# Chapter 4

# Assessment of the Yellowfin sole stock in the Bering Sea and Aleutian Islands

Thomas K. Wilderbuer, Daniel G. Nichol and James Ianelli

## Executive Summary

### Summary of Changes in Assessment Inputs

*Changes to the input data*

1) 2010 fishery age composition.
2) 2010 survey age composition.
3) 2011 trawl survey biomass point estimate and standard error.
4) Estimate of the discarded and retained portions of the 2010 catch.
5) Estimate of total catch made through the end of 2011.

*Changes to the assessment methodology*

Implemented time-varying growth by age, year and gender

### Summary of Results

| Quantity | As estimated or *specified last* year for: 2011 | 2012 | As estimated or *recommended this* year for: 2012 | 2013 |
|---|---|---|---|---|
| *M* (natural mortality rate) | 0.12 | 0.12 | 0.12 | 0.12 |
| Tier | 1a | 1a | 1a | 1a |
| Projected total (age 6+) biomass (t) | 1,958,600 | 1,983,200 | 1,945,000 | 1,985,000 |
| Female spawning biomass (t) | | | | |
| Projected | 587,300 | 636,300 | 592,700 | 604,900 |
| $B_0$ | 955,600 | | 954,100 | |
| $B_{MSY}$ | 374,000 | | 341,000 | |
| $F_{OFL}$ | 0.13 | 0.13 | 0.114 | 0.114 |
| $maxF_{ABC}$ | 0.12 | 0.12 | 0.104 | 0.104 |
| $F_{ABC}$ | 0.12 | 0.12 | 0.104 | 0.104 |
| OFL (t) | 262,300 | 265,500 | 221,900 | 226,400 |
| maxABC (t) | 239,200 | 242,200 | 202,600 | 206,700 |
| ABC (t) | 239,200 | 242,200 | 202,600 | 206,700 |
| **Status** | As determined *last* year for: 2009 | 2010 | As determined *this* year for: 2011 | 2012 |
| Overfishing | No | No | No | No |
| Overfished | No | No | No | No |
| Approaching overfished | No | No | No | No |

# 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 world. 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 late winter through autumn (Wilderbuer et al. 1992).

# 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, top panel). 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 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.

The management of the yellowfin sole fishery changed significantly in 2008 with the implementation of Amendment 80 to the BSAI Fisheries Management Plan. The Amendment directly allocated fishery resources among BSAI trawl harvesters in consideration of their historic harvest patterns and future harvest needs in order to improve retention and utilization of fishery resources by the non-AFA trawl catcher/processor fleet. This was accomplished by extending the groundfish retention standards to all H&G vessels and also by providing the ability to form cooperatives within the newly formed Amendment 80 sector. In addition, Amendment 80 also mandated additional monitoring requirements which included observer coverage on all hauls, motion-compensating scales for weighing samples, flow scales to obtain accurate catch weight estimates for the entire catch, no mixing of hauls and no on-deck sorting. The partitioning of TAC and PSC (prohibited species catch) among cooperatives has significantly changed the way the annual catch has accumulated and the rate of target catch per bycatch ton (Fig 4.1, bottom panel).

Yellowfin sole are usually headed and gutted, frozen at sea, and then shipped to Asian countries for further processing (see “market profile” in the economic SAFE report for details (Appendix C)). In 2010, following a comprehensive assessment process, the yellowfin sole fishery was certified under the Marine Stewardship Council environmental standard for sustainable and well-managed fisheries. The certification also applies to all the major flatfish fisheries in the BSAI and GOA. The total annual catch (t) since implementation of the MFCMA in 1977 is shown in Table 4.1.

The 1997 catch of 181,389 t was the largest since the fishery became completely domestic but it has since been at lower levels, averaging 95,600 t from 1998-2010. The 2008 catch totaled 148,894 t, the highest annual catch in the past 11 years. The 2011 fishery caught over 60% of the total (through September) during February through May, primarily from areas 509, 513, 516 and 521. As of late October 2011, the fishing season is ongoing. In order to estimate the total 2011 catch for the stock assessment model, the 2010 catch made after mid September was applied to the 2011 catch amount at the same time period and results in a 2011catch estimate of 117,115 t. The size composition of the 2011 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 2011, by month, are shown in Figure 4.4.

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 5% of the total catch in 2008 -2010 to 30% in 1992. The trend has been toward fuller retention of the catch in recent years, and with the advent of the Amendment 80 harvest practices, discarding is at its lowest level since these estimates have become available. Historically, discarding primarily occurred in the yellowfin sole directed fishery, with lesser amounts in the Pacific cod, Pollock, 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- 2010 (Table 4.1), including an estimate of the 2011 catch, and fishery catch-at-age (numbers) from 1964-2010 (Table 4.4, 1977-2010).

*Survey Biomass Estimates and Population Age Composition Estimates*

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. 4.5). From 1990-2006, the estimated CPUE was relatively stable but have declined the past few years. Fluctuations of the magnitude shown between 1980 and 1990 and again between 1998 and 1999 and also 2009 and 2010 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.

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 2011 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 estimates since 2006 indicate a stable level with some annual variability (the 2011 estimate of 2.4 million t was a 1% increase over 2010)..

Variability of yellowfin sole survey abundance estimates (Fig. 4.6) 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 havegenerally been lower 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 2009 when the temperatures and the bottom trawl survey point estimates 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 2009, a colder than average year in the Bering Sea, it is unclear from examining survey station catches along the survey border near Kuskowkim bay if a significant portion of the biomass lies outside this border (Fig 4.7 ).

Yellowfin sole population numbers-at-age estimated from the annual bottom trawl surveys are shown in Table 4.6 and their occurrence in trawl survey hauls and associated collections of lengths and age structures since 1982 are shown in Table 4.7. Their total tonnage caught in the resource assessment surveys since 1982 are listed in Table 4.8 and also in an appendix table with IPHC survey catches.

*Length and Weight-at-Age*

Past assessments of yellowfin sole have used sex-specific, time-invariant growth based on the average length-at-age and weight-at-length relationships from the time-series of survey observations summed over all years since 1982. These weight-at-age estimates were estimated from the following relationships:

Parameters of the von Bertalanffy growth curve have been estimated for yellowfin sole, by sex, from the trawl survey database as follows:

| | $L_{inf}$ | K | $t_0$ | n |
|---|---|---|---|---|
| Males | 33.7 | 0.161 | -0.111 | 656 |
| Females | 37.8 | 0.137 | 0.112 | 709 |

A sex-specific length-weight relationship was also calculated from the survey database 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).

| | a | b | n |
|---|---|---|---|
| males | 0.00854 | 3.081 | 2,701 |
| females | 0.0054 | 3.227 | 3,662 |

These estimates of weight at length were applied to the annual trawl survey estimates of population length at age averaged over all years, by sex, to calculate the weight at each age (Fig. 4.8).

Recent applications of dendrochronology (tree-ring techniques) have been used to develop biochronologies from the otolith growth increments of northern rock sole (*Lepidopsetta polyxystra*), yellowfin sole and Alaska plaice (*Pleuronectes quadrituberculatus*) in the eastern Bering Sea. These techniques ensure that all growth increments are assigned the correct calendar year, allowing for estimation of somatic growth by age and year for chronologies that span approximately 25 years (Matta et al. 2010). The analysis indicated that yellowfin sole somatic growth has annual variability and is positively correlated with May bottom water temperature in the Bering Sea (Fig. 4.9).

This detailed growth study led to a reanalysis of yellowfin sole growth by age and year. Length-weight data collected when obtaining otolith (age) samples in RACE surveys (n=7,000 from 1987, 1994 and 1999-2009) also indicate that weight at age exhibits annual variability and is highly correlated with summer bottom water temperature observations with a lag of 2-3 years for the temperature effect to be seen (shown for age 5 fish in figure 4.10) . These observations were then extended back to 1979 using survey population length-at-age estimates (since weight-at-age is a power function of the length-at-age, Clark et al. 1999, Walters and Wilderbuer 2000).

These results for yellowfin sole were used to explore climate impacts on growth by incorporating both time-varying and temperature-dependent growth into an age-structured stock assessment model and then comparing the results with the base model that uses time-invariant growth. Four growth models were developed as follows: Mean age-specific somatic body mass (here referred to as weight-at-age) is modeled as a von Bertalanfy growth function in the initial year of the stock assessment (1954) and projected forward such that the model expected mean weight at age *j* in year *i* for a given sex is constant over the projection (Model 0). In Model 1 the annual observed population mean weight-at-age (time-varying) is used in the stock assessment model. Model 2 is a fit to the data used in Model 1 by the estimation of year and age specific parameters and Model 3 estimates annual weight-at-age as a function of annual May sea surface temperature anomalies. The growth models are as follows:

| Model | | | |
|---|---|---|---|
| 0 | $\hat{w}_{ij} = \hat{w}_{i-1,j-1} + g_j$ | $i > 1954,\ j > 1$ | Constant fixed growth |
| 1 | $\hat{w}_{ij} = w_{ij}$, <br> $\hat{w}_{ij} = \overline{w}_{\bullet j}$ | $1982 \le i \le 2009$, <br> $i < 1982,\ i > 2009$ | As estimated for each age from survey data |
| 2 | $\hat{w}_{ij} = \hat{w}_{i-1,j-1} + g_j e^{\varepsilon_{ij}}$ | $i > 1954,\ j > 1 \quad \varepsilon_i \sim N\left(0, \sigma_g^2\right)$ | Year-effect freely estimated on growth increment |
| 3 | $\hat{w}_{ij} = \hat{w}_{i-1,j-1} + g_j e^{\varepsilon_{ij}}$ <br> $\varepsilon_{ij} = T_i \alpha + \delta_i$ | $i > 1954,\ j > 1$ <br> $\delta_i \sim N\left(0, \sigma_{res}^2\right)$ | Year-effect on growth increment linked to temperature conditions |

where $w_{ij}$ represents the observed estimates of mean weights at age and year, $g_j$ is the expected growth increment in the most recent completed year (as estimated from the a sex-specific von-Bertalanfy growth curve) and $\varepsilon_i$ is a process error term which is modeled as to have an optional year-effect and separate age effect in model 2. For model 3 temperature anomalies are introduced for the entire period and the parameter $\alpha$ scales them and the residual variance is computed $\sigma_g^2$.

For all models except 1, the negative log-likelihood function for the weight-at-age data applied was:

$$-\ln L_w = \sum_{i=1982}^{2009} \sum_{j=5}^{15} \frac{n_{ij}\left(\ln w_{ij} - \ln \hat{w}_{ij}\right)^2}{2\sigma_{ij}^2}$$

*Maturity-at-age*

Maturity information collected from yellowfin sole females during the 1992 and 1993 eastern Bering Sea trawl surveys is used in this assessment (Table 4.10). Nichol (1995) 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 61% 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.

Since the sex-specific weight-at-age for yellowfin sole diverges after age of maturity (about age 10 for 50% of the stock) with females growing larger than males, the current assessment model is coded to accommodate the sex-specific aspects of the population dynamics of yellowfin sole. The model allows for the input of sex-specific estimates of fishery and survey age composition and weight-at-age and provides sex-specific estimates of population numbers, fishing mortality, selectivity, fishery and survey age composition and allows for the estimation of sex-specific natural mortality and catchability. The model retains the utility to fit combined sex data inputs.

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 4.11). 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 4.11 also presents the key equations used to model the yellowfin sole population dynamics in the Bering Sea and Table 4.12 provides a description of the variables used in Table 4.11.

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). Since then, natural mortality has been estimated as a free parameter in some of the stock assessment model runs which have been evaluated for the past five years. A natural mortality value of 0.12 is used for both sexes 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 4.10).

## Parameters Estimated Conditionally

The parameters estimated by the model are presented below:

| Fishing mortality | Selectivity | Survey catchability | Year class strength | Spawner-recruit | Total |
|---|---|---|---|---|---|
| 60 | 240 | 2 | 58 | 2 | 362 |

The increase in the number of parameters estimated in this assessment compared to last year (7) can be accounted for by the input of another year of fishery data, the entry of another year class into the observed population and the formulation of time-varying fisheries selectivity.

*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 4.11.

*Selectivity*

Fishery and survey selectivity was modeled separately for males and females using the two parameter formulation of the logistic function (Table 4.11). 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, for both males and females, was fit for all years of survey data.

Given that there have been annual changes in management, vessel participation and most likely gear selectivity, the SSC has requested that a time-varying fishing selectivity curve be evaluated. A logistic equation was used to model fishery selectivity and is a function of time-varying parameters specifying the age and slope at 50% selection, $\varphi_t$ and $\eta_t$, respectively. The fishing selectivity ($S^f$) for age *a* and year *t* is modeled as,

$$S^f_{a,t} = \left[1 + e^{\eta_t (a-\varphi_t)}\right]^{-1}$$

where $\eta_t$ and $\varphi_t$ are time-varying and partitioned (for estimation) into parameters representing the mean and a vector of deviations (log-scale) conditioned to sum to zero. The deviations are constrained by a lognormal prior with a variance that was iteratively estimated. The process of iterating was to first set the variance to a high value (diffuse prior) of $0.5^2$ and estimate the deviations. The next step was to compare the variability of model estimates. These values were then rounded up slightly and fixed for subsequent runs.

*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 to force the model to match the observed catch.

*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 catchability equation has two parts. The $e^{-\alpha}$ term is a constant or time-independent estimate of q. The model estimate of α = -0.128 indicates that q > 1 suggesting that yellowfin sole are herded into the trawl path of the net which is consistent with the experimental results for other flatfish species. The second term, $e^{\beta T}$ is a time-varying (annual) q which responds to metabolic aspects of herding or distribution (availability) which can vary annually with bottom water temperature. The result of incorporating bottom temperature to estimate annual q is shown in Figure 4.11 (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.

*Model Evaluation*

The model evaluation for this stock assessment involved a three-step process. The first step was to evaluate the productivity of the yellowfin sole stock by an examination of which data sets to include for spawner-recruit fitting. The second step then evaluated the growth models presented in a previous section and the third step evaluated various hypothesized states of nature by fitting natural mortality and catchability estimates in various combinations.

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 estimates which are assumed to represent the equilibrium stock size-recruitment relationship and the model used to fit the estimates. In the yellowfin sole stock assessment model, a Ricker form of the stock-recruit relationship was fit to various combinations of these data and estimates of $F_{MSY}$ and $B_{MSY}$ were calculated, assuming that the fit to the stock-recruitment data represents the long-term productivity of the stock.

For this assessment, 3 different stock-recruitment time-series were investigated: the full time-series 1955-2005 (Model A), the pre-regime shift era of 1955-1977 (Model C) and the post-regime shift era, 1978-2005 (Model B) (Fig. 4.12) 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 were included in the fitting procedure (Table 4.13). When the entire time-series from 1955-2005 and also the 1955-1977 subset was fit, the large recruitments that occurred at low spawning stock sizes in the 1960s and early 1970s determined that the yellowfin sole stock was most productive at a smaller stock size with the result that

$F_{MSY}$ is 1.2 times $F_{35\%}$ (recall that $F_{35\%}$ = 0.137). Therefore, $F_{MSY}$ is a relatively high value (0.16-0.169) and $B_{MSY}$ is 277,000 (Model A) or 262,000 t (Model C). If we limit the analysis to consider only recruitments which occurred after the well-documented regime shift in 1977, a lower value of $F_{MSY}$ is obtained (0.114) and $B_{MSY}$ is 363,000 t. Table 4.13 indicates that the ABC values from Model A and C harvest scenarios would also be quite high. Posterior distributions of $F_{MSY}$ for these models indicate that this parameter is estimated with less uncertainty for Models A and C resulting in the reduced buffer between ABC and OFL relative to Model B (Table 4.13 and Fig 4.13).

It is important 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 relatively high values and $B_{MSY}$ is a lower 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.

Given the uncertainty of the productivity of yellowfin sole at low spawning stock sizes, the more precautionary characterization of the productivity of yellowfin sole is employed by fitting the 1977-2005 spawner-recruit data in the model used in the next step of the model evaluation.

The second step in the model evaluation is the evaluation of the growth model for yellowfin sole. Estimates of female spawning biomass from the four growth models (described in a previous section) are shown in Figure 4.15 and indicate that all 4 models estimate the same trend with Model 1estimates trending lower in the last six years than the others. Estimates of 2012 ABC and $F_{ABC}$ are also similar with Model 1 values lower than the others.

| | model 0 | model 1 | model 2 | model 3 |
|---|---|---|---|---|
| 2011 FSB | 619.966 | 558.674 | 630.736 | 619.349 |
| 2012 Fabc | 0.108 | 0.104 | 0.114 | 0.124 |
| 2012 ABC | 235.374 | 202.600 | 245.185 | 245.185 |

Growth Model 1 was selected as the model of choice for this assessment since 1) It does not use time invariant growth as in Model 0 (which is not realistic and unsupported by the growth data) but instead relies on the annually collected survey population and age data to calculate annual estimates of length at age and weight-at-age, and 2) in its present formulation, Model 2 does not fit the FSB trend of model 1 in the most recent years and thus warrants more exploration before incorporation into the assessment model. Both Models 2 and 3 could further benefit from using the estimated population as a covariate to model the annual growth increment due to density dependent effects.

The third step in the model evaluation for this assessment entails the use of a single structural model to consider the uncertainty in the key parameters M and catchability. This is the Model which has been the model of choice is the past 5 assessments and operates by fixing M at 0.12 for both sexes 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). The other models used in the evaluation represented various combinations of estimating M or q as free parameters with different amounts of uncertainty in the parameter estimates (Wilderbuer et al. 2010). The results are detailed in those assessments and are not repeated here except for the following observations.

Modeling survey catchability as a nonlinear function of bottom water temperature returns a mean value of 1.15. 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). It is also consistent with 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).

A model that allowing M to be estimated as a free parameter for males with females fixed at 0.12 provided a better fit to the sex ratio estimated from the annual trawl survey age compositions than did the base model (both sexes fixed at M = 0.12). However, since the population sex ratio annually observed at the time of the survey is a function of the timing of the annual spawning in adjacent inshore areas, it is questionable that providing the best fit to these observations is really fitting the population sex ratio better. Thus, the model configuration which utilizes the relationship between annual seafloor temperature and survey catchability with M fixed at 0.12 for both sexes is used to base the assessment of the condition of the Bering Sea yellowfin sole resource for the 2012 fishing season.

## Model Results

The 2011 trawl survey point estimate was very close to the 2010 estimate, differing by only 1% and the stock assessment model indicates the stock condition is about the same as last year. The model results indicate the stock has been in a slowly declining condition since the mid-1980s. The main difference in female spawning biomass, total biomass and ABC between the 2010 and 2011 assessments are attributable to the time-invariant growth modeling since there has been a decrease in weight-at-age in the most recent years. The declining population trend has now flattened out and may start to increase due to an above-average year class spawned in 2003.

*Fishing Mortality and Selectivity*
The assessment model estimates of the annual fishing mortality in terms of age-specific annual F and on fully selected ages are given in Tables 4.14 and 4.15, respectively. The full-selection F has averaged 0.08 over the period of 1978-2010 with a maximum of 0.12 in 1978 and a minimum in 2001 at 0.046. Selectivities estimated by the model (Table 4.16, Fig. 4.14) indicate that both sexes of yellowfin sole are 50% selected by the fishery at about age 9 and nearly fully selected by age 13, with annual variability.

*Abundance Trend*
The model estimates q at an average value of 1.15 for the period 1982-2011 which results in the model estimate of the 2011 age 2+ total biomass at 2,077,500 t (Table 4.17). 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 4.17, Fig. 4.16, bottom left panel). Sustained above average recruitment from 1967-76 combined with light exploitation resulted in a biomass increase to a peak of 2.9 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 72% of the peak level.

The female spawning biomass has also declined since the peak in 1985, with a 2011 estimate of 558,700 t (35% decline). The spawning biomass has been in a gradual decline for the past 8 years and is about 1% above the $B_{40\%}$ level and 1.65 times the $B_{MSY}$ level (Fig. 4.16). The model estimate of yellowfin sole population numbers at age for all years is shown in Table 4.18 and the resulting fit to the observed fishery and survey age compositions input into the model are shown in the Figure 4.17. The fit to the trawl survey biomass estimates are shown in Figure 4.15. Allowing q to be correlated with annual bottom temperature provides a better fit to the bottom trawl survey estimates (fig. 4.18). Table 4.19 lists the numbers of female spawners estimated by the model for all ages and years.

Both the trawl survey and the stock assessment model indicate that the yellowfin sole resource increased during the 1970s and early 1980s to a peak level during the mid-1980s. The yellowfin sole population biomass slowly decreased over the sixteen years since the mid-1990s as the majority of year-classes during those years were below average strength. Above-average recruitment from the 1995 year-class is expected to maintain the abundance of yellowfin sole at a level near $B_{40}$ in the near future with the help of the emerging 2003 year class. The stock assessment projection model indicates an increasing trend 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 4.19 and Table 4.20). 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 and 1995 year classes were above average. With the exception of these 4 year classes, recruitment from 14 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 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 2003 year-class whose strength is estimated at well-above average and have now been observed as seven year old fish in the 2010 population age samples.

*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 4.14). Posterior distributions of selected parameters from the preferred stock assessment model used in the assessment are shown in Figure 4.20. The values and standard deviations of some selected model parameters are listed in Table 4.21.

## Acceptable Biological Catch

After increasing during the 1970s and early 1980s, estimates from the stock assessment model indicate the total biomass has been in a slow decline from high levels of stock biomass since the peak in 1985. The estimate of age 2+ total biomass for 2012 is 2,168,900 t.

The SSC has determined that yellowfin sole qualify as a Tier 1 stock and therefore the 2012 ABC is calculated using Tier 1 methodology. 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 2012 harvest (1978-2005 time-series) recommendation (Model B in Table 4.13 with growth option 1), the $F_{ABC} = F_{harmonic\ mean} = 0.104$.

The Tier 1 harvest level is calculated as the product of the harmonic mean of $F_{MSY}$ and the geometric mean of the 2011 biomass estimate, as follows:

$B_{gm} = e^{\ln \hat{B} - \frac{cv^2}{2}}$, where $B_{gm}$ is the geometric mean of the 2011 biomass estimate, $\hat{B}$ is the point estimate of the 2011 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 **202,600 t** and an OFL of 221,900 t for 2012. This gives a 9% (19,200 t) buffer between ABC and OFL, the same level calculated for 2010 in last year's assessment.

## 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:

| Harvest level | F value | 2012 Yield |
|---|---|---|
| **Tier 1 $F_{OFL}$ = $F_{MSY}$** | **0.114** | **221,900 t** |
| **Tier 1 $F_{ABC}$ = $F_{harmonic\ mean}$** | **0.104** | **202,600 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 2011 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2011. 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 2012, are as follows ("*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 2012 recommended in the assessment to the *max* $F_{ABC}$ for 2012. (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 50% 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 2007-2011 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 follows (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 2011 and above its MSY level in 2023 under this scenario, then the stock is not overfished.)

*Scenario 7*: In 2012 and 2013, $F$ 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 2024 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results shown in Table 4.22 indicate that yellowfin sole are not currently overfished and are not approaching an overfished condition. The projection of yellowfin sole female spawning biomass through 2022 is shown in Figure 4.21 and a phase plane figure of the estimated time-series of yellowfin sole female spawning biomass relative to the harvest control rule is shown in Figure 4.22.

*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 2011 numbers at age from the stock assessment model are projected to 2012 given the 2011 catch and then a 2012 catch of 140,000 t is applied to the projected 2012 population biomass to obtain the 2013 OFL.

**Tier 1 Projection**

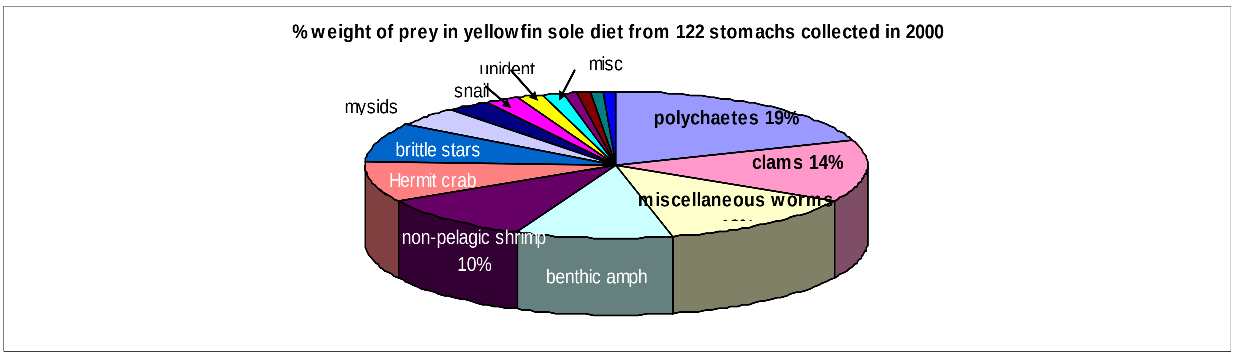
| Year | Catch | SSB | Geometric mean 6+ total biomass | ABC | OFL |
|---|---|---|---|---|---|
| 2012 | 140,000 | 592,700 | 1,945,600 | 202,600 | 221,900 |
| 2013 | | 604,900 | 1,985,000 | 206,700 | 226,400 |

# 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-five 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 target species is shown for 1992-2010 in Table 4.23. The catch of non-target species from 2003-2010 is shown in Table 4.24. The yellowfin sole target fishery contribution to the total bycatch of prohibited species is shown for 2008 and 2009 in Table 13 of the Economic SAFE (Appendix C) and is summarized for 2009 as follows:

| Prohibited species | Yellowfin sole fishery % of total bycatch |
|---|---|
| Halibut mortality | 28.4 |
| Herring | 36.0 |
| Red King crab | 26.4 |
| C. bairdi | 34.4 |
| Other Tanner crab | 23.4 |
| Salmon | 0 |

2) Relative to the predator needs in space and time, the yellowfin sole target fishery has a low selectivity for fish 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 yellowfin 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 |

## References

Bakkala, R. G. and V. Wespestad. 1984. Yellowfin sole. In R. G. Bakkala and L. resources of the eastern Bering Sea and Aleutian Islands region in 1983, p. 37-60. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-53.

Bakkala, R. G., V. Wespestad, and L. Low. 1982. The yellowfin sole (Limanda aspera) resource of the eastern Bering Sea--its current and future potential for commercial fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-33, 43p.

Bakkala, R. G., and T. K. Wilderbuer. 1990. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1990, p. 60-78. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, Ak 99510.

Clark, W. G., Hare, S. R., Parms, A. M., Sullivan, P, J., Trumble, R. J. 1999. Decadal changes in growth and recruitment of Pacific halibut (*Hipplglossus stenolepis*). Can. J. fish. Aquat. Sci. 56, 242-252.

Fournier, D. A. and C.P. Archibald. 1982. A general theory for analyzing catch-at-age data. Can. J. Fish Aquat. Sci. 39:1195-1207.

Greiwank, A. and G. F. Corliss (eds) 1991. Automatic differentiation of algorithms: theory, implementation and application. Proceedings of the SIAM Workshop on the Automatic Differentiation of Algorithms, held Jan. 6-8, Breckenridge, CO. Soc. Indust. And Applied Mathematics, Philadelphia.

Haflinger, K. 1981. A survey of benthic infaunal communities of the Southeastern Bering Sea shelf. *In* Hood and Calder (editors) The Eastern Bering Sea Shelf: Oceanography and Resources, Vol. 2. P. 1091-1104. Office Mar. Pol. Assess., NOAA. Univ. Wash. Press, Seattle, Wa 98105.

Ianelli, J. N. and D. A. Fournier. 1998. Alternative age-structured analyses of the NRC simulated stock assessment data. In Restrepo, V. R. [ed.] Analyses of simulated data sets in support of the NRC study on stock assessment methods. NOAA Tech. Memo. NMFS-F/SPO-30. 96 p.

Low, L. and R.E. Narita. 1990. Condition of groundfish resources in the Bering Sea-Aleutian Islands region as assessed in 1988. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/NWC-178, 224 p.

Matta, M. E., B. A. Black and T. K. Wilderbuer. 2010. Climate-driven synchrony in otolith growth-increment chronologies for three Bering Sea flatfish species. MEPS, Vol. 413:137-145, 2010.

Nichol, D. R . 1995. Spawning and maturation of female yellowfin sole in the eastern Bering Sea. In Proceedings of the international flatfish symposium, October 1994, Anchorage, Alaska, p. 35-50. Univ. Alaska, Alaska Sea Grant Rep. 95-04.

Nichol, D.R. 1998. Annual and between sex variability of yellowfin sole, *Pleuronectes asper*, spring-summer distributions in the eastern Bering Sea. Fish. Bull., U.S. 96: 547-561.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Bd. Can., (119) 300 p.

Somerton, D.. A. and P. Munro. 2001. Bridle efficiency of a survey trawl for flatfish. Fish. Bull. 99:641-652 (2001).

Wakabayashi, K. 1989. Studies on the fishery biology of yellowfin sole in the eastern Bering Sea. [In Jpn., Engl. Summ.] Bull. Far Seas Fish. Res. Lab. 26:21-152.

Wakabayashi, K., R. Bakkala, and L. Low. 1977. Status of the yellowfin sole resource in the eastern Bering Sea through 1976. Unpubl. manuscr., 45p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C 15700, Seattle, Wa 98115.

Walters, G. E. and T. K. Wilderbuer. 2000. Decreasing length at age in a rapidly expanding population of northern rock sole in the eastern Bering Sea and its effect on management advice. Journal of Sea Research 44(2000)17-26.

Wilderbuer, T. K. 1992. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1993, chapter 3. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, Ak 99510.

Wilderbuer, T. K. 1993. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1994, chapter 3. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, Ak 99510.

Wilderbuer, T. K. and D. Nichol. 2001. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 2004, chapter 4. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, Ak 99510.

Wilderbuer, T. K. and D. Nichol. 2003. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 2004, chapter 4. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, Ak 99510.

Wilderbuer, T. K. and D. Nichol. 2007. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 2004, chapter 4. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, Ak 99510.

Wilderbuer, T. K. D. G. Nichol, and J. Ianelli. 2010. Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 2011, chapter 4. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, Ak 99510.

Wilderbuer, T.K., G.E. Walters, and R.G. Bakkala 1992. Yellowfin sole, *Pleuronectes asper*, of the eastern Bering Sea: biological characteristics, history of exploitation, and management. Mar Fish. Rev. 54(4):1-18.

