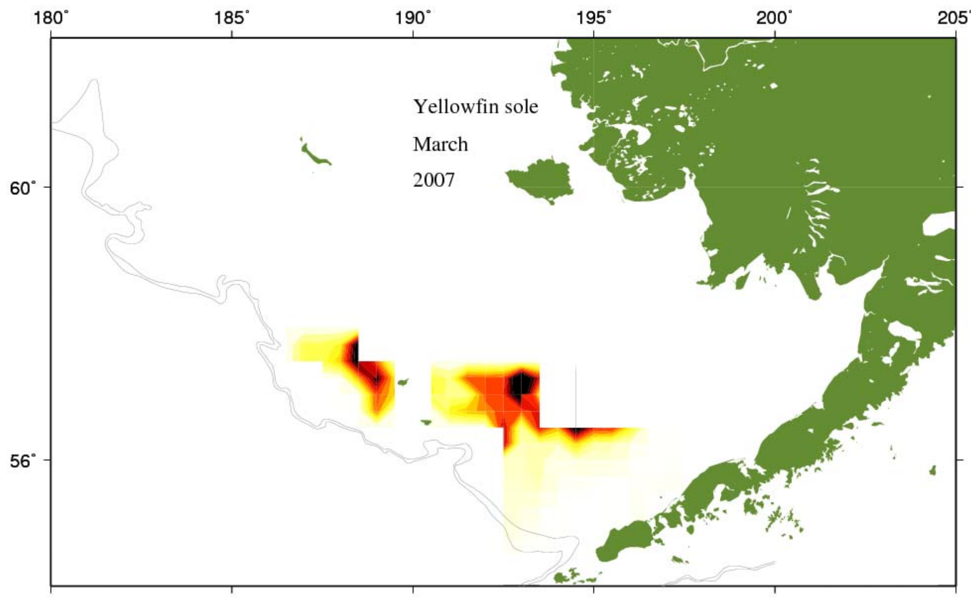
5) Selected parameter estimates and their standard deviation from the stock assessment model.

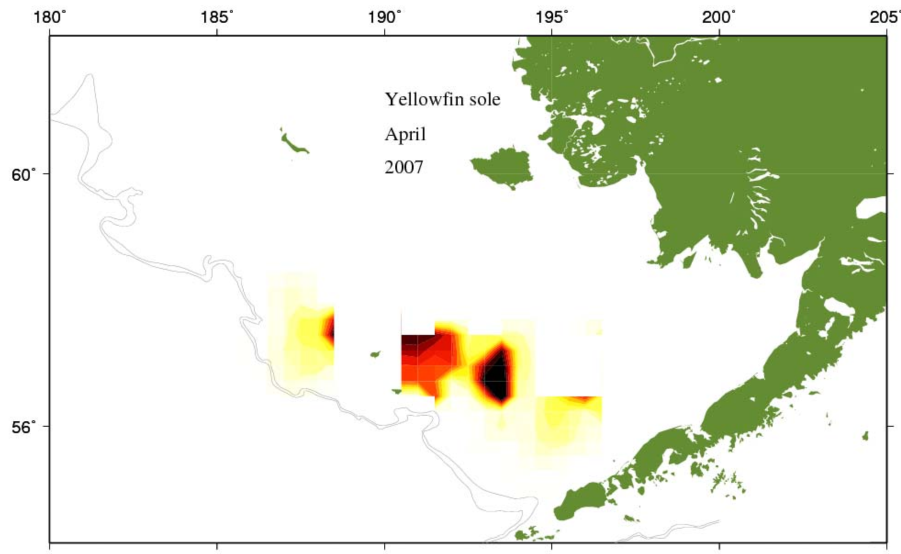
6) Posterior distributions of F_{MSY} from the models evaluated for Tier 1.

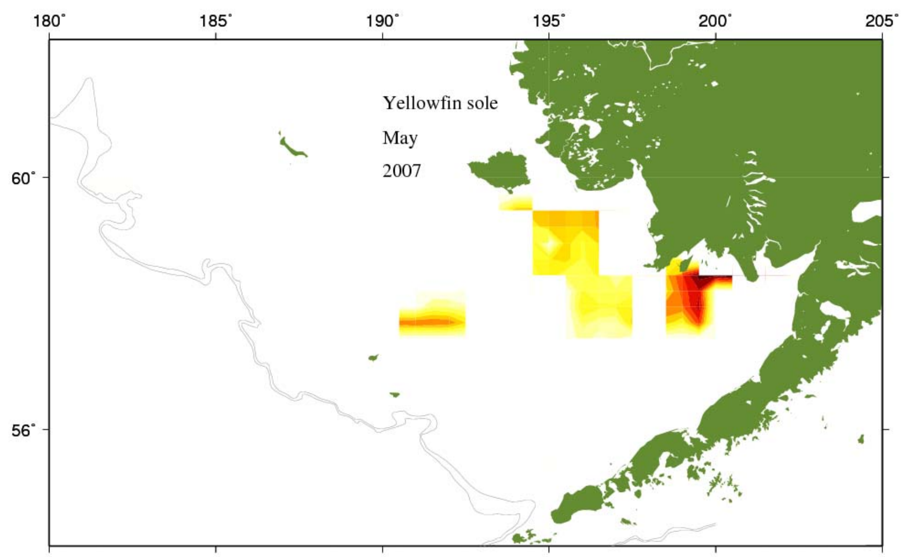
7) Posterior distributions of selected parameters from the stock assessment model used in this assessment.

