Chapter 4 YELLOWFIN SOLE

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

Executive Summary

The following changes have been made to this assessment relative to the November 2009 SAFE:

Changes to the input data

1) 2009 fishery age composition.
2) 2009 survey age composition.
3) 2010 trawl survey biomass point estimate and standard error.
4) Estimate of the discarded and retained portions of the 2009 catch.
5) Estimate of total catch made through the end of 2010.

Changes to the assessment methodology

Implemented time-varying, gender-specific fishery selectivity

Assessment results

1) The projected age 2+ total biomass estimate for 2011 is 2,173,700 t.
2) The projected female spawning biomass estimate for 2011 is 587,300 t.
3) The Tier 1 2011 ABC is 239,200 t based on an $F_{\text{har mean of FMSY}}$ (0.12) harvest level.
4) The Tier 1 2011 overfishing level is 262,300 t based on an F_{MSY} (0.13) harvest level.

Summary

	Last year		**This year**	
Quantity/Status	2010	2011	**2011**	2012
M (natural mortality)	0.12	0.12	0.12	0.12
Specified/recommended Tier	1a	1a	**1a**	1a
Projected total biomass (ages X+)	1,788,900	1,737,000	**1,958,600**	1,983,200
Female spawning biomass (t)				
Projected	581,800	558,500	**587,300**	636,300
B_0			**955,600**	
B_{msy} (or proxy assumption)	333,000		**374,000**	
F_{OFL}	0.13	0.13	0.13	0.13
$maxF_{ABC}$ (maximum allowable = F40%)	0.12	0.12	0.12	0.12
Specified/recommended F_{ABC}	0.12	0.12	0.12	0.12
Specified/recommended OFL (t)	233,600	226,800	**262,300**	265,500
Specified/recommended ABC (t)	219,400	213,000	**239,200**	242,200
Is the stock being subjected to overfishing?	No	No	No	No
Is the stock currently overfished?	No	No	No	No
Is the stock approaching a condition of being overfished?	No	No	No	No

SSC Comments from December 2009

The SSC discussed Tier 1 stocks in which certainty in F_{msy} leads to little difference between the arithmetic and harmonic means and therefore very similar estimates of ABC and OFL. From a practical standpoint, the closeness of ABC to OFL would create potential overfishing, if the TAC is set equal to ABC and if actual catch slightly exceeds ABC. A pragmatic approach may be to set catch limits lower based on estimated implementation error such that the probability of realized catch exceeding OFL is low. However, an analytical approach may be to reexamine the apparent certainty in F_{msy} estimates and other sources of uncertainty that are not accounted for in current estimation procedures. The SSC recommends conducting a workshop to address this and related issues (see also EBS pollock) when ACL revisions to groundfish are being considered.

Annual time-varying fishery selectivity was implemented in the stock assessment model which allowed for the estimation of the two parameters of the logistic equation for males and females for each year 1964-2009. This resulted in an increase in the buffer between ABC and OFL from 6% (14,197 t) in the 2009 assessment to 9% (23,095 t) in this assessment.

The SSC also recommends a research topic to flatfish assessment scientists. A meta-analysis of stock-recruit relationships for flatfish stocks may be very useful to evaluate productivity of these stocks, similar to one previously conducted for rockfish. This could help inform decisions about when a flatfish assessment using Tier 3 may qualify for Tier 1. In this year's SAFE, this question was raised in discussions about the Alaska plaice assessment, for which a new model and a stock-recruit relationship were presented.

No progress to report on this research recommendation, however the authors plan to examine the research previously conducted for rockfish and perform a similar analysis for flatfish.

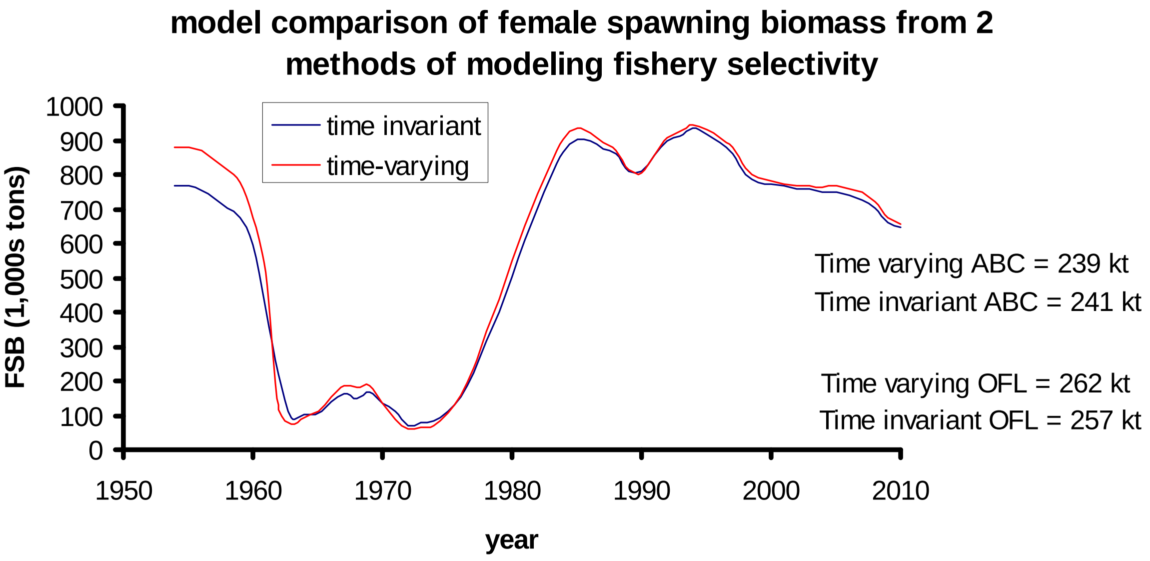
In future assessments, the SSC requests that the table heading for Table 4-24 clarify that PSC catches (shown on p. 567) are not included. The SSC also noted that exploitation rates are estimated back to 1964 (Table 4.15) while catches are presented only back to 1977 (Table 4.1). If catches are sufficiently accurate to allow for estimation of exploitation rates in these early years, then the SSC requests reporting these older catches, as well.

These requests were addressed in the SAFE chapter.

SSC Comments from October 2010

The SSC received a very brief report on the need to consider time-varying selectivity in the BSAI yellowfin sole and northern rock sole stock assessments. The SSC supports the GPT's recommendation to explore the utility of this time-varying selectivity in the next assessment. The current (base) model should also be retained in the assessment to facilitate evaluation of the alternative model incorporating time-varying selectivity.

The following chart shows the comparison of model results for female spawning biomass and ABC and OFL estimates when the stock assessment model is configured with time invariant and also time-varying fisheries selectivity. Estimates of stock size and productivity are very similar between models but the time-varying fishery selectivity model provides a larger buffer between ABC and OFL (9%) than does the time invariant model (6%).



Time varying ABC = 239 kt
Time invariant ABC = 241 kt

Time varying OFL = 262 kt
Time invariant OFL = 257 kt

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° N) to the Chukchi Sea (about lat. 70° N) and south along the Asian coast to about lat. 35° 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 94,000 t from 1998-2010. The 2008 catch totaled 148,894 t, the highest annual catch in the past 11 years. The fishery caught 58% of the annual total from February through

May, primarily from areas 509, 513, 514 and 521. As of late September 2010, the fishing season is ongoing. In order to estimate the total 2010 catch for the stock assessment model, the average of the proportions of the 2008 and 2009 catch made after mid September was applied to the 2010 catch amount at the same time period. Applying the two year average to the 2010 catch of 93,282 t at week 37 of 2010, we estimate the catch will total (93,282 x 1.27) = 118,691. Rounding up, a value of 119,000 t was used in the model. The size composition of the 2010 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 2010, 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 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, 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- 2009 (Table 4.1), including an estimate of the 2010 catch, and fishery catch-at-age (numbers) from 1964-2009 (Table 4.4, 1977-2009).