# Tables

Table 4.1--Catch (t) of yellowfin sole 1964-2011. Catch for 2011 is an estimate through the end of 2011.

| | | Domestic | | |
|---|---|---|---|---|
| Year | Foreign | JVP | DAP | Total |
| 1964 | 111,777 | | | 111,777 |
| 1965 | 53,810 | | | 53,810 |
| 1966 | 102,353 | | | 102,353 |
| 1967 | 162,228 | | | 162,228 |
| 1968 | 84,189 | | | 84,189 |
| 1969 | 167,134 | | | 167,134 |
| 1970 | 133,079 | | | 133,079 |
| 1971 | 160,399 | | | 160,399 |
| 1972 | 47,856 | | | 47,856 |
| 1973 | 78,240 | | | 78,240 |
| 1974 | 42,235 | | | 42,235 |
| 1975 | 64,690 | | | 64,690 |
| 1976 | 56,221 | | | 56,221 |
| 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 | | | 121,029 | 121,029 |
| 2008 | | | 148,894 | 148,894 |
| 2009 | | | 107,528 | 107,528 |
| 2010 | | | 118,624 | 118,624 |
| 2011 | | | 117,115 | 117,115 |

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 |
| 2007 | 109,084 | 11,945 |
| 2008 | 141,253 | 7,659 |
| 2009 | 92,488 | 5,733 |
| 2010 | 113,244 | 5,380 |

Table 4.3. Discarded and retained catch of yellowfin sole, by fishery, in 2010. Source: AKFIN.

| Trip Target Name | Discarded | Retained |
|---|---|---|
| Atka Mackerel | | |
| Pollock - bottom | 42 | 595 |
| Pacific Cod | 230 | 439 |
| Alaska Plaice | 5 | 108 |
| Other Flatfish | 0 | 0 |
| Halibut | 0 | 0 |
| Rockfish | 0 | 0 |
| Flathead Sole | 83 | 1,977 |
| Other Species | 0 | 0 |
| Pollock - midwater | 308 | 72 |
| Rock Sole | 407 | 11,631 |
| Sablefish | 0 | 0 |
| Greenland Turbot | 0 | 0 |
| Arrowtooth Flounder | 0 | 1 |
| Yellowfin Sole | 4,305 | 98,425 |
| Total catch | | 113,248 |

Table 4.4. Model estimated yellowfin sole fishery catch-at-age numbers (millions), 1977-2011.

| | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1977** | 45.69 | 63.51 | 56.52 | 50.81 | 27.07 | 9.04 | 5.67 | 2.84 | 1.99 | 1.86 | 1.09 |
| **1978** | 57.63 | 126.47 | 142.79 | 105.41 | 88.09 | 45.79 | 15.15 | 9.47 | 4.73 | 3.30 | 4.89 |
| **1979** | 26.72 | 63.14 | 96.26 | 83.64 | 54.41 | 43.32 | 22.15 | 7.29 | 4.55 | 2.27 | 3.93 |
| **1980** | 20.00 | 22.06 | 41.73 | 61.38 | 57.49 | 41.18 | 35.35 | 18.98 | 6.45 | 4.10 | 5.63 |
| **1981** | 29.13 | 36.65 | 34.45 | 53.66 | 65.44 | 52.44 | 33.40 | 26.49 | 13.55 | 4.46 | 6.58 |
| **1982** | 27.15 | 56.76 | 53.00 | 36.97 | 46.04 | 48.80 | 36.12 | 22.05 | 17.12 | 8.67 | 7.01 |
| **1983** | 42.63 | 44.77 | 69.46 | 53.64 | 34.17 | 41.01 | 42.87 | 31.56 | 19.23 | 14.93 | 13.66 |
| **1984** | 23.61 | 63.15 | 61.18 | 91.52 | 69.94 | 44.46 | 53.35 | 55.75 | 41.05 | 25.02 | 37.18 |
| **1985** | 21.54 | 58.82 | 106.82 | 83.44 | 114.80 | 85.35 | 53.81 | 64.41 | 67.28 | 49.53 | 75.03 |
| **1986** | 43.59 | 42.35 | 74.15 | 101.30 | 68.31 | 87.97 | 63.69 | 39.76 | 47.42 | 49.46 | 91.52 |
| **1987** | 13.13 | 45.42 | 33.58 | 54.29 | 76.20 | 52.92 | 69.18 | 50.41 | 31.54 | 37.66 | 112.00 |
| **1988** | 41.81 | 41.86 | 90.05 | 47.89 | 65.32 | 82.97 | 54.89 | 70.33 | 50.86 | 31.73 | 150.35 |
| **1989** | 2.35 | 40.17 | 32.30 | 60.45 | 30.05 | 39.70 | 49.84 | 32.86 | 42.06 | 30.40 | 108.83 |
| **1990** | 16.28 | 8.77 | 71.79 | 25.68 | 28.92 | 11.71 | 14.50 | 17.87 | 11.72 | 14.98 | 49.57 |
| **1991** | 6.47 | 44.09 | 14.53 | 83.65 | 25.78 | 27.76 | 11.13 | 13.76 | 16.97 | 11.13 | 61.32 |
| **1992** | 10.02 | 25.54 | 103.29 | 24.88 | 124.88 | 36.18 | 37.95 | 15.06 | 18.54 | 22.82 | 97.38 |
| **1993** | 7.73 | 8.80 | 15.92 | 56.22 | 13.58 | 71.27 | 21.55 | 23.26 | 9.39 | 11.67 | 76.01 |
| **1994** | 20.99 | 29.72 | 28.31 | 36.73 | 94.39 | 18.03 | 81.66 | 22.70 | 23.43 | 9.24 | 84.79 |
| **1995** | 22.70 | 40.12 | 34.95 | 24.63 | 28.21 | 69.52 | 13.11 | 59.15 | 16.42 | 16.94 | 67.99 |
| **1996** | 14.20 | 39.61 | 45.25 | 32.78 | 22.07 | 25.19 | 62.31 | 11.79 | 53.28 | 14.81 | 76.61 |
| **1997** | 17.42 | 24.10 | 59.77 | 62.08 | 42.40 | 27.70 | 31.18 | 76.68 | 14.47 | 65.35 | 112.04 |
| **1998** | 18.98 | 15.76 | 18.99 | 38.71 | 34.64 | 21.70 | 13.56 | 14.94 | 36.39 | 6.84 | 83.57 |
| **1999** | 1.86 | 7.52 | 6.83 | 9.43 | 22.05 | 21.41 | 13.89 | 8.80 | 9.74 | 23.76 | 59.05 |
| **2000** | 2.28 | 6.59 | 22.67 | 15.19 | 14.90 | 27.50 | 23.74 | 14.69 | 9.14 | 10.05 | 85.21 |
| **2001** | 2.84 | 5.94 | 11.47 | 25.05 | 12.06 | 10.11 | 17.69 | 15.04 | 9.27 | 5.76 | 60.05 |
| **2002** | 4.91 | 5.81 | 13.09 | 21.16 | 35.87 | 14.12 | 10.52 | 17.41 | 14.46 | 8.83 | 62.41 |
| **2003** | 4.41 | 26.88 | 16.84 | 18.95 | 20.89 | 30.97 | 11.73 | 8.64 | 14.26 | 11.84 | 58.30 |
| **2004** | 3.75 | 9.40 | 35.49 | 16.17 | 15.99 | 16.86 | 24.62 | 9.28 | 6.83 | 11.26 | 55.40 |
| **2005** | 10.17 | 13.82 | 22.12 | 56.61 | 20.77 | 18.85 | 19.30 | 27.96 | 10.51 | 7.73 | 75.44 |
| **2006** | 38.53 | 34.32 | 25.05 | 26.17 | 53.69 | 17.84 | 15.53 | 15.65 | 22.52 | 8.45 | 66.72 |
| **2007** | 13.13 | 36.27 | 33.25 | 26.60 | 29.16 | 60.95 | 20.39 | 17.79 | 17.94 | 25.82 | 86.20 |
| **2008** | 20.95 | 27.90 | 57.19 | 41.99 | 30.01 | 31.40 | 64.51 | 21.45 | 18.68 | 18.82 | 117.45 |
| **2009** | 9.91 | 23.56 | 25.34 | 42.09 | 27.85 | 19.19 | 19.86 | 40.67 | 13.51 | 11.76 | 85.80 |
| **2010** | 26.50 | 27.69 | 41.24 | 30.53 | 42.27 | 26.25 | 17.75 | 18.27 | 37.36 | 12.41 | 89.57 |
| **2011** | 12.76 | 66.17 | 46.03 | 46.16 | 27.08 | 33.94 | 20.32 | 13.57 | 13.92 | 28.42 | 77.53 |

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

| Year | Total | Lower CI | Upper CI |
|---|---|---|---|
| 1975 | 972,500 | 812,300 | 1,132,700 |
| 1979 | 1,866,500 | 1,586,000 | 2,147,100 |
| 1980 | 1,842,400 | 1,553,200 | 2,131,700 |
| 1981 | 2,394,700 | 2,072,900 | 2,716,500 |
| 1982 | 3,377,800 | 2,571,000 | 4,184,600 |
| 1983 | 3,535,300 | 2,958,100 | 4,112,400 |
| 1984 | 3,141,200 | 2,636,800 | 3,645,600 |
| 1985 | 2,443,700 | 1,563,400 | 3,324,000 |
| 1986 | 1,909,900 | 1,480,700 | 2,339,000 |
| 1987 | 2,613,100 | 2,051,800 | 3,174,400 |
| 1988 | 2,402,400 | 1,808,400 | 2,996,300 |
| 1989 | 2,316,300 | 1,836,700 | 2,795,800 |
| 1990 | 2,183,800 | 1,886,200 | 2,479,400 |
| 1991 | 2,393,300 | 2,116,000 | 2,670,700 |
| 1992 | 2,172,900 | | |
| 1993 | 2,465,400 | 2,151,500 | 2,779,300 |
| 1994 | 2,610,500 | 2,266,800 | 2,954,100 |
| 1995 | 2,009,700 | 1,724,800 | 2,294,600 |
| 1996 | 2,298,600 | 1,749,900 | 2,847,300 |
| 1997 | 2,163,400 | 1,907,900 | 2,418,900 |
| 1998 | 2,329,600 | 2,033,130 | 2,626,070 |
| 1999 | 1,306,470 | 1,118,800 | 1,494,150 |
| 2000 | 1,581,900 | 1,382,000 | 1,781,800 |
| 2001 | 1,863,700 | 1,605,000 | 2,122,300 |
| 2002 | 2,016,700 | 1,740,700 | 2,292,700 |
| 2003 | 2,239,600 | 1,822,700 | 2,656,600 |
| 2004 | 2,530,600 | 2,147,900 | 2,913,300 |
| 2005 | 2,823,500 | 2,035,800 | 3,499,800 |
| 2006 | 2,133,070 | 1,818,253 | 2,447,932 |
| 2007 | 2,152,738 | 1,775,191 | 2,530,285 |
| 2008 | 2,099,521 | 1,599,100 | 2,600,000 |
| 2009 | 1,739,238 | 1,435,188 | 2,043,288 |
| 2010 | 2,367,830 | 1,807,430 | 2,928,230 |
| 2011 | 2,403,021 | 1,926,371 | 2,879,671 |

Table 4.6. Yellowfin sole population numbers-at-age (millions) estimated from the annual bottom trawl surveys, 1982-2010. **Females**

| year / age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1979** | 21 | 113 | 150 | 442 | 616 | 386 | 555 | 801 | 626 | 528 | 219 | 274 | 59 | 35 | 29 | 15 |
| **1980** | 1 | 92 | 342 | 518 | 800 | 1055 | 413 | 661 | 880 | 651 | 765 | 285 | 113 | 33 | 23 | 23 |
| **1981** | 0 | 20 | 195 | 839 | 692 | 1321 | 1155 | 261 | 477 | 744 | 527 | 311 | 168 | 55 | 23 | 45 |
| **1982** | 38 | 183 | 349 | 1211 | 1485 | 1424 | 1619 | 843 | 829 | 832 | 704 | 409 | 246 | 159 | 51 | 84 |
| **1983** | 0 | 5 | 59 | 154 | 751 | 1413 | 843 | 1065 | 936 | 753 | 1155 | 866 | 295 | 160 | 60 | 54 |
| **1984** | 0 | 53 | 278 | 264 | 427 | 745 | 841 | 1111 | 1080 | 941 | 541 | 583 | 480 | 239 | 174 | 133 |
| **1985** | 0 | 3 | 105 | 442 | 587 | 406 | 632 | 915 | 441 | 518 | 545 | 384 | 298 | 321 | 205 | 127 |
| **1986** | 0 | 8 | 24 | 219 | 349 | 666 | 279 | 574 | 519 | 377 | 284 | 318 | 196 | 250 | 136 | 259 |
| **1987** | 0 | 0 | 70 | 120 | 803 | 458 | 843 | 259 | 376 | 599 | 356 | 449 | 243 | 270 | 247 | 688 |
| **1988** | 0 | 0 | 7 | 370 | 71 | 1495 | 560 | 557 | 184 | 239 | 351 | 208 | 360 | 273 | 219 | 886 |
| **1989** | 0 | 0 | 14 | 98 | 718 | 234 | 1337 | 593 | 446 | 74 | 179 | 308 | 234 | 238 | 183 | 565 |
| **1990** | 0 | 0 | 70 | 102 | 325 | 1066 | 192 | 1257 | 408 | 482 | 101 | 72 | 107 | 78 | 231 | 605 |
| **1991** | 0 | 10 | 127 | 248 | 123 | 405 | 896 | 151 | 1263 | 213 | 525 | 63 | 128 | 87 | 123 | 807 |
| **1992** | 0 | 19 | 247 | 485 | 520 | 213 | 286 | 938 | 94 | 825 | 75 | 309 | 129 | 137 | 170 | 715 |
| **1993** | 0 | 24 | 100 | 357 | 634 | 434 | 269 | 224 | 1314 | 78 | 866 | 157 | 165 | 69 | 68 | 674 |
| **1994** | 0 | 54 | 95 | 223 | 518 | 905 | 555 | 482 | 284 | 1170 | 516 | 44 | 274 | 142 | 42 | 588 |
| **1995** | 0 | 19 | 153 | 288 | 181 | 889 | 627 | 274 | 135 | 25 | 634 | 21 | 561 | 104 | 80 | 512 |
| **1996** | 0 | 16 | 154 | 809 | 288 | 279 | 434 | 517 | 206 | 146 | 151 | 602 | 116 | 637 | 47 | 619 |
| **1997** | 0 | 18 | 324 | 502 | 725 | 256 | 239 | 506 | 228 | 114 | 176 | 184 | 500 | 44 | 314 | 533 |
| **1998** | 0 | 10 | 83 | 479 | 420 | 900 | 260 | 203 | 370 | 413 | 369 | 170 | 176 | 265 | 67 | 1167 |
| **1999** | 0 | 3 | 65 | 198 | 175 | 185 | 727 | 104 | 107 | 245 | 190 | 186 | 72 | 102 | 175 | 425 |
| **2000** | 0 | 11 | 54 | 248 | 208 | 304 | 444 | 537 | 189 | 198 | 237 | 219 | 65 | 117 | 145 | 572 |
| **2001** | 0 | 1 | 71 | 239 | 522 | 248 | 403 | 415 | 654 | 374 | 83 | 191 | 154 | 127 | 189 | 617 |
| **2002** | 0 | 16 | 123 | 170 | 255 | 778 | 346 | 290 | 229 | 457 | 221 | 91 | 307 | 116 | 152 | 805 |
| **2003** | 0 | 15 | 115 | 241 | 251 | 287 | 1143 | 225 | 279 | 286 | 251 | 103 | 115 | 170 | 168 | 943 |
| **2004** | 10 | 33 | 192 | 430 | 560 | 441 | 217 | 966 | 221 | 212 | 218 | 219 | 106 | 20 | 167 | 1020 |
| **2005** | 0 | 53 | 167 | 194 | 602 | 433 | 213 | 487 | 834 | 196 | 144 | 191 | 324 | 170 | 53 | 1332 |
| **2006** | 0 | 67 | 302 | 376 | 276 | 634 | 470 | 176 | 325 | 738 | 133 | 133 | 71 | 156 | 175 | 514 |
| **2007** | 0 | 37 | 515 | 348 | 376 | 277 | 504 | 308 | 124 | 227 | 504 | 119 | 137 | 127 | 105 | 724 |
| **2008** | 0 | 24 | 115 | 736 | 621 | 546 | 359 | 355 | 198 | 117 | 259 | 350 | 153 | 79 | 85 | 732 |
| **2009** | 5 | 38 | 204 | 204 | 1187 | 609 | 488 | 259 | 210 | 218 | 129 | 138 | 196 | 88 | 43 | 444 |
| **2010** | 0 | 33 | 328 | 386 | 438 | 895 | 554 | 517 | 329 | 335 | 155 | 166 | 135 | 173 | 99 | 684 |

Table 4.6.(continued) **Males**

| year / age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1979** | 21 | 115 | 143 | 390 | 381 | 303 | 583 | 847 | 604 | 406 | 349 | 247 | 54 | 76 | 29 | 36 |
| **1980** | 20 | 78 | 306 | 632 | 853 | 1221 | 457 | 558 | 616 | 568 | 444 | 370 | 147 | 18 | 8 | 8 |
| **1981** | 0 | 50 | 200 | 1047 | 640 | 1280 | 858 | 394 | 372 | 546 | 534 | 266 | 66 | 83 | 55 | 12 |
| **1982** | 89 | 193 | 428 | 1780 | 1781 | 1059 | 1673 | 644 | 774 | 463 | 471 | 482 | 302 | 8 | 24 | 8 |
| **1983** | 0 | 1 | 65 | 183 | 724 | 1729 | 808 | 1049 | 676 | 699 | 722 | 566 | 425 | 550 | 77 | 51 |
| **1984** | 0 | 68 | 246 | 323 | 497 | 734 | 830 | 612 | 788 | 718 | 358 | 379 | 201 | 316 | 122 | 106 |
| **1985** | 0 | 41 | 172 | 419 | 559 | 263 | 652 | 527 | 401 | 451 | 360 | 224 | 260 | 157 | 112 | 65 |
| **1986** | 0 | 13 | 47 | 108 | 373 | 652 | 262 | 327 | 284 | 335 | 211 | 205 | 115 | 210 | 82 | 252 |
| **1987** | 0 | 5 | 41 | 106 | 838 | 467 | 673 | 445 | 328 | 277 | 210 | 147 | 106 | 142 | 185 | 600 |
| **1988** | 0 | 2 | 10 | 435 | 49 | 1163 | 553 | 443 | 85 | 187 | 28 | 177 | 336 | 189 | 28 | 599 |
| **1989** | 0 | 2 | 23 | 181 | 788 | 177 | 1306 | 513 | 357 | 135 | 50 | 103 | 54 | 204 | 35 | 478 |
| **1990** | 0 | 11 | 47 | 121 | 316 | 888 | 195 | 1144 | 318 | 263 | 40 | 65 | 67 | 24 | 55 | 389 |
| **1991** | 0 | 0 | 103 | 354 | 139 | 275 | 1046 | 68 | 1137 | 328 | 244 | 74 | 64 | 60 | 53 | 420 |
| **1992** | 0 | 0 | 146 | 445 | 566 | 262 | 226 | 812 | 114 | 907 | 193 | 213 | 12 | 12 | 61 | 607 |
| **1993** | 0 | 20 | 52 | 233 | 646 | 393 | 279 | 247 | 1096 | 69 | 842 | 53 | 53 | 50 | 0 | 341 |
| **1994** | 4 | 22 | 71 | 166 | 427 | 953 | 656 | 308 | 191 | 822 | 26 | 622 | 46 | 132 | 11 | 303 |
| **1995** | 0 | 0 | 169 | 120 | 270 | 667 | 565 | 94 | 179 | 75 | 478 | 13 | 603 | 49 | 24 | 418 |
| **1996** | 0 | 76 | 95 | 837 | 244 | 227 | 425 | 344 | 331 | 141 | 139 | 399 | 61 | 449 | 125 | 495 |
| **1997** | 0 | 10 | 214 | 425 | 798 | 181 | 184 | 446 | 245 | 194 | 214 | 108 | 514 | 79 | 264 | 416 |
| **1998** | 0 | 48 | 70 | 351 | 569 | 832 | 159 | 226 | 204 | 272 | 346 | 140 | 157 | 191 | 113 | 814 |
| **1999** | 0 | 5 | 100 | 142 | 225 | 243 | 575 | 146 | 94 | 309 | 269 | 75 | 53 | 28 | 119 | 425 |
| **2000** | 0 | 0 | 36 | 219 | 259 | 143 | 509 | 583 | 78 | 215 | 133 | 77 | 92 | 78 | 66 | 547 |
| **2001** | 0 | 0 | 87 | 141 | 652 | 341 | 375 | 357 | 562 | 208 | 87 | 158 | 65 | 73 | 140 | 432 |
| **2002** | 0 | 58 | 72 | 158 | 309 | 758 | 318 | 333 | 262 | 442 | 194 | 120 | 220 | 161 | 133 | 507 |
| **2003** | 0 | 24 | 95 | 178 | 258 | 251 | 1074 | 238 | 363 | 53 | 284 | 173 | 10 | 71 | 57 | 682 |
| **2004** | 4 | 63 | 114 | 469 | 447 | 199 | 395 | 993 | 263 | 81 | 195 | 223 | 103 | 47 | 249 | 456 |
| **2005** | 0 | 49 | 166 | 187 | 474 | 476 | 204 | 288 | 972 | 123 | 142 | 121 | 133 | 69 | 93 | 726 |
| **2006** | 0 | 101 | 173 | 348 | 332 | 505 | 393 | 288 | 298 | 384 | 116 | 155 | 89 | 39 | 11 | 590 |
| **2007** | 0 | 58 | 481 | 352 | 405 | 284 | 545 | 209 | 166 | 252 | 338 | 101 | 133 | 72 | 59 | 620 |
| **2008** | 0 | 10 | 99 | 662 | 462 | 483 | 344 | 453 | 225 | 144 | 185 | 329 | 63 | 66 | 35 | 581 |
| **2009** | 0 | 65 | 144 | 289 | 946 | 462 | 555 | 248 | 249 | 217 | 78 | 31 | 195 | 30 | 29 | 363 |
| **2010** | 0 | 78 | 199 | 418 | 371 | 1032 | 462 | 510 | 171 | 189 | 159 | 53 | 117 | 151 | 78 | 678 |

Table 4.7-Occurrence of yellowfin sole in the Bering Sea trawl survey and collections of length and age structures and the number of otoliths aged from each survey.

| Year | Total Hauls | Hauls w/length | Number lengths | Hauls w/otolith | Number otoliths | Number ages |
|---|---|---|---|---|---|---|
| 1982 | 334 | 246 | 37,023 | 35 | 744 | 744 |
| 1983 | 353 | 256 | 33,924 | 37 | 709 | 709 |
| 1984 | 355 | 271 | 33,894 | 56 | 821 | 796 |
| 1985 | 358 | 262 | 33,831 | 44 | 810 | 802 |
| 1986 | 354 | 249 | 30,470 | 34 | 739 | 739 |
| 1987 | 360 | 224 | 31,241 | 16 | 798 | 798 |
| 1988 | 373 | 254 | 27,138 | 14 | 543 | 543 |
| 1989 | 373 | 235 | 29,518 | 24 | 740 | 740 |
| 1990 | 371 | 251 | 30,257 | 28 | 792 | 792 |
| 1991 | 372 | 249 | 27,988 | 26 | 742 | 742 |
| 1992 | 356 | 229 | 23,628 | 16 | 606 | 606 |
| 1993 | 375 | 242 | 26,651 | 20 | 549 | 549 |
| 1994 | 376 | 270 | 24,451 | 14 | 526 | 522 |
| 1995 | 376 | 254 | 22,116 | 20 | 654 | 647 |
| 1996 | 375 | 247 | 27,505 | 16 | 729 | 721 |
| 1997 | 376 | 262 | 26,034 | 11 | 470 | 466 |
| 1998 | 375 | 310 | 34,509 | 15 | 575 | 570 |
| 1999 | 373 | 276 | 28,431 | 31 | 777 | 770 |
| 2000 | 372 | 255 | 24,880 | 20 | 517 | 511 |
| 2001 | 375 | 251 | 26,558 | 25 | 604 | 593 |
| 2002 | 375 | 246 | 26,309 | 32 | 738 | 723 |
| 2003 | 376 | 241 | 27,135 | 37 | 699 | 695 |
| 2004 | 375 | 251 | 26,103 | 26 | 725 | 712 |
| 2005 | 373 | 251 | 24,658 | 34 | 644 | 635 |
| 2006 | 376 | 246 | 28,470 | 39 | 440 | 426 |
| 2007 | 376 | 247 | 24,790 | 66 | 779 | 772 |
| 2008 | 375 | 238 | 25,848 | 65 | 858 | 830 |
| 2009 | 376 | 235 | 22,018 | 70 | 784 | 752 |
| 2010 | 376 | 228 | 20,619 | 77 | 841 | 535 |
| 2011 | 376 | 228 | 21,665 | 65 | 784 | |

Table 4.8—Total tonnage of yellowfin sole caught in resource assessment surveys in the eastern Bering Sea from 1977-2011.

| 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 |
| 2008 | 69 |
| 2009 | 60 |
| 2010 | 79 |
| 2011 | 77 |

Table 4.9—Mean length and weight at age for yellowfin sole.

| average mean length at age (cm) | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| males | 7.4 | 10.7 | 11.8 | 14.3 | 16.9 | 19.5 | 22.0 | 24.0 | 25.7 | 27 | 28 | 28.9 | 29.7 | 30.3 | 30.5 | 31 | 31.3 | 31.6 | 32.2 | 32.2 |
| females | | 9.8 | 12.6 | 14.6 | 17.4 | 19.8 | 22.4 | 24.5 | 26.7 | 28.5 | 29.6 | 30.8 | 31.7 | 32.5 | 33 | 33.4 | 34.2 | 34.3 | 33.2 | 33.8 |

| weight at age (g) | | | males | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
| 1954 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1955 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1956 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1957 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1958 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1959 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1960 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1961 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1962 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1963 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1964 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1965 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1966 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1967 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1968 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1969 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1970 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1971 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1972 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1973 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1974 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1975 | 4 | 14 | 18 | 32 | 54 | 85 | 120 | 156 | 193 | 225 | 253 | 280 | 303 | 324 | 330 | 344 | 355 | 366 | 390 | 423 |
| 1976 | 4 | 14 | 18 | 32 | 54 | 85 | 120 | 156 | 193 | 225 | 253 | 280 | 303 | 324 | 330 | 344 | 355 | 366 | 390 | 423 |
| 1977 | 4 | 14 | 18 | 32 | 54 | 85 | 120 | 156 | 193 | 225 | 253 | 280 | 303 | 324 | 330 | 344 | 355 | 366 | 390 | 423 |
| 1978 | 4 | 14 | 18 | 32 | 54 | 85 | 120 | 156 | 193 | 225 | 253 | 280 | 303 | 324 | 330 | 344 | 355 | 366 | 390 | 423 |
| 1979 | 4 | 14 | 18 | 32 | 54 | 85 | 120 | 156 | 193 | 225 | 253 | 280 | 303 | 324 | 330 | 344 | 355 | 366 | 390 | 423 |
| 1980 | 4 | 14 | 18 | 32 | 54 | 85 | 120 | 156 | 193 | 225 | 253 | 280 | 303 | 324 | 330 | 344 | 355 | 366 | 390 | 423 |
| 1981 | 4 | 14 | 18 | 32 | 54 | 85 | 120 | 156 | 193 | 225 | 253 | 280 | 303 | 324 | 330 | 344 | 355 | 366 | 390 | 423 |
| 1982 | 4 | 11 | 25 | 50 | 83 | 112 | 133 | 142 | 158 | 182 | 196 | 212 | 218 | 249 | 403 | 386 | 386 | 455 | 532 | 408 |
| 1983 | 4 | 5 | 5 | 23 | 57 | 95 | 156 | 156 | 155 | 176 | 212 | 227 | 227 | 254 | 262 | 287 | 271 | 370 | 370 | 408 |
| 1984 | 4 | 10 | 20 | 31 | 57 | 121 | 150 | 181 | 202 | 193 | 202 | 213 | 246 | 252 | 257 | 262 | 282 | 415 | 290 | 370 |
| 1985 | 4 | 11 | 23 | 32 | 51 | 84 | 148 | 186 | 214 | 227 | 228 | 246 | 277 | 267 | 283 | 305 | 407 | 389 | 532 | 387 |
| 1986 | 4 | 9 | 18 | 27 | 34 | 61 | 98 | 176 | 217 | 233 | 239 | 229 | 271 | 263 | 258 | 324 | 265 | 318 | 300 | 370 |
| 1987 | 4 | 8 | 14 | 17 | 27 | 53 | 97 | 157 | 211 | 226 | 260 | 267 | 311 | 309 | 276 | 291 | 307 | 296 | 329 | 394 |
| 1988 | 4 | 7 | 10 | 18 | 45 | 75 | 76 | 138 | 207 | 242 | 261 | 304 | 301 | 297 | 339 | 304 | 308 | 315 | 326 | 386 |
| 1989 | 4 | 7 | 10 | 27 | 47 | 72 | 142 | 130 | 179 | 244 | 270 | 351 | 338 | 352 | 317 | 302 | 391 | 309 | 361 | 348 |
| 1990 | 4 | 9 | 16 | 22 | 44 | 64 | 98 | 120 | 175 | 197 | 273 | 323 | 341 | 326 | 337 | 286 | 348 | 353 | 343 | 388 |
| 1991 | 4 | 9 | 17 | 29 | 51 | 75 | 100 | 132 | 180 | 212 | 266 | 267 | 325 | 355 | 326 | 359 | 352 | 304 | 532 | 381 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1992 | 4 | 9 | 17 | 28 | 53 | 86 | 97 | 125 | 174 | 208 | 239 | 264 | 306 | 508 | 407 | 395 | 344 | 360 | 406 | 360 |
| 1993 | 4 | 9 | 18 | 45 | 56 | 93 | 135 | 145 | 206 | 209 | 238 | 265 | 387 | 303 | 349 | 363 | 376 | 349 | 342 | 384 |
| 1994 | 4 | 23 | 32 | 53 | 76 | 92 | 116 | 182 | 198 | 207 | 259 | 336 | 311 | 345 | 345 | 407 | 356 | 479 | 349 | 424 |
| 1995 | 4 | 10 | 19 | 32 | 59 | 88 | 110 | 154 | 177 | 207 | 249 | 258 | 336 | 294 | 319 | 377 | 367 | 383 | 401 | 448 |
| 1996 | 4 | 10 | 19 | 32 | 54 | 107 | 134 | 163 | 184 | 215 | 221 | 264 | 281 | 295 | 314 | 326 | 333 | 418 | 326 | 435 |
| 1997 | 4 | 8 | 14 | 37 | 64 | 75 | 149 | 174 | 185 | 239 | 231 | 248 | 261 | 303 | 349 | 336 | 384 | 370 | 346 | 444 |
| 1998 | 4 | 10 | 20 | 27 | 49 | 79 | 113 | 156 | 208 | 207 | 259 | 262 | 289 | 301 | 291 | 332 | 330 | 354 | 350 | 392 |
| 1999 | 4 | 6 | 7 | 18 | 37 | 63 | 95 | 123 | 170 | 171 | 245 | 281 | 269 | 269 | 347 | 330 | 395 | 350 | 350 | 450 |
| 2000 | 4 | 10 | 20 | 36 | 32 | 64 | 88 | 133 | 161 | 284 | 233 | 271 | 302 | 255 | 291 | 331 | 351 | 349 | 373 | 385 |
| 2001 | 4 | 9 | 16 | 27 | 38 | 51 | 91 | 152 | 161 | 198 | 268 | 240 | 280 | 299 | 292 | 320 | 343 | 357 | 430 | 434 |
| 2002 | 4 | 9 | 18 | 21 | 57 | 59 | 81 | 134 | 188 | 204 | 241 | 248 | 269 | 306 | 303 | 343 | 336 | 304 | 368 | 414 |
| 2003 | 4 | 11 | 22 | 39 | 53 | 83 | 109 | 161 | 179 | 251 | 248 | 304 | 263 | 468 | 330 | 339 | 305 | 339 | 352 | 405 |
| 2004 | 4 | 7 | 20 | 40 | 64 | 94 | 157 | 157 | 213 | 266 | 334 | 310 | 297 | 356 | 360 | 338 | 387 | 414 | 443 | 446 |
| 2005 | 4 | 11 | 24 | 44 | 77 | 110 | 136 | 170 | 201 | 262 | 278 | 332 | 366 | 308 | 328 | 350 | 375 | 347 | 349 | 434 |
| 2006 | 4 | 10 | 19 | 36 | 71 | 124 | 139 | 180 | 207 | 237 | 233 | 315 | 330 | 380 | 385 | 446 | 369 | 335 | 382 | 390 |
| 2007 | 4 | 10 | 19 | 36 | 63 | 107 | 140 | 181 | 208 | 248 | 291 | 286 | 311 | 340 | 375 | 342 | 353 | 369 | 422 | 430 |
| 2008 | 4 | 8 | 13 | 29 | 50 | 91 | 113 | 181 | 194 | 252 | 262 | 289 | 306 | 364 | 366 | 369 | 372 | 374 | 417 | 481 |
| 2009 | 4 | 7 | 11 | 20 | 39 | 74 | 112 | 133 | 194 | 273 | 270 | 302 | 348 | 321 | 379 | 320 | 405 | 370 | 391 | 460 |
| 2010 | 4 | 14 | 18 | 32 | 54 | 85 | 120 | 156 | 193 | 225 | 253 | 280 | 303 | 324 | 330 | 344 | 355 | 366 | 390 | 423 |
| 2011 | 4 | 14 | 17 | 25 | 47 | 81 | 134 | 164 | 174 | 305 | 283 | 330 | 291 | 346 | 332 | 344 | 389 | 364 | 375 | 400 |