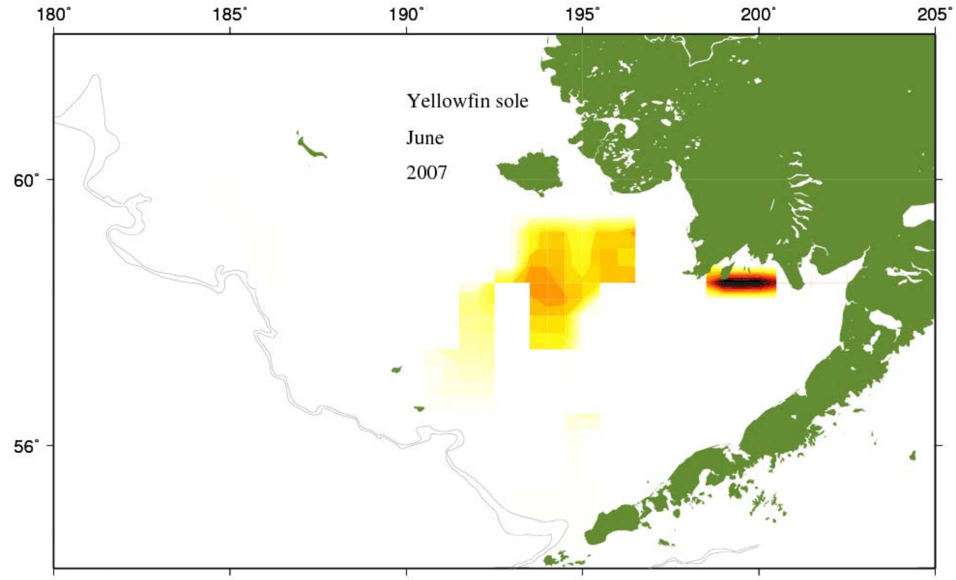


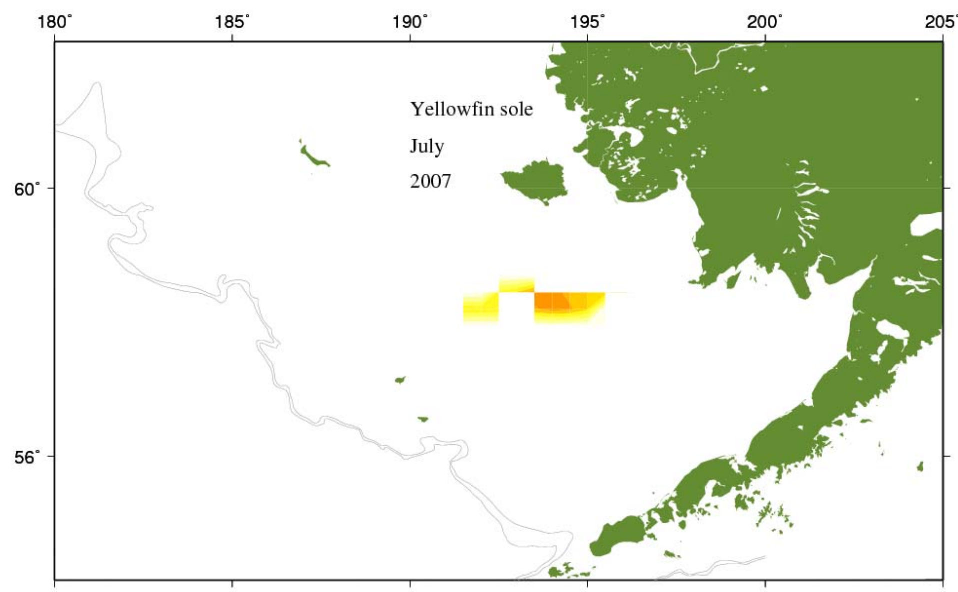

180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Yellowfin sole
February
2007

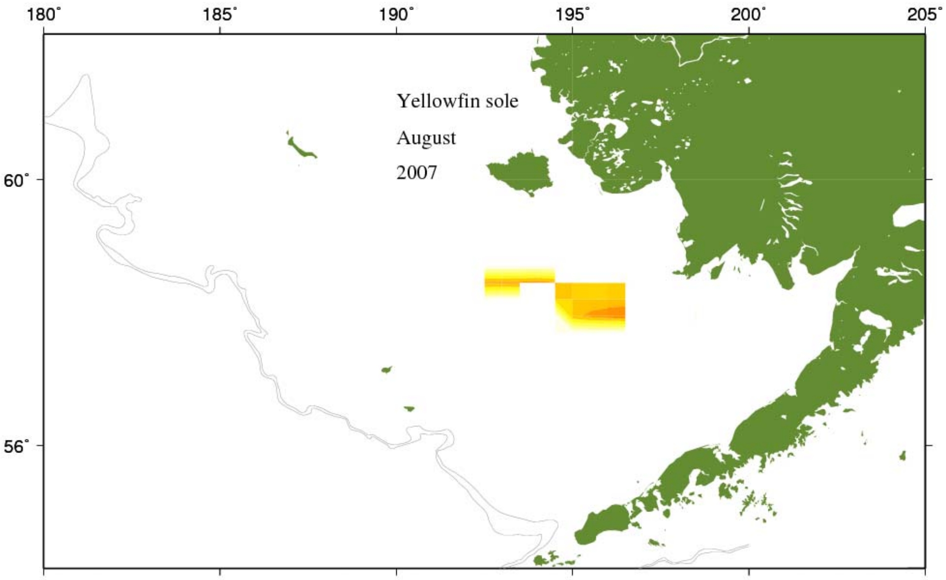

180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Yellowfin sole
March
2007