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 2010 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 2010 estimate of 2.36 million t was a 36% increase over 2009). .

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 have been low during cold years. The 1999 survey, which was conducted in exceptionally cold waters, indicated a decline in biomass that was unrealistic. The bottom temperatures during the 2000 survey were much warmer than in 1999, and the biomass increased, but still did not approach estimates from earlier years. Average bottom temperature and biomass both increased again during the period 2001 – 2003, with the 2003 value the highest temperature and biomass observed over the 22 year time series. Given that both 1999 and 2000 surveys were conducted two weeks earlier than previous surveys, it is possible that the time difference may also have affected the availability of yellowfin sole to the survey. If, for example, the timing of peak yellowfin sole spawning in nearshore waters corresponded to the time of the survey, a greater proportion of the population would be unavailable to the standard survey area. This trend was observed again in 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 presented in Table 4.8.

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

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

Since changes in mean length and mean weight at age over time have been documented for Bering Sea northern rock sole (Walters and Wilderbuer 2000) and Bering Sea and Gulf of Alaska Pacific halibut

(Clark et al 1999), we re-examined the assumption of time-invariant growth in length and weight of yellowfin sole by comparing the weight and length at age from fish collected during the 1988, 1993, 1998, 2003 and 2008 surveys (Fig. 4.8). Over this range of 20 years only small differences in length and weight at age have been observed. Based on these findings, we concluded that use of a single weight at age vector for each sex was justified for this assessment.

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. 4.9).

This method was selected to update the population weight at age because the weight at age in a population is a function of the length at age (Clark et al. 1999, Walters and Wilderbuer 2000) and this method uses the average population length at age in the calculation (Table 4.9). Male and female yellowfin sole exhibit similar growth until about the age of sexual maturity (50% mature and age 10.5) at which point females grow at a faster rate than males and reach a larger size (Table 4.9, Fig 4.8).

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). In addition, natural mortality is also allowed to be estimated as a free parameter in some of the stock assessment model runs which are evaluated in a latter section. A natural mortality value of 0.12 is used 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
58	236	2	57	2	355

The increase in the number of parameters estimated in this assessment compared to last year can be accounted for by the input of another year of fishery data, 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, φ_t and η_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 η_t and φ_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 $\alpha = -0.128$ 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 4.10 (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 two-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 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 1955-2004 (Model 1), the pre-regime shift era of 1955-1977 (Model 3) and the post-regime shift era, 1978-2004 (Model 2) (Fig. 4.11) 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 1955-2004 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} over is 1.5 times higher than $F_{40\%}$ (recall that $F_{40\%} = 0.11$). Therefore, F_{MSY} is a relatively high value (0.17) and B_{MSY} is 329,000 t. 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 (0.13) and B_{MSY} is 379,000 t.

It is critical for the Tier 1 calculations to identify which subset of the stock recruitment data is used. Using the full time series to fit the spawner recruit curve estimates that the stock is most productive at a small stock size. Thus MSY and F_{MSY} are 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 high recruitments at low stock size have only been observed one time) we use the more precautionary characterization of the productivity of yellowfin sole by fitting the 1977-2004 spawner-recruit data set in the next step of the model evaluation.

The second step in the model evaluation for this assessment entails the use of a single structural model (Model 2 in Table 4.13) to consider the uncertainty in the key parameters M and catchability. Model 2 (from above) is the base model which has been used in past assessments and operates by fixing M at 0.12 and then estimates q using the relationship between survey catchability and the annual average water temperature at the sea floor (from survey stations at less than 100 m). Models 4 and 5 fix q at 1.12 (the value resulting from the base Model) but estimate male M (Model 4) and female M (Model 5) as free parameters with moderate amounts of uncertainty in the parameter estimate ($\sigma_M = 0.5$). Models 6 and 7 fix M at 0.12 but estimate q as a free parameter (without consideration of the relationship with annual bottom water temperature) with different amounts of uncertainty in the parameter estimate (σ_q values of 0.2 and 0.5 for Models 6 and 7, respectively). Models 8 and 9 estimate both male and female M and q (sexes combined) as free parameters, again with varying amounts of uncertainty (σ_M and σ_q values of 0.2 and 0.5 for Models 8 and 9, respectively).

Results from these runs indicate that fixing either M or q at values estimated from the base Model (Model 2) and then estimating the other parameter give similar estimates of 2010 female spawning biomass, total biomass, $F_{40\%}$ and 2011 tier 1 ABC (Models 4-7, Table 4.14). When male and female M and q are all estimated as free parameters with no constraints, the best fit to the observable population characteristics occur at high values of q and low values of M (Models 8 and 9). These Models result in low estimates of female spawning biomass, total biomass and ABC, which are not credible.

Model runs 4-7 indicate that, even with a high level of uncertainty, M and q are fairly well estimated within a narrow range, as long as one of the parameters is constrained at its value in the base model. In Models 4 and 5 male M is consistently estimated at a slightly higher value than female M. The values of M estimated in Models 8 and 9 (0.07 and 0.05) seem unrealistic given the maximum age of yellowfin sole observed from 43 years of data collection and age determination (most collections have a maximum at age 30 although a single female was aged at 37 years old) and the resulting low biomass estimates.

Modeling survey catchability as a nonlinear function of bottom water temperature returns a mean value of 1.09. 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).

Allowing M to be estimated as a free parameter for males with females fixed at 0.12 provides a better fit to the sex ratio estimated from the annual trawl survey age compositions than does 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 (Model 2), will be used to base our assessment of the condition of the Bering Sea yellowfin sole resource for the 2011 fishing season.

Model Results

Although the trawl survey point estimate increased 36% from 2008 to 2009, the stock assessment model indicates the stock condition is about the same as last year, although with a higher biomass time-trend and higher ABC recommendation. The model results indicate the stock has been in a slowly declining condition since the mid-1980s. The 2010 survey value was not fit very well by the model although it did have the effect of estimating the female spawning biomass and total biomass at higher levels for the past few years. The trend has not changed and is still estimated to be declining but may level off in the near future if fishing is maintained at the present level 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 1978-2009 with a maximum of 0.13 in 1978 and a minimum in 2001 at 0.046. Selectivities estimated by the model (Table 4.16, Fig. 4.12) 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 1.09 for the period 1982-2010 which results in the model estimate of the 2010 total biomass at 2,130,050 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. 4.12, 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 74% of the peak level.