| | Females | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
| 1954 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1955 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1956 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1957 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1958 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1959 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1960 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1961 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1962 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1963 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1964 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1965 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1966 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1967 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1968 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1969 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1970 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1971 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1972 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1973 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1974 | 0 | 4 | 15 | 34 | 60 | 91 | 125 | 160 | 195 | 230 | 263 | 294 | 322 | 348 | 372 | 393 | 412 | 429 | 444 | 481 |
| 1975 | 6 | 8 | 20 | 31 | 55 | 84 | 124 | 165 | 217 | 266 | 301 | 341 | 374 | 407 | 428 | 443 | 480 | 483 | 499 | 590 |
| 1976 | 6 | 8 | 20 | 31 | 55 | 84 | 124 | 165 | 217 | 266 | 301 | 341 | 374 | 407 | 428 | 443 | 480 | 483 | 499 | 590 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 6 | 8 | 20 | 31 | 55 | 84 | 124 | 165 | 217 | 266 | 301 | 341 | 374 | 407 | 428 | 443 | 480 | 483 | 499 | 590 |
| 1978 | 6 | 8 | 20 | 31 | 55 | 84 | 124 | 165 | 217 | 266 | 301 | 341 | 374 | 407 | 428 | 443 | 480 | 483 | 499 | 590 |
| 1979 | 6 | 8 | 20 | 31 | 55 | 84 | 124 | 165 | 217 | 266 | 301 | 341 | 374 | 407 | 428 | 443 | 480 | 483 | 499 | 590 |
| 1980 | 6 | 8 | 20 | 31 | 55 | 84 | 124 | 165 | 217 | 266 | 301 | 341 | 374 | 407 | 428 | 443 | 480 | 483 | 499 | 590 |
| 1981 | 6 | 8 | 20 | 31 | 55 | 84 | 124 | 165 | 217 | 266 | 301 | 341 | 374 | 407 | 428 | 443 | 480 | 483 | 499 | 590 |
| 1982 | 6 | 8 | 20 | 42 | 75 | 98 | 139 | 176 | 214 | 233 | 235 | 289 | 300 | 339 | 336 | 406 | 490 | 417 | 386 | 568 |
| 1983 | 6 | 10 | 14 | 26 | 60 | 103 | 162 | 185 | 201 | 243 | 255 | 280 | 329 | 395 | 477 | 539 | 583 | 578 | 630 | 685 |
| 1984 | 6 | 14 | 26 | 33 | 57 | 110 | 156 | 177 | 222 | 246 | 294 | 338 | 332 | 325 | 422 | 436 | 458 | 497 | 665 | 654 |
| 1985 | 6 | 11 | 16 | 28 | 46 | 77 | 177 | 202 | 251 | 286 | 302 | 323 | 371 | 370 | 421 | 425 | 499 | 624 | 600 | 620 |
| 1986 | 6 | 14 | 27 | 23 | 41 | 71 | 103 | 173 | 239 | 284 | 338 | 342 | 350 | 402 | 351 | 391 | 422 | 440 | 455 | 611 |
| 1987 | 6 | 10 | 14 | 20 | 47 | 55 | 127 | 179 | 256 | 317 | 324 | 373 | 373 | 385 | 384 | 422 | 412 | 458 | 436 | 523 |
| 1988 | 6 | 9 | 12 | 16 | 34 | 66 | 85 | 159 | 237 | 286 | 307 | 378 | 396 | 404 | 388 | 415 | 437 | 429 | 485 | 578 |
| 1989 | 6 | 12 | 21 | 33 | 67 | 71 | 112 | 133 | 197 | 279 | 339 | 402 | 430 | 449 | 456 | 456 | 456 | 578 | 476 | 516 |
| 1990 | 6 | 11 | 17 | 24 | 38 | 65 | 99 | 126 | 197 | 243 | 321 | 449 | 450 | 416 | 446 | 464 | 455 | 471 | 523 | 569 |
| 1991 | 6 | 11 | 16 | 23 | 58 | 56 | 100 | 142 | 156 | 238 | 310 | 370 | 457 | 446 | 473 | 474 | 490 | 492 | 484 | 598 |
| 1992 | 6 | 12 | 21 | 29 | 55 | 85 | 121 | 177 | 176 | 283 | 305 | 284 | 352 | 435 | 516 | 459 | 484 | 519 | 459 | 547 |
| 1993 | 6 | 15 | 28 | 35 | 64 | 93 | 155 | 165 | 232 | 244 | 301 | 333 | 368 | 442 | 452 | 497 | 499 | 471 | 538 | 586 |
| 1994 | 6 | 20 | 46 | 53 | 86 | 87 | 125 | 155 | 235 | 276 | 284 | 337 | 396 | 351 | 461 | 464 | 480 | 476 | 514 | 553 |
| 1995 | 6 | 12 | 20 | 28 | 60 | 84 | 123 | 160 | 217 | 284 | 332 | 340 | 443 | 384 | 414 | 454 | 439 | 619 | 482 | 589 |
| 1996 | 6 | 11 | 16 | 36 | 51 | 108 | 137 | 167 | 202 | 222 | 311 | 318 | 334 | 405 | 399 | 432 | 534 | 462 | 523 | 558 |
| 1997 | 6 | 16 | 34 | 33 | 72 | 85 | 157 | 200 | 236 | 260 | 292 | 353 | 373 | 401 | 469 | 440 | 490 | 431 | 515 | 600 |
| 1998 | 6 | 10 | 14 | 36 | 51 | 90 | 104 | 177 | 237 | 278 | 279 | 318 | 370 | 416 | 405 | 403 | 448 | 407 | 532 | 581 |
| 1999 | 6 | 9 | 12 | 18 | 37 | 67 | 103 | 131 | 239 | 284 | 296 | 328 | 348 | 384 | 396 | 416 | 461 | 502 | 477 | 639 |
| 2000 | 6 | 11 | 16 | 33 | 33 | 91 | 81 | 158 | 175 | 237 | 306 | 310 | 373 | 401 | 440 | 422 | 494 | 506 | 483 | 636 |
| 2001 | 6 | 6 | 6 | 32 | 41 | 57 | 83 | 148 | 179 | 255 | 305 | 357 | 372 | 447 | 415 | 420 | 422 | 476 | 522 | 598 |
| 2002 | 6 | 11 | 18 | 27 | 48 | 65 | 87 | 120 | 224 | 243 | 261 | 337 | 346 | 374 | 408 | 434 | 452 | 505 | 489 | 585 |
| 2003 | 6 | 9 | 12 | 31 | 53 | 86 | 124 | 156 | 213 | 289 | 303 | 344 | 407 | 425 | 399 | 434 | 365 | 438 | 457 | 536 |
| 2004 | 6 | 9 | 18 | 43 | 63 | 101 | 168 | 172 | 245 | 299 | 346 | 380 | 407 | 483 | 543 | 450 | 461 | 464 | 500 | 604 |
| 2005 | 6 | 14 | 26 | 44 | 78 | 114 | 152 | 213 | 238 | 277 | 337 | 347 | 397 | 439 | 461 | 531 | 522 | 438 | 539 | 629 |
| 2006 | 6 | 9 | 13 | 40 | 82 | 125 | 153 | 204 | 245 | 319 | 314 | 375 | 370 | 533 | 460 | 476 | 865 | 480 | 537 | 691 |
| 2007 | 6 | 11 | 16 | 36 | 66 | 115 | 173 | 198 | 244 | 316 | 311 | 362 | 358 | 417 | 461 | 462 | 497 | 491 | 611 | 640 |
| 2008 | 6 | 13 | 24 | 28 | 54 | 98 | 129 | 199 | 226 | 286 | 320 | 355 | 384 | 442 | 434 | 471 | 530 | 530 | 552 | 630 |
| 2009 | 6 | 6 | 9 | 18 | 45 | 69 | 127 | 163 | 239 | 306 | 322 | 375 | 416 | 381 | 413 | 473 | 736 | 539 | 491 | 679 |
| 2010 | 6 | 8 | 20 | 31 | 55 | 84 | 124 | 165 | 217 | 266 | 301 | 341 | 374 | 407 | 428 | 443 | 480 | 483 | 499 | 590 |
| 2011 | 6 | 8 | 18 | 25 | 56 | 80 | 126 | 188 | 205 | 327 | 332 | 372 | 403 | 415 | 440 | 426 | 369 | 491 | 542 | 590 |

Table 4.10. 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 4.11. 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 |

Table 4.11—continued.

$$qprior = \lambda \frac{0.5(\ln q_{est,t} - \ln q_{prior})^2}{\sigma_q^2}$$

survey catchability prior (when estimated)

$$mprior = \lambda \frac{0.5(\ln m_{est} - \ln m_{prior})^2}{\sigma_m^2}$$

natural mortality prior (when estimated)

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

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 4.12. 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 |
| $R_\gamma$ | Geometric mean value of age 1 recruitment, 1976-96 |
| $\tau_t$ | 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* |
| $\phi_a$ | 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 |
| $\mu^F$ | Median year-effect of fishing mortality |
| $\varepsilon_t^F$ | The residual year-effect of fishing mortality |
| $\nu_a$ | Age-specific survey selectivity |
| $\alpha$ | Slope parameter in the logistic selectivity equation |
| $\beta$ | Age at 50% selectivity parameter in the logistic selectivity equation |
| $\sigma_t$ | Standard error of the survey biomass in year t |

Table 4.13. Models evaluated for stock productivity in the 2011 stock assessment of yellowfin sole

| | **Model A** | **Model B** | **Model C** |
|---|---|---|---|
| **Years included** | 1955-2005 | 1978-2005 | 1955-1978 |
| **Fmsy** | 0.161 | 0.114 | 0.169 |
| **Bmsy (t)** | 277,000 | 363,000 | 262,000 |
| **ABC (t)** | 340,400 | 202,600 | 358,500 |
| **OFL (t)** | 348,400 | 221,900 | 367,300 |
| **Buffer between ABC and OFL** | 2% | 9% | 2% |

Table 4-14. Model estimates of annual average fishing mortality for male and female yellowfin sole.

Females

| year/age | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 0.09 | 0.18 | 0.27 | 0.32 | 0.34 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| 1965 | 0.01 | 0.04 | 0.11 | 0.19 | 0.23 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| 1966 | 0.02 | 0.05 | 0.14 | 0.27 | 0.38 | 0.43 | 0.44 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| 1967 | 0.03 | 0.08 | 0.21 | 0.38 | 0.50 | 0.56 | 0.58 | 0.58 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 |
| 1968 | 0.01 | 0.03 | 0.07 | 0.14 | 0.24 | 0.33 | 0.39 | 0.41 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| 1969 | 0.04 | 0.12 | 0.30 | 0.50 | 0.61 | 0.65 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 |
| 1970 | 0.00 | 0.01 | 0.04 | 0.15 | 0.40 | 0.62 | 0.69 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 |
| 1971 | 0.01 | 0.02 | 0.08 | 0.21 | 0.51 | 0.92 | 1.22 | 1.36 | 1.41 | 1.42 | 1.43 | 1.43 | 1.43 | 1.43 |
| 1972 | 0.00 | 0.00 | 0.00 | 0.09 | 0.38 | 0.42 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| 1973 | 0.02 | 0.08 | 0.21 | 0.34 | 0.40 | 0.42 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| 1974 | 0.01 | 0.02 | 0.05 | 0.08 | 0.12 | 0.13 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| 1975 | 0.02 | 0.06 | 0.10 | 0.12 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| 1976 | 0.01 | 0.03 | 0.06 | 0.09 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| 1977 | 0.03 | 0.04 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| 1978 | 0.03 | 0.07 | 0.10 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| 1979 | 0.02 | 0.04 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| 1980 | 0.02 | 0.03 | 0.04 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| 1981 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| 1982 | 0.02 | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 1983 | 0.02 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 1984 | 0.02 | 0.04 | 0.06 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| 1985 | 0.02 | 0.04 | 0.07 | 0.10 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| 1986 | 0.03 | 0.06 | 0.09 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 1987 | 0.01 | 0.02 | 0.05 | 0.07 | 0.09 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 1988 | 0.01 | 0.03 | 0.08 | 0.11 | 0.13 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| 1989 | 0.00 | 0.01 | 0.04 | 0.07 | 0.09 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 1990 | 0.00 | 0.01 | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 1991 | 0.01 | 0.01 | 0.03 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 1992 | 0.01 | 0.03 | 0.05 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| 1993 | 0.01 | 0.02 | 0.02 | 0.04 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| 1994 | 0.02 | 0.03 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| 1995 | 0.02 | 0.04 | 0.05 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| 1996 | 0.02 | 0.03 | 0.05 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| 1997 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 1998 | 0.02 | 0.03 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| 1999 | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 2000 | 0.00 | 0.01 | 0.02 | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| 2001 | 0.01 | 0.02 | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 2002 | 0.00 | 0.01 | 0.02 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 2003 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 2004 | 0.01 | 0.02 | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2005** | 0.01 | 0.03 | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **2006** | 0.04 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **2007** | 0.02 | 0.04 | 0.06 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| **2008** | 0.02 | 0.05 | 0.08 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| **2009** | 0.01 | 0.03 | 0.06 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| **2010** | 0.01 | 0.03 | 0.05 | 0.08 | 0.09 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| **2011** | 0.01 | 0.03 | 0.05 | 0.07 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |

Table 4.14 continued.

Males

| year/age | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1964** | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| **1965** | 0.01 | 0.03 | 0.11 | 0.20 | 0.23 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| **1966** | 0.02 | 0.11 | 0.30 | 0.42 | 0.44 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| **1967** | 0.15 | 0.42 | 0.55 | 0.58 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 |
| **1968** | 0.05 | 0.20 | 0.37 | 0.42 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| **1969** | 0.02 | 0.14 | 0.46 | 0.64 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 |
| **1970** | 0.29 | 0.62 | 0.70 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 |
| **1971** | 0.67 | 1.32 | 1.42 | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 |
| **1972** | 0.14 | 0.35 | 0.42 | 0.42 | 0.42 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| **1973** | 0.12 | 0.36 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| **1974** | 0.09 | 0.12 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| **1975** | 0.05 | 0.10 | 0.12 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| **1976** | 0.01 | 0.03 | 0.06 | 0.09 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| **1977** | 0.01 | 0.03 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **1978** | 0.03 | 0.06 | 0.09 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| **1979** | 0.02 | 0.04 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| **1980** | 0.01 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| **1981** | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **1982** | 0.02 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **1983** | 0.03 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **1984** | 0.03 | 0.05 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| **1985** | 0.04 | 0.08 | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| **1986** | 0.04 | 0.08 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| **1987** | 0.02 | 0.06 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| **1988** | 0.02 | 0.06 | 0.12 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| **1989** | 0.00 | 0.02 | 0.05 | 0.09 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| **1990** | 0.01 | 0.02 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **1991** | 0.01 | 0.03 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **1992** | 0.02 | 0.04 | 0.07 | 0.08 | 0.08 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| **1993** | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| **1994** | 0.02 | 0.05 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| **1995** | 0.02 | 0.05 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| **1996** | 0.03 | 0.05 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| **1997** | 0.03 | 0.06 | 0.09 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1998** | 0.01 | 0.03 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **1999** | 0.00 | 0.01 | 0.01 | 0.02 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **2000** | 0.00 | 0.01 | 0.02 | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **2001** | 0.00 | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **2002** | 0.00 | 0.01 | 0.03 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **2003** | 0.01 | 0.02 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **2004** | 0.01 | 0.02 | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **2005** | 0.02 | 0.03 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **2006** | 0.04 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **2007** | 0.02 | 0.05 | 0.07 | 0.08 | 0.08 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| **2008** | 0.02 | 0.05 | 0.09 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| **2009** | 0.01 | 0.02 | 0.05 | 0.07 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| **2010** | 0.02 | 0.04 | 0.07 | 0.09 | 0.09 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| **2011** | 0.02 | 0.05 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |

Table 4.15. Model estimates of yellowfin sole full selection fishing mortality and exploitation rate (catch/total biomass).

| Year | Full selection F | Exploitation Rate |
|---|---|---|
| 1964 | 0.22 | 0.14 |
| 1965 | 0.14 | 0.07 |
| 1966 | 0.24 | 0.12 |
| 1967 | 0.32 | 0.19 |
| 1968 | 0.21 | 0.11 |
| 1969 | 0.38 | 0.21 |
| 1970 | 0.34 | 0.18 |
| 1971 | 0.64 | 0.21 |
| 1972 | 0.21 | 0.06 |
| 1973 | 0.25 | 0.08 |
| 1974 | 0.08 | 0.04 |
| 1975 | 0.08 | 0.05 |
| 1976 | 0.07 | 0.03 |
| 1977 | 0.04 | 0.03 |
| 1978 | 0.08 | 0.06 |
| 1979 | 0.05 | 0.04 |
| 1980 | 0.05 | 0.04 |
| 1981 | 0.04 | 0.04 |
| 1982 | 0.03 | 0.03 |
| 1983 | 0.03 | 0.04 |
| 1984 | 0.05 | 0.06 |
| 1985 | 0.07 | 0.08 |
| 1986 | 0.07 | 0.07 |
| 1987 | 0.06 | 0.07 |
| 1988 | 0.08 | 0.08 |
| 1989 | 0.06 | 0.06 |
| 1990 | 0.03 | 0.03 |
| 1991 | 0.03 | 0.04 |
| 1992 | 0.05 | 0.06 |
| 1993 | 0.04 | 0.04 |
| 1994 | 0.05 | 0.06 |
| 1995 | 0.04 | 0.05 |
| 1996 | 0.05 | 0.06 |
| 1997 | 0.07 | 0.08 |
| 1998 | 0.04 | 0.05 |
| 1999 | 0.03 | 0.03 |
| 2000 | 0.03 | 0.04 |
| 2001 | 0.03 | 0.03 |
| 2002 | 0.03 | 0.03 |
| 2003 | 0.03 | 0.04 |
| 2004 | 0.03 | 0.03 |
| 2005 | 0.04 | 0.05 |

| | | |
|---|---|---|
| 2006 | 0.04 | 0.05 |
| 2007 | 0.05 | 0.06 |
| 2008 | 0.07 | 0.07 |
| 2009 | 0.05 | 0.05 |
| 2010 | 0.06 | 0.06 |
| 2011 | | 0.06 |

Table 4.16-Model estimates of yellowfin sole age-specific selectivities for the survey and fishery.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **survey females** | | | | | | | | | | | | |
| 1982-2011 | 0.00 | 0.01 | 0.03 | 0.15 | 0.46 | 0.81 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | | | | | | | | **survey males** | | | | | | | | | | | | |
| | 0.00 | 0.01 | 0.03 | 0.14 | 0.43 | 0.78 | 0.94 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | | | | | | | | **fishery females** | | | | | | | | | | | | |
| 1964 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.24 | 0.50 | 0.76 | 0.91 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1965 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.05 | 0.18 | 0.47 | 0.79 | 0.94 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1966 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.12 | 0.31 | 0.61 | 0.84 | 0.95 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1967 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.05 | 0.14 | 0.35 | 0.64 | 0.85 | 0.95 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1968 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.07 | 0.16 | 0.33 | 0.56 | 0.77 | 0.90 | 0.96 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1969 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.06 | 0.18 | 0.45 | 0.75 | 0.92 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1970 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.05 | 0.21 | 0.57 | 0.87 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1971 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.05 | 0.15 | 0.36 | 0.64 | 0.85 | 0.95 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1972 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.20 | 0.89 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1973 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.06 | 0.19 | 0.48 | 0.79 | 0.94 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1974 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.05 | 0.13 | 0.32 | 0.59 | 0.82 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1975 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.16 | 0.46 | 0.80 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1976 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.11 | 0.26 | 0.52 | 0.76 | 0.91 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1977 | 0.01 | 0.02 | 0.04 | 0.08 | 0.16 | 0.30 | 0.49 | 0.68 | 0.82 | 0.91 | 0.96 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1978 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.11 | 0.29 | 0.57 | 0.81 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1979 | 0.00 | 0.00 | 0.01 | 0.02 | 0.04 | 0.12 | 0.30 | 0.56 | 0.80 | 0.92 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1980 | 0.00 | 0.01 | 0.01 | 0.02 | 0.05 | 0.10 | 0.20 | 0.35 | 0.53 | 0.71 | 0.84 | 0.92 | 0.96 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1981 | 0.00 | 0.01 | 0.01 | 0.03 | 0.06 | 0.12 | 0.24 | 0.42 | 0.62 | 0.79 | 0.89 | 0.95 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1982 | 0.00 | 0.00 | 0.01 | 0.02 | 0.06 | 0.16 | 0.34 | 0.58 | 0.79 | 0.91 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1983 | 0.00 | 0.00 | 0.01 | 0.03 | 0.08 | 0.22 | 0.48 | 0.75 | 0.91 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1984 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.23 | 0.47 | 0.72 | 0.89 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1985 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.07 | 0.18 | 0.37 | 0.62 | 0.82 | 0.92 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1986 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.07 | 0.25 | 0.58 | 0.85 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.21 | 0.42 | 0.66 | 0.84 | 0.94 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.25 | 0.53 | 0.80 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1989 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.14 | 0.36 | 0.66 | 0.87 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1990 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.27 | 0.58 | 0.83 | 0.95 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1991 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.05 | 0.12 | 0.28 | 0.52 | 0.75 | 0.89 | 0.96 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.06 | 0.15 | 0.32 | 0.57 | 0.78 | 0.91 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1993 | 0.00 | 0.00 | 0.01 | 0.02 | 0.04 | 0.07 | 0.13 | 0.23 | 0.37 | 0.54 | 0.70 | 0.82 | 0.90 | 0.95 | 0.97 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.07 | 0.20 | 0.45 | 0.73 | 0.90 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1995 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.10 | 0.27 | 0.55 | 0.80 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1996 | 0.00 | 0.01 | 0.01 | 0.03 | 0.06 | 0.14 | 0.27 | 0.45 | 0.66 | 0.81 | 0.91 | 0.96 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1997 | 0.00 | 0.01 | 0.01 | 0.03 | 0.06 | 0.12 | 0.22 | 0.39 | 0.58 | 0.75 | 0.87 | 0.93 | 0.97 | 0.99 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1998 | 0.00 | 0.00 | 0.01 | 0.02 | 0.06 | 0.14 | 0.31 | 0.54 | 0.76 | 0.89 | 0.96 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1999 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.06 | 0.16 | 0.37 | 0.65 | 0.85 | 0.95 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.06 | 0.17 | 0.38 | 0.65 | 0.85 | 0.95 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2001 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.06 | 0.15 | 0.35 | 0.62 | 0.83 | 0.94 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2002 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.07 | 0.20 | 0.45 | 0.74 | 0.91 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2003 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.13 | 0.31 | 0.58 | 0.81 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2004 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.06 | 0.15 | 0.35 | 0.61 | 0.82 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2005 | 0.00 | 0.00 | 0.01 | 0.02 | 0.04 | 0.10 | 0.21 | 0.40 | 0.61 | 0.79 | 0.90 | 0.96 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2006 | 0.00 | 0.00 | 0.00 | 0.02 | 0.09 | 0.32 | 0.70 | 0.92 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2007 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.08 | 0.20 | 0.42 | 0.68 | 0.86 | 0.95 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2008 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.07 | 0.20 | 0.45 | 0.74 | 0.90 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2009 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.13 | 0.40 | 0.74 | 0.93 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2010 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.12 | 0.29 | 0.55 | 0.78 | 0.92 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | | | | | | | **fishery males** | | | | | | | | | | | | | |
| 1964 | 0.00 | 0.00 | 0.03 | 0.64 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1965 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.14 | 0.47 | 0.83 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1966 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.05 | 0.25 | 0.67 | 0.92 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1967 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.05 | 0.26 | 0.71 | 0.94 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1968 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.11 | 0.47 | 0.86 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1969 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.20 | 0.69 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1970 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.06 | 0.41 | 0.88 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1971 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.47 | 0.93 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1972 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.32 | 0.82 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1973 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.27 | 0.83 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1974 | 0.00 | 0.00 | 0.00 | 0.02 | 0.07 | 0.26 | 0.62 | 0.88 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1975 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.09 | 0.41 | 0.83 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1976 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.26 | 0.55 | 0.81 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1977 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.17 | 0.49 | 0.82 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1978 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.24 | 0.48 | 0.73 | 0.89 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1979 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.11 | 0.29 | 0.56 | 0.80 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1980 | 0.00 | 0.01 | 0.01 | 0.02 | 0.03 | 0.05 | 0.09 | 0.16 | 0.26 | 0.39 | 0.54 | 0.68 | 0.80 | 0.88 | 0.93 | 0.96 | 0.98 | 0.98 | 0.98 | 0.98 |
| 1981 | 0.00 | 0.01 | 0.02 | 0.03 | 0.06 | 0.12 | 0.21 | 0.34 | 0.51 | 0.67 | 0.80 | 0.89 | 0.94 | 0.97 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1982 | 0.00 | 0.01 | 0.02 | 0.04 | 0.11 | 0.26 | 0.50 | 0.74 | 0.89 | 0.96 | 0.99 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1983 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.25 | 0.54 | 0.80 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1984 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.11 | 0.33 | 0.66 | 0.89 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1985 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.10 | 0.35 | 0.71 | 0.92 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1986 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.09 | 0.35 | 0.75 | 0.94 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.15 | 0.52 | 0.87 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1988 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.12 | 0.45 | 0.83 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1989 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.16 | 0.47 | 0.81 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1990 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.05 | 0.20 | 0.53 | 0.83 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1991 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.18 | 0.53 | 0.85 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.08 | 0.23 | 0.52 | 0.80 | 0.94 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1993 | 0.00 | 0.01 | 0.01 | 0.02 | 0.04 | 0.08 | 0.15 | 0.26 | 0.42 | 0.60 | 0.75 | 0.86 | 0.93 | 0.96 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.09 | 0.28 | 0.62 | 0.87 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1995 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.11 | 0.34 | 0.68 | 0.90 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1996 | 0.00 | 0.01 | 0.02 | 0.04 | 0.10 | 0.23 | 0.45 | 0.68 | 0.85 | 0.94 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1997 | 0.00 | 0.00 | 0.01 | 0.02 | 0.05 | 0.13 | 0.30 | 0.55 | 0.78 | 0.91 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1998 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.14 | 0.42 | 0.75 | 0.93 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1999 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.10 | 0.24 | 0.47 | 0.72 | 0.88 | 0.95 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.05 | 0.15 | 0.35 | 0.64 | 0.85 | 0.95 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2001 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.04 | 0.10 | 0.22 | 0.43 | 0.66 | 0.84 | 0.93 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2002 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.05 | 0.21 | 0.56 | 0.86 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2003 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.13 | 0.44 | 0.80 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2004 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.13 | 0.32 | 0.61 | 0.83 | 0.94 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2005 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.24 | 0.49 | 0.75 | 0.90 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.16 | 0.60 | 0.92 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2007 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.29 | 0.62 | 0.86 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2008 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.07 | 0.21 | 0.48 | 0.77 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2009 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.10 | 0.27 | 0.55 | 0.80 | 0.93 | 0.98 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2010 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.05 | 0.15 | 0.38 | 0.67 | 0.87 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Table 4.17. Model estimates of yellowfin sole age 2+ total biomass (t) and begin-year female spawning biomass (t) from the 2010 and 2011 stock assessments.