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Yellowfin sole
April
2007


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Yellowfin sole
May
2007


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Yellowfin sole
June
2007


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Yellowfin sole
July
2007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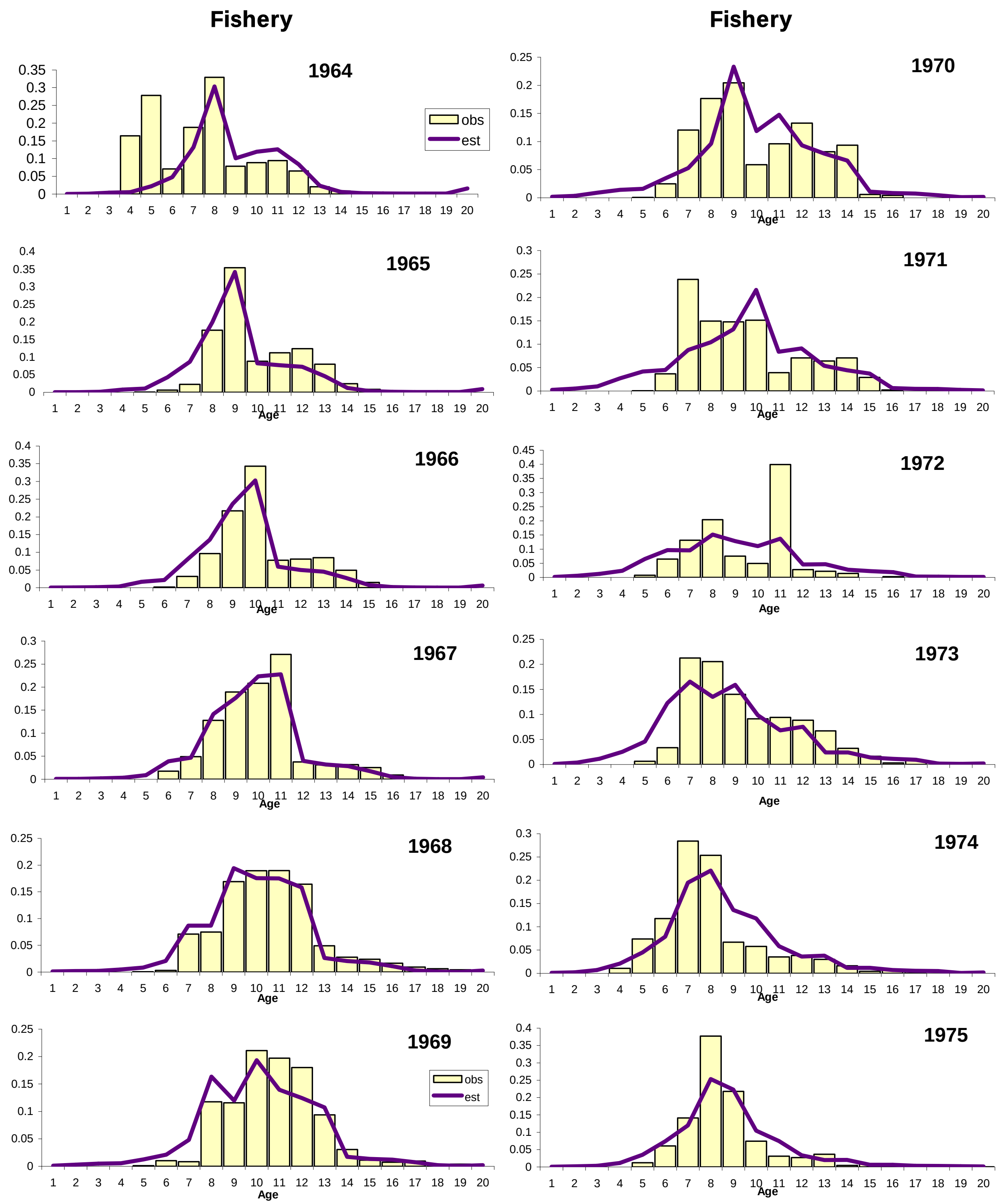
Yellowfin sole
August
2007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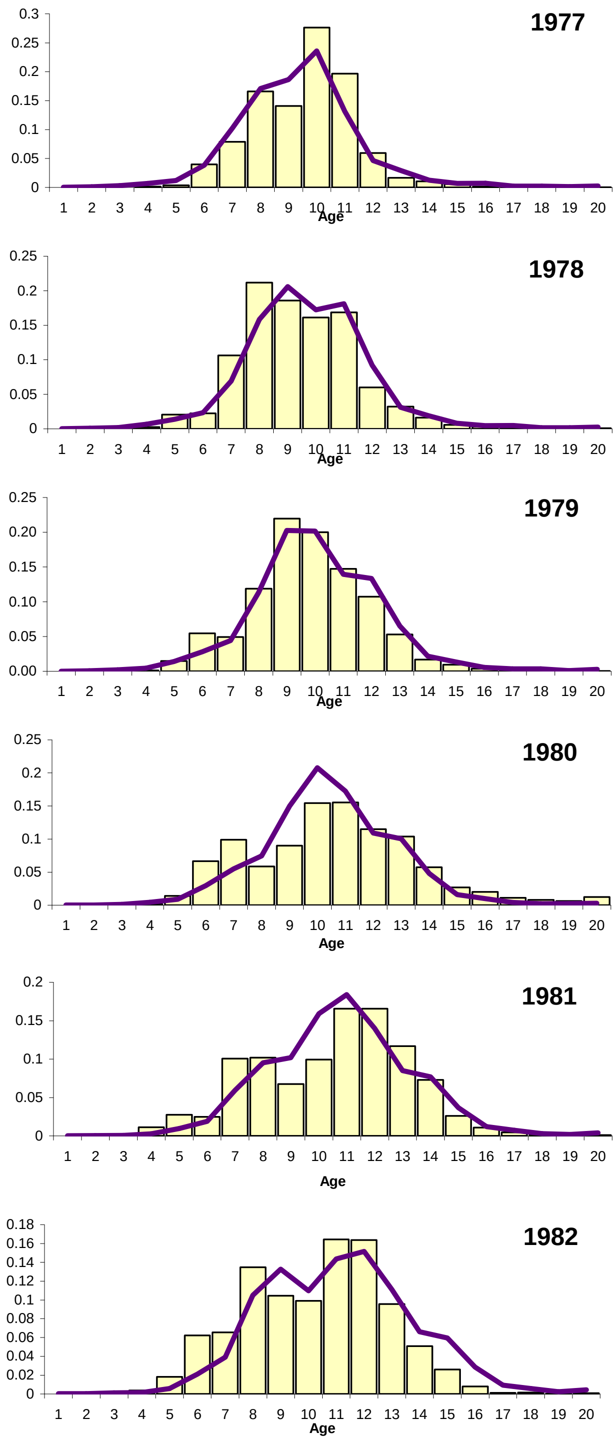

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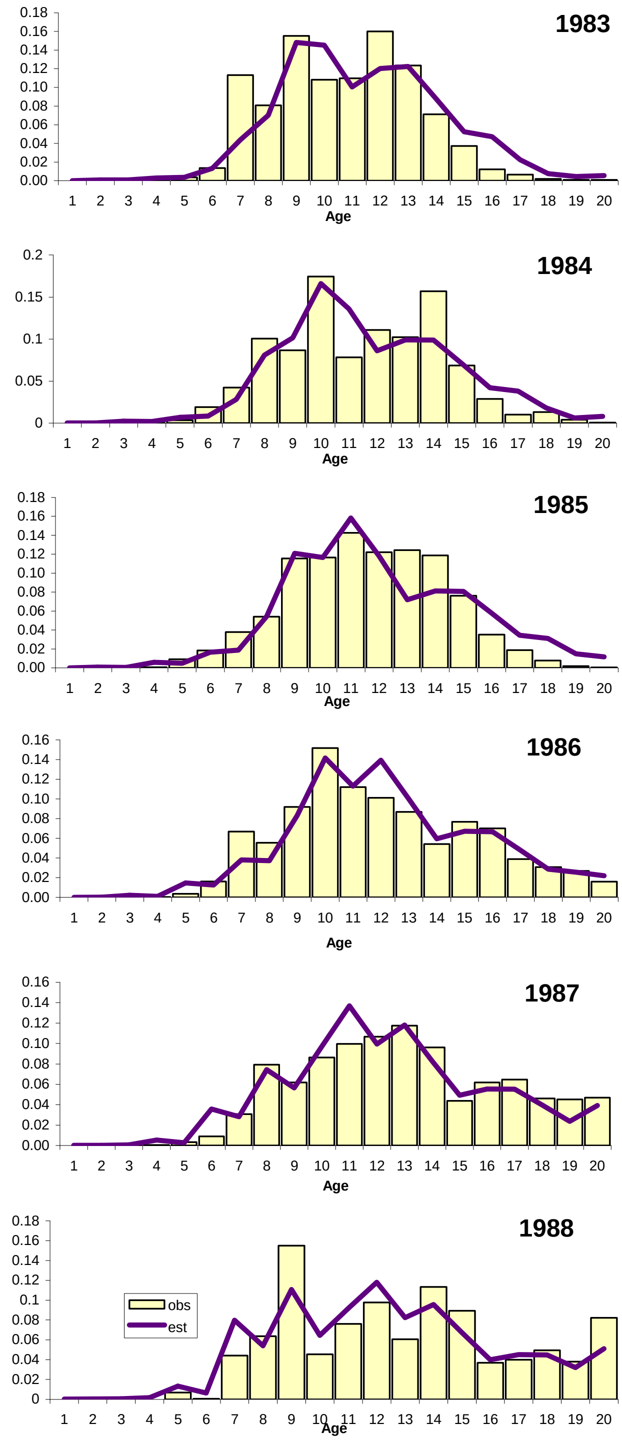