The female spawning biomass has also declined since the peak in 1985, with a 2010 estimate of 654,800 t (38% decline). The spawning biomass has been in a gradual decline for the past 8 years and is about 106% of the $B_{40\%}$ level and 175% of the B_{MSY} level (Fig. 4.13). 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 4.14. 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. 4.15). 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 sixteen years since the mid 1990s have seen the yellowfin sole population biomass slowly decrease as the majority of year-classes since then have been below average strength. Above-average recruitment from the 1995 and 1999 year-classes is expected to maintain the abundance of yellowfin sole at a level near B_{40} in the near future. The stock assessment projection model (later section) indicates a stable 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 4.16 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, 1995 and 1999 year classes are above average. With the exception of these 5 year classes, recruitment from 13 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 1999 year-class whose strength is estimated at the long-term average and the apparent strong 2003 year-class which have now been observed as six year old fish in the 2009 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 F_{MSY} for the models evaluated for stock productivity (Models 1-3) and posterior distributions of selected parameters from the preferred stock assessment model used in the assessment are shown in Figures 4.17 and 4.18. The 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 total biomass for 2011 is 2,173,700 t.

The SSC has determined that yellowfin sole qualify as a Tier 1 stock and therefore the 2011 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 2011 harvest (1978-2004 time-series) recommendation (Model 2 in Table 4.13), the $F_{ABC} = F_{\text{harmonic mean}} = 0.12$.

The Tier 1 harvest level is calculated as the product of the harmonic mean of F_{MSY} and the geometric mean of the 2010 biomass estimate, as follows:

$B_{gm} = e^{\ln \hat{B} - \frac{cv^2}{2}}$, where B_{gm} is the geometric mean of the 2010 biomass estimate, $\hat{B}$ is the point estimate of the 2010 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 **239,200 t** and an OFL of 262,300 t for 2011. This gives a 9% (23,000 t) buffer between ABC and OFL compared to the 6% (14,200 t) buffer calculated 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 (Tier 3a values are also included):

Harvest level	F value	2011 Yield
Tier 3 $F_{OFL} = F_{0.35}$	0.12	131,750 t
Tier 3 $F_{ABC} = F_{0.40}$	0.10	123,700 t
Tier 1 $F_{OFL} = F_{MSY}$	**0.12**	**262,300 t**
Tier 1 $F_{ABC} = F_{\text{harmonic mean}}$	**0.13**	**239,200 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 2010 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2011 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2010. 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 2011, 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 2011 recommended in the assessment to the *max* F_{ABC} for 2011. (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 2006-2010 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

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

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2010 and above its MSY level in 2022 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2011 and 2012, 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 2023 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 2021 is shown in Figure 4.19 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 4.20.

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 2010 numbers at age from the stock assessment model are projected to 2011 given the 2010 catch and then a 2011 catch of 140,000 t is applied to the projected 2011 population biomass to obtain the 2012 OFL.

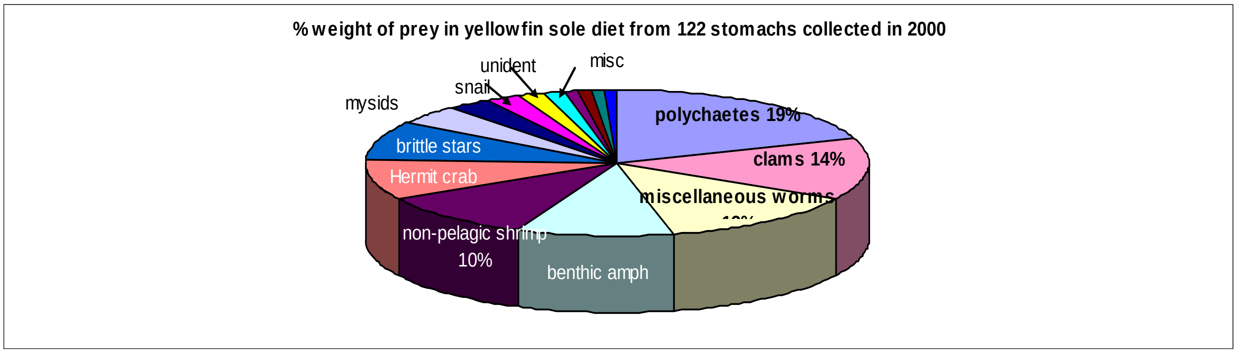
	Tier 1 Projection				
Year	**Catch**	**SSB**	**Geometric mean 6+ total biomass**	**ABC**	**OFL**
2011	140,000	643,400	1,958,600	239,200	262,300
2012		636,300	1,983,180	242,200	265,500

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 1992-2009 in Table 4.23. The catch of non-target species from 2003-2009 is shown in Table 4.24. The yellowfin sole target fishery contribution to the total bycatch of prohibited species is shown for 2007 and 2008 in Table 13 of the Economic SAFE (Appendix C) and is summarized for 2008 as follows:

Prohibited species	Yellowfin sole fishery % of total bycatch
Halibut mortality	28.1
Herring	37.7
Red King crab	28.6
C. bairdi	24.7
Other Tanner crab	52.4
Salmon	0

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

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

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

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

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

Ecosystem effects on yellowfin sole

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Benthic infauna	Stomach contents	Stable, data limited	Unknown
Predator population trends			
Fish (Pacific cod, halibut, skates)	Stable	Possible increases to 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

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Tables

Table 4.1--Catch (t) of yellowfin sole 1964-2010. Catch for 2010 is the total through September 25, 2010.

		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			99,501	99,501

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

Table 4.3. Discarded and retained catch of yellowfin sole, by fishery, in 2009.

Trip Target Name	**Discarded**	**Retained**
Atka Mackerel	0	0
Pollock - bottom	10	167
Pacific Cod	706	288
Alaska Plaice	1	8
Other Flatfish - BSAI	0	0
Halibut	0	0
Rockfish	0	1
Flathead Sole	28	1,390
Other Species	0	0
Pollock - midwater	31	63
Rock Sole - BSAI	347	6,263
Sablefish - BSAI	0	0
Greenland Turbot - BSAI	0	0
Arrowtooth Flounder	0	2
Yellowfin Sole - BSAI	5,733	92,488

Table 4.4. Model estimated yellowfin sole fishery catch-at-age numbers (millions), 1977-2010.