| Year | 2011 Assessment Female spawning biomass | Total biomass | 2010 Assessment Female spawning biomass | Total biomass |
|---|---|---|---|---|
| 1964 | 139,362 | 780,308 | 90,859 | 769,577 |
| 1965 | 167,014 | 781,471 | 112,915 | 774,043 |
| 1966 | 205,430 | 838,305 | 154,995 | 836,760 |
| 1967 | 216,786 | 831,268 | 185,597 | 831,366 |
| 1968 | 212,659 | 760,966 | 181,908 | 755,747 |
| 1969 | 197,417 | 778,939 | 187,799 | 777,166 |
| 1970 | 144,670 | 725,519 | 135,659 | 717,819 |
| 1971 | 106,535 | 747,700 | 87,753 | 734,857 |
| 1972 | 90,836 | 774,704 | 58,406 | 744,142 |
| 1973 | 97,747 | 948,921 | 64,586 | 917,781 |
| 1974 | 109,601 | 1,128,100 | 70,719 | 1,094,160 |
| 1975 | 145,220 | 1,387,300 | 107,157 | 1,353,880 |
| 1976 | 194,006 | 1,637,640 | 160,037 | 1,605,310 |
| 1977 | 264,874 | 1,899,120 | 235,865 | 1,869,260 |
| 1978 | 353,086 | 2,146,950 | 342,435 | 2,119,770 |
| 1979 | 440,852 | 2,286,760 | 435,975 | 2,262,780 |
| 1980 | 540,465 | 2,446,710 | 548,192 | 2,425,410 |
| 1981 | 634,779 | 2,593,320 | 651,003 | 2,574,240 |
| 1982 | 719,625 | 2,717,610 | 742,125 | 2,701,370 |
| 1983 | 796,589 | 2,807,460 | 828,628 | 2,793,320 |
| 1984 | 852,453 | 2,867,460 | 901,535 | 2,855,100 |
| 1985 | 867,750 | 2,851,680 | 935,930 | 2,840,990 |
| 1986 | 852,850 | 2,766,960 | 920,721 | 2,758,360 |
| 1987 | 828,568 | 2,696,570 | 894,627 | 2,690,630 |
| 1988 | 793,115 | 2,670,800 | 869,459 | 2,668,140 |
| 1989 | 752,543 | 2,587,080 | 814,879 | 2,588,380 |
| 1990 | 759,509 | 2,574,790 | 805,588 | 2,579,870 |
| 1991 | 803,565 | 2,605,200 | 856,195 | 2,613,460 |
| 1992 | 837,044 | 2,604,970 | 905,828 | 2,616,470 |
| 1993 | 859,981 | 2,532,270 | 923,880 | 2,546,960 |
| 1994 | 872,684 | 2,488,080 | 945,860 | 2,505,630 |
| 1995 | 860,272 | 2,397,370 | 930,333 | 2,417,450 |
| 1996 | 837,648 | 2,330,420 | 908,870 | 2,353,740 |
| 1997 | 796,679 | 2,254,840 | 878,227 | 2,281,590 |
| 1998 | 753,953 | 2,123,080 | 817,308 | 2,153,240 |
| 1999 | 732,818 | 2,073,090 | 790,111 | 2,107,250 |
| 2000 | 722,844 | 2,080,120 | 783,617 | 2,120,300 |
| 2001 | 716,424 | 2,070,420 | 773,325 | 2,117,250 |

| | | | | |
|---|---|---|---|---|
| 2002 | 707,861 | 2,066,670 | 766,810 | 2,120,270 |
| 2003 | 707,040 | 2,061,690 | 767,171 | 2,122,860 |
| 2004 | 701,645 | 2,061,730 | 762,464 | 2,131,980 |
| 2005 | 697,860 | 2,063,330 | 765,879 | 2,142,860 |
| 2006 | 687,063 | 2,041,540 | 757,170 | 2,131,370 |
| 2007 | 670,161 | 2,039,230 | 748,884 | 2,133,090 |
| 2008 | 636,839 | 2,036,040 | 723,091 | 2,131,940 |
| 2009 | 597,012 | 2,009,360 | 675,957 | 2,107,380 |
| 2010 | 572,579 | 2,041,070 | 654,802 | 2,139,050 |
| 2011 | 558,674 | 2,077,490 | | |

Table 4.18—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2011.

| | Females | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 1954 | 1.04 | 0.70 | 0.30 | 0.22 | 0.22 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| 1955 | 0.84 | 0.92 | 0.62 | 0.27 | 0.20 | 0.19 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.35 |
| 1956 | 0.73 | 0.75 | 0.82 | 0.55 | 0.24 | 0.17 | 0.17 | 0.16 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.46 |
| 1957 | 2.93 | 0.65 | 0.66 | 0.72 | 0.49 | 0.21 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.53 |
| 1958 | 2.33 | 2.60 | 0.58 | 0.59 | 0.64 | 0.43 | 0.19 | 0.14 | 0.13 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.58 |
| 1959 | 1.59 | 2.07 | 2.31 | 0.51 | 0.52 | 0.57 | 0.38 | 0.16 | 0.12 | 0.12 | 0.11 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.60 |
| 1960 | 1.00 | 1.41 | 1.83 | 2.05 | 0.45 | 0.46 | 0.50 | 0.34 | 0.14 | 0.10 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.53 |
| 1961 | 0.49 | 0.89 | 1.25 | 1.62 | 1.82 | 0.40 | 0.41 | 0.44 | 0.29 | 0.11 | 0.07 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.30 |
| 1962 | 0.90 | 0.44 | 0.79 | 1.11 | 1.44 | 1.61 | 0.36 | 0.36 | 0.39 | 0.25 | 0.09 | 0.04 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.05 |
| 1963 | 0.49 | 0.79 | 0.39 | 0.70 | 0.98 | 1.28 | 1.43 | 0.32 | 0.32 | 0.34 | 0.22 | 0.07 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1964 | 0.47 | 0.43 | 0.70 | 0.34 | 0.62 | 0.86 | 1.10 | 1.16 | 0.23 | 0.22 | 0.22 | 0.14 | 0.04 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1965 | 0.61 | 0.42 | 0.38 | 0.62 | 0.30 | 0.54 | 0.74 | 0.89 | 0.86 | 0.16 | 0.14 | 0.14 | 0.08 | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1966 | 0.59 | 0.54 | 0.37 | 0.34 | 0.55 | 0.27 | 0.48 | 0.65 | 0.76 | 0.68 | 0.12 | 0.10 | 0.10 | 0.06 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1967 | 1.22 | 0.52 | 0.48 | 0.33 | 0.30 | 0.49 | 0.24 | 0.42 | 0.54 | 0.58 | 0.46 | 0.07 | 0.06 | 0.06 | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1968 | 1.82 | 1.08 | 0.46 | 0.43 | 0.29 | 0.27 | 0.43 | 0.21 | 0.34 | 0.39 | 0.36 | 0.25 | 0.04 | 0.03 | 0.03 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 |
| 1969 | 1.81 | 1.61 | 0.96 | 0.41 | 0.38 | 0.26 | 0.24 | 0.38 | 0.18 | 0.28 | 0.30 | 0.25 | 0.16 | 0.02 | 0.02 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 |
| 1970 | 2.37 | 1.61 | 1.43 | 0.85 | 0.36 | 0.33 | 0.23 | 0.20 | 0.30 | 0.12 | 0.15 | 0.15 | 0.11 | 0.07 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| 1971 | 2.62 | 2.10 | 1.43 | 1.27 | 0.75 | 0.32 | 0.30 | 0.20 | 0.18 | 0.25 | 0.09 | 0.09 | 0.07 | 0.05 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1972 | 2.05 | 2.32 | 1.87 | 1.27 | 1.12 | 0.67 | 0.29 | 0.26 | 0.17 | 0.15 | 0.18 | 0.05 | 0.03 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1973 | 1.42 | 1.82 | 2.06 | 1.65 | 1.12 | 1.00 | 0.59 | 0.25 | 0.23 | 0.15 | 0.12 | 0.11 | 0.03 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1974 | 1.92 | 1.26 | 1.61 | 1.83 | 1.47 | 0.99 | 0.88 | 0.51 | 0.21 | 0.17 | 0.10 | 0.07 | 0.06 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1975 | 2.25 | 1.70 | 1.12 | 1.43 | 1.62 | 1.30 | 0.88 | 0.77 | 0.45 | 0.17 | 0.14 | 0.08 | 0.05 | 0.05 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1976 | 1.48 | 1.99 | 1.51 | 0.99 | 1.27 | 1.43 | 1.15 | 0.76 | 0.65 | 0.36 | 0.14 | 0.11 | 0.06 | 0.04 | 0.04 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| 1977 | 1.86 | 1.31 | 1.77 | 1.34 | 0.88 | 1.12 | 1.27 | 1.01 | 0.66 | 0.54 | 0.29 | 0.11 | 0.08 | 0.05 | 0.03 | 0.03 | 0.01 | 0.01 | 0.00 | 0.00 |
| 1978 | 1.21 | 1.65 | 1.16 | 1.57 | 1.18 | 0.77 | 0.98 | 1.09 | 0.86 | 0.56 | 0.45 | 0.24 | 0.09 | 0.07 | 0.04 | 0.03 | 0.03 | 0.01 | 0.00 | 0.01 |
| 1979 | 0.78 | 1.08 | 1.46 | 1.03 | 1.39 | 1.04 | 0.67 | 0.84 | 0.90 | 0.69 | 0.44 | 0.36 | 0.19 | 0.07 | 0.06 | 0.03 | 0.02 | 0.02 | 0.00 | 0.01 |
| 1980 | 1.50 | 0.69 | 0.96 | 1.30 | 0.91 | 1.23 | 0.92 | 0.59 | 0.71 | 0.76 | 0.57 | 0.36 | 0.30 | 0.16 | 0.06 | 0.05 | 0.03 | 0.02 | 0.02 | 0.01 |

Table 4.18—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2011 (continued).

| | Females | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 1981 | 1.11 | 1.33 | 0.61 | 0.85 | 1.15 | 0.81 | 1.08 | 0.80 | 0.51 | 0.61 | 0.63 | 0.47 | 0.30 | 0.24 | 0.13 | 0.05 | 0.04 | 0.02 | 0.01 | 0.02 |
| 1982 | 3.19 | 0.98 | 1.18 | 0.54 | 0.75 | 1.01 | 0.71 | 0.94 | 0.69 | 0.43 | 0.51 | 0.53 | 0.40 | 0.25 | 0.20 | 0.11 | 0.04 | 0.03 | 0.02 | 0.03 |
| 1983 | 0.59 | 2.83 | 0.87 | 1.04 | 0.48 | 0.66 | 0.89 | 0.62 | 0.81 | 0.59 | 0.37 | 0.43 | 0.45 | 0.33 | 0.21 | 0.17 | 0.09 | 0.03 | 0.03 | 0.04 |
| 1984 | 2.61 | 0.52 | 2.51 | 0.77 | 0.92 | 0.42 | 0.58 | 0.77 | 0.53 | 0.69 | 0.50 | 0.31 | 0.36 | 0.38 | 0.28 | 0.18 | 0.14 | 0.08 | 0.03 | 0.06 |
| 1985 | 0.89 | 2.31 | 0.46 | 2.22 | 0.68 | 0.82 | 0.37 | 0.51 | 0.66 | 0.44 | 0.57 | 0.41 | 0.25 | 0.30 | 0.31 | 0.23 | 0.15 | 0.12 | 0.06 | 0.07 |
| 1986 | 0.68 | 0.79 | 2.05 | 0.41 | 1.97 | 0.60 | 0.72 | 0.32 | 0.43 | 0.54 | 0.36 | 0.45 | 0.32 | 0.20 | 0.24 | 0.24 | 0.18 | 0.12 | 0.09 | 0.10 |
| 1987 | 0.92 | 0.61 | 0.70 | 1.82 | 0.36 | 1.74 | 0.53 | 0.62 | 0.27 | 0.35 | 0.43 | 0.28 | 0.36 | 0.26 | 0.16 | 0.19 | 0.19 | 0.14 | 0.09 | 0.16 |
| 1988 | 1.25 | 0.82 | 0.54 | 0.62 | 1.61 | 0.32 | 1.54 | 0.47 | 0.54 | 0.23 | 0.29 | 0.35 | 0.23 | 0.29 | 0.20 | 0.13 | 0.15 | 0.15 | 0.12 | 0.20 |
| 1989 | 1.23 | 1.11 | 0.73 | 0.48 | 0.55 | 1.43 | 0.28 | 1.35 | 0.40 | 0.44 | 0.18 | 0.22 | 0.27 | 0.18 | 0.22 | 0.16 | 0.10 | 0.11 | 0.12 | 0.24 |
| 1990 | 0.61 | 1.09 | 0.98 | 0.64 | 0.42 | 0.49 | 1.26 | 0.25 | 1.18 | 0.34 | 0.37 | 0.15 | 0.18 | 0.22 | 0.14 | 0.18 | 0.13 | 0.08 | 0.09 | 0.29 |
| 1991 | 0.67 | 0.54 | 0.97 | 0.87 | 0.57 | 0.37 | 0.43 | 1.12 | 0.22 | 1.02 | 0.29 | 0.31 | 0.12 | 0.15 | 0.18 | 0.12 | 0.15 | 0.11 | 0.07 | 0.32 |
| 1992 | 1.46 | 0.59 | 0.48 | 0.86 | 0.77 | 0.51 | 0.33 | 0.38 | 0.98 | 0.19 | 0.87 | 0.25 | 0.26 | 0.10 | 0.13 | 0.15 | 0.10 | 0.13 | 0.09 | 0.32 |
| 1993 | 0.85 | 1.30 | 0.53 | 0.42 | 0.76 | 0.68 | 0.45 | 0.29 | 0.33 | 0.82 | 0.16 | 0.71 | 0.20 | 0.21 | 0.08 | 0.10 | 0.13 | 0.08 | 0.10 | 0.34 |
| 1994 | 0.71 | 0.75 | 1.15 | 0.47 | 0.37 | 0.67 | 0.60 | 0.39 | 0.25 | 0.29 | 0.71 | 0.13 | 0.60 | 0.17 | 0.18 | 0.07 | 0.09 | 0.10 | 0.07 | 0.36 |
| 1995 | 0.69 | 0.63 | 0.67 | 1.02 | 0.41 | 0.33 | 0.59 | 0.53 | 0.34 | 0.21 | 0.24 | 0.58 | 0.11 | 0.49 | 0.14 | 0.15 | 0.06 | 0.07 | 0.09 | 0.35 |
| 1996 | 1.77 | 0.62 | 0.56 | 0.59 | 0.90 | 0.37 | 0.29 | 0.52 | 0.45 | 0.28 | 0.18 | 0.20 | 0.48 | 0.09 | 0.41 | 0.11 | 0.12 | 0.05 | 0.06 | 0.37 |
| 1997 | 0.74 | 1.57 | 0.55 | 0.50 | 0.52 | 0.80 | 0.32 | 0.25 | 0.44 | 0.38 | 0.24 | 0.15 | 0.16 | 0.40 | 0.07 | 0.34 | 0.09 | 0.10 | 0.04 | 0.35 |
| 1998 | 0.61 | 0.65 | 1.39 | 0.48 | 0.44 | 0.46 | 0.70 | 0.28 | 0.22 | 0.37 | 0.31 | 0.19 | 0.12 | 0.13 | 0.32 | 0.06 | 0.27 | 0.08 | 0.08 | 0.31 |
| 1999 | 0.78 | 0.55 | 0.58 | 1.24 | 0.43 | 0.39 | 0.41 | 0.61 | 0.24 | 0.18 | 0.31 | 0.26 | 0.16 | 0.10 | 0.11 | 0.26 | 0.05 | 0.22 | 0.06 | 0.32 |
| 2000 | 1.08 | 0.69 | 0.48 | 0.51 | 1.10 | 0.38 | 0.34 | 0.36 | 0.53 | 0.21 | 0.16 | 0.26 | 0.22 | 0.13 | 0.08 | 0.09 | 0.22 | 0.04 | 0.19 | 0.32 |
| 2001 | 0.70 | 0.96 | 0.61 | 0.43 | 0.46 | 0.97 | 0.34 | 0.30 | 0.32 | 0.46 | 0.18 | 0.13 | 0.22 | 0.18 | 0.11 | 0.07 | 0.08 | 0.19 | 0.03 | 0.43 |
| 2002 | 1.04 | 0.62 | 0.85 | 0.55 | 0.38 | 0.40 | 0.86 | 0.30 | 0.27 | 0.27 | 0.39 | 0.15 | 0.11 | 0.19 | 0.16 | 0.09 | 0.06 | 0.06 | 0.16 | 0.39 |
| 2003 | 1.07 | 0.92 | 0.55 | 0.75 | 0.48 | 0.34 | 0.36 | 0.76 | 0.26 | 0.23 | 0.23 | 0.33 | 0.13 | 0.09 | 0.16 | 0.13 | 0.08 | 0.05 | 0.05 | 0.46 |
| 2004 | 2.18 | 0.95 | 0.82 | 0.49 | 0.67 | 0.43 | 0.30 | 0.32 | 0.66 | 0.22 | 0.20 | 0.20 | 0.28 | 0.11 | 0.08 | 0.13 | 0.11 | 0.07 | 0.04 | 0.43 |
| 2005 | 0.90 | 1.93 | 0.85 | 0.73 | 0.43 | 0.59 | 0.38 | 0.26 | 0.28 | 0.57 | 0.19 | 0.17 | 0.17 | 0.24 | 0.09 | 0.07 | 0.11 | 0.09 | 0.06 | 0.40 |
| 2006 | 1.37 | 0.80 | 1.71 | 0.75 | 0.64 | 0.38 | 0.52 | 0.33 | 0.23 | 0.24 | 0.48 | 0.16 | 0.14 | 0.14 | 0.20 | 0.08 | 0.06 | 0.09 | 0.08 | 0.38 |
| 2007 | 2.05 | 1.22 | 0.71 | 1.52 | 0.66 | 0.57 | 0.33 | 0.44 | 0.28 | 0.19 | 0.20 | 0.40 | 0.13 | 0.12 | 0.12 | 0.17 | 0.06 | 0.05 | 0.08 | 0.38 |
| 2008 | 1.37 | 1.82 | 1.08 | 0.63 | 1.35 | 0.59 | 0.50 | 0.29 | 0.38 | 0.23 | 0.16 | 0.16 | 0.33 | 0.11 | 0.09 | 0.09 | 0.14 | 0.05 | 0.04 | 0.38 |
| 2009 | 1.07 | 1.22 | 1.61 | 0.96 | 0.56 | 1.19 | 0.52 | 0.43 | 0.25 | 0.31 | 0.19 | 0.12 | 0.13 | 0.26 | 0.09 | 0.07 | 0.07 | 0.11 | 0.04 | 0.33 |
| 2010 | 1.13 | 0.95 | 1.08 | 1.43 | 0.85 | 0.49 | 1.05 | 0.45 | 0.37 | 0.20 | 0.25 | 0.15 | 0.10 | 0.10 | 0.21 | 0.07 | 0.06 | 0.06 | 0.09 | 0.30 |
| 2011 | 1.14 | 1.01 | 0.84 | 0.96 | 1.27 | 0.75 | 0.44 | 0.92 | 0.39 | 0.31 | 0.17 | 0.21 | 0.12 | 0.08 | 0.08 | 0.17 | 0.06 | 0.05 | 0.05 | 0.31 |

Table 4.18—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2011 (continued).

| | Males | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
| **1954** | 1.04 | 0.37 | 0.25 | 0.21 | 0.21 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| **1955** | 0.84 | 0.92 | 0.33 | 0.22 | 0.19 | 0.19 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.35 |
| **1956** | 0.73 | 0.75 | 0.82 | 0.29 | 0.20 | 0.17 | 0.17 | 0.16 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.46 |
| **1957** | 2.93 | 0.65 | 0.66 | 0.72 | 0.26 | 0.17 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.53 |
| **1958** | 2.33 | 2.60 | 0.58 | 0.59 | 0.64 | 0.23 | 0.15 | 0.13 | 0.13 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.58 |
| **1959** | 1.59 | 2.07 | 2.31 | 0.51 | 0.52 | 0.57 | 0.21 | 0.13 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.60 |
| **1960** | 1.00 | 1.41 | 1.83 | 2.05 | 0.45 | 0.46 | 0.50 | 0.18 | 0.11 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.53 |
| **1961** | 0.49 | 0.89 | 1.25 | 1.62 | 1.81 | 0.40 | 0.39 | 0.38 | 0.11 | 0.06 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.30 |
| **1962** | 0.90 | 0.44 | 0.79 | 1.10 | 1.42 | 1.50 | 0.28 | 0.17 | 0.09 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.05 |
| **1963** | 0.49 | 0.79 | 0.36 | 0.48 | 0.16 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1964** | 0.47 | 0.43 | 0.70 | 0.32 | 0.43 | 0.14 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1965** | 0.61 | 0.42 | 0.38 | 0.61 | 0.23 | 0.27 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1966** | 0.59 | 0.54 | 0.37 | 0.34 | 0.54 | 0.20 | 0.24 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1967** | 1.22 | 0.52 | 0.48 | 0.33 | 0.30 | 0.48 | 0.18 | 0.21 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1968** | 1.82 | 1.08 | 0.46 | 0.43 | 0.29 | 0.27 | 0.42 | 0.14 | 0.12 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1969** | 1.81 | 1.61 | 0.96 | 0.41 | 0.38 | 0.26 | 0.23 | 0.35 | 0.10 | 0.07 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1970** | 2.37 | 1.61 | 1.43 | 0.85 | 0.36 | 0.33 | 0.23 | 0.20 | 0.27 | 0.06 | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1971** | 2.62 | 2.10 | 1.43 | 1.27 | 0.75 | 0.32 | 0.28 | 0.15 | 0.10 | 0.12 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1972** | 2.05 | 2.32 | 1.87 | 1.27 | 1.12 | 0.66 | 0.26 | 0.13 | 0.04 | 0.02 | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1973** | 1.42 | 1.82 | 2.06 | 1.65 | 1.12 | 0.99 | 0.58 | 0.20 | 0.08 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1974** | 1.92 | 1.26 | 1.61 | 1.83 | 1.47 | 0.99 | 0.87 | 0.46 | 0.13 | 0.05 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1975** | 2.25 | 1.70 | 1.12 | 1.43 | 1.62 | 1.29 | 0.85 | 0.71 | 0.36 | 0.10 | 0.04 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1976** | 1.48 | 1.99 | 1.51 | 0.99 | 1.27 | 1.43 | 1.13 | 0.72 | 0.57 | 0.28 | 0.08 | 0.03 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1977** | 1.86 | 1.31 | 1.77 | 1.34 | 0.88 | 1.12 | 1.26 | 0.99 | 0.62 | 0.47 | 0.23 | 0.06 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1978** | 1.21 | 1.65 | 1.16 | 1.57 | 1.19 | 0.78 | 0.99 | 1.11 | 0.85 | 0.52 | 0.39 | 0.19 | 0.05 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1979** | 0.78 | 1.08 | 1.46 | 1.03 | 1.39 | 1.05 | 0.68 | 0.86 | 0.93 | 0.69 | 0.42 | 0.31 | 0.15 | 0.04 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1980** | 1.50 | 0.69 | 0.96 | 1.30 | 0.91 | 1.23 | 0.92 | 0.59 | 0.73 | 0.78 | 0.58 | 0.34 | 0.26 | 0.12 | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 4.18—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2011 (continued).

Males

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 1.11 | 1.33 | 0.61 | 0.85 | 1.15 | 0.81 | 1.09 | 0.81 | 0.52 | 0.63 | 0.67 | 0.49 | 0.29 | 0.21 | 0.1 | 0.03 | 0.01 | 0 | 0 | 0 |
| 1982 | 3.19 | 0.98 | 1.18 | 0.54 | 0.75 | 1.01 | 0.71 | 0.95 | 0.7 | 0.45 | 0.54 | 0.56 | 0.41 | 0.24 | 0.18 | 0.08 | 0.02 | 0.01 | 0 | 0 |
| 1983 | 0.59 | 2.83 | 0.87 | 1.04 | 0.48 | 0.66 | 0.89 | 0.62 | 0.81 | 0.6 | 0.38 | 0.45 | 0.48 | 0.35 | 0.2 | 0.15 | 0.07 | 0.02 | 0.01 | 0 |
| 1984 | 2.61 | 0.52 | 2.51 | 0.77 | 0.92 | 0.42 | 0.58 | 0.77 | 0.53 | 0.69 | 0.5 | 0.32 | 0.38 | 0.4 | 0.29 | 0.17 | 0.13 | 0.06 | 0.02 | 0.01 |
| 1985 | 0.89 | 2.31 | 0.46 | 2.22 | 0.68 | 0.82 | 0.37 | 0.5 | 0.65 | 0.43 | 0.56 | 0.41 | 0.26 | 0.31 | 0.33 | 0.24 | 0.14 | 0.1 | 0.05 | 0.02 |
| 1986 | 0.68 | 0.79 | 2.05 | 0.41 | 1.97 | 0.6 | 0.72 | 0.32 | 0.41 | 0.51 | 0.34 | 0.45 | 0.33 | 0.21 | 0.25 | 0.26 | 0.19 | 0.11 | 0.08 | 0.06 |
| 1987 | 0.92 | 0.61 | 0.7 | 1.82 | 0.36 | 1.74 | 0.53 | 0.61 | 0.26 | 0.33 | 0.41 | 0.27 | 0.35 | 0.26 | 0.16 | 0.2 | 0.21 | 0.15 | 0.09 | 0.11 |
| 1988 | 1.25 | 0.82 | 0.54 | 0.62 | 1.61 | 0.32 | 1.54 | 0.46 | 0.51 | 0.21 | 0.26 | 0.32 | 0.22 | 0.28 | 0.21 | 0.13 | 0.16 | 0.16 | 0.12 | 0.16 |
| 1989 | 1.23 | 1.11 | 0.73 | 0.48 | 0.55 | 1.43 | 0.28 | 1.34 | 0.39 | 0.4 | 0.16 | 0.2 | 0.25 | 0.17 | 0.22 | 0.16 | 0.1 | 0.12 | 0.13 | 0.21 |
| 1990 | 0.61 | 1.09 | 0.98 | 0.64 | 0.42 | 0.49 | 1.27 | 0.25 | 1.17 | 0.33 | 0.33 | 0.13 | 0.16 | 0.2 | 0.13 | 0.17 | 0.13 | 0.08 | 0.1 | 0.27 |
| 1991 | 0.67 | 0.54 | 0.97 | 0.87 | 0.57 | 0.37 | 0.43 | 1.11 | 0.22 | 1 | 0.28 | 0.28 | 0.11 | 0.14 | 0.17 | 0.11 | 0.15 | 0.11 | 0.07 | 0.31 |
| 1992 | 1.46 | 0.59 | 0.48 | 0.86 | 0.77 | 0.51 | 0.33 | 0.38 | 0.96 | 0.18 | 0.84 | 0.23 | 0.23 | 0.09 | 0.11 | 0.14 | 0.09 | 0.12 | 0.09 | 0.32 |
| 1993 | 0.85 | 1.3 | 0.53 | 0.42 | 0.76 | 0.68 | 0.45 | 0.29 | 0.32 | 0.8 | 0.15 | 0.69 | 0.19 | 0.19 | 0.07 | 0.09 | 0.12 | 0.08 | 0.1 | 0.33 |
| 1994 | 0.71 | 0.75 | 1.15 | 0.47 | 0.37 | 0.67 | 0.6 | 0.39 | 0.25 | 0.28 | 0.68 | 0.13 | 0.58 | 0.16 | 0.16 | 0.06 | 0.08 | 0.1 | 0.06 | 0.36 |
| 1995 | 0.69 | 0.63 | 0.67 | 1.02 | 0.41 | 0.33 | 0.59 | 0.52 | 0.33 | 0.21 | 0.23 | 0.56 | 0.1 | 0.47 | 0.13 | 0.13 | 0.05 | 0.06 | 0.08 | 0.35 |
| 1996 | 1.77 | 0.62 | 0.56 | 0.59 | 0.9 | 0.37 | 0.29 | 0.51 | 0.44 | 0.28 | 0.17 | 0.19 | 0.46 | 0.09 | 0.39 | 0.11 | 0.11 | 0.04 | 0.05 | 0.35 |
| 1997 | 0.74 | 1.57 | 0.55 | 0.5 | 0.52 | 0.79 | 0.32 | 0.25 | 0.43 | 0.37 | 0.23 | 0.14 | 0.16 | 0.38 | 0.07 | 0.32 | 0.09 | 0.09 | 0.03 | 0.33 |
| 1998 | 0.61 | 0.65 | 1.4 | 0.48 | 0.44 | 0.46 | 0.69 | 0.27 | 0.21 | 0.35 | 0.3 | 0.18 | 0.11 | 0.12 | 0.3 | 0.06 | 0.26 | 0.07 | 0.07 | 0.29 |
| 1999 | 0.78 | 0.55 | 0.58 | 1.24 | 0.43 | 0.39 | 0.41 | 0.61 | 0.24 | 0.18 | 0.29 | 0.25 | 0.15 | 0.09 | 0.1 | 0.25 | 0.05 | 0.21 | 0.06 | 0.3 |
| 2000 | 1.08 | 0.69 | 0.48 | 0.52 | 1.1 | 0.38 | 0.35 | 0.36 | 0.54 | 0.21 | 0.15 | 0.25 | 0.21 | 0.13 | 0.08 | 0.09 | 0.21 | 0.04 | 0.18 | 0.3 |
| 2001 | 0.7 | 0.96 | 0.61 | 0.43 | 0.46 | 0.97 | 0.34 | 0.31 | 0.32 | 0.47 | 0.18 | 0.13 | 0.21 | 0.17 | 0.11 | 0.07 | 0.07 | 0.18 | 0.03 | 0.4 |
| 2002 | 1.04 | 0.62 | 0.85 | 0.55 | 0.38 | 0.41 | 0.86 | 0.3 | 0.27 | 0.28 | 0.41 | 0.15 | 0.11 | 0.18 | 0.15 | 0.09 | 0.06 | 0.06 | 0.15 | 0.37 |
| 2003 | 1.07 | 0.92 | 0.55 | 0.75 | 0.48 | 0.34 | 0.36 | 0.76 | 0.26 | 0.23 | 0.24 | 0.34 | 0.13 | 0.09 | 0.15 | 0.12 | 0.08 | 0.05 | 0.05 | 0.44 |
| 2004 | 2.18 | 0.95 | 0.82 | 0.49 | 0.67 | 0.43 | 0.3 | 0.32 | 0.66 | 0.22 | 0.2 | 0.2 | 0.29 | 0.11 | 0.08 | 0.13 | 0.11 | 0.06 | 0.04 | 0.41 |
| 2005 | 0.9 | 1.93 | 0.85 | 0.73 | 0.43 | 0.59 | 0.38 | 0.26 | 0.28 | 0.57 | 0.19 | 0.17 | 0.17 | 0.24 | 0.09 | 0.07 | 0.11 | 0.09 | 0.05 | 0.38 |
| 2006 | 1.37 | 0.8 | 1.71 | 0.75 | 0.64 | 0.38 | 0.52 | 0.33 | 0.23 | 0.23 | 0.48 | 0.16 | 0.14 | 0.14 | 0.2 | 0.08 | 0.05 | 0.09 | 0.07 | 0.36 |
| 2007 | 2.05 | 1.22 | 0.71 | 1.52 | 0.66 | 0.57 | 0.34 | 0.45 | 0.28 | 0.19 | 0.19 | 0.4 | 0.13 | 0.12 | 0.12 | 0.17 | 0.06 | 0.05 | 0.07 | 0.37 |
| 2008 | 1.37 | 1.82 | 1.08 | 0.63 | 1.35 | 0.59 | 0.5 | 0.29 | 0.38 | 0.23 | 0.15 | 0.16 | 0.32 | 0.11 | 0.09 | 0.1 | 0.14 | 0.05 | 0.04 | 0.36 |
| 2009 | 1.07 | 1.22 | 1.61 | 0.96 | 0.56 | 1.19 | 0.52 | 0.44 | 0.25 | 0.31 | 0.18 | 0.12 | 0.13 | 0.26 | 0.09 | 0.07 | 0.08 | 0.11 | 0.04 | 0.31 |
| 2010 | 1.13 | 0.95 | 1.08 | 1.43 | 0.85 | 0.49 | 1.05 | 0.46 | 0.38 | 0.21 | 0.25 | 0.15 | 0.1 | 0.1 | 0.21 | 0.07 | 0.06 | 0.06 | 0.09 | 0.29 |
| 2011 | 1.14 | 1.01 | 0.84 | 0.96 | 1.27 | 0.75 | 0.44 | 0.92 | 0.39 | 0.31 | 0.17 | 0.2 | 0.12 | 0.08 | 0.08 | 0.17 | 0.06 | 0.05 | 0.05 | 0.30 |