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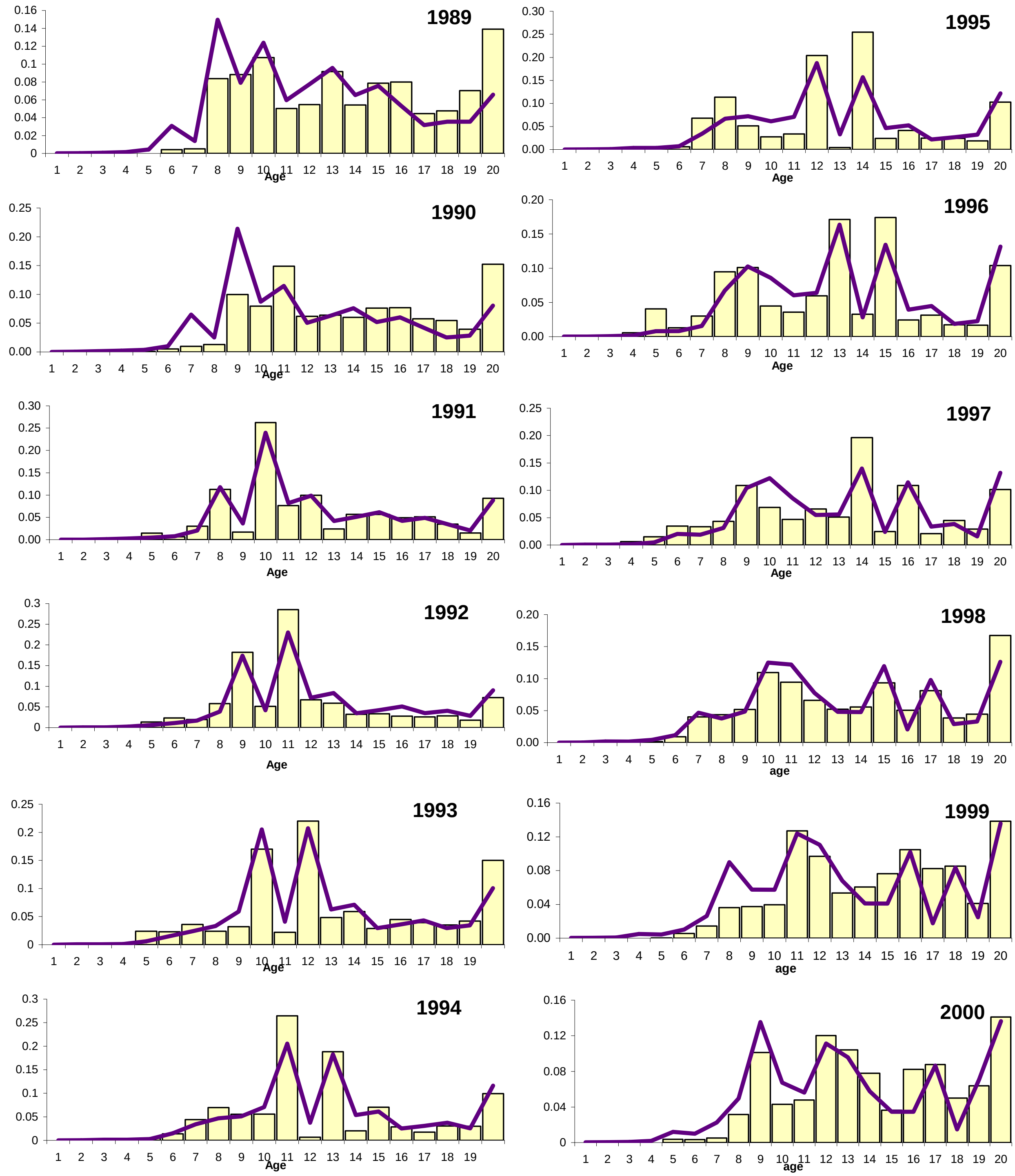