	7	8	9	10	11	12	13	14	15	16	17+
1977	45.14	63.74	58.66	52.84	27.60	9.10	4.72	1.84	1.29	1.83	1.58
1978	57.56	127.47	146.01	109.01	89.63	45.28	14.72	7.57	2.93	2.06	5.43
1979	26.63	63.44	98.12	85.79	55.83	43.46	21.53	6.95	3.57	1.38	3.53
1980	19.84	21.92	41.82	62.24	58.75	42.37	35.81	18.75	6.27	3.27	4.52
1981	28.98	36.46	34.53	54.30	66.72	53.49	34.01	26.37	13.07	4.22	5.15
1982	26.96	56.97	53.53	37.55	46.89	49.69	36.55	22.18	16.78	8.21	5.84
1983	42.47	44.93	70.14	54.21	34.63	41.62	43.46	31.80	19.26	14.56	12.19
1984	23.49	62.81	61.42	92.43	70.65	45.01	54.07	56.46	41.31	25.01	34.75
1985	21.30	58.44	106.64	83.76	115.65	85.96	54.31	65.09	67.93	49.70	71.89
1986	43.47	42.60	74.65	101.34	68.42	88.37	63.98	40.04	47.81	49.83	89.14
1987	13.10	45.19	33.82	54.75	76.33	53.03	69.49	50.61	31.74	37.94	110.31
1988	41.90	41.74	90.58	48.37	65.58	82.65	54.75	70.37	50.88	31.83	148.47
1989	2.37	40.11	32.22	60.76	30.30	39.82	49.66	32.79	42.10	30.44	107.83
1990	16.19	8.72	71.91	25.90	29.17	11.80	14.52	17.78	11.68	14.98	49.17
1991	6.48	43.99	14.60	84.12	25.96	27.92	11.18	13.74	16.82	11.05	60.72
1992	9.93	25.43	103.40	25.02	125.20	36.32	38.08	15.09	18.48	22.60	96.34
1993	7.69	8.74	15.87	56.14	13.60	71.35	21.64	23.39	9.43	11.67	75.46
1994	20.94	29.71	28.47	37.06	95.01	18.14	81.80	22.77	23.49	9.25	83.95
1995	22.71	40.52	35.33	24.81	28.41	69.80	13.16	59.11	16.44	16.95	67.25
1996	14.02	39.46	45.48	33.00	22.20	25.38	62.64	11.85	53.32	14.84	76.04
1997	17.38	24.10	60.16	62.74	42.75	27.86	31.38	76.98	14.52	65.30	111.21
1998	19.19	15.75	18.94	38.81	34.84	21.80	13.62	15.04	36.57	6.87	83.31
1999	1.84	7.53	6.84	9.41	22.02	21.45	13.92	8.82	9.80	23.86	58.88
2000	2.27	6.48	22.54	15.11	14.86	27.54	23.84	14.73	9.16	10.11	85.09
2001	2.84	5.99	11.42	25.08	12.01	10.08	17.68	15.08	9.29	5.77	59.97
2002	4.95	5.72	12.99	21.02	36.14	14.17	10.52	17.40	14.47	8.82	62.12
2003	4.36	26.78	16.67	19.05	20.80	31.15	11.75	8.63	14.24	11.83	57.99
2004	3.65	9.18	35.54	16.05	16.03	16.76	24.77	9.31	6.83	11.27	55.26
2005	9.91	13.22	21.76	57.72	20.85	18.96	19.17	28.05	10.51	7.71	75.00
2006	39.50	34.73	25.10	26.51	55.24	17.88	15.53	15.42	22.40	8.37	65.77
2007	13.00	36.56	33.30	26.59	29.58	62.91	20.51	17.86	17.75	25.78	85.34
2008	19.88	27.68	58.41	42.34	30.04	31.84	66.54	21.56	18.73	18.60	116.45
2009	10.03	22.54	25.53	43.30	28.09	19.16	20.08	41.81	13.53	11.76	84.76
2010	27.73	32.47	45.31	33.33	44.72	26.30	17.31	17.92	37.17	12.02	85.64

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

	Age				
Year	0-6	7 +	Total	Lower CI	Upper CI
1975	169,500	803,000	972,500	812,300	1,132,700
1979	211,500	1,655,000	1,866,500	1,586,000	2,147,100
1980	235,900	1,606,500	1,842,400	1,553,200	2,131,700
1981	343,200	2,051,500	2,394,700	2,072,900	2,716,500
1982	685,700	2,692,100	3,377,800	2,571,000	4,184,600
1983	198,000	3,337,300	3,535,300	2,958,100	4,112,400
1984	172,800	2,968,400	3,141,200	2,636,800	3,645,600
1985	166,200	2,277,500	2,443,700	1,563,400	3,324,000
1986	80,200	1,829,700	1,909,900	1,480,700	2,339,000
1987	125,500	2,487,600	2,613,100	2,051,800	3,174,400
1988	45,600	2,356,800	2,402,400	1,808,400	2,996,300
1989	196,900	2,119,400	2,316,300	1,836,700	2,795,800
1990	69,600	2,114,200	2,183,800	1,886,200	2,479,400
1991	60,000	2,333,300	2,393,300	2,116,000	2,670,700
1992	145,900	2,027,000	2,172,900		
1993	188,200	2,277,200	2,465,400	2,151,500	2,779,300
1994	142,000	2,468,500	2,610,500	2,266,800	2,954,100
1995	213,000	1,796,700	2,009,700	1,724,800	2,294,600
1996	161,600	2,137,000	2,298,600	1,749,900	2,847,300
1997	239,330	1,924,070	2,163,400	1,907,900	2,418,900
1998	150,756	2,178,844	2,329,600	2,033,130	2,626,070
1999	57,700	1,246,770	1,306,470	1,118,800	1,494,150
2000	73,200	1,508,700	1,581,900	1,382,000	1,781,800
2001	135,900	1,727,800	1,863,700	1,605,000	2,122,300
2002	83,200	1,933,500	2,016,700	1,740,700	2,292,700
2003	2,900	2,236,700	2,239,600	1,822,700	2,656,600
2004	191,800	2,338,800	2,530,600	2,147,900	2,913,300
2005	158,865	2,664,635	2,823,500	2,035,800	3,499,800
2006	141,053	1,992,017	2,133,070	1,818,253	2,447,932
2007	173,185	1,979,553	2,152,738	1,775,191	2,530,285
2008	217,088	1,882,433	2,099,521	1,599,100	2,600,000
2009	269,197	1,470,041	1,739,238	1,435,188	2,043,288
2010			2,367,830	1,807,430	2,928,230

Table 4.6. Yellowfin sole population numbers-at-age (millions) estimated from the annual bottom trawl surveys, 1982-2009.

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

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

Table 4.7-Occurance 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			

Table 4.8—Total tonnage of yellowfin sole caught in resource assessment surveys in the eastern Bering Sea from 1977-2010.

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

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

	mean length at age (cm)		**mean weight at age (g)**	
	males	females	males	females
1	7.4		4	6
2	10.7	9.8	14	8
3	11.8	12.6	18	20
4	14.3	14.6	32	31
5	16.9	17.4	54	55
6	19.6	19.8	85	84
7	22.0	22.4	120	124
8	24.0	24.5	156	165
9	25.7	26.7	193	217
10	27.0	28.5	225	266
11	28.0	29.6	253	301
12	28.9	30.8	280	341
13	29.7	31.7	303	374
14	30.3	32.5	324	407
15	30.5	33.0	330	428
16	31.0	33.4	344	443
17	31.3	34.2	355	480
18	31.6	34.3	366	483
19	32.2	33.2	390	499
20	32.1	33.8	423	588

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)

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

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

Table 4.13. Models evaluated for the 2010 stock assessment of yellowfin sole. σ_M and σ_q are the level of uncertainty placed on the parameter estimates of natural mortality and catchability, respectively. Biomass is in 1,000s t.

		Model 2	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**
model	**2009 Preferred model**	**2010 BASE model**	**Male M estimated with σ_M = 0.5**	**Male and female M estimated with σ_M = 0.5**	**q estimated with σ_q = 0.2**	**q estimated with σ_q = 0.5**	**Male and female M and q estimated with σ = 0.2**	**Male and female M and q estimated with σ = 0.5**
ending FSB	604.762	654.802	649.021	723.279	619.04	620.05	486.01	409.785
ending total biomass	1984.56	2139.05	1940.63	2005.29	2003.38	2005.58	1322.7	1095.13
M	0.12	fixed at 0.12	female 0.12 male 0.136	female 0.106 male 0.124	fixed at 0.12	fixed at 0.12	female 0.07 male 0.09	female 0.045 male 0.063
q	1.14	1.08	fixed at 1.12	fixed at 1.12	1.11	1.11	1.71	2.08
F40%	0.104	0.11	0.114	0.10	0.11	0.11	0.07	0.05
Fharmonic	0.122	0.122	0.122	0.128	0.12	0.12	0.149	0.163
Tier 1 ABC	219.417	239.16	212.533	234.182	218.65	218.65	180.294	164.504
survey, catch, age and recruit likelihood	1617.01	1116.1	1067.05	1051.67	1124.48	1124.48	1041.62	1033.61