Table 4.19—Model estimates of the number of female spawners (millions) 1964-2011.

| year/age | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1964** | 5.2 | 10.3 | 50.7 | 120.4 | 50.5 | 85.8 | 134.6 | 106.9 | 40.4 | 15.0 | 2.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| **1965** | 2.6 | 6.5 | 34.3 | 92.7 | 186.6 | 62.7 | 85.2 | 109.6 | 76.1 | 26.8 | 9.6 | 1.6 | 0.1 | 0.0 | 0.0 | 0.0 |
| **1966** | 4.6 | 3.2 | 22.2 | 67.3 | 164.3 | 270.3 | 71.0 | 77.8 | 87.2 | 56.4 | 19.2 | 6.8 | 1.1 | 0.0 | 0.0 | 0.0 |
| **1967** | 2.5 | 5.9 | 11.0 | 43.5 | 118.0 | 231.6 | 281.5 | 55.8 | 51.3 | 52.8 | 32.8 | 11.0 | 3.8 | 0.6 | 0.0 | 0.0 |
| **1968** | 2.4 | 3.2 | 19.9 | 21.3 | 74.0 | 155.9 | 217.4 | 195.3 | 32.2 | 27.1 | 26.8 | 16.4 | 5.4 | 1.9 | 0.3 | 0.0 |
| **1969** | 3.2 | 3.1 | 10.9 | 39.2 | 38.4 | 112.3 | 185.1 | 195.6 | 141.4 | 20.6 | 16.3 | 15.7 | 9.5 | 3.1 | 1.1 | 0.2 |
| **1970** | 3.1 | 4.0 | 10.5 | 20.9 | 64.2 | 46.1 | 92.9 | 114.6 | 102.6 | 68.5 | 9.6 | 7.5 | 7.2 | 4.3 | 1.4 | 0.6 |
| **1971** | 6.3 | 3.9 | 13.7 | 20.8 | 38.4 | 100.6 | 54.3 | 71.0 | 62.3 | 48.4 | 30.7 | 4.2 | 3.3 | 3.1 | 1.9 | 0.9 |
| **1972** | 9.4 | 8.0 | 13.2 | 27.0 | 37.5 | 57.8 | 111.1 | 37.2 | 28.6 | 17.4 | 11.4 | 6.7 | 0.9 | 0.7 | 0.7 | 0.6 |
| **1973** | 9.4 | 12.0 | 27.5 | 26.3 | 50.0 | 60.8 | 72.5 | 87.0 | 24.6 | 17.6 | 10.4 | 6.7 | 3.9 | 0.5 | 0.4 | 0.7 |
| **1974** | 12.3 | 11.9 | 40.7 | 53.3 | 44.7 | 65.8 | 59.2 | 55.5 | 57.5 | 15.1 | 10.4 | 6.0 | 3.9 | 2.3 | 0.3 | 0.7 |
| **1975** | 13.6 | 15.6 | 40.7 | 80.4 | 96.8 | 69.4 | 82.8 | 60.4 | 49.1 | 47.2 | 11.9 | 8.1 | 4.7 | 3.0 | 1.8 | 0.7 |
| **1976** | 10.6 | 17.2 | 53.1 | 79.5 | 140.3 | 142.0 | 84.2 | 83.7 | 53.8 | 40.8 | 37.9 | 9.4 | 6.4 | 3.7 | 2.3 | 1.9 |
| **1977** | 7.4 | 13.5 | 58.6 | 104.4 | 142.5 | 214.3 | 177.6 | 86.6 | 75.4 | 45.1 | 33.0 | 30.2 | 7.5 | 5.1 | 2.9 | 3.4 |
| **1978** | 9.9 | 9.3 | 45.2 | 113.3 | 185.6 | 220.4 | 277.8 | 192.2 | 82.5 | 67.0 | 38.7 | 27.9 | 25.4 | 6.3 | 4.2 | 5.2 |
| **1979** | 11.6 | 12.5 | 31.2 | 86.9 | 195.8 | 273.4 | 269.5 | 282.8 | 172.2 | 69.0 | 54.1 | 30.8 | 22.1 | 20.0 | 4.9 | 7.4 |
| **1980** | 7.7 | 14.7 | 42.4 | 60.9 | 154.5 | 300.3 | 350.0 | 287.9 | 265.9 | 151.1 | 58.5 | 45.2 | 25.6 | 18.3 | 16.5 | 10.2 |
| **1981** | 9.6 | 9.7 | 49.9 | 83.0 | 109.5 | 240.4 | 388.3 | 375.0 | 270.2 | 232.2 | 127.3 | 48.5 | 37.2 | 21.0 | 15.0 | 21.9 |
| **1982** | 6.3 | 12.2 | 32.9 | 97.8 | 149.6 | 170.9 | 312.6 | 419.7 | 356.0 | 239.0 | 198.4 | 107.1 | 40.5 | 31.0 | 17.5 | 30.7 |
| **1983** | 4.0 | 8.0 | 41.3 | 64.4 | 175.9 | 233.6 | 223.5 | 341.4 | 403.7 | 319.5 | 207.4 | 169.5 | 90.9 | 34.3 | 26.2 | 40.7 |
| **1984** | 7.8 | 5.1 | 26.9 | 80.3 | 114.7 | 272.8 | 304.2 | 243.5 | 327.7 | 361.7 | 276.8 | 176.8 | 143.6 | 76.9 | 29.0 | 56.4 |
| **1985** | 5.7 | 9.8 | 17.2 | 52.6 | 143.1 | 175.9 | 348.0 | 323.0 | 227.4 | 285.5 | 304.5 | 229.4 | 145.7 | 118.1 | 63.0 | 70.0 |

Table 4.19 (continued).

| year/age | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 16.5 | 7.3 | 33.3 | 33.6 | 93.1 | 215.9 | 218.4 | 357.2 | 290.7 | 190.6 | 231.2 | 242.7 | 181.7 | 115.1 | 93.0 | 104.8 |
| **1987** | 3.0 | 20.9 | 24.6 | 64.5 | 58.3 | 137.6 | 265.7 | 224.3 | 323.1 | 245.4 | 155.6 | 185.8 | 193.8 | 144.8 | 91.5 | 157.2 |
| **1988** | 13.5 | 3.9 | 71.3 | 48.5 | 116.6 | 90.3 | 175.0 | 277.3 | 204.3 | 273.5 | 200.5 | 125.1 | 148.4 | 154.5 | 115.1 | 197.6 |
| **1989** | 4.6 | 17.1 | 13.1 | 140.2 | 86.7 | 175.6 | 110.4 | 175.7 | 243.8 | 167.3 | 216.5 | 156.2 | 96.8 | 114.6 | 119.0 | 240.9 |
| **1990** | 3.6 | 5.9 | 58.5 | 26.0 | 255.5 | 135.5 | 223.7 | 115.1 | 160.0 | 206.5 | 136.9 | 174.3 | 125.0 | 77.4 | 91.3 | 286.7 |
| **1991** | 4.8 | 4.5 | 20.1 | 116.0 | 47.6 | 403.8 | 178.2 | 245.0 | 111.0 | 143.9 | 179.6 | 117.2 | 148.3 | 106.2 | 65.5 | 319.9 |
| **1992** | 6.5 | 6.1 | 15.4 | 39.8 | 211.5 | 75.1 | 531.1 | 194.8 | 235.2 | 99.3 | 124.4 | 152.8 | 99.1 | 125.2 | 89.3 | 324.3 |
| **1993** | 6.4 | 8.2 | 20.7 | 30.2 | 71.6 | 327.1 | 96.1 | 562.8 | 181.1 | 203.7 | 83.1 | 102.5 | 125.1 | 81.0 | 102.0 | 336.9 |
| **1994** | 3.1 | 8.1 | 27.9 | 40.8 | 55.0 | 113.4 | 431.7 | 105.1 | 538.1 | 160.8 | 174.3 | 69.9 | 85.6 | 104.2 | 67.3 | 364.5 |
| **1995** | 3.5 | 4.0 | 27.5 | 54.8 | 72.9 | 84.4 | 144.8 | 459.0 | 98.4 | 469.6 | 135.7 | 144.8 | 57.7 | 70.5 | 85.6 | 354.7 |
| **1996** | 7.6 | 4.4 | 13.5 | 53.7 | 97.7 | 112.1 | 108.4 | 155.2 | 433.4 | 86.7 | 400.1 | 113.8 | 120.7 | 48.0 | 58.5 | 365.1 |
| **1997** | 4.4 | 9.6 | 14.9 | 26.4 | 96.2 | 151.1 | 144.5 | 116.2 | 146.0 | 380.0 | 73.4 | 333.5 | 94.2 | 99.8 | 39.6 | 349.1 |
| **1998** | 3.7 | 5.6 | 32.3 | 28.8 | 46.8 | 146.4 | 190.2 | 150.3 | 105.7 | 123.6 | 310.3 | 59.0 | 266.1 | 75.0 | 79.2 | 308.5 |
| **1999** | 3.6 | 4.7 | 18.8 | 63.0 | 51.5 | 72.4 | 189.1 | 204.8 | 142.4 | 93.4 | 105.6 | 261.0 | 49.3 | 222.0 | 62.4 | 322.4 |
| **2000** | 9.2 | 4.6 | 15.9 | 37.3 | 115.6 | 82.1 | 95.9 | 207.5 | 197.1 | 127.7 | 81.0 | 90.0 | 221.2 | 41.7 | 187.2 | 324.6 |
| **2001** | 3.8 | 11.7 | 15.6 | 31.6 | 68.4 | 183.4 | 107.9 | 104.2 | 197.6 | 174.8 | 109.4 | 68.3 | 75.5 | 185.0 | 34.8 | 426.8 |
| **2002** | 3.2 | 4.9 | 39.8 | 30.8 | 57.5 | 107.8 | 241.4 | 118.3 | 100.5 | 177.8 | 152.1 | 93.7 | 58.1 | 64.1 | 156.7 | 390.8 |
| **2003** | 4.1 | 4.0 | 16.6 | 79.0 | 56.4 | 91.2 | 142.0 | 263.7 | 113.5 | 89.9 | 153.8 | 129.5 | 79.3 | 49.1 | 54.0 | 461.0 |
| **2004** | 5.6 | 5.1 | 13.8 | 32.8 | 143.8 | 88.9 | 119.8 | 155.1 | 253.4 | 101.7 | 77.9 | 131.2 | 109.8 | 67.1 | 41.4 | 434.3 |
| **2005** | 3.6 | 7.1 | 17.5 | 27.3 | 59.7 | 226.9 | 117.0 | 131.3 | 149.6 | 227.9 | 88.4 | 66.7 | 111.6 | 93.2 | 56.7 | 402.5 |
| **2006** | 5.4 | 4.6 | 24.2 | 34.5 | 49.2 | 93.3 | 295.0 | 126.5 | 124.7 | 132.4 | 194.9 | 74.4 | 55.8 | 93.1 | 77.5 | 382.2 |
| **2007** | 5.6 | 6.8 | 15.5 | 46.1 | 60.3 | 75.3 | 120.0 | 317.8 | 120.1 | 110.5 | 113.5 | 164.4 | 62.4 | 46.7 | 77.7 | 383.6 |
| **2008** | 11.3 | 7.0 | 23.2 | 30.3 | 82.3 | 92.4 | 95.7 | 126.8 | 295.1 | 104.0 | 92.5 | 93.5 | 134.6 | 51.0 | 38.0 | 375.7 |
| **2009** | 4.7 | 14.3 | 23.9 | 45.1 | 53.2 | 123.1 | 114.3 | 98.4 | 114.7 | 248.9 | 84.8 | 74.2 | 74.6 | 107.2 | 40.5 | 328.4 |
| **2010** | 7.1 | 5.9 | 48.8 | 47.1 | 80.5 | 81.0 | 155.3 | 120.2 | 91.1 | 99.1 | 207.9 | 69.7 | 60.7 | 60.8 | 87.1 | 300.0 |
| **2011** | 10.7 | 9.0 | 20.2 | 96.0 | 84.7 | 123.9 | 102.6 | 162.5 | 110.2 | 77.9 | 81.8 | 169.0 | 56.3 | 48.9 | 48.9 | 311.1 |

Table 4.20. Model estimates of yellowfin sole age 5 recruitment (millions) from the 2010 and 2011 stock assessments. Average from the 2011 assessment is 1,487 million.

| Year class | 2011 Assessment | 2010 Assessment |
|---|---|---|
| **1964** | 754 | 721 |
| **1965** | 727 | 714 |
| **1966** | 1,509 | 1,470 |
| **1967** | 2,248 | 2,224 |
| **1968** | 2,245 | 2,253 |
| **1969** | 2,935 | 2,948 |
| **1970** | 3,234 | 3,256 |
| **1971** | 2,532 | 2,546 |
| **1972** | 1,756 | 1,764 |
| **1973** | 2,365 | 2,369 |
| **1974** | 2,776 | 2,781 |
| **1975** | 1,828 | 1,825 |
| **1976** | 2,296 | 2,285 |
| **1977** | 1,499 | 1,501 |
| **1978** | 957 | 962 |
| **1979** | 1,849 | 1,859 |
| **1980** | 1,368 | 1,375 |
| **1981** | 3,938 | 3,957 |
| **1982** | 726 | 732 |
| **1983** | 3,224 | 3,251 |
| **1984** | 1,107 | 1,118 |
| **1985** | 846 | 853 |
| **1986** | 1,142 | 1,153 |
| **1987** | 1,545 | 1,563 |
| **1988** | 1,522 | 1,537 |
| **1989** | 749 | 757 |
| **1990** | 826 | 837 |
| **1991** | 1,806 | 1,839 |
| **1992** | 1,049 | 1,060 |
| **1993** | 880 | 901 |
| **1994** | 858 | 880 |
| **1995** | 2,194 | 2,313 |
| **1996** | 914 | 949 |
| **1997** | 761 | 784 |
| **1998** | 967 | 1,016 |
| **1999** | 1,337 | 1,455 |
| **2000** | 869 | 942 |
| **2001** | 1,288 | 1,331 |
| **2002** | 1,328 | 1,431 |
| **2003** | 2,694 | 2,790 |
| **2004** | 1,116 | 1,226 |

Table 4.21—Selected parameter estimates and their standard deviation from the preferred stock assessment model.

| | parameter | value | std dev | | parameter | value | std dev |
|---|---|---|---|---|---|---|---|
| | alpha (q-temp model) | -0.14 | 0.04 | 1972 | total biomass | 783430 | 23154 |
| | beta (q-temp model) | 0.09 | 0.02 | 1973 | total biomass | 964510 | 27693 |
| | mean_log_rec | 0.82 | 0.10 | 1974 | total biomass | 1146800 | 32911 |
| | sel_slope_fsh (females) | 1.15 | 0.08 | 1975 | total biomass | 1408400 | 38681 |
| | sel50_fsh (females) | 8.84 | 0.26 | 1976 | total biomass | 1660500 | 44567 |
| | sel_slope_fsh_males | 1.45 | 0.11 | 1977 | total biomass | 1922900 | 50250 |
| | sel50_fsh_males | 7.84 | 0.24 | 1978 | total biomass | 2171000 | 55564 |
| | sel_slope_srv (females) | 1.61 | 0.10 | 1979 | total biomass | 2310700 | 60121 |
| | sel50_srv (females) | 5.10 | 0.07 | 1980 | total biomass | 2470400 | 64270 |
| | sel_slope_srv_males | -0.04 | 0.08 | 1981 | total biomass | 2616500 | 67808 |
| | sel50_srv_males | 0.02 | 0.02 | 1982 | total biomass | 2740700 | 70948 |
| | F40 | 0.11 | 0.03 | 1983 | total biomass | 2830600 | 73483 |
| | F35 | 0.14 | 0.04 | 1984 | total biomass | 2890700 | 75633 |
| | F30 | 0.17 | 0.05 | 1985 | total biomass | 2874700 | 77207 |
| | Ricker SR logalpha | -4.17 | 0.56 | 1986 | total biomass | 2789800 | 78570 |
| | Ricker SR logbeta | -6.07 | 0.33 | 1987 | total biomass | 2719300 | 79862 |
| | Fmsy | 0.21 | 0.12 | 1988 | total biomass | 2693500 | 81516 |
| | log (Fmsy) | -1.57 | 0.57 | 1989 | total biomass | 2609700 | 82617 |
| | ABC_biomass 2010 | 1950400 | 145220 | 1990 | total biomass | 2597400 | 84005 |
| | ABC_biomass 2011 | 1992400 | 174980 | 1991 | total biomass | 2627800 | 84836 |
| | msy | 328430 | 118990 | 1992 | total biomass | 2627500 | 85305 |
| | Bmsy | 363380 | 68644 | 1993 | total biomass | 2554700 | 85575 |
| 1954 | total biomass | 1920500 | 108960 | 1994 | total biomass | 2510300 | 85458 |
| 1955 | total biomass | 1894200 | 97024 | 1995 | total biomass | 2419400 | 85072 |
| 1956 | total biomass | 1857400 | 85502 | 1996 | total biomass | 2352400 | 85110 |
| 1957 | total biomass | 1834900 | 74940 | 1997 | total biomass | 2276700 | 85166 |
| 1958 | total biomass | 1837900 | 66072 | 1998 | total biomass | 2144800 | 84872 |
| 1959 | total biomass | 1842600 | 58714 | 1999 | total biomass | 2094800 | 85184 |
| 1960 | total biomass | 1727600 | 51989 | 2000 | total biomass | 2102100 | 86554 |
| 1961 | total biomass | 1383900 | 41344 | 2001 | total biomass | 2092600 | 88072 |
| 1962 | total biomass | 1001800 | 23888 | 2002 | total biomass | 2089000 | 89084 |
| 1963 | total biomass | 734590 | 14503 | 2003 | total biomass | 2084300 | 90664 |
| 1964 | total biomass | 775950 | 14861 | 2004 | total biomass | 2084600 | 92585 |
| 1965 | total biomass | 782490 | 15388 | 2005 | total biomass | 2086400 | 94613 |
| 1966 | total biomass | 846950 | 16617 | 2006 | total biomass | 2064900 | 97077 |
| 1967 | total biomass | 843140 | 17216 | 2007 | total biomass | 2063300 | 101390 |
| 1968 | total biomass | 769510 | 16721 | 2008 | total biomass | 2061400 | 107970 |
| 1969 | total biomass | 792890 | 17859 | 2009 | total biomass | 2036400 | 116380 |
| 1970 | total biomass | 735760 | 18266 | 2010 | total biomass | 2070400 | 128040 |
| 1971 | total biomass | 756980 | 20276 | 2011 | total biomass | 2110000 | 144500 |

Table 4.22. 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.

**Scenarios 1 and 2**
**Maximum Tier 1 ABC harvest permissible**

| Year | Female spawning biomass | catch | F |
|---|---|---|---|
| 2011 | 572.962 | 117.115 | 0.09 |
| 2012 | 562.863 | 142.655 | 0.11 |
| 2013 | 584.901 | 151.899 | 0.11 |
| 2014 | 595.141 | 152.103 | 0.11 |
| 2015 | 610.917 | 157.250 | 0.11 |
| 2016 | 629.224 | 161.133 | 0.11 |
| 2017 | 638.302 | 160.030 | 0.11 |
| 2018 | 638.93 | 156.207 | 0.11 |
| 2019 | 629.807 | 152.354 | 0.11 |
| 2020 | 614.027 | 149.421 | 0.11 |
| 2021 | 610.327 | 147.667 | 0.11 |
| 2022 | 598.108 | 145.568 | 0.11 |
| 2023 | 588.336 | 143.434 | 0.11 |
| 2024 | 586.499 | 141.857 | 0.11 |

**Scenario 3**
**1/2 Maximum Tier 1 ABC harvest permissible**

| Year | Female spawning biomass | catch | F |
|---|---|---|---|
| 2011 | 572.962 | 117.115 | 0.09 |
| 2012 | 572.879 | 71.327 | 0.05 |
| 2013 | 625.340 | 79.305 | 0.05 |
| 2014 | 665.932 | 82.650 | 0.05 |
| 2015 | 711.628 | 88.390 | 0.05 |
| 2016 | 758.279 | 93.190 | 0.05 |
| 2017 | 793.949 | 95.310 | 0.05 |
| 2018 | 818.401 | 95.537 | 0.05 |
| 2019 | 828.490 | 95.301 | 0.05 |
| 2020 | 826.669 | 95.243 | 0.05 |
| 2021 | 840.292 | 95.660 | 0.05 |
| 2022 | 837.627 | 95.545 | 0.05 |
| 2023 | 835.446 | 95.582 | 0.05 |
| 2024 | 842.584 | 95.743 | 0.05 |

**Scenario 4**
**Harvest at average F over the past 5 years**

| Year | Female spawning biomass | catch | F |
|---|---|---|---|
| 2011 | 572.962 | 117.115 | 0.09 |
| 2012 | 566.069 | 120.063 | 0.09 |
| 2013 | 598.125 | 125.946 | 0.09 |
| 2014 | 619.028 | 128.013 | 0.09 |
| 2015 | 645.031 | 134.025 | 0.09 |
| 2016 | 672.785 | 138.788 | 0.09 |
| 2017 | 690.488 | 139.323 | 0.09 |
| 2018 | 698.617 | 137.302 | 0.09 |
| 2019 | 695.268 | 134.979 | 0.09 |
| 2020 | 683.399 | 133.237 | 0.09 |
| 2021 | 684.553 | 132.383 | 0.09 |
| 2022 | 674.650 | 131.073 | 0.09 |
| 2023 | 666.497 | 130.147 | 0.09 |
| 2024 | 666.589 | 129.553 | 0.09 |

**Scenario 5**
**No fishing**

| Year | Female spawning biomass | catch | F |
|---|---|---|---|
| 2011 | 572.962 | 117.12 | 0.09 |
| 2012 | 582.600 | 0 | 0 |
| 2013 | 666.606 | 0 | 0 |
| 2014 | 741.737 | 0 | 0 |
| 2015 | 824.574 | 0 | 0 |
| 2016 | 909.363 | 0 | 0 |
| 2017 | 983.689 | 0 | 0 |
| 2018 | 1045.700 | 0 | 0 |
| 2019 | 1089.700 | 0 | 0 |
| 2020 | 1116.570 | 0 | 0 |
| 2021 | 1165.550 | 0 | 0 |
| 2022 | 1188.160 | 0 | 0 |
| 2023 | 1208.960 | 0 | 0 |
| 2024 | 1241.340 | 0 | 0 |

Table 4.22—continued.

| Scenario 6<br>Determination of whether yellowfin sole are currently overfished | | B35=480.000 | | Scenario 7<br>Determination of whether the stock is approaching an overfished condition | | B35=480.000 | |
|---|---|---|---|---|---|---|---|
| Year | Female spawning biomass | catch | F | Year | Female spawning biomass | catch | F |
| 2011 | 572.962 | 117.115 | 0.09 | 2011 | 572.962 | 117.115 | 0.09 |
| 2012 | 559.021 | 169.437 | 0.13 | 2012 | 562.863 | 142.655 | 0.11 |
| 2013 | 569.952 | 177.316 | 0.13 | 2013 | 584.902 | 151.899 | 0.11 |
| 2014 | 569.894 | 174.879 | 0.13 | 2014 | 591.091 | 180.661 | 0.13 |
| 2015 | 576.186 | 178.537 | 0.13 | 2015 | 595.217 | 183.530 | 0.13 |
| 2016 | 586.068 | 181.069 | 0.13 | 2016 | 602.536 | 185.192 | 0.13 |
| 2017 | 587.726 | 177.944 | 0.13 | 2017 | 601.612 | 181.325 | 0.13 |
| 2018 | 582.158 | 172.094 | 0.13 | 2018 | 593.584 | 174.804 | 0.13 |
| 2019 | 568.571 | 166.611 | 0.13 | 2019 | 577.810 | 168.775 | 0.13 |
| 2020 | 550.224 | 161.678 | 0.13 | 2020 | 557.501 | 164.056 | 0.13 |
| 2021 | 543.707 | 156.878 | 0.13 | 2021 | 549.422 | 159.094 | 0.13 |
| 2022 | 531.950 | 151.304 | 0.13 | 2022 | 536.171 | 153.017 | 0.13 |
| 2023 | 523.981 | 147.678 | 0.13 | 2023 | 527.028 | 148.902 | 0.13 |
| 2024 | 523.522 | 146.593 | 0.12 | 2024 | 525.647 | 147.393 | 0.12 |

Table 4-23. Catch and bycatch (t) of other BSAI target species in the yellowfin sole directed fisheryfrom 1992-2010 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 |
|---|---|---|---|---|---|---|---|---|---|
| Pollock | 13,100 | 15,253 | 33,200 | 27,041 | 22,254 | 24,100 | 15,335 | 8,701 | 13,425 |
| Arrowtooth Flounder | 366 | 1,017 | 1,595 | 346 | 820 | 386 | 2,382 | 1,627 | 1,998 |
| Pacific Cod | 8,700 | 8,723 | 16,415 | 13,181 | 8,684 | 12,825 | 10,224 | 4,380 | 5,192 |
| Groundfish, General | 7,990 | 3,847 | 3,983 | 2,904 | 2,565 | 4,755 | 3,580 | 2,524 | 3,541 |
| Rock Sole | 14,646 | 7,301 | 8,097 | 7,486 | 12,903 | 16,693 | 9,825 | 10,773 | 7,345 |
| Flathead Sole | | 1,198 | 2,491 | 3,929 | 3,166 | 3,896 | 5,328 | 2,303 | 2,644 |
| Sablefish | 0 | 0 | | 0 | 0 | 0 | 0 | 4 | 0 |
| Atka Mackerel | 1 | 0 | | | 0 | 0 | 1 | 33 | 0 |
| Pacific ocean Perch | 0 | 5 | | 0 | | 0 | 1 | 12 | 1 |
| Rex Sole | | | 1 | 1 | | 0 | 20 | 36 | 1 |
| Flounder, General | 16,826 | 6,615 | 7,080 | 11,092 | 10,372 | 10,743 | 6,362 | 8,812 | 7,913 |
| Squid | 0 | | 5 | 0 | 11 | 0 | 2 | 1 | 0 |
| Dover Sole | | | 35 | | | | | | |
| Thornyhead | | | | | 0 | | 1 | | |
| Shortraker/Rougheye | 0 | | | | 1 | 0 | 1 | 15 | |
| Butter Sole | | | 0 | | | 3 | 3 | | 2 |
| Eulachon smelt | | | | | | | | 0 | |
| Starry Flounder | | 227 | 106 | 16 | 37 | 124 | 35 | 48 | 71 |
| Northern Rockfish | | | | | | 1 | 0 | 0 | |
| Dusky Rockfish | | | | | | | | 0 | |
| Yellowfin Sole | 136,804 | 91,931 | 126,163 | 108,493 | 112,818 | 169,661 | 90,062 | 62,941 | 71,479 |
| English Sole | | 1 | | | | | | | |
| Unsp.demersal rockfish | | | | | | 12 | 0 | | |
| Greenland Turbot | 1 | 5 | 5 | 67 | 8 | 4 | 103 | 70 | 24 |
| Alaska Plaice | | 1,579 | 2,709 | 1,130 | 553 | 6,351 | 2,758 | 2,530 | 2,299 |
| Sculpin, General | | | | | | | | 215 | 97 |
| Skate, General | | | | | | | | 26 | 4 |
| Sharpchin Rockfish | | | | | | | | 1 | |
| Bocaccio | 0 | | | | | | | | |
| Rockfish, General | 0 | | 0 | 3 | 23 | 0 | 1 | 3 | 4 |
| Octopus | | | | | | | | 0 | |
| Smelt, general | | | | | | | | 0 | 0 |
| Chilipepper | | 1 | | | | | | | |
| Eels | | | | | | | | 1 | 1 |
| Lingcod | | | | | | | | | |
| Jellyfish (unspecified) | | | | | | | | | 127 |
| Snails | | | | | | | | 12 | 4 |
| Sea cucumber | | | | | | | | 0 | 56 |
| Korean horsehair crab | | | | | | | | 0 | 0 |
| Greenling, General | | | | | | | | | 0 |

Table 4-23. (continued).