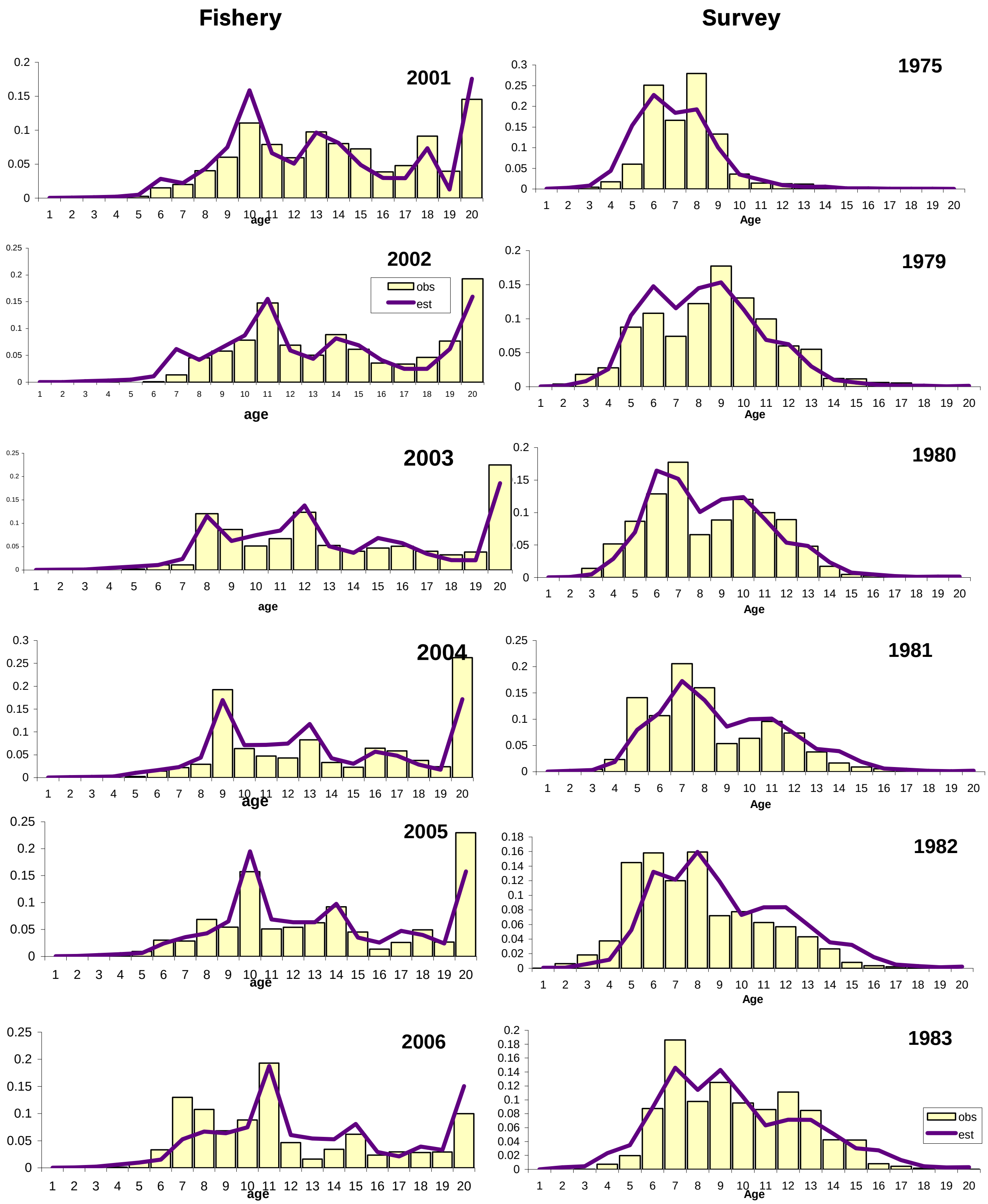
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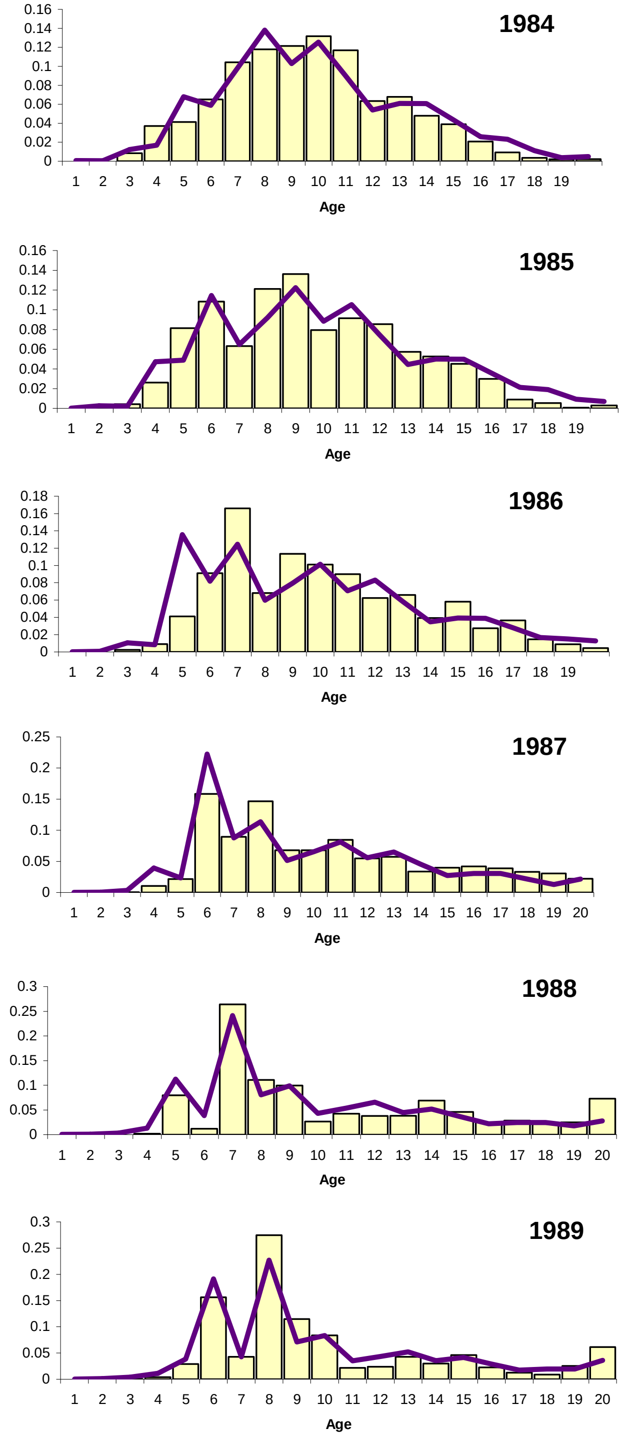

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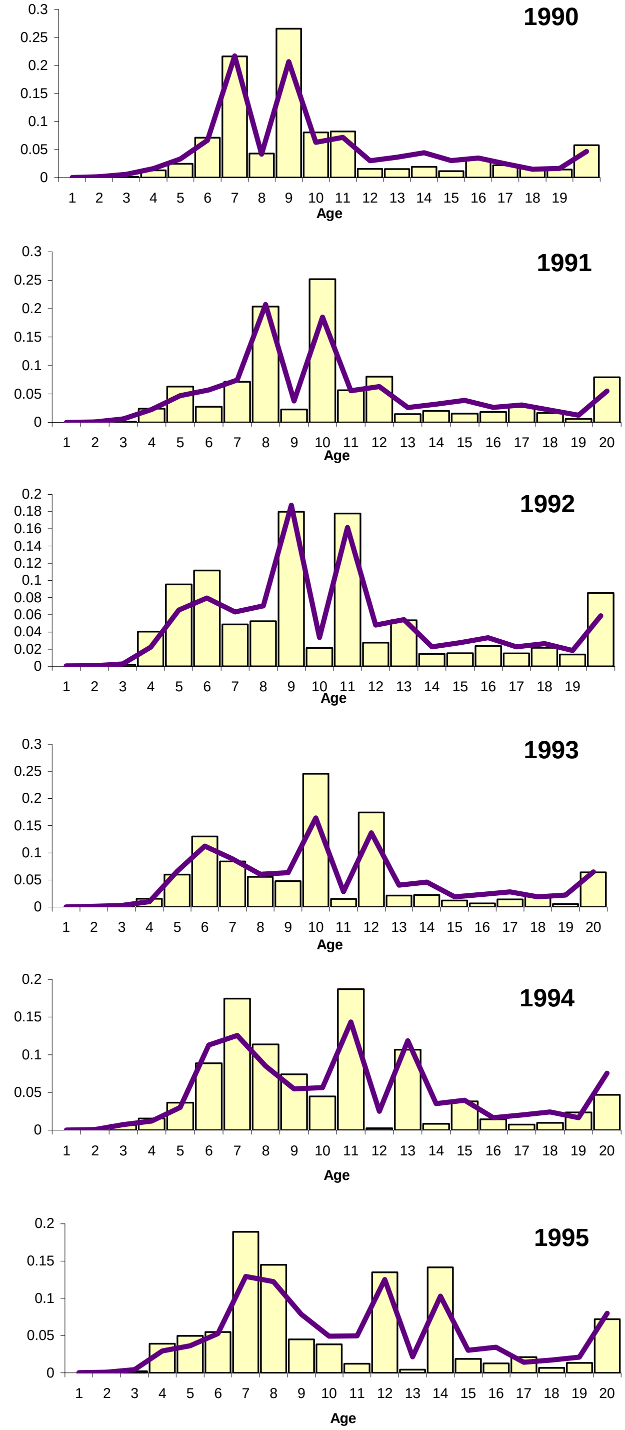