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	0.02	0.09	0.20	0.26	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
1965	0.00	0.01	0.04	0.11	0.18	0.22	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.25
1966	0.01	0.02	0.08	0.19	0.32	0.39	0.42	0.42	0.43	0.43	0.43	0.43	0.43	0.43
1967	0.01	0.04	0.12	0.29	0.45	0.53	0.56	0.56	0.56	0.56	0.57	0.57	0.57	0.57
1968	0.05	0.14	0.24	0.29	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
1969	0.04	0.16	0.40	0.58	0.65	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
1970	0.36	0.65	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
1971	0.46	0.63	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
1972	0.00	0.00	0.02	0.10	0.26	0.30	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
1973	0.01	0.04	0.12	0.27	0.40	0.46	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.49
1974	0.00	0.01	0.04	0.08	0.12	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
1975	0.02	0.06	0.11	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
1976	0.01	0.03	0.06	0.10	0.12	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
1977	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	0.06
1978	0.03	0.07	0.10	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
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	0.08	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	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
1982	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	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	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
1986	0.03	0.07	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	0.08	0.08	0.08	0.08	0.08	0.08
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	0.04	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	0.06	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	0.03	0.04	0.07	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	0.04	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	0.04	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	0.01	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
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	0.02	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	0.05	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	0.03	0.06	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
2008	0.02	0.05	0.08	0.10	0.10	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	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

2010	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

Table 4.14 continued.

Males

year/age	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1964	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
1965	0.02	0.11	0.22	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
1966	0.03	0.13	0.30	0.39	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
1967	0.16	0.42	0.54	0.56	0.56	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
1968	0.00	0.00	0.01	0.04	0.12	0.24	0.29	0.31	0.31	0.31	0.31	0.31	0.31	0.31
1969	0.01	0.08	0.29	0.55	0.65	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
1970	0.00	0.00	0.01	0.06	0.28	0.57	0.67	0.69	0.70	0.70	0.70	0.70	0.70	0.70
1971	0.31	0.60	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
1972	0.12	0.26	0.30	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
1973	0.13	0.40	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
1974	0.09	0.14	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
1975	0.05	0.11	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
1976	0.01	0.03	0.07	0.10	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
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	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
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	0.06	0.07	0.07	0.08	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	0.07	0.07	0.07	0.07	0.07	0.07
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	0.09	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	0.08	0.08	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	0.04	0.06	0.06	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	0.08	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	0.00	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	0.04	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	0.01	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
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	0.03	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2007	0.02	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

2008	0.02	0.05	0.08	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
2009	0.01	0.02	0.04	0.06	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
2010	0.02	0.04	0.07	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	0.28	0.15
1965	0.25	0.07
1966	0.43	0.13
1967	0.57	0.20
1968	0.31	0.11
1969	0.67	0.22
1970	0.70	0.19
1971	0.64	0.22
1972	0.31	0.06
1973	0.49	0.08
1974	0.16	0.04
1975	0.14	0.05
1976	0.14	0.03
1977	0.06	0.03
1978	0.13	0.06
1979	0.07	0.04
1980	0.08	0.04
1981	0.07	0.04
1982	0.05	0.04
1983	0.05	0.04
1984	0.08	0.06
1985	0.12	0.08
1986	0.11	0.08
1987	0.11	0.07
1988	0.14	0.08
1989	0.11	0.06
1990	0.05	0.03
1991	0.05	0.04
1992	0.09	0.06
1993	0.07	0.04
1994	0.08	0.06
1995	0.07	0.05
1996	0.07	0.05
1997	0.11	0.08
1998	0.06	0.05
1999	0.05	0.03
2000	0.06	0.04
2001	0.05	0.03
2002	0.05	0.03
2003	0.05	0.03
2004	0.05	0.03

2005	0.06	0.04
2006	0.06	0.05
2007	0.08	0.06
2008	0.11	0.07
2009	0.08	0.05
2010		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												
1982-2010	0.00	0.01	0.03	0.14	0.45	0.80	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	0.42	0.77	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	0.00	0.00	0.02	0.08	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
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.18	0.44	0.74	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.18	0.44	0.74	0.91	0.97	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	0.00	0.02	0.07	0.22	0.51	0.80	0.94	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	0.01	0.04	0.16	0.46	0.78	0.94	0.99	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	0.01	0.06	0.24	0.59	0.87	0.97	0.99	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	0.09	0.52	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
1971	0.00	0.00	0.00	0.00	0.01	0.12	0.72	0.98	1.00	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	0.00	0.00	0.01	0.05	0.34	0.84	0.98	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	0.01	0.03	0.09	0.25	0.55	0.81	0.94	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1974	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.09	0.23	0.50	0.77	0.91	0.97	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	0.14	0.43	0.77	0.94	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	0.03	0.09	0.23	0.46	0.72	0.88	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1977	0.01	0.02	0.04	0.08	0.15	0.27	0.44	0.63	0.78	0.88	0.94	0.97	0.99	0.99	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	0.28	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
1979	0.00	0.00	0.00	0.01	0.04	0.12	0.29	0.55	0.79	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	0.19	0.32	0.50	0.68	0.82	0.90	0.95	0.98	0.99	0.99	1.00	1.00	1.00	1.00
1981	0.00	0.01	0.01	0.03	0.06	0.12	0.23	0.40	0.61	0.78	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	0.15	0.34	0.58	0.80	0.92	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	0.49	0.76	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	0.73	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	0.93	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	0.59	0.86	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	0.67	0.85	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	0.08	0.25	0.54	0.81	0.94	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	0.67	0.88	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	0.84	0.95	0.99	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	0.99	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	0.79	0.91	0.97	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	0.83	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	0.46	0.74	0.91	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	0.57	0.82	0.94	0.98	1.00	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	0.46	0.67	0.82	0.92	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	0.23	0.40	0.60	0.77	0.88	0.94	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	0.55	0.77	0.90	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	0.38	0.66	0.86	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	0.66	0.86	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	0.06	0.19	0.46	0.75	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	0.12	0.30	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	0.34	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	0.39	0.61	0.80	0.91	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	0.41	0.67	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	0.73	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
							fishery males													
1964	0.00	0.00	0.03	0.71	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	0.08	0.44	0.87	0.98	1.00	1.00	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	0.02	0.08	0.30	0.69	0.92	0.98	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	0.29	0.74	0.95	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	0.00	0.00	0.01	0.03	0.12	0.39	0.75	0.93	0.99	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	0.02	0.11	0.43	0.82	0.96	0.99	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	0.00	0.00	0.00	0.00	0.02	0.09	0.40	0.81	0.96	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	0.06	0.49	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	0.01	0.07	0.40	0.86	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	0.26	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