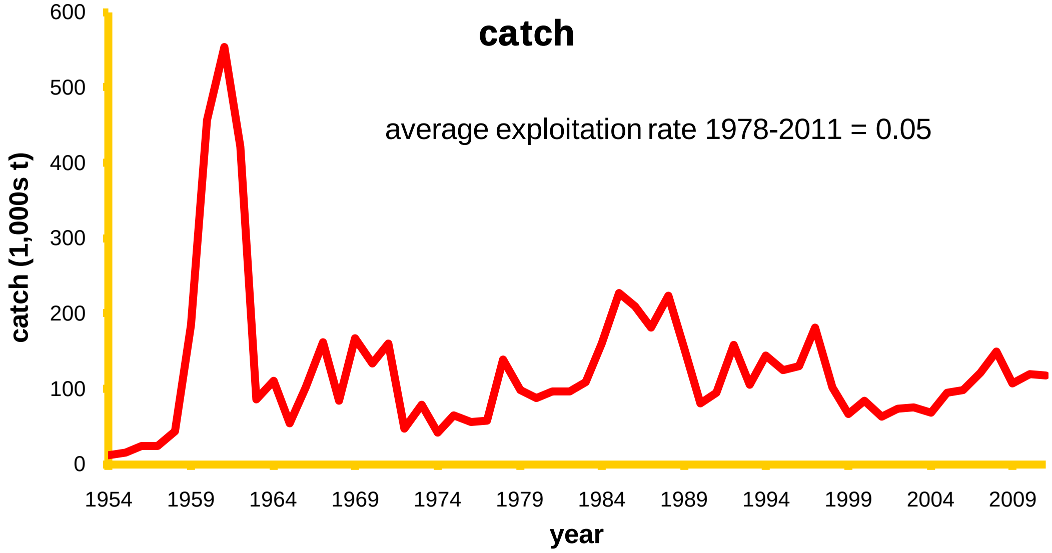
| Species | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pollock | 16,502 | 14,489 | 11,396 | 10,382 | 10,312 | 6,084 | 4,041 | 9,867 | 7,024 | 3,749 |
| Arrowtooth Flounder | 1,845 | 998 | 1,125 | 279 | 645 | 352 | 216 | 1,969 | 1,858 | 868 |
| Pacific Cod | 6,531 | 6,259 | 4,621 | 3,606 | 3,767 | 2,588 | 2,529 | 5,769 | 10,849 | 8,649 |
| Groundfish, General | 3,936 | 2,678 | 3,133 | 1,612 | 2,134 | 2,333 | 4003 | | | 3,048 |
| Rock Sole | 5,810 | 10,665 | 8,419 | 10,068 | 10,086 | 8,113 | 8,218 | 10,487 | 9,109 | 9,030 |
| Flathead Sole | 3,231 | 2,190 | 2,899 | 1,102 | 1,246 | 2,039 | 1,744 | 5,581 | 3,525 | 1,895 |
| Sablefish | 0 | | | | 1 | | | <1 | <1 | |
| Atka Mackerel | 0 | 0 | 17 | | 110 | 17 | | <1 | <1 | |
| Pacific ocean Perch | 1 | 1 | 11 | | 15 | | | <1 | <1 | |
| Rex Sole | 2 | 0 | | | | | | 2 | | |
| Flounder, General | 4,854 | 378 | 214 | 434 | 654 | 877 | 2,852 | 1,132 | | 981 |
| Squid | 0 | 0 | 1 | | | | | <1 | | |
| Dover Sole | | | | | | | | | | |
| Thornyhead | | | | | | | | | | |
| Shortraker/Rougheye | 1 | | | | | | | | | |
| Butter Sole | | 7 | | | | | | | | |
| Eulachon smelt | | | | | | | | | | |
| Starry Flounder | 82 | 133 | | | | | | | | |
| Northern Rockfish | | 1 | | | 3 | | | | | |
| Dusky Rockfish | | 0 | | | | | | | | |
| Yellowfin Sole | 54,722 | 66,178 | 68,954 | 65,604 | 82,420 | 84,178 | 108,254 | 131,000 | 98,194 | 90,008 |
| English Sole | | 1 | | | | | | | | |
| Unsp.demersal rockfish | | | | | | | | | | |
| Greenland Turbot | 32 | 2 | | 1 | 7 | 8 | 1 | <1 | 4 | |
| Alaska Plaice | 1,905 | 10,396 | 365 | 5,891 | 8,707 | 14,043 | 16,389 | 13,519 | 10,748 | 10,749 |
| Sculpin, General | 12 | 1,226 | | | | | | 2,891 | 1,438 | |
| Skate, General | 21 | 1,042 | | | | | | 1,301 | 1,481 | |
| Sharpchin Rockfish | | | | | | | | | | |
| Bocaccio | | | | | | | | | | |
| Rockfish, General | 1 | | 1 | 3 | 1 | 1 | | <1 | | |
| Octopus | | | | | | | | | | |
| Smelt, general | 0 | | | | | | | | | |
| Chilipepper | | | | | | | | | | |
| Eels | 0 | 0 | | | | | | | | |
| Lingcod | 2 | | | | | | | | | |
| Jellyfish (unspecified) | 173 | 161 | | | | | | | | |
| Snails | 0 | 4 | | | | | | | | |
| Sea cucumber | | 0 | | | | | | | | |
| Korean horsehair crab | 0 | | | | | | | | | |
| Greenling, General | | | | | | | | | | |

Table 4-24. Estimated non-target species catch (t) in the yellowfin sole fishery, 2003-2011 (PSC not included).

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| Sea star | 1,939,624 | 1,865,768 | 1,606,948 | 1,308,482 | 1,456,620 | 1,830,467 | 684,451 | 792,404 | 948,347 |
| Benthic urochordata | 1,670,846 | 1,695,563 | 674,762 | 520,091 | 114,427 | 347,552 | 206,478 | 155,572 | 51,040 |
| Invertebrate unidentified | 556,495 | 625,561 | 418,512 | 177,181 | 40,009 | 70,401 | 30,667 | 25,884 | 42,423 |
| Scypho jellies | 111,900 | 299,034 | 115,550 | 46,785 | 42,346 | 146,153 | 223,104 | 152,416 | 276,545 |
| Snails | 118,257 | 191,064 | 69,769 | 141,517 | 95,876 | 139,760 | 58,362 | 57,682 | 39,658 |
| Misc fish | 95,745 | 91,469 | 66,164 | 42,470 | 70,971 | 66,421 | 48,927 | 29,274 | 36,395 |
| Hermit crab unidentified | 87,940 | 51,999 | 82,996 | 26,898 | 35,820 | 36,602 | 15,626 | 16,999 | 6,352 |
| Brittle star unidentified | 34,303 | 32,271 | 28,706 | 19,961 | 7,526 | 19,047 | 5,212 | 4,154 | 3,192 |
| Sponge unidentified | 11,434 | 6,807 | 12,205 | 3,118 | 405 | 6,717 | 69,498 | 16,623 | 10,065 |
| Misc crabs | 14,432 | 21,524 | 11,774 | 10,571 | 27,967 | 14,083 | 11,056 | 11,684 | 7,429 |
| Sea anemone unidentified | 6,087 | 6,202 | 2,581 | 4,896 | 8,791 | 24,834 | 25,573 | 20,551 | 13,719 |
| Eelpouts | 19,044 | 12,256 | 7,729 | 4,514 | 2,344 | 5,598 | 5,201 | 5,148 | 21,481 |
| Other osmerids | 4,258 | 4,292 | 497 | 634 | 35,770 | 9,833 | 849 | 2,830 | 2,066 |
| urchins dollars cucumbers | 2,254 | 315 | 2,549 | 845 | 3,477 | 4,897 | 7,548 | 1,282 | 807 |
| Corals Bryozoans | 240 | 46 | 1,232 | 9,378 | 162 | 8,309 | 313 | 504 | 475 |
| Bivalves | 1,543 | 1,113 | 1,327 | 343 | 448 | 1,483 | 1,301 | 1,825 | 757 |
| Capelin | 3 | 4,518 | 45 | 108 | 321 | 161 | 251 | 718 | 3,760 |
| Misc crustaceans | 14 | 186 | 225 | 2,325 | 1,402 | 719 | 1,335 | 935 | 521 |
| Eulachon | 12 | 278 | 33 | 115 | 5,075 | 22 | 89 | 136 | 405 |
| Pandalid shrimp | 216 | 920 | 115 | 772 | 101 | 305 | 494 | 745 | 2,097 |
| Greenlings | 646 | 753 | 283 | 703 | 474 | 183 | 24 | 53 | 49 |
| Stichaeidae | 72 | 32 | | 10 | 784 | 239 | 10 | 171 | 382 |
| Sea pens whips | 9 | 28 | 164 | 3 | 12 | 324 | 185 | 635 | 20 |
| Polychaete unidentified | 16 | 68 | 42 | 360 | 69 | 175 | 75 | 102 | 179 |
| Misc inverts (worms etc) | 20 | 123 | 25 | 50 | 46 | 152 | 171 | 105 | 144 |
| Birds | | | 254 | | | | 319 | 250 | |
| Pacific Sand lance | 9 | 167 | 97 | 33 | 17 | 37 | 15 | 35 | 395 |
| Grenadier | | | | | 339 | | 358 | | |
| Giant Grenadier | | | | | | | | | 236 |
| Gunnels | | | | | 1 | | | | |
| Surf smelt | | | | | | 1 | | | |

Table 4.25--Yellowfin sole TAC and ABC levels, 1980-2011

| 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 |
| 2008 | 225,000 | 248,000 |
| 2009 | 210,000 | 210,000 |
| 2010 | 219,000 | 219,000 |
| 2011 | 196,000 | 239,000 |



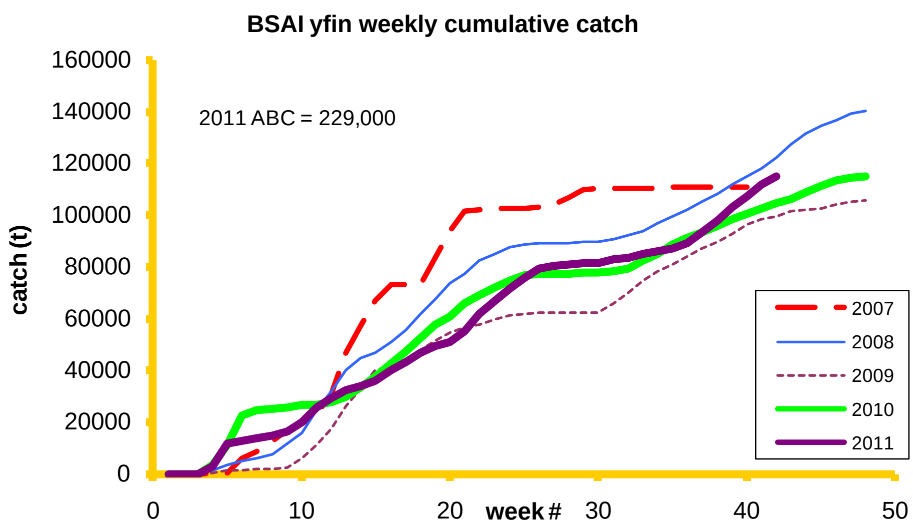




Figure 4.1—Yellowfin sole annual catch (1,000s t) in the Eastern Bering Sea from 1954-2011 (top panel) and catch by week from 2007 – September 2011 (bottom panel).

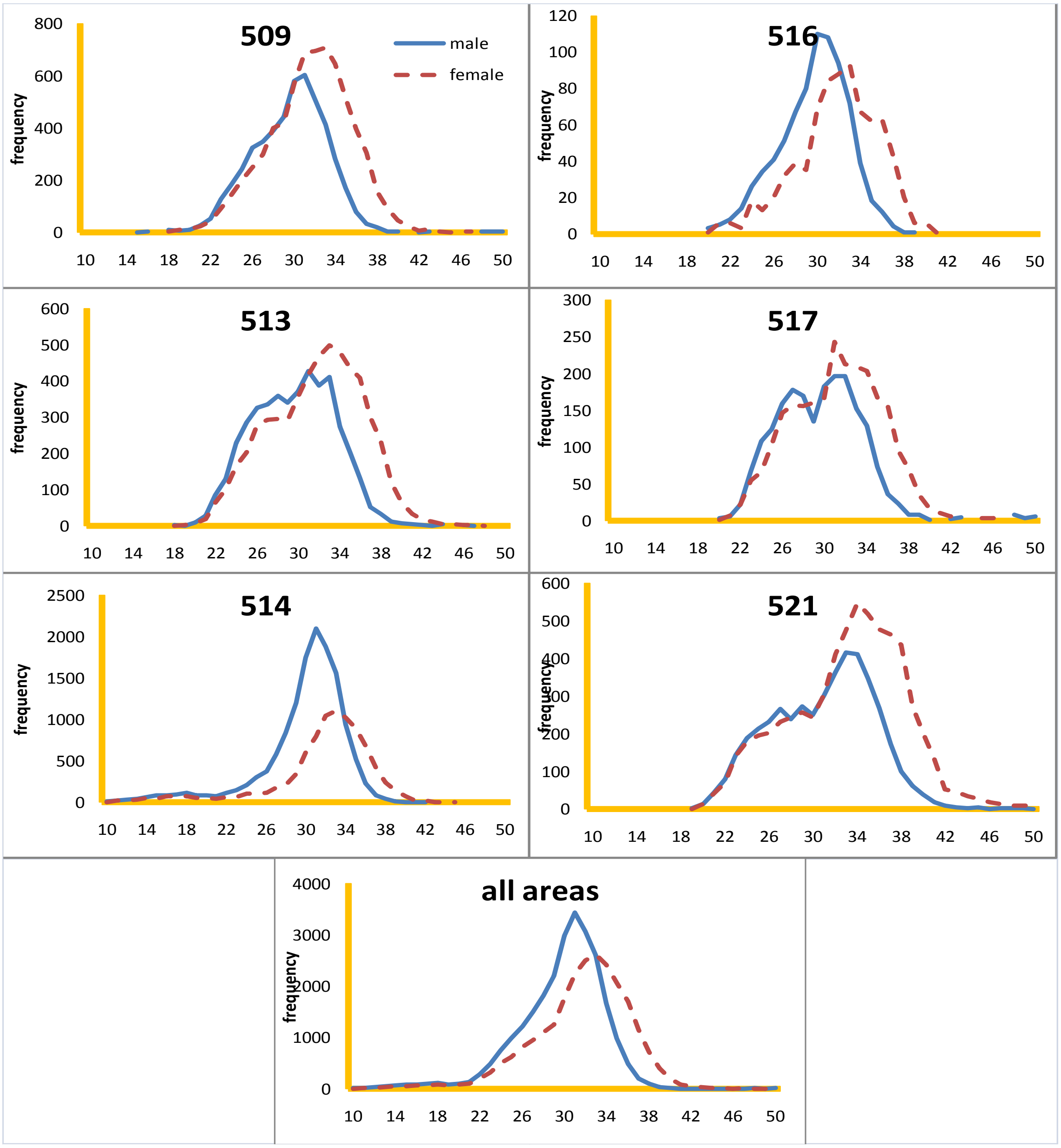
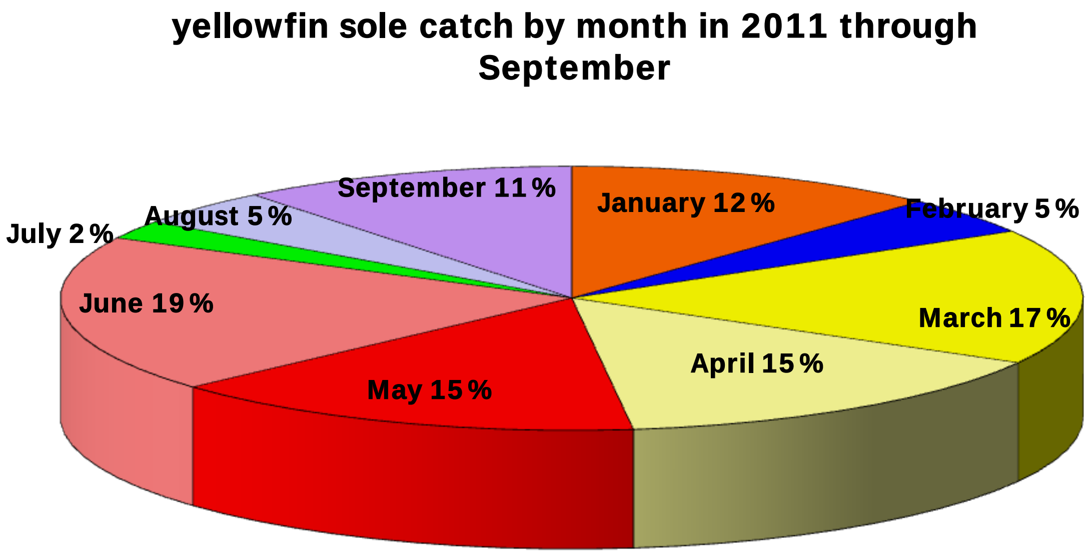



Figure 4.2--Size composition of the yellowfin sole catch in 2011 (through September), by subarea and total.



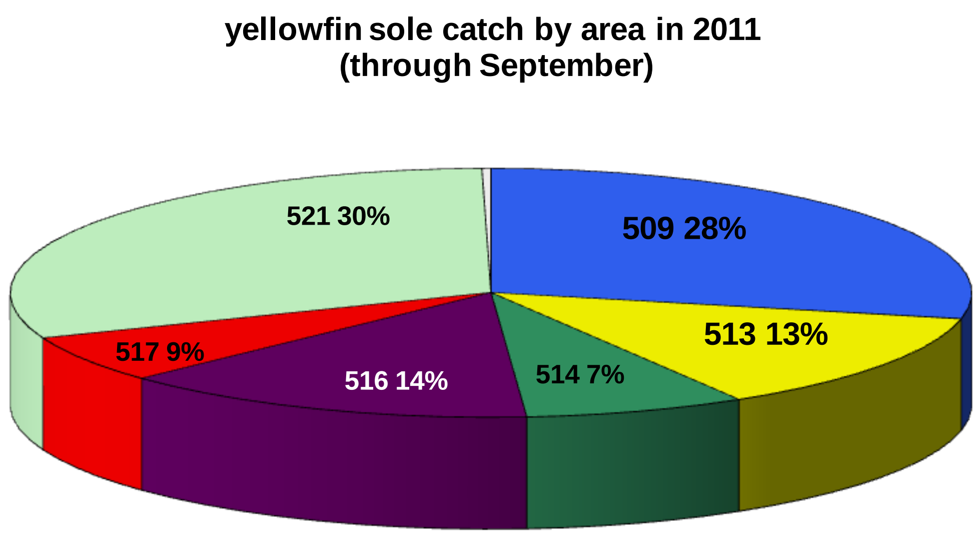
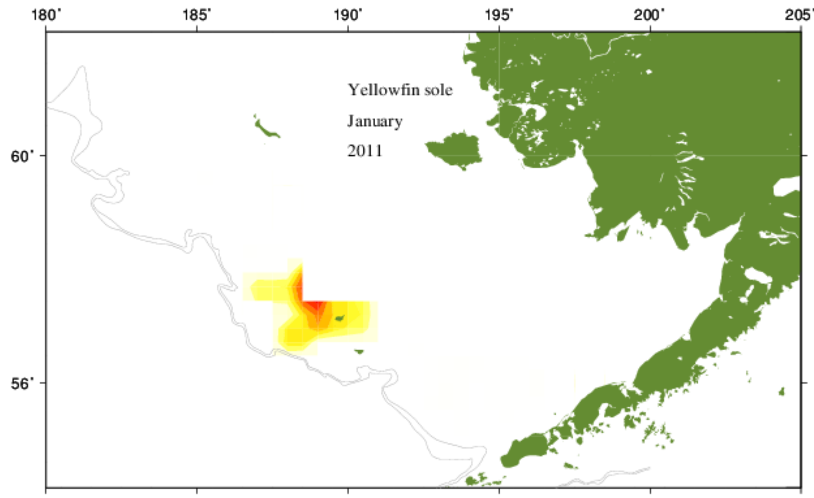




Figure 4.3 Yellowfin sole catch by month and area in the Eastern Bering Sea in 2011.



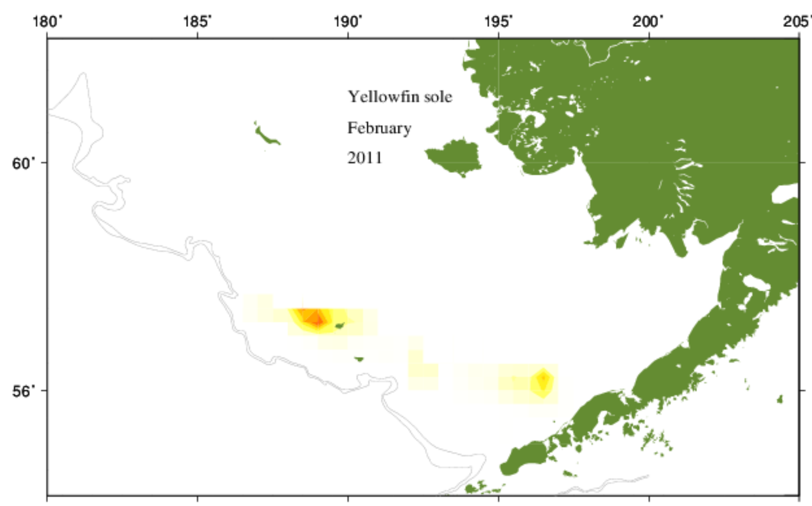
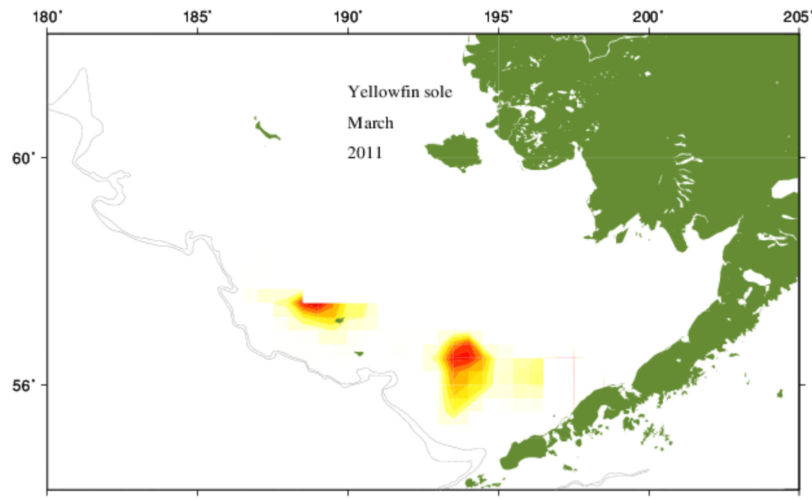




Figure 4.4—General fishery locations by month.



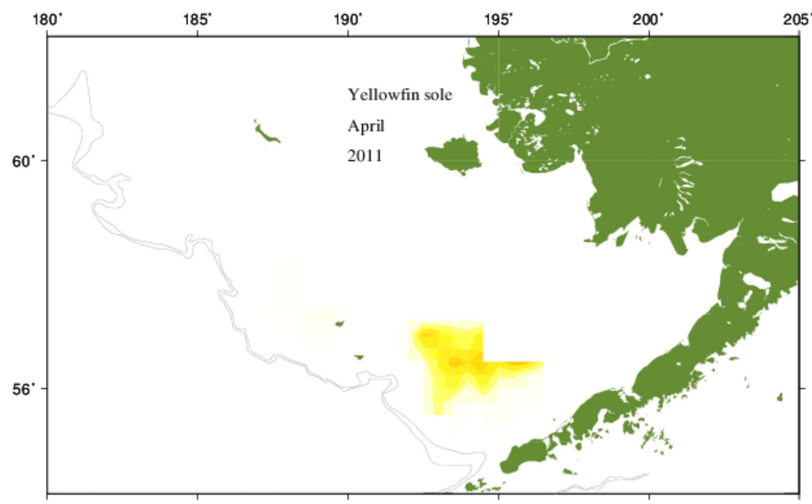
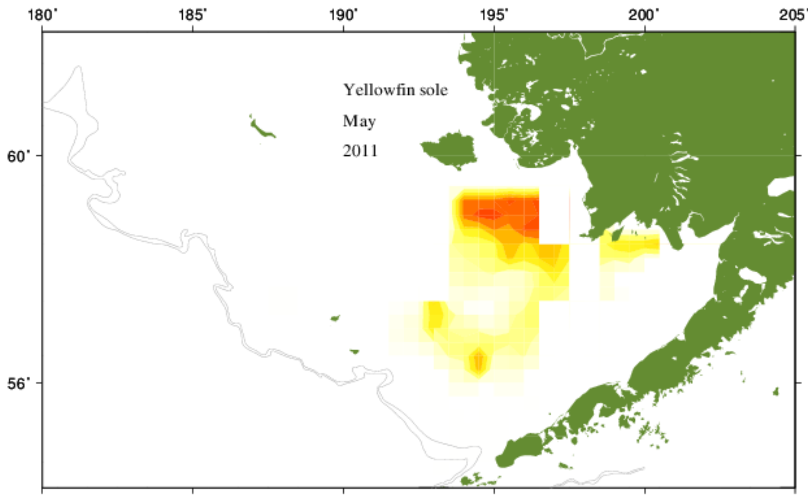




Figure 4.4—(continued).



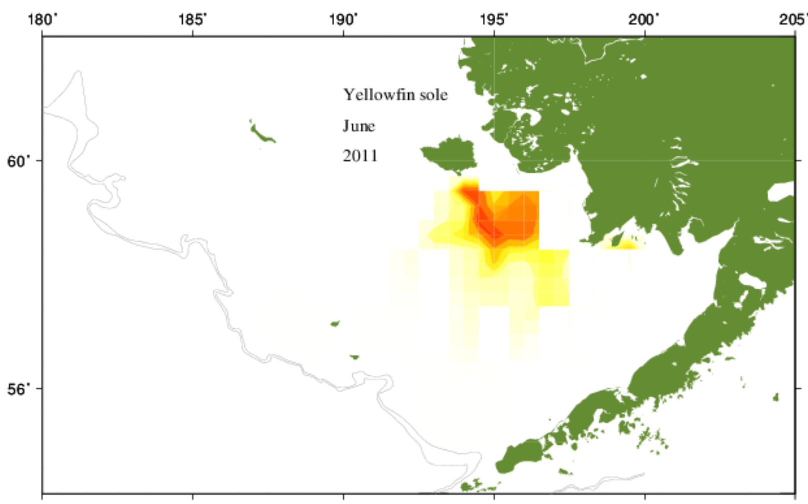
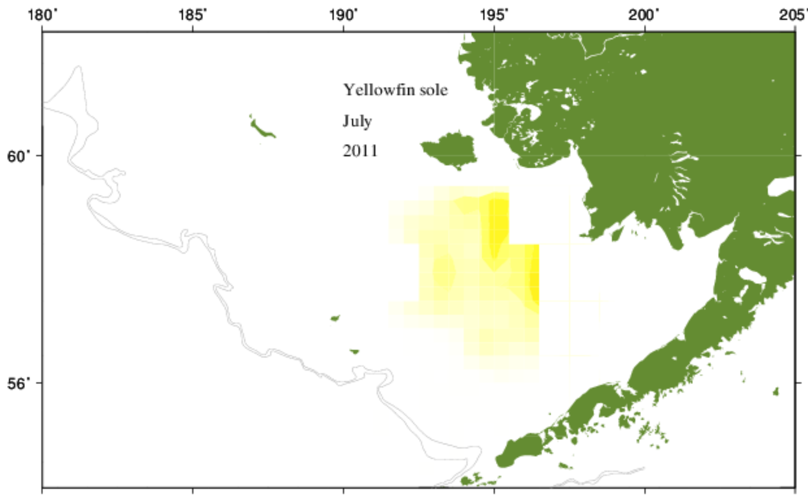




Figure 4.4—(continued).



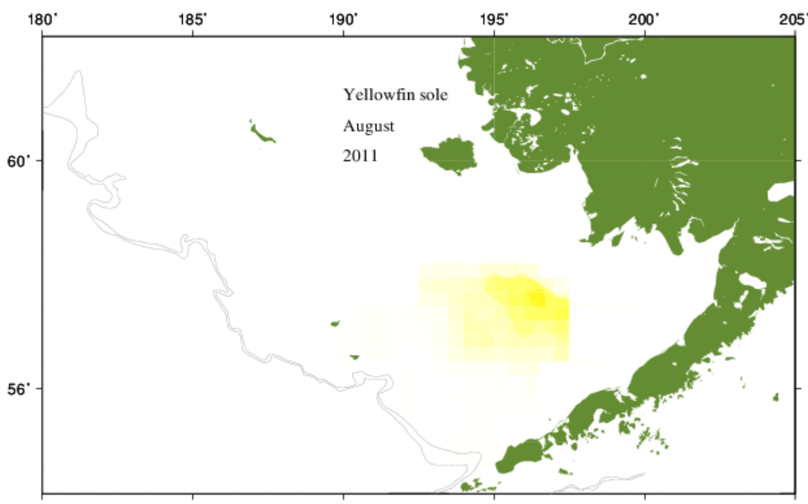




Figure 4.4—(continued).

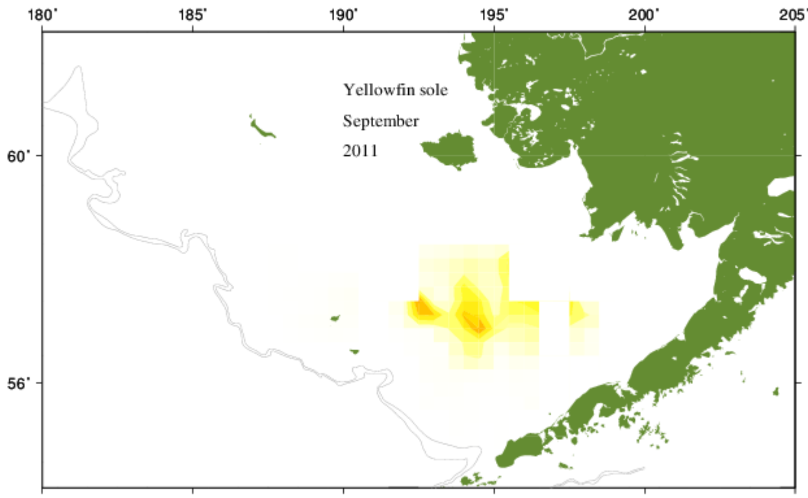



Figure 4.4— (continued).

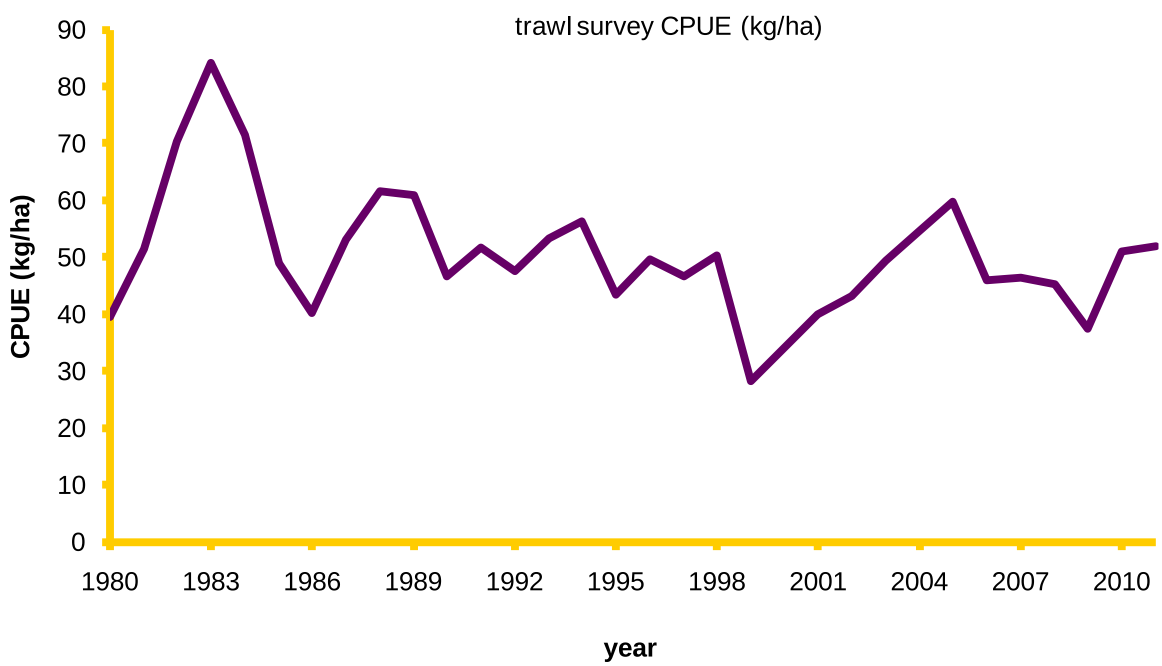



Figure 4.5.--Yellowfn sole CPUE (catch per unit effort in kg/ha) from the annual Bering Sea shelf trawl surveys, 1982-2011.