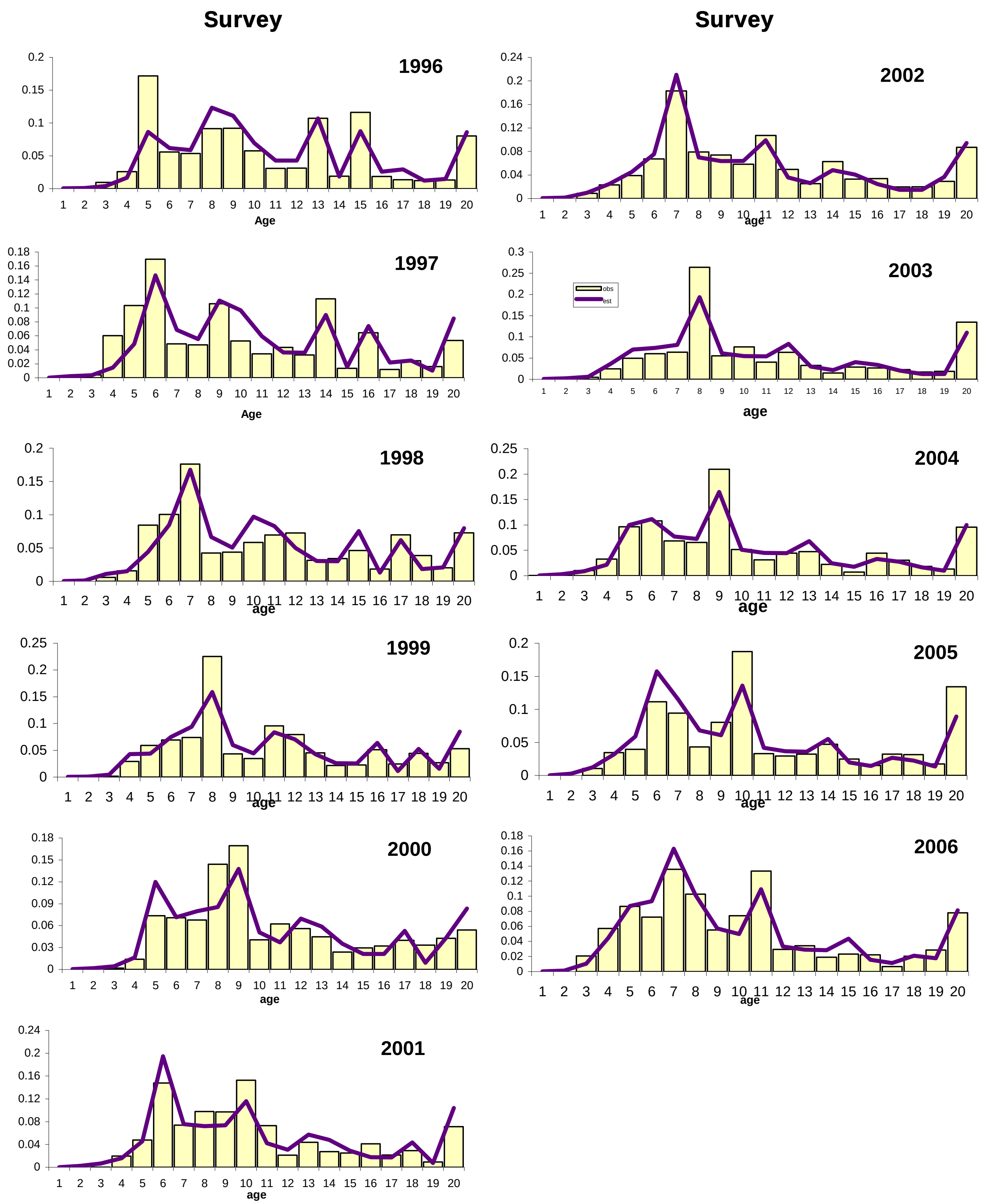
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Total catch of yellowfin sole in Alaska Fisheries Science Center surveys in the Bering Sea.

Year	Research catch (t)
1977	60
1978	71
1979	147
1980	92
1981	74
1982	158
1983	254
1984	218
1985	105
1986	68
1987	92
1988	138
1989	148
1990	129
1991	118
1992	60
1993	95
1994	91
1995	95
1996	72
1997	76
1998	79
1999	61
2000	72
2001	75
2002	76
2003	78
2004	114
2005	94
2006	74
2007	74

Model estimates of yellowfin sole female spawners (millions) from 1954-2007.

	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1954	1.7	2	7.4	16.2	32.8	57.9	88.9	114.6	130.1	137.3	140.2	141.4	141.9	142.2	142.1	142
1955	3.2	2.1	7	14.7	29.9	52.9	78.5	100.8	114.4	121.2	123.7	124.3	124.7	124.9	124.7	249.1
1956	7.2	4	7.3	13.8	27	48.1	71.7	88.8	100.4	106.4	109	109.5	109.4	109.5	109.3	327.2
1957	13	9.1	13.7	14.6	25.4	43.3	64.6	80.3	87.7	92.5	94.7	95.6	95.4	95.1	94.9	378.5
1958	8.8	16.4	31.2	27.2	26.7	40.6	58.1	72.5	79.3	80.7	82.4	83	83.2	82.9	82.4	410.3
1959	4.2	11.1	56.1	61.7	49.6	42.3	53.7	64	70.1	71.6	70.5	70.8	70.9	71	70.5	418.7
1960	2.5	5.2	37.7	108.4	106.9	71.9	49.6	51.6	53.6	54.7	54	52.3	52.2	52.2	52.1	359
1961	8.4	3.1	17.3	68.6	165.3	124.3	62.6	33.8	30	28.8	28.4	27.6	26.6	26.5	26.4	207.8
1962	5.9	10.3	10	29.3	89.7	147.6	75.6	28.2	12.7	10.3	9.6	9.3	9	8.6	8.6	75.8
1963	4.4	7.2	32.2	15.9	33.4	63.2	65	23.5	7.2	2.9	2.3	2.1	2	2	1.9	18.3
1964	4.6	5.5	24.1	60.1	25.6	42.6	62.3	51	15.9	4.5	1.8	1.4	1.2	1.2	1.2	11.9
1965	2.6	5.7	18.2	44.4	94.5	31.3	39.7	45.9	32.3	9.3	2.5	1	0.8	0.7	0.7	7.2
1966	4.6	3.3	19.3	35.2	77	136.9	36.7	38.1	38.4	25.2	7	1.9	0.7	0.6	0.5	5.8
1967	2.4	5.8	11.2	36.6	58.7	104.6	147	31.8	28.7	26.8	17	4.7	1.2	0.5	0.4	4.1
1968	2.2	3	19.4	20.7	57.6	71.9	97.6	108.4	20.2	16.8	15.2	9.5	2.6	0.7	0.3	2.5
1969	3	2.8	10	37.1	35	80.5	80.3	88.4	85.5	14.8	11.9	10.6	6.6	1.8	0.5	1.9
1970	3.2	3.8	9.1	18.2	56.7	41	70.5	55	51.9	46.3	7.7	6.1	5.4	3.4	0.9	1.2
1971	6.6	4	12.5	16.7	28	67	36.5	49.2	33	28.7	24.7	4.1	3.2	2.8	1.7	1.1
1972	10.3	8.2	12.8	21.8	23.1	27.7	46.7	19.2	21.9	13.4	11.3	9.6	1.6	1.2	1.1	1.1
1973	8.8	12.9	27.7	24.4	36.5	31.7	30.1	41.1	14.7	15.5	9.2	7.6	6.4	1	0.8	1.5
1974	11.6	11.1	43.1	51.6	39.2	46.5	31.2	23.6	27.8	9.2	9.4	5.5	4.5	3.8	0.6	1.3
1975	12.9	14.6	37.5	83.6	90.4	58	56.1	30.9	20.4	22.4	7.2	7.2	4.2	3.4	2.9	1.5
1976	10.4	16.3	49.7	72.9	147.1	134.8	70.7	56.2	27.1	16.7	17.7	5.6	5.6	3.2	2.6	3.4
1977	7.6	13.2	55.4	97	129.4	222.7	167.7	72.6	50.5	22.7	13.5	14.1	4.4	4.4	2.5	4.7
1978	10.4	9.6	44.9	108.6	174.1	199.4	283.7	176.9	67.2	43.6	18.9	11.1	11.5	3.6	3.6	5.9
1979	12.2	13.2	32.4	87.2	190.6	257.9	240.8	281.6	153.6	54.2	34	14.5	8.5	8.8	2.7	7.2