1974	0.00	0.00	0.00	0.01	0.06	0.23	0.57	0.85	0.96	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	0.08	0.37	0.79	0.96	0.99	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	0.08	0.22	0.49	0.76	0.91	0.97	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	0.15	0.45	0.78	0.94	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	0.22	0.45	0.70	0.87	0.95	0.98	0.99	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	0.28	0.54	0.78	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	0.00	0.01	0.02	0.03	0.05	0.09	0.15	0.24	0.37	0.51	0.65	0.77	0.86	0.92	0.95	0.97	0.97	0.97	0.97
1981	0.00	0.01	0.02	0.03	0.06	0.11	0.20	0.33	0.48	0.65	0.78	0.87	0.93	0.96	0.98	0.99	0.99	0.99	0.99	0.99
1982	0.00	0.01	0.02	0.04	0.11	0.25	0.49	0.72	0.88	0.95	0.98	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	0.52	0.79	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	0.32	0.65	0.88	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	0.34	0.70	0.91	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	0.34	0.73	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	0.01	0.03	0.15	0.51	0.86	0.97	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	0.44	0.82	0.96	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	0.46	0.80	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	0.52	0.82	0.95	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	0.52	0.84	0.96	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	0.51	0.79	0.93	0.98	0.99	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	0.41	0.58	0.74	0.85	0.92	0.96	0.98	0.99	0.99	0.99	0.99	0.99
1994	0.00	0.00	0.00	0.01	0.02	0.09	0.28	0.60	0.86	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	0.33	0.67	0.89	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	0.43	0.66	0.84	0.93	0.97	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	0.29	0.54	0.76	0.90	0.96	0.99	0.99	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	0.40	0.73	0.92	0.98	0.99	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	0.01	0.01	0.04	0.10	0.23	0.46	0.70	0.87	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	0.14	0.34	0.62	0.83	0.94	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	0.21	0.41	0.64	0.82	0.92	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	0.20	0.53	0.84	0.96	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	0.42	0.77	0.94	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	0.12	0.30	0.57	0.80	0.92	0.97	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	0.22	0.45	0.70	0.87	0.95	0.98	0.99	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	0.15	0.57	0.91	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	0.27	0.57	0.83	0.95	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	0.06	0.19	0.43	0.72	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	0.10	0.25	0.50	0.75	0.90	0.96	0.99	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 2009 and 2010 stock assessments.

	2009 Assessment		**2010 Assessment**	
Year	**Female spawning biomass**	**Total biomass**	**Female spawning biomass**	**Total biomass**
1964	87,188	780,408	90,859	769,577
1965	97,914	783,538	112,915	774,043
1966	122,192	842,208	154,995	836,760
1967	132,185	836,593	185,597	831,366
1968	132,608	765,127	181,908	755,747
1969	129,742	784,744	187,799	777,166
1970	105,234	726,083	135,659	717,819
1971	79,120	735,101	87,753	734,857
1972	61,026	746,900	58,406	744,142
1973	64,620	914,587	64,586	917,781
1974	73,231	1,083,830	70,719	1,094,160
1975	99,083	1,330,700	107,157	1,353,880
1976	140,619	1,570,780	160,037	1,605,310
1977	205,057	1,823,930	235,865	1,869,260
1978	284,821	2,067,810	342,435	2,119,770
1979	367,947	2,210,430	435,975	2,262,780
1980	466,913	2,377,950	548,192	2,425,410
1981	567,339	2,533,960	651,003	2,574,240
1982	656,468	2,670,690	742,125	2,701,370
1983	736,697	2,775,580	828,628	2,793,320
1984	798,949	2,851,940	901,535	2,855,100
1985	824,400	2,851,510	935,930	2,840,990
1986	818,968	2,780,000	920,721	2,758,360
1987	804,531	2,719,470	894,627	2,690,630
1988	779,044	2,699,570	869,459	2,668,140
1989	747,706	2,618,280	814,879	2,588,380
1990	759,960	2,603,990	805,588	2,579,870
1991	802,083	2,632,540	856,195	2,613,460
1992	831,919	2,631,300	905,828	2,616,470
1993	852,344	2,558,690	923,880	2,546,960
1994	863,627	2,514,230	945,860	2,505,630
1995	848,805	2,423,440	930,333	2,417,450
1996	825,602	2,357,660	908,870	2,353,740
1997	785,591	2,282,810	878,227	2,281,590
1998	744,643	2,151,070	817,308	2,153,240
1999	726,894	2,101,330	790,111	2,107,250
2000	720,941	2,109,520	783,617	2,120,300
2001	716,506	2,100,600	773,325	2,117,250
2002	708,909	2,098,420	766,810	2,120,270
2003	706,873	2,096,600	767,171	2,122,860

2004	699,923	2,099,670	762,464	2,131,980
2005	695,314	2,105,180	765,879	2,142,860
2006	683,267	2,081,480	757,170	2,131,370
2007	666,750	2,065,780	748,884	2,133,090
2008	638,651	2,040,490	723,091	2,131,940
2009	604,762	1,984,560	675,957	2,107,380
2010			654,802	2,139,050

Table 4.18—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2010.

	Females																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1954	1.32	0.9	0.37	0.25	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1955	0.97	1.17	0.79	0.33	0.23	0.2	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.36
1956	0.68	0.86	1.04	0.7	0.29	0.2	0.18	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.47
1957	2.04	0.6	0.76	0.92	0.62	0.26	0.18	0.16	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.55
1958	1.29	1.81	0.53	0.68	0.82	0.55	0.23	0.16	0.14	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.6
1959	0.92	1.14	1.61	0.47	0.6	0.73	0.49	0.2	0.14	0.12	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.62
1960	0.85	0.82	1.02	1.42	0.42	0.53	0.64	0.43	0.17	0.11	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.55
1961	0.5	0.76	0.72	0.9	1.26	0.37	0.47	0.56	0.37	0.14	0.08	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.32
1962	0.94	0.44	0.67	0.64	0.8	1.12	0.33	0.42	0.49	0.32	0.11	0.04	0.01	0	0	0	0	0	0	0.01
1963	0.47	0.84	0.39	0.59	0.56	0.67	0.83	0.19	0.18	0.18	0.11	0.04	0.01	0	0	0	0	0	0	0
1964	0.43	0.42	0.74	0.35	0.52	0.49	0.58	0.69	0.14	0.12	0.12	0.07	0.02	0.01	0	0	0	0	0	0
1965	0.58	0.39	0.37	0.66	0.31	0.46	0.43	0.5	0.56	0.11	0.08	0.08	0.05	0.01	0.01	0	0	0	0	0
1966	0.58	0.52	0.34	0.33	0.58	0.27	0.41	0.38	0.44	0.47	0.08	0.06	0.05	0.03	0.01	0	0	0	0	0
1967	1.19	0.51	0.46	0.3	0.29	0.52	0.24	0.36	0.33	0.36	0.35	0.05	0.04	0.03	0.02	0.01	0	0	0	0
1968	1.8	1.05	0.45	0.41	0.27	0.26	0.46	0.21	0.31	0.26	0.24	0.2	0.03	0.02	0.02	0.01	0	0	0	0
1969	1.82	1.59	0.93	0.4	0.36	0.24	0.23	0.39	0.16	0.21	0.17	0.16	0.13	0.02	0.01	0.01	0.01	0	0	0
1970	2.38	1.61	1.41	0.83	0.36	0.32	0.21	0.19	0.29	0.1	0.11	0.08	0.07	0.06	0.01	0.01	0	0	0	0
1971	2.63	2.11	1.43	1.25	0.73	0.31	0.27	0.13	0.09	0.13	0.04	0.05	0.04	0.03	0.03	0	0	0	0	0
1972	2.06	2.34	1.87	1.27	1.11	0.65	0.26	0.15	0.06	0.04	0.06	0.02	0.02	0.02	0.01	0.01	0	0	0	0
1973	1.43	1.83	2.07	1.66	1.13	0.99	0.58	0.23	0.13	0.05	0.03	0.04	0.01	0.01	0.01	0.01	0.01	0	0	0
1974	1.92	1.26	1.62	1.84	1.47	1	0.87	0.5	0.19	0.1	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0	0	0
1975	2.25	1.7	1.12	1.44	1.63	1.31	0.88	0.77	0.44	0.17	0.08	0.03	0.02	0.02	0.01	0.01	0	0	0	0
1976	1.48	2	1.51	0.99	1.27	1.44	1.15	0.77	0.64	0.35	0.13	0.07	0.02	0.01	0.01	0	0	0	0	0
1977	1.85	1.31	1.77	1.34	0.88	1.13	1.27	1.01	0.66	0.53	0.28	0.1	0.05	0.02	0.01	0.01	0	0	0	0
1978	1.22	1.64	1.16	1.57	1.18	0.77	0.98	1.1	0.86	0.56	0.45	0.24	0.08	0.04	0.01	0.01	0.01	0	0	0.01
1979	0.78	1.08	1.46	1.03	1.39	1.04	0.68	0.84	0.91	0.69	0.44	0.35	0.18	0.07	0.03	0.01	0.01	0.01	0	0.01
1980	1.51	0.69	0.96	1.29	0.91	1.23	0.92	0.59	0.72	0.76	0.57	0.36	0.29	0.15	0.05	0.03	0.01	0	0.01	0.01