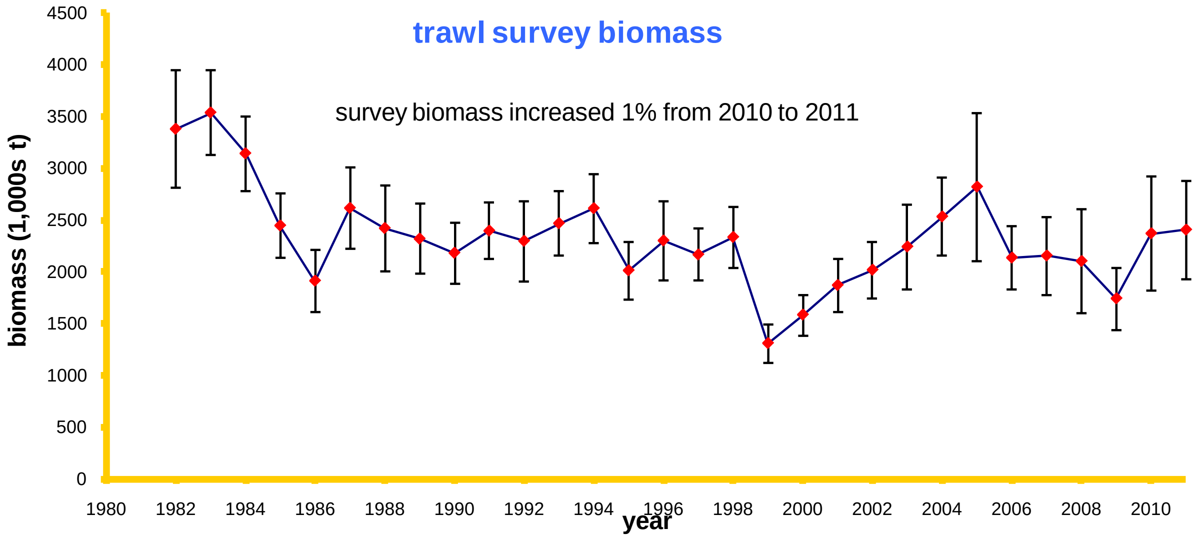



Figure 4.6.--Annual bottom trawl survey biomass point-estimates and 95% confidence intervals for yellowfin sole, 1982-2011.

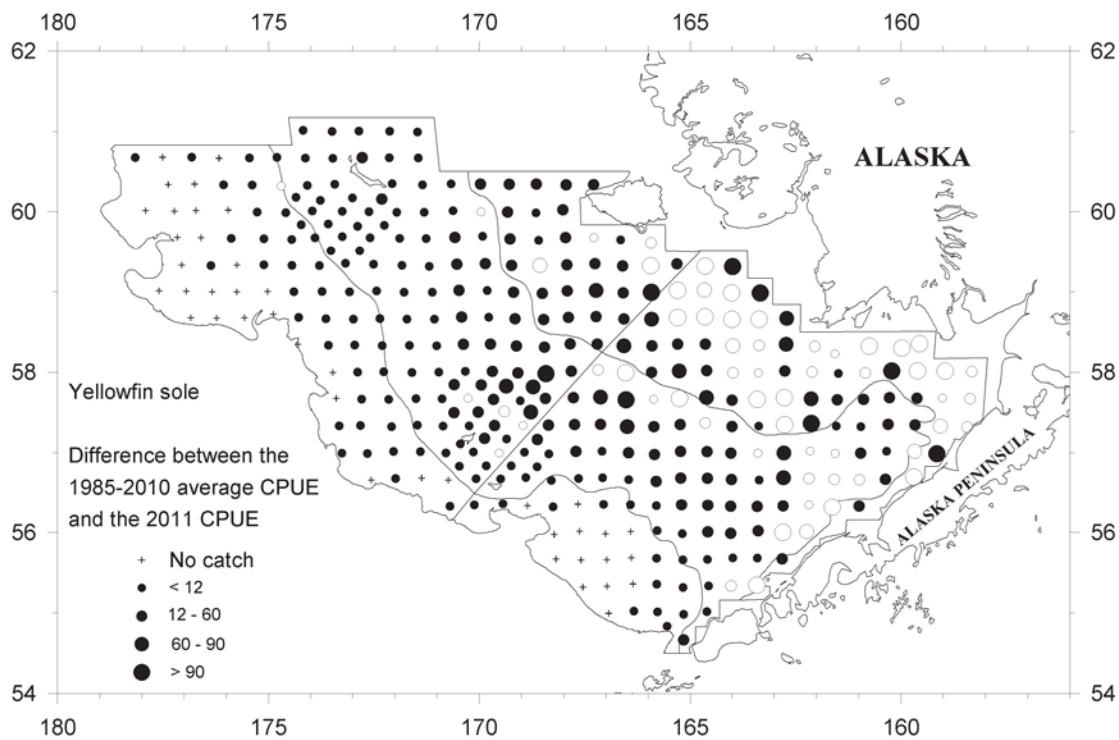



Figure 4.7.--Difference between the 1985-2010 average trawl survey CPUE for yellowfin sole and the 2011 survey CPUE. Open circles indicate that the magnitude of the catch was greater in 2011 than the long-term average, closed circles indicate the catch was greater in the long-term average than in 2011.

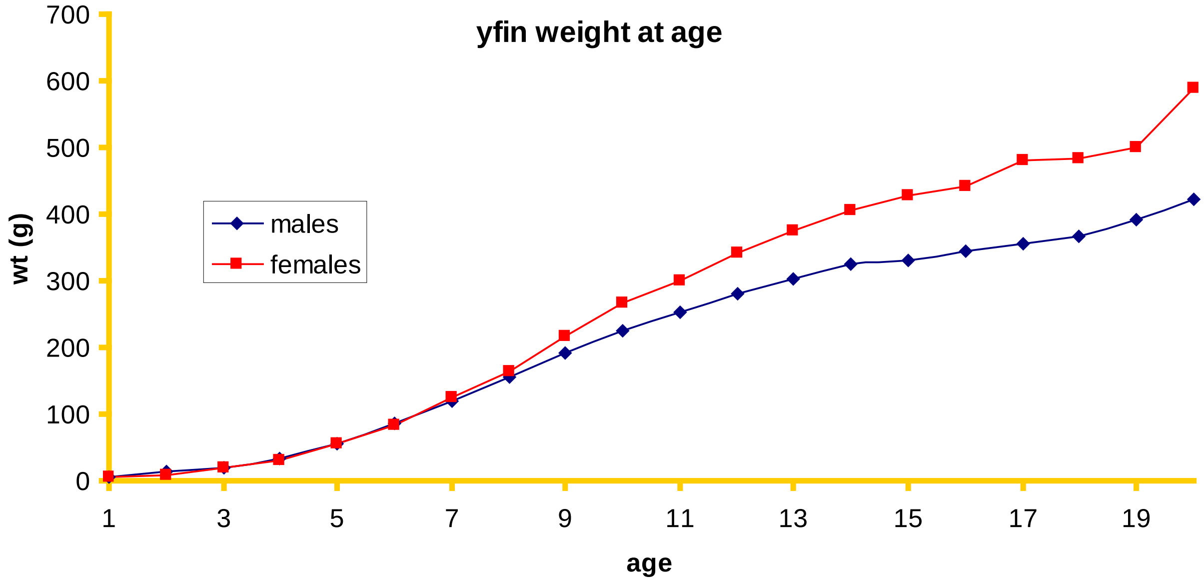



Figure 4.8--Estimates of yellowfin sole weight-at-age (g) from trawl survey observations.

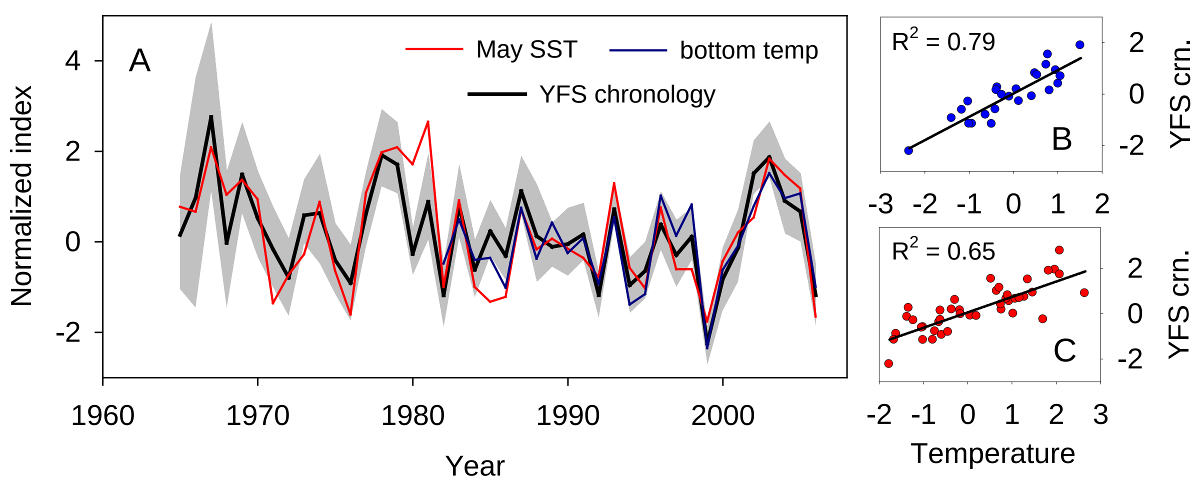



Figure 4.9--Master chronology for yellowfin sole and time series of mean summer bottom temperature and May sea surface temperature for the southeastern Bering Sea (Panel A). All data re normalized to a mean of 0 and standard deviation of 1. Correlations of chronologies with bottom temperature and sea surface temperature are shown in panels B and C, respectively. From Matta et al. 2010.

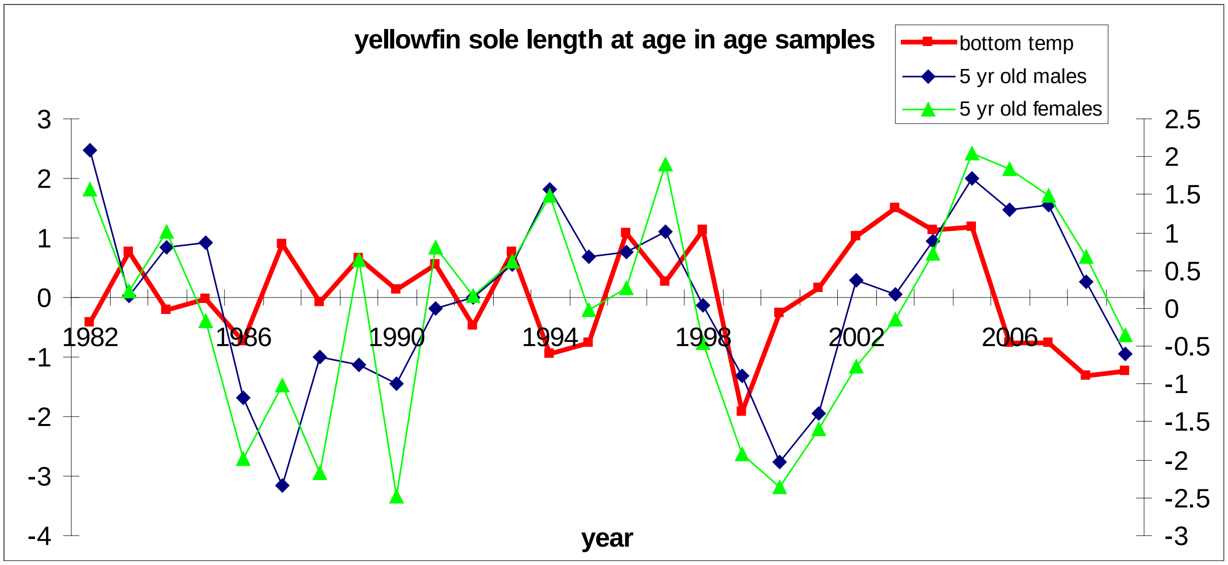



Figure 4.10—Yellowfin sole length-at-age anomalies, for males and females, and bottom temperature anomalies. Correspondence in these residuals is apparent with a 2-3 year lag effect from the mid-1990s to 2009. Late 1980s and early 1990s pattern may be a density-dependent response in growth from the large 1981 and 1983 year-classes.

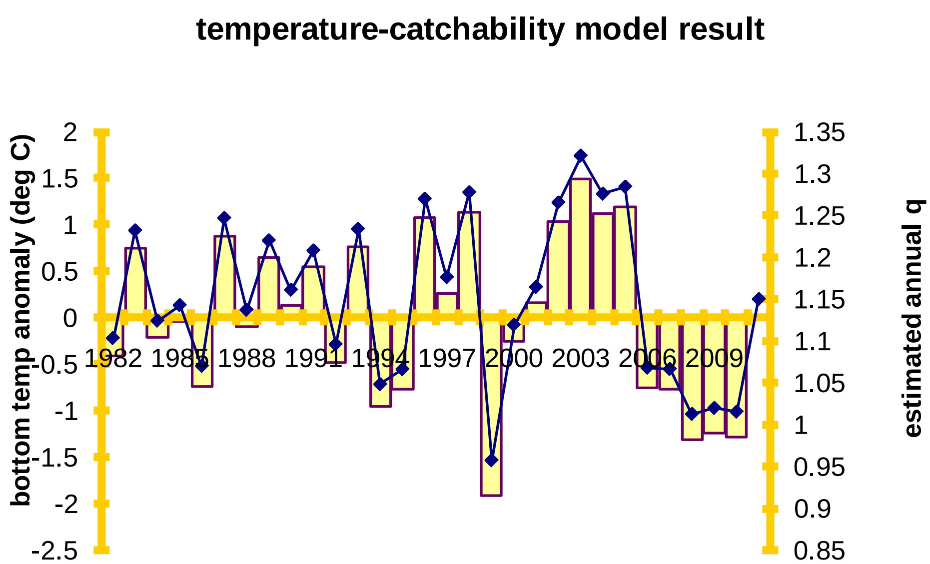



Figure 4.11.--Average bottom water temperature from stations less than or equal to 100 m in the Bering Sea trawl survey (bars) and the stock assessment model estimate of q for each year 1982-2011.

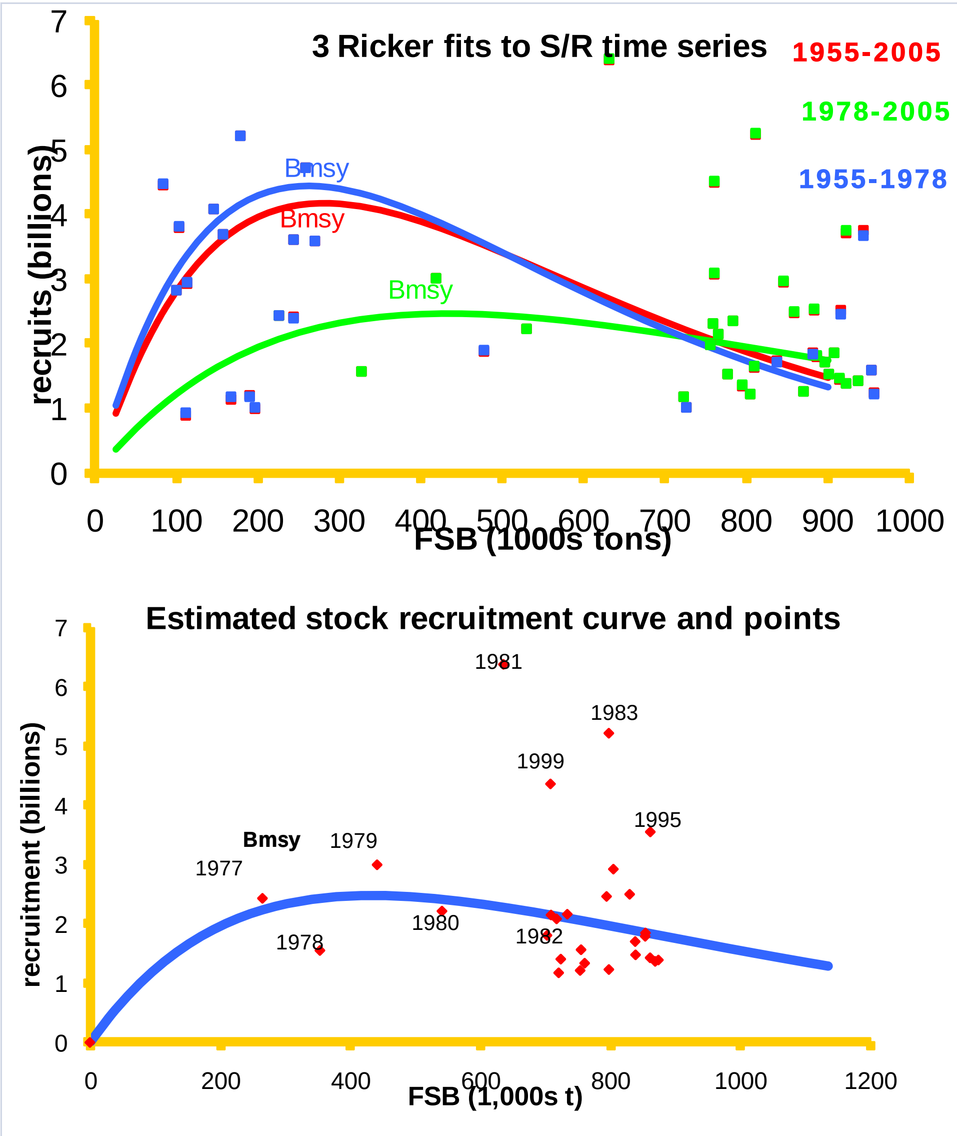



Figure 4.12--Fit of the Ricker (1958) stock recruitment model to three distinct stock recruitment time-series data sets (top panel), and the fit to the assessment preferred model (model B, lower panel).

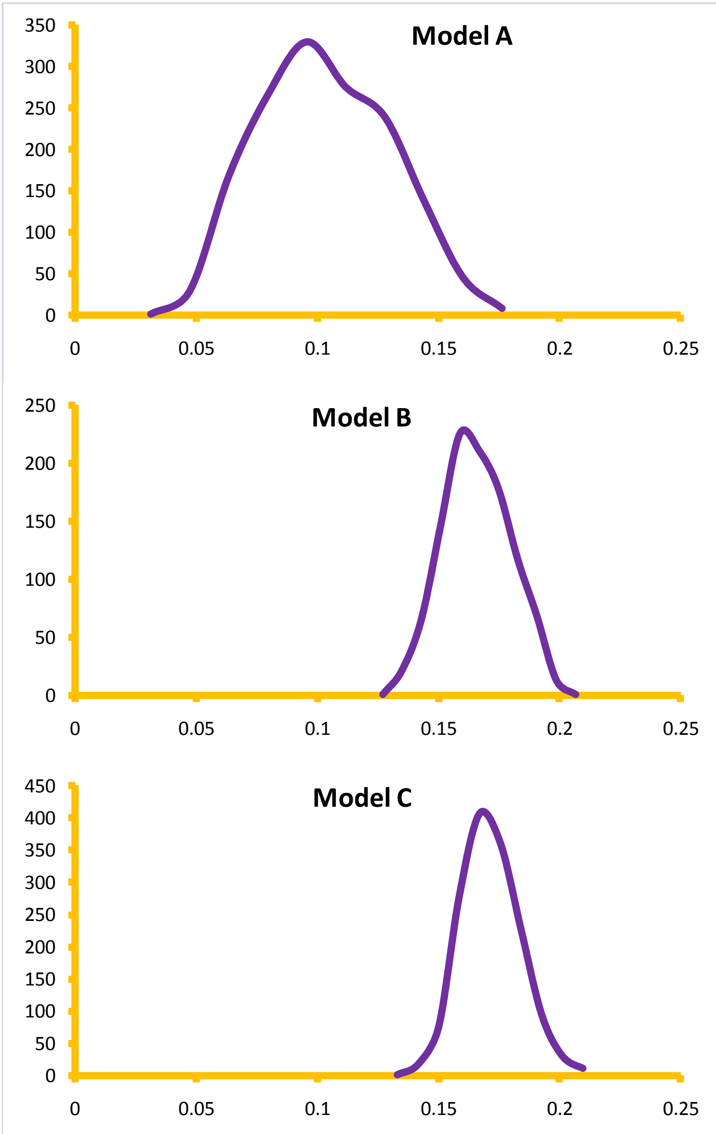



Figure 4.13--Posterior distributions of $F_{msy}$ (x-axis) for three models considered in the stock productivity analysis.

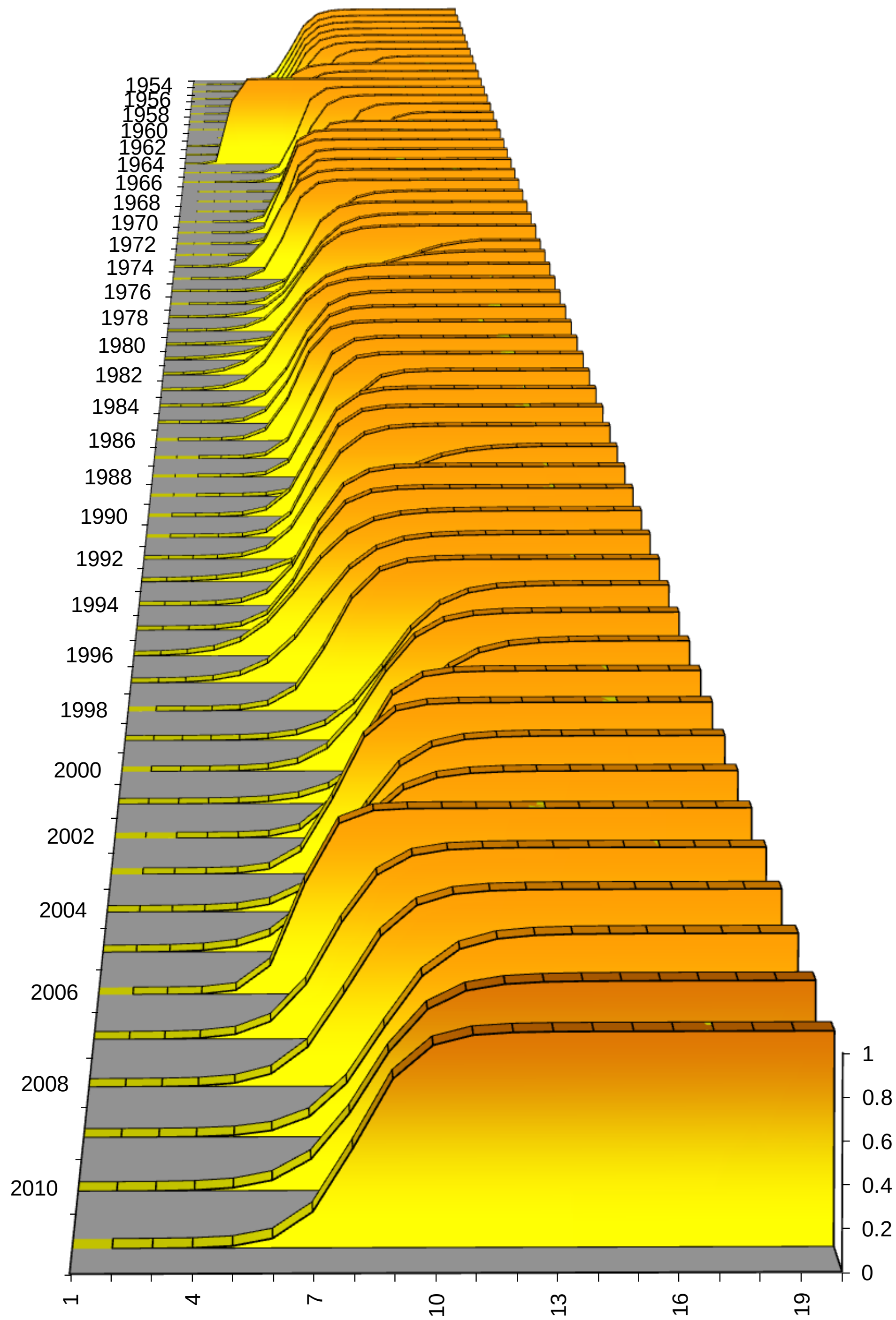



Figure 4.14a--Estimated male fishery selectivity by age and year.

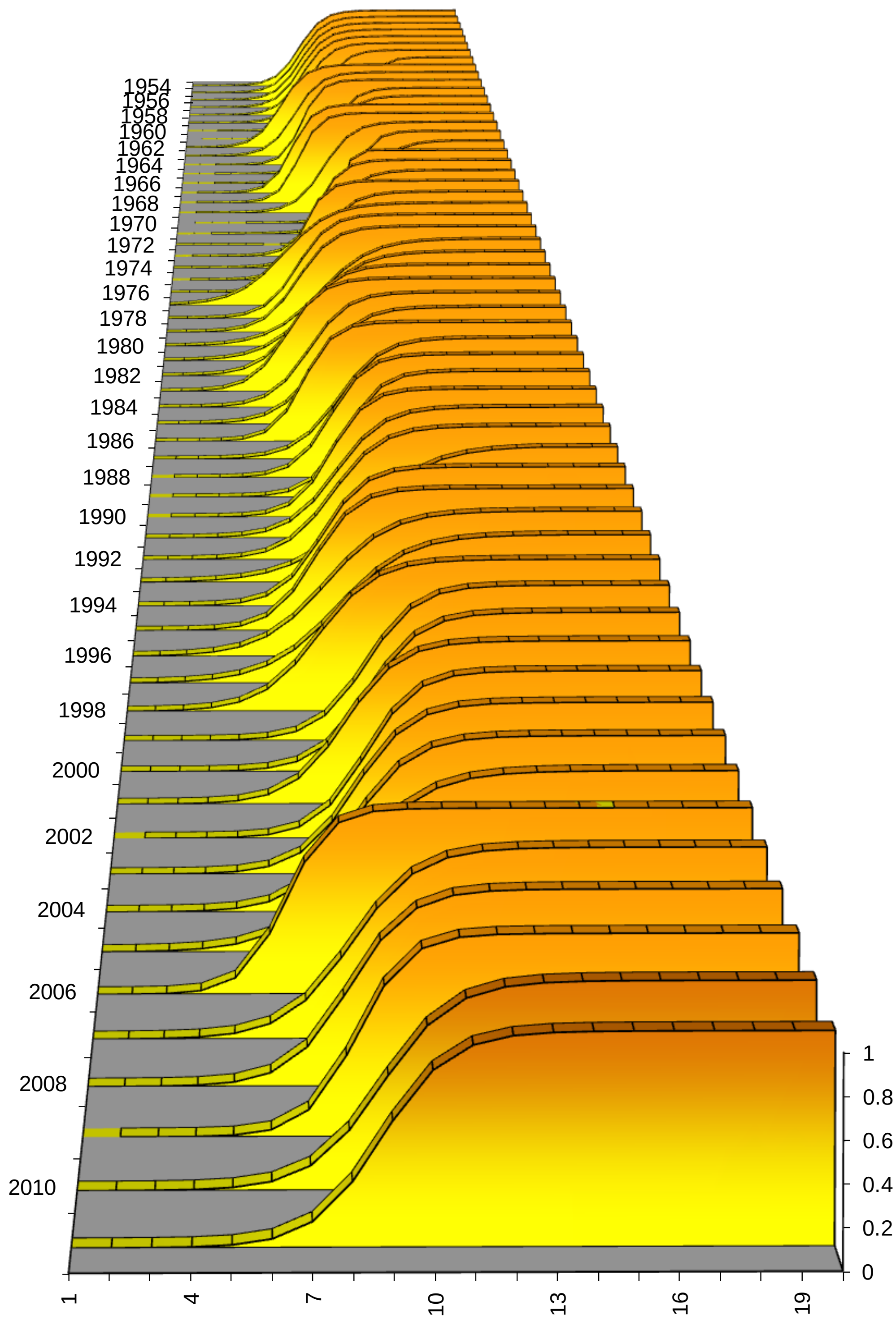



Figure 4.14b.--Estimated female fishery selectivity by age and year.

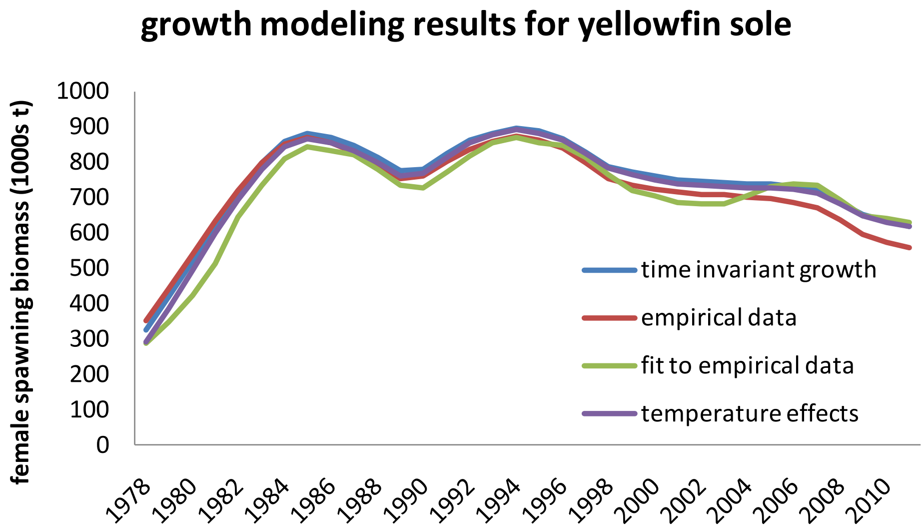



Figure 4.15—Estimates of female spawning biomass (1978-2010) from the 4 growth models considered in the assessment.