Model estimates of yellowfin sole female spawners (millions) from 1954-2007 (continued).

	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	8.5	15.4	44.8	63.7	156.6	294	329.2	254.7	261.3	132.8	45.3	28	11.9	6.9	7.1	8.1
1981	10	10.8	52.4	88.2	115.1	244.4	381.1	354.3	240.8	230.3	113.1	38	23.3	9.9	5.7	12.6
1982	6.6	12.7	36.7	103	158.9	178.3	313.7	405.6	331	209.6	193.8	93.7	31.3	19.2	8.1	15
1983	4.2	8.3	43.1	72.2	186.4	248.4	231.7	338.7	384.7	292.6	179.2	163.1	78.4	26.2	16	19.2
1984	8.1	5.4	28.2	84.9	130.5	290.4	321.1	248.6	319.2	337.9	248.6	149.8	135.6	65	21.6	29.1
1985	5.7	10.2	18.2	55.4	151.9	200.2	367.8	336.6	228.6	273.4	279.8	202.6	121.4	109.6	52.4	40.9
1986	15.6	7.2	34.6	35.5	97.6	226.9	244.4	369.7	296	187.1	216.3	218	156.9	93.8	84.5	71.9
1987	2.7	19.7	24.4	67.6	63	147.3	281.3	249.9	331	246.7	150.8	171.7	171.9	123.5	73.6	122.7
1988	12.9	3.4	66.8	47.7	120.4	95.7	184.3	290.7	226.3	279.1	201.2	121	137	136.9	98	155.8
1989	4.2	16.2	11.5	129.9	84.1	179.7	116.8	185.1	255.4	185	220.7	156.6	93.6	105.7	105.4	195.4
1990	3.5	5.4	55.2	22.5	232.2	128.6	226.7	121.9	169.3	217.6	152.5	179	126.2	75.3	84.8	241.3
1991	4.8	4.4	18.3	109.1	41	366.6	169.4	248.4	117.5	152.2	189.1	130.4	152.2	107.1	63.7	275.8
1992	6.5	6	15.2	36.2	198.3	64.6	481.4	185.1	238.7	105.2	131.8	161.2	110.5	128.7	90.3	286.3
1993	6.3	8.2	20.6	29.8	64.9	305.3	82.2	507.2	171.1	205.5	87.6	108.1	131.4	89.9	104.3	305.3
1994	2.8	8	28	40.5	53.9	101.6	397.8	89	482.7	151.8	176.3	74	90.7	110	75.1	342.1
1995	3.1	3.5	27.1	55	72.8	83.3	129.9	421.6	82.8	418.3	127.2	145.4	60.7	74.2	89.8	340.3
1996	7.2	4	11.9	53.4	99.2	113.1	107.3	138.8	395.4	72.4	353.6	105.8	120.3	50.1	61.1	353.9
1997	3.9	9.2	13.5	23.4	96.2	153.8	145.4	114.4	129.9	344.9	61	293.6	87.3	99.1	41.1	340.7
1998	3.4	5	31.1	26.4	41.5	145.6	191.3	149.3	102.9	108.8	279.3	48.7	232.6	69	78.1	301
1999	3.3	4.3	17	61.2	47.6	64.3	187	203.8	139.6	89.7	91.7	231.7	40.1	191.4	56.6	311
2000	9.1	4.1	14.6	33.5	111.3	75.1	84.5	204.4	195.9	125.1	77.7	78.2	196.4	33.9	161.4	310.1
2001	3.5	11.5	14.1	28.8	60.7	174.4	97.9	91.6	194.6	173.9	107.4	65.6	65.7	164.6	28.4	394
2002	3.5	4.5	39.2	27.9	52.5	95.9	229.7	107.3	88.3	175	151.2	91.9	55.8	55.8	139.3	357.5
2003	5.4	4.4	15.2	77.5	50.8	82.7	126	251.1	103.2	79.2	151.7	129	77.9	47.3	47	419.2
2004	8	6.9	15	30	140.9	80.1	108.7	137.9	241.6	92.5	68.7	129.5	109.5	66	39.9	393.7
2005	5	10.1	23.4	29.6	54.7	222.8	105.7	119.5	133.3	217.7	80.6	58.9	110.4	93.1	56	367.9
2006	7.6	6.3	34.6	46	53.5	85.2	288.1	113.5	112.7	117.1	185	67.5	49	91.6	77	350.6
2007	11	9.6	21.4	68.1	83.3	83.6	110.6	310.5	107.4	99.4	99.9	155.4	56.3	40.8	76.1	355.3

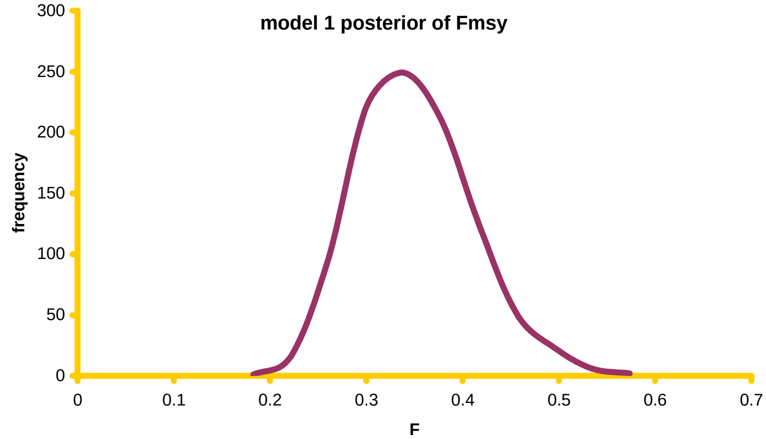
Selected parameter estimates and their standard deviation from the stock assessment model.