Table 4.18—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2009 (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	1.34	0.61	0.85	1.14	0.81	1.08	0.8	0.51	0.61	0.64	0.47	0.3	0.24	0.12	0.04	0.02	0.01	0	0.01
1982	3.2	0.99	1.18	0.54	0.75	1.01	0.71	0.94	0.69	0.43	0.51	0.53	0.39	0.25	0.2	0.1	0.04	0.02	0.01	0.01
1983	0.59	2.84	0.88	1.05	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	0.02	0.02
1984	2.63	0.52	2.52	0.78	0.93	0.43	0.58	0.77	0.53	0.69	0.5	0.31	0.37	0.38	0.28	0.18	0.14	0.07	0.03	0.03
1985	0.9	2.33	0.47	2.23	0.69	0.82	0.37	0.51	0.66	0.44	0.57	0.41	0.25	0.3	0.31	0.23	0.14	0.11	0.06	0.04
1986	0.69	0.8	2.07	0.41	1.98	0.61	0.72	0.33	0.43	0.54	0.36	0.45	0.32	0.2	0.24	0.24	0.18	0.11	0.09	0.08
1987	0.93	0.61	0.71	1.83	0.37	1.75	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	0.14
1988	1.26	0.83	0.54	0.63	1.62	0.32	1.55	0.47	0.54	0.23	0.29	0.35	0.23	0.29	0.2	0.13	0.15	0.15	0.11	0.18
1989	1.24	1.12	0.73	0.48	0.56	1.44	0.29	1.36	0.4	0.44	0.18	0.22	0.27	0.17	0.22	0.16	0.1	0.11	0.12	0.23
1990	0.61	1.1	0.99	0.65	0.43	0.5	1.28	0.25	1.19	0.34	0.37	0.15	0.18	0.21	0.14	0.18	0.13	0.08	0.09	0.28
1991	0.68	0.54	0.98	0.88	0.58	0.38	0.44	1.13	0.22	1.02	0.29	0.31	0.12	0.15	0.18	0.12	0.15	0.11	0.07	0.31
1992	1.49	0.6	0.48	0.87	0.78	0.51	0.33	0.39	0.98	0.19	0.87	0.25	0.26	0.1	0.13	0.15	0.1	0.12	0.09	0.32
1993	0.86	1.32	0.53	0.43	0.77	0.69	0.45	0.29	0.33	0.83	0.16	0.72	0.2	0.21	0.08	0.1	0.12	0.08	0.1	0.33
1994	0.73	0.76	1.17	0.47	0.38	0.68	0.61	0.4	0.26	0.29	0.71	0.13	0.6	0.17	0.18	0.07	0.09	0.1	0.07	0.36
1995	0.71	0.65	0.68	1.04	0.42	0.33	0.6	0.53	0.34	0.21	0.24	0.59	0.11	0.49	0.14	0.15	0.06	0.07	0.08	0.35
1996	1.87	0.63	0.57	0.6	0.92	0.37	0.3	0.52	0.46	0.28	0.18	0.2	0.49	0.09	0.41	0.12	0.12	0.05	0.06	0.36
1997	0.77	1.66	0.56	0.51	0.53	0.81	0.33	0.26	0.45	0.38	0.24	0.15	0.16	0.4	0.08	0.34	0.1	0.1	0.04	0.35
1998	0.63	0.68	1.47	0.5	0.45	0.47	0.71	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	0.82	0.56	0.6	1.3	0.44	0.4	0.41	0.62	0.24	0.18	0.31	0.26	0.16	0.1	0.11	0.27	0.05	0.22	0.06	0.32
2000	1.18	0.73	0.5	0.53	1.16	0.39	0.35	0.36	0.54	0.21	0.16	0.26	0.22	0.13	0.08	0.09	0.22	0.04	0.19	0.32
2001	0.76	1.04	0.65	0.44	0.47	1.02	0.35	0.31	0.32	0.47	0.18	0.13	0.22	0.18	0.11	0.07	0.08	0.19	0.04	0.43
2002	1.08	0.68	0.92	0.57	0.39	0.42	0.91	0.3	0.27	0.27	0.4	0.15	0.11	0.19	0.16	0.1	0.06	0.06	0.16	0.39
2003	1.16	0.95	0.6	0.82	0.51	0.35	0.37	0.8	0.27	0.24	0.23	0.34	0.13	0.1	0.16	0.13	0.08	0.05	0.05	0.46
2004	2.26	1.03	0.85	0.53	0.73	0.45	0.31	0.33	0.7	0.23	0.2	0.2	0.29	0.11	0.08	0.13	0.11	0.07	0.04	0.44
2005	0.99	2	0.91	0.75	0.47	0.64	0.4	0.27	0.29	0.6	0.2	0.17	0.17	0.24	0.09	0.07	0.11	0.09	0.06	0.41
2006	1.55	0.88	1.77	0.81	0.67	0.42	0.57	0.35	0.23	0.24	0.51	0.16	0.14	0.14	0.2	0.08	0.06	0.09	0.08	0.39
2007	1.42	1.37	0.78	1.57	0.71	0.59	0.36	0.48	0.29	0.2	0.2	0.43	0.14	0.12	0.12	0.17	0.06	0.05	0.08	0.39
2008	1.07	1.26	1.22	0.69	1.39	0.63	0.52	0.32	0.41	0.25	0.16	0.17	0.35	0.11	0.1	0.1	0.14	0.05	0.04	0.38
2009	1.11	0.95	1.11	1.08	0.61	1.23	0.56	0.45	0.27	0.34	0.2	0.13	0.13	0.28	0.09	0.08	0.08	0.11	0.04	0.33
2010	1.12	0.98	0.84	0.99	0.96	0.54	1.09	0.49	0.39	0.22	0.28	0.16	0.11	0.11	0.23	0.07	0.06	0.06	0.09	0.31

Table 4.18—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2010 (continued).