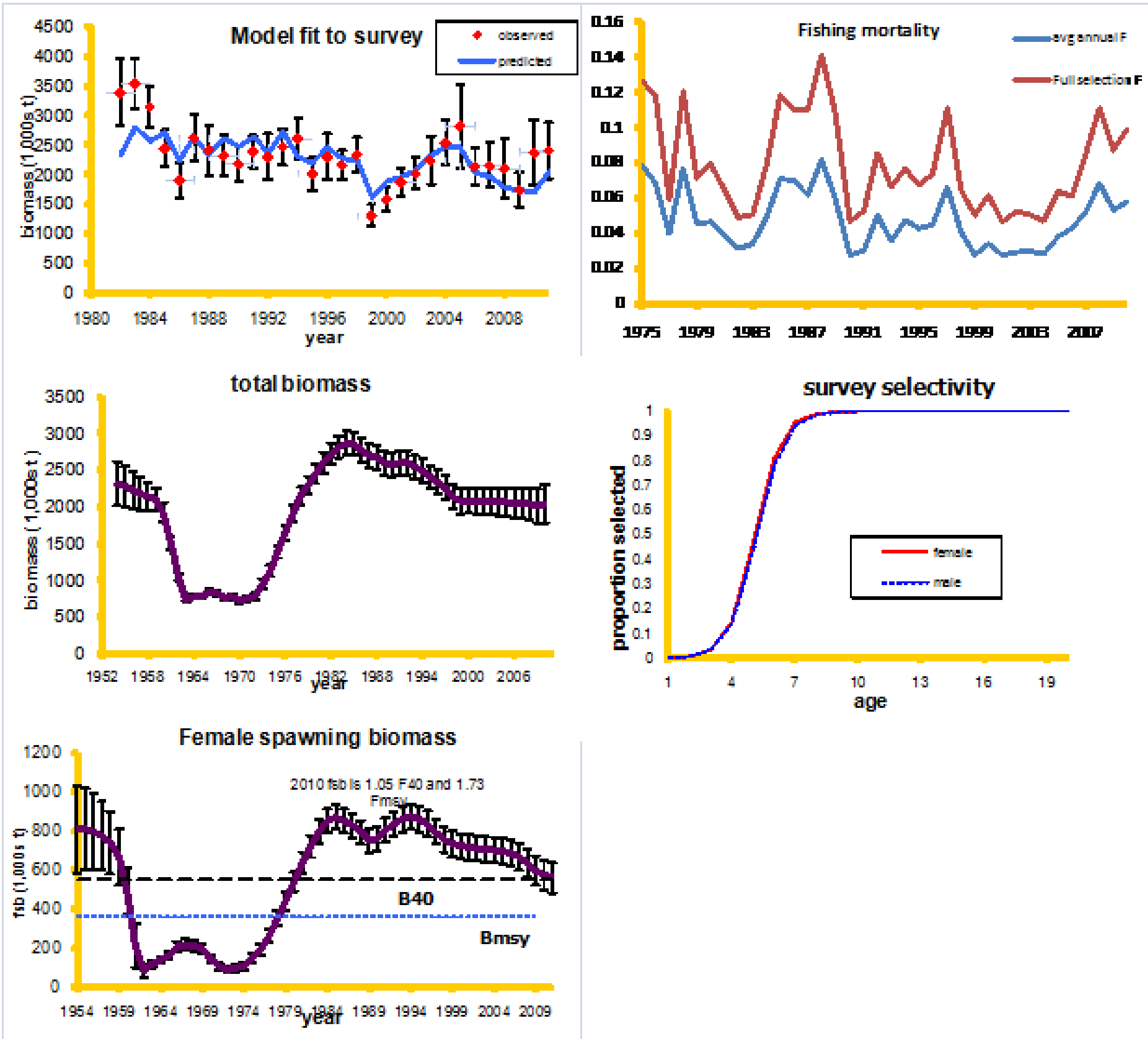



Figure 4.16. Model fit to the survey biomass estimates (top left panel), model estimate of the full selection fishing mortality rate throughout the time-series (top right panel), model estimate of total biomass (middle left panel), the model estimate of survey selectivity (middle right panel) and the estimate of female spawning biomass (bottom left panel).

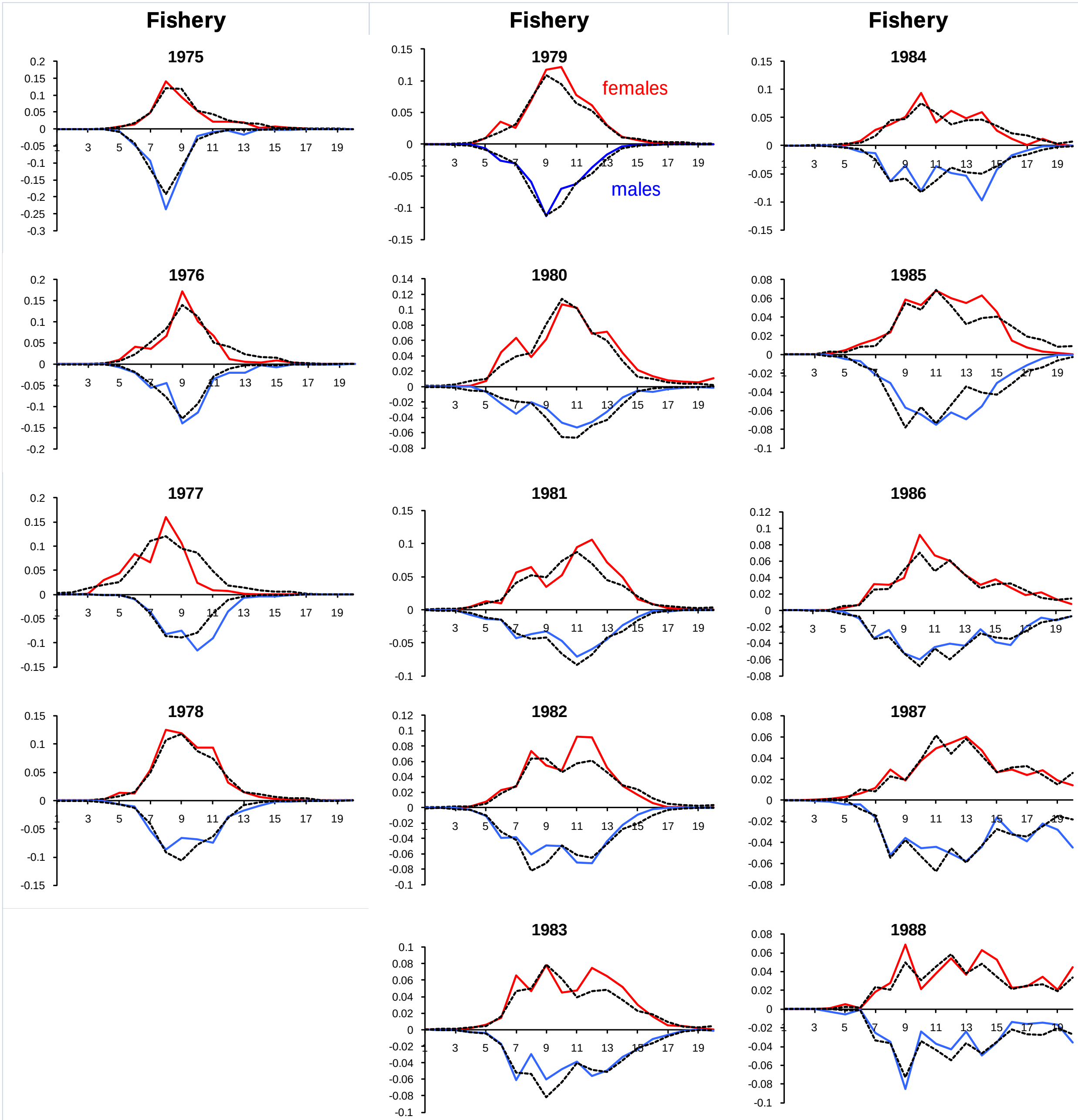



Figure 4.17. Stock assessment model fit to the time-series of fishery and survey age composition, by sex.

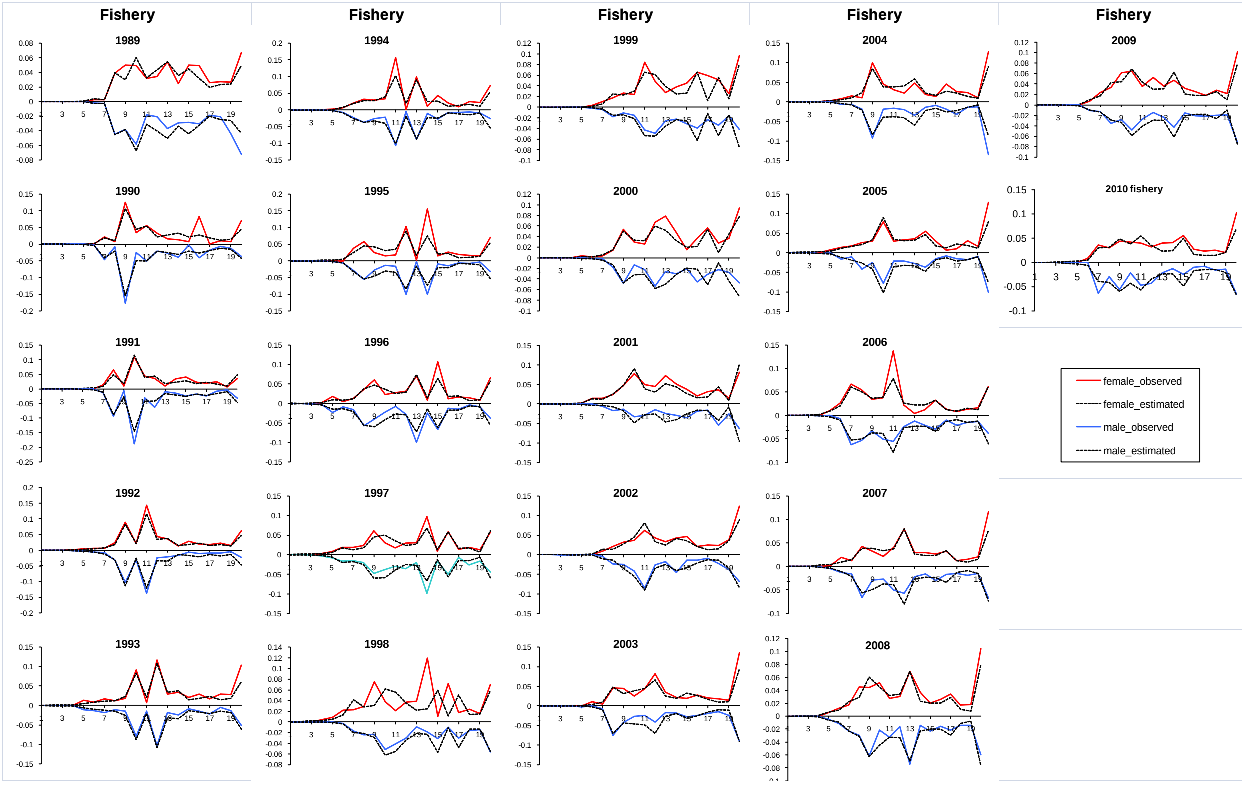



Figure 4.17 (continued).

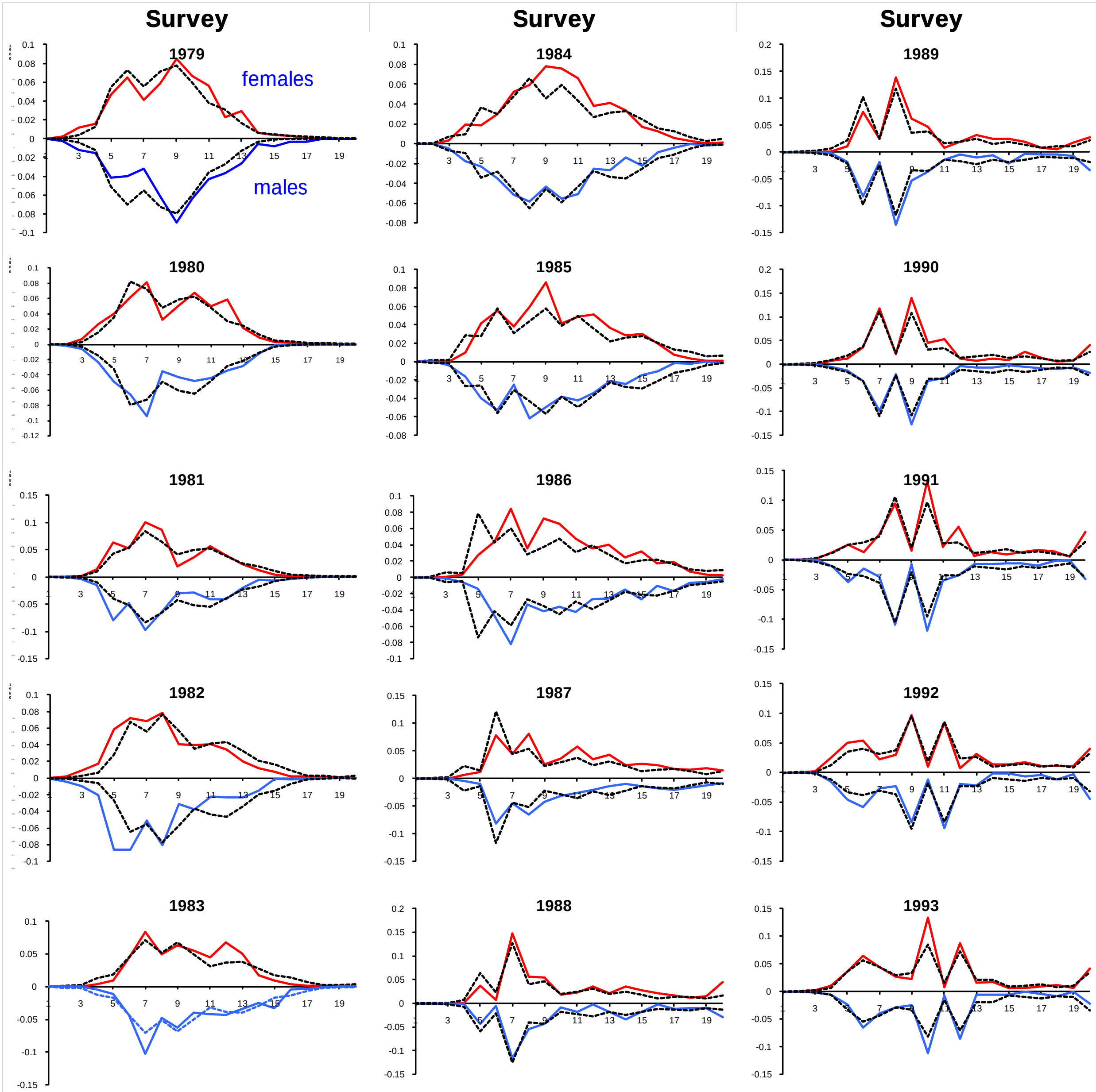



Figure 4.17 (continued).

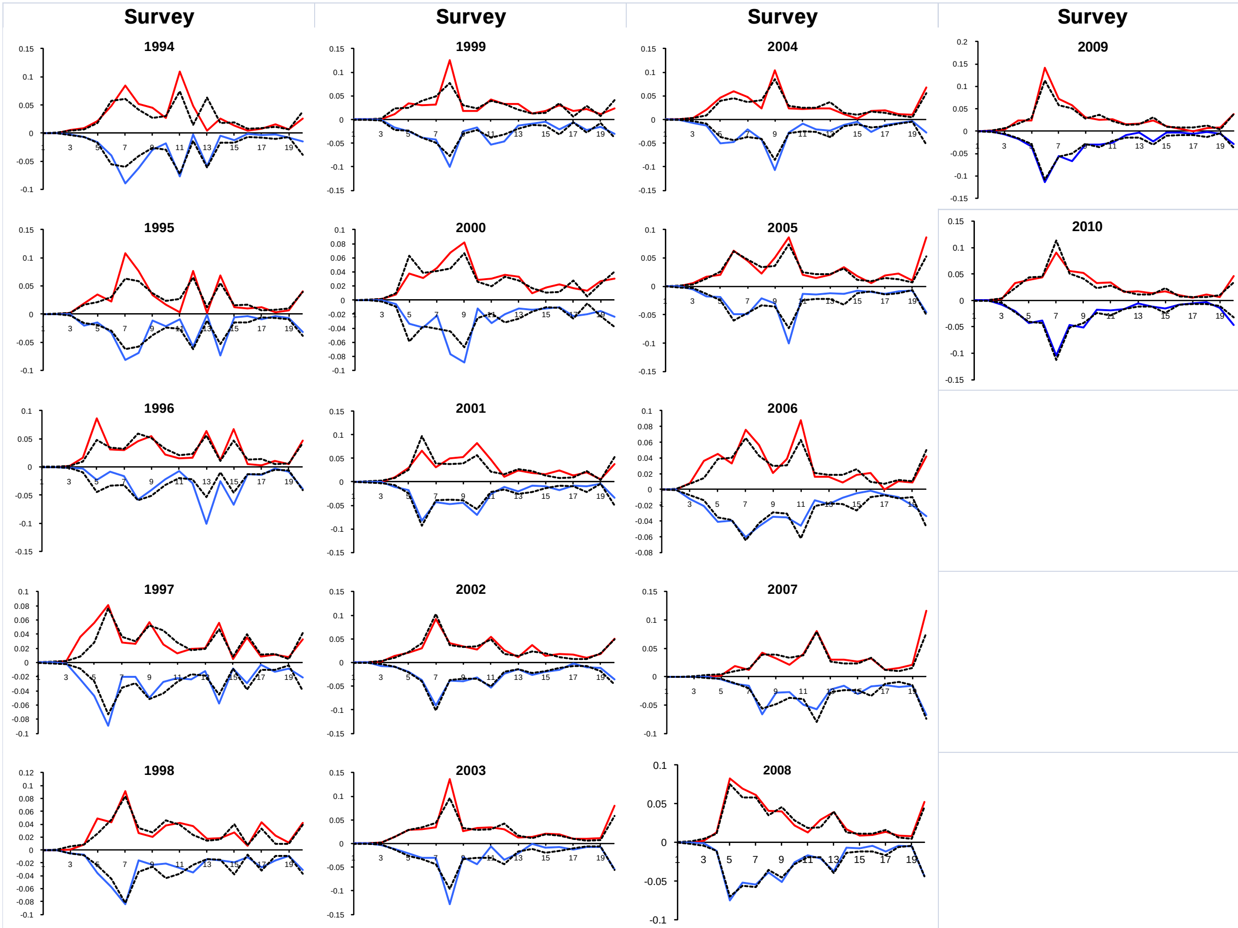



Figure 4.17 (continued).

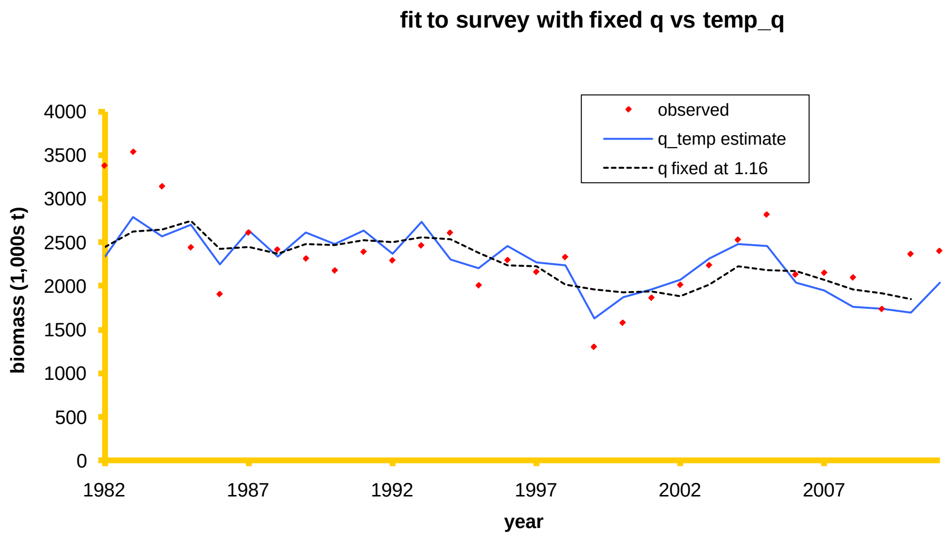



Figure 4.18.--Comparison of the fit to the survey biomass using a fixed q and the q-bottom temperature relationship.

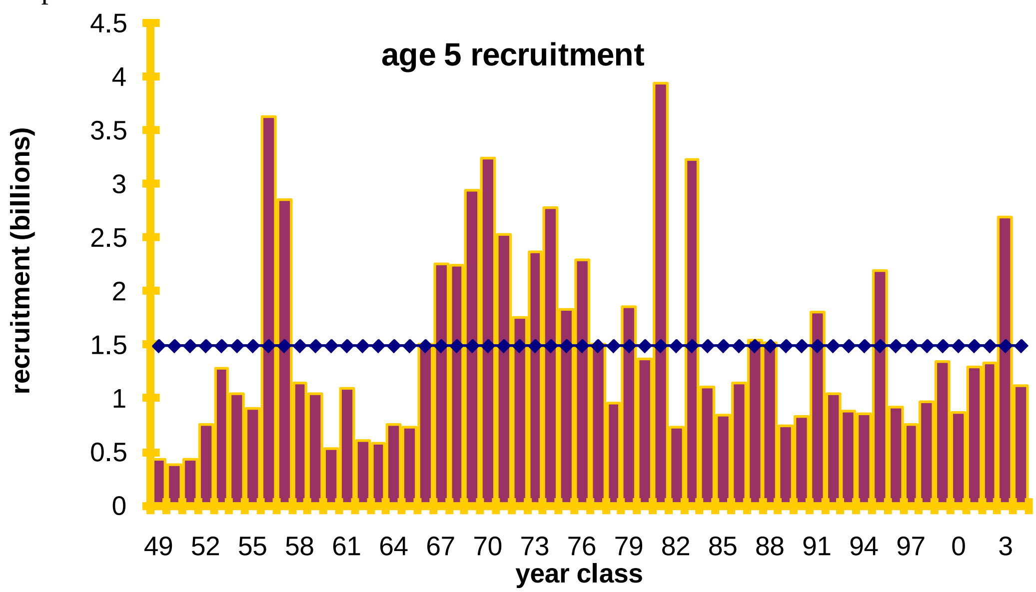



Figure 4.19--Year class strength of age 5 yellowfin sole estimated by the stock assessment model. The dotted line is the average of the estimates from 56 years of recruitment.

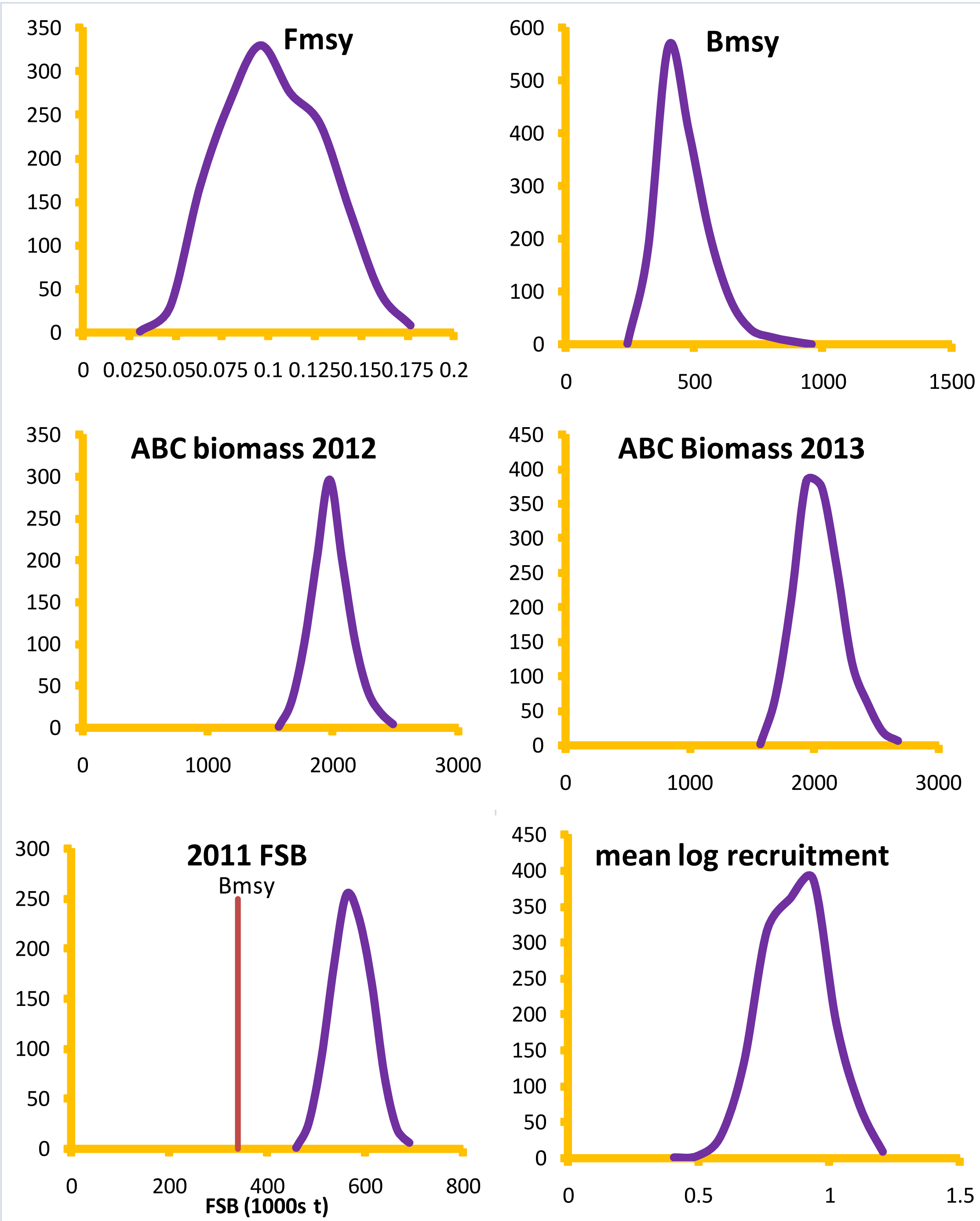



Figure 4.20.--Posterior distributions of some important parameters estimated by the preferred stock assessment model (from mcmc integration).

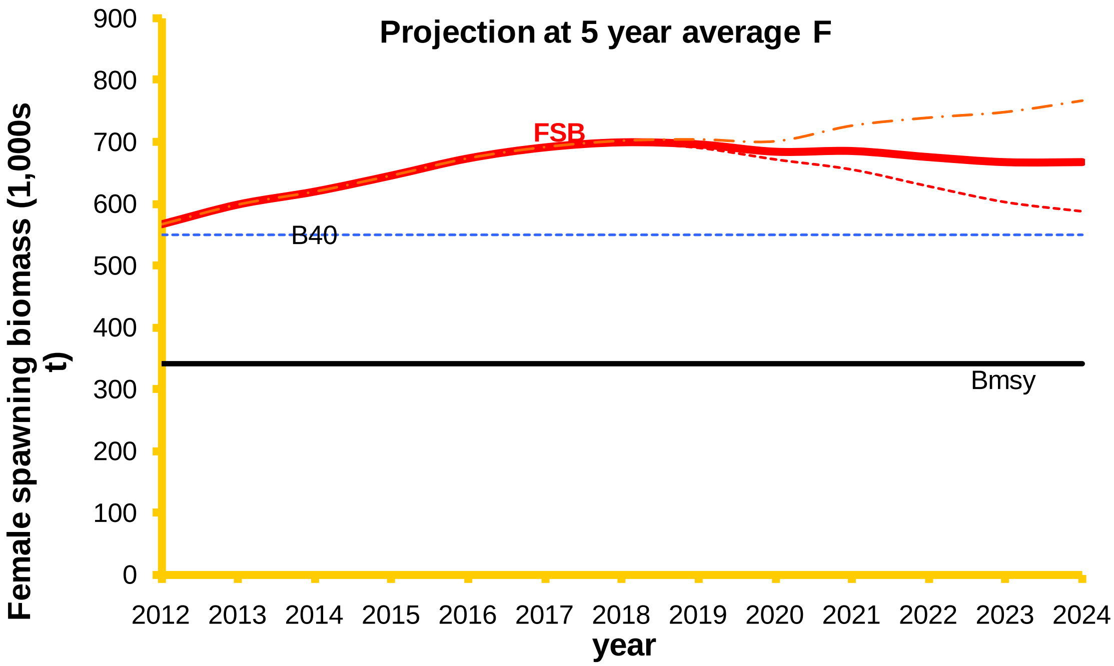



Figure 4.21.--Projection of yellowfin sole female spawning biomass (1,000s t) at the average F from the past 5 years (0.055) through 2023 with $B_{40\%}$ and $B_{msy}$ levels indicated.

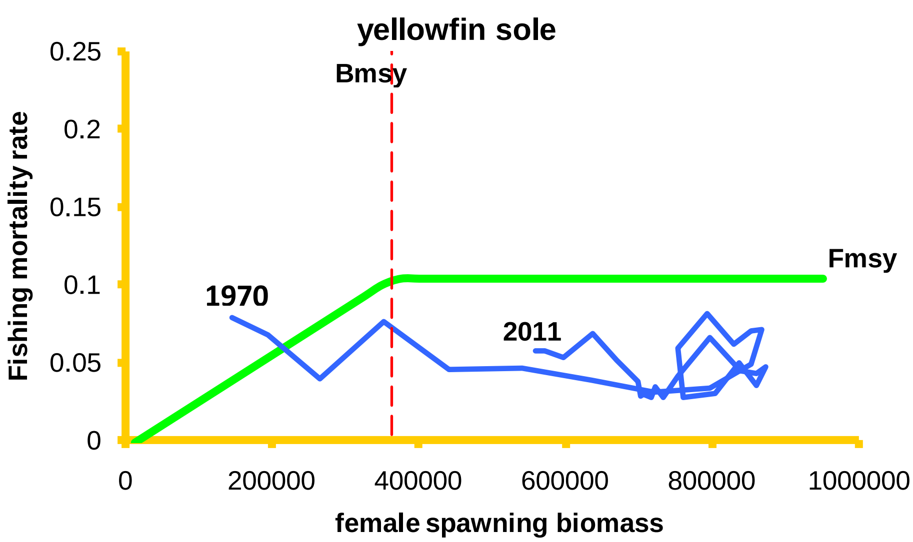



Figure 4.22.--Phase plane figure of the time-series of yellowfin sole female spawning biomass relative to the harvest control rule with 1970 and 2011 indicated.

# Appendix

IPHC research catch of yellowfin sole

| | number | weight (kg) |
|---|---|---|
| 2007 | 707 | 502 |
| 2008 | 0 | 0 |
| 2009 | 0 | 0 |
| 2010 | 898 | 741 |

**AFSC Bottom Trawl survey catch weight**

| 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 |
| 2008 | 69 |
| 2009 | 60 |
| 2010 | 79 |
| 2011 | 77 |