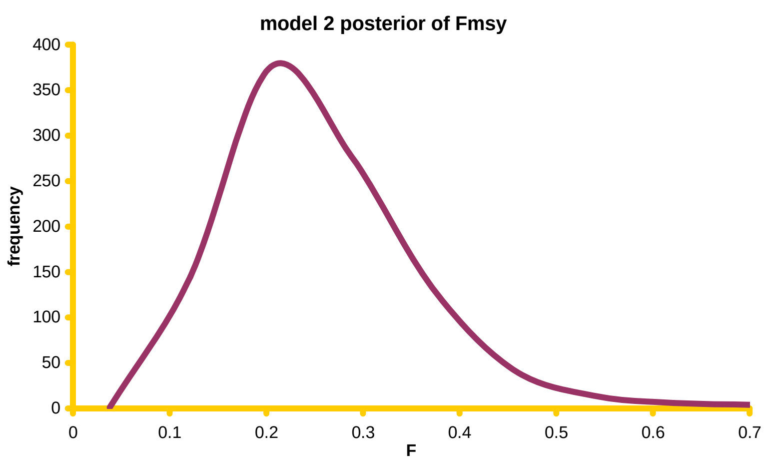
rul	parameter	value	std dev		parameter	value	std dev
	alpha	-0.16	0.04	1973	totbiom	877.66	23.38
	beta	0.11	0.02	1974	totbiom	1058.20	28.36
	mean_log_rec	0.78	0.10	1975	totbiom	1300.80	33.86
	sel_slope_fsh	1.01	0.02	1976	totbiom	1557.70	39.71
	sel_slope_srv	1.56	0.07	1977	totbiom	1813.80	45.54
	sel50_fsh	8.66	0.07	1978	totbiom	2056.50	51.01
	sel50_srv	5.23	0.06	1979	totbiom	2209.90	55.92
	F40	0.11	0.00	1980	totbiom	2386.00	60.44
	F35	0.13	0.00	1981	totbiom	2541.30	64.34
	F30	0.16	0.00	1982	totbiom	2646.40	67.67
	Ricker SR logalpha	-3.92	0.53	1983	totbiom	2739.40	70.56
	Ricker SR logbeta	-5.89	0.29	1984	totbiom	2811.80	73.32
	Fmsy	0.21	0.09	1985	totbiom	2781.80	74.96
	logFmsy	-1.56	0.44	1986	totbiom	2698.90	76.65
	msy	174.52	63.33	1987	totbiom	2630.00	78.04
	Bmsy	302.54	51.12	1988	totbiom	2590.50	79.57
1954	totbiom	1435.40	155.58	1989	totbiom	2491.00	80.54
1955	totbiom	1488.80	137.13	1990	totbiom	2470.70	82.25
1956	totbiom	1552.50	116.91	1991	totbiom	2505.50	83.74
1957	totbiom	1620.20	95.22	1992	totbiom	2499.20	84.39
1958	totbiom	1706.50	73.56	1993	totbiom	2415.60	84.89
1959	totbiom	1803.60	54.60	1994	totbiom	2376.70	85.61
1960	totbiom	1752.90	41.85	1995	totbiom	2288.10	85.89
1961	totbiom	1420.60	32.45	1996	totbiom	2205.50	85.98
1962	totbiom	980.79	21.70	1997	totbiom	2130.30	86.43
1963	totbiom	669.81	13.11	1998	totbiom	2003.60	86.77
1964	totbiom	711.92	13.69	1999	totbiom	1948.80	87.92
1965	totbiom	717.85	14.05	2000	totbiom	1934.20	89.10
1966	totbiom	776.17	14.98	2001	totbiom	1935.10	91.79
1967	totbiom	770.67	15.32	2002	totbiom	1943.40	94.03
1968	totbiom	695.41	14.74	2003	totbiom	1964.60	97.43
1969	totbiom	713.16	15.55	2004	totbiom	1997.60	101.77
1970	totbiom	661.97	15.59	2005	totbiom	2059.50	108.84
1971	totbiom	669.50	16.98	2006	totbiom	2098.40	119.91
1972	totbiom	691.40	19.00	2007	totbiom	2155.70	135.25

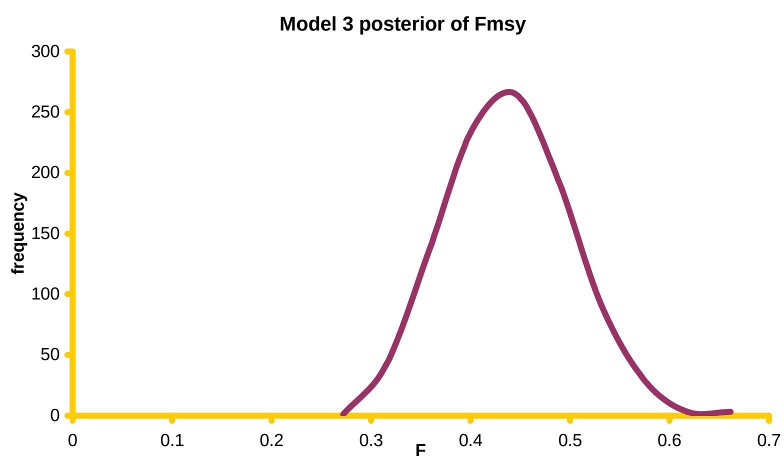
Yellowfin sole TAC and ABC levels, 1980-2007

Year	TAC	ABC
1980	117,000	169,000
1981	117,000	214,500
1982	117,000	214,500
1983	117,000	214,500
1984	230,000	310,000
1985	229,900	310,000
1986	209,500	230,000
1987	187,000	187,000
1988	254,000	254,000
1989	182,675	241,000
1990	207,650	278,900
1991	135,000	250,600
1992	235,000	372,000
1993	220,000	238,000
1994	150,325	230,000
1995	190,000	277,000
1996	200,000	278,000
1997	230,000	233,000
1998	220,000	220,000
1999	207,980	212,000
2000	123,262	191,000
2001	113,000	176,000
2002	86,000	115,000
2003	83,750	114,000
2004	86,075	114,000
2005	90,686	124,000
2006	95,701	121,000
2007	136,000	225,000

Posterior Distributions of F_{msy} from fitting the 3 time-series of stock recruitment points







posterior distributions from the assessment model