Males	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1954	1.32	0.87	0.37	0.25	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1955	0.97	1.17	0.77	0.32	0.22	0.2	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.36
1956	0.68	0.86	1.04	0.69	0.29	0.2	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.47
1957	2.04	0.6	0.76	0.92	0.61	0.26	0.17	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.55
1958	1.29	1.81	0.53	0.68	0.82	0.54	0.23	0.15	0.14	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.6
1959	0.92	1.14	1.61	0.47	0.6	0.73	0.48	0.2	0.13	0.12	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.62
1960	0.85	0.82	1.02	1.42	0.42	0.53	0.64	0.42	0.17	0.11	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.55
1961	0.5	0.76	0.72	0.9	1.26	0.37	0.47	0.56	0.35	0.13	0.07	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.32
1962	0.94	0.44	0.67	0.64	0.8	1.12	0.33	0.42	0.5	0.3	0.1	0.03	0	0	0	0	0	0	0	0.01
1963	0.47	0.83	0.39	0.58	0.53	0.58	0.64	0.14	0.15	0.17	0.1	0.03	0.01	0	0	0	0	0	0	0
1964	0.43	0.42	0.74	0.34	0.51	0.47	0.5	0.5	0.1	0.1	0.11	0.06	0.02	0.01	0	0	0	0	0	0
1965	0.58	0.39	0.37	0.65	0.25	0.34	0.31	0.33	0.34	0.07	0.07	0.07	0.04	0.01	0	0	0	0	0	0
1966	0.58	0.52	0.34	0.33	0.58	0.22	0.3	0.27	0.26	0.24	0.05	0.05	0.05	0.03	0.01	0	0	0	0	0
1967	1.19	0.51	0.46	0.3	0.29	0.51	0.19	0.26	0.21	0.17	0.14	0.03	0.03	0.03	0.02	0.01	0	0	0	0
1968	1.8	1.05	0.45	0.41	0.27	0.26	0.44	0.15	0.15	0.11	0.09	0.07	0.01	0.01	0.01	0.01	0	0	0	0
1969	1.82	1.59	0.93	0.4	0.36	0.24	0.23	0.39	0.13	0.13	0.09	0.07	0.05	0.01	0.01	0.01	0.01	0	0	0
1970	2.38	1.61	1.41	0.83	0.36	0.32	0.21	0.2	0.32	0.09	0.07	0.04	0.03	0.02	0	0	0	0	0	0
1971	2.63	2.11	1.43	1.25	0.74	0.32	0.28	0.19	0.18	0.28	0.07	0.05	0.02	0.01	0.01	0	0	0	0	0
1972	2.06	2.34	1.87	1.27	1.11	0.65	0.27	0.18	0.09	0.08	0.13	0.03	0.02	0.01	0.01	0	0	0	0	0
1973	1.43	1.83	2.07	1.66	1.13	0.98	0.56	0.21	0.13	0.06	0.05	0.09	0.02	0.01	0.01	0	0	0	0	0
1974	1.92	1.26	1.62	1.84	1.47	1	0.86	0.44	0.13	0.07	0.03	0.03	0.05	0.01	0.01	0	0	0	0	0
1975	2.25	1.7	1.12	1.44	1.63	1.29	0.85	0.7	0.34	0.1	0.05	0.02	0.02	0.04	0.01	0.01	0	0	0	0
1976	1.48	2	1.51	0.99	1.27	1.44	1.14	0.72	0.55	0.26	0.07	0.04	0.02	0.02	0.03	0.01	0	0	0	0
1977	1.85	1.31	1.77	1.34	0.88	1.13	1.27	1	0.62	0.46	0.21	0.06	0.03	0.01	0.01	0.02	0.01	0	0	0
1978	1.22	1.64	1.16	1.57	1.19	0.78	1	1.12	0.86	0.52	0.38	0.18	0.05	0.03	0.01	0.01	0.02	0	0	0
1979	0.78	1.08	1.46	1.03	1.39	1.05	0.69	0.86	0.94	0.7	0.41	0.3	0.14	0.04	0.02	0.01	0.01	0.01	0	0
1980	1.51	0.69	0.96	1.29	0.91	1.23	0.92	0.6	0.73	0.78	0.58	0.34	0.25	0.11	0.03	0.02	0.01	0.01	0.01	0.01

Table 4.18—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2010 (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	1.34	0.61	0.85	1.14	0.81	1.09	0.81	0.52	0.64	0.67	0.49	0.29	0.21	0.09	0.03	0.01	0.01	0.01	0.01
1982	3.2	0.99	1.18	0.54	0.75	1.01	0.71	0.95	0.7	0.45	0.54	0.57	0.41	0.24	0.17	0.08	0.02	0.01	0.01	0.02
1983	0.59	2.84	0.88	1.05	0.48	0.66	0.88	0.62	0.81	0.6	0.38	0.46	0.48	0.35	0.2	0.14	0.07	0.02	0.01	0.02
1984	2.63	0.52	2.52	0.78	0.93	0.42	0.58	0.76	0.52	0.69	0.51	0.32	0.39	0.4	0.29	0.17	0.12	0.06	0.01	0.02
1985	0.9	2.33	0.47	2.23	0.69	0.82	0.37	0.5	0.64	0.43	0.57	0.41	0.26	0.32	0.33	0.24	0.14	0.1	0.05	0.03
1986	0.69	0.8	2.07	0.41	1.98	0.61	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	0.93	0.61	0.71	1.83	0.37	1.75	0.53	0.62	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	1.26	0.83	0.54	0.63	1.63	0.32	1.55	0.47	0.52	0.21	0.26	0.32	0.22	0.28	0.21	0.13	0.16	0.16	0.12	0.16
1989	1.24	1.12	0.73	0.48	0.56	1.44	0.29	1.35	0.39	0.41	0.16	0.2	0.25	0.17	0.22	0.16	0.1	0.12	0.13	0.21
1990	0.61	1.1	0.99	0.65	0.43	0.5	1.28	0.25	1.18	0.33	0.33	0.13	0.16	0.2	0.13	0.17	0.13	0.08	0.1	0.27
1991	0.68	0.54	0.98	0.88	0.58	0.38	0.44	1.12	0.22	1.01	0.28	0.28	0.11	0.14	0.17	0.11	0.15	0.11	0.07	0.31
1992	1.49	0.6	0.48	0.87	0.78	0.51	0.33	0.39	0.97	0.19	0.85	0.23	0.24	0.09	0.11	0.14	0.09	0.12	0.09	0.32
1993	0.86	1.32	0.53	0.43	0.77	0.69	0.45	0.29	0.33	0.8	0.15	0.69	0.19	0.19	0.08	0.09	0.12	0.08	0.1	0.33
1994	0.73	0.76	1.17	0.47	0.38	0.68	0.61	0.4	0.25	0.28	0.69	0.13	0.58	0.16	0.16	0.06	0.08	0.1	0.06	0.36
1995	0.71	0.65	0.68	1.04	0.42	0.33	0.6	0.53	0.34	0.21	0.23	0.56	0.11	0.48	0.13	0.13	0.05	0.06	0.08	0.35
1996	1.87	0.63	0.57	0.6	0.92	0.37	0.29	0.52	0.45	0.28	0.18	0.19	0.47	0.09	0.4	0.11	0.11	0.04	0.05	0.35
1997	0.77	1.66	0.56	0.51	0.53	0.81	0.32	0.25	0.44	0.38	0.23	0.14	0.16	0.39	0.07	0.33	0.09	0.09	0.04	0.33
1998	0.63	0.68	1.47	0.5	0.45	0.47	0.71	0.28	0.21	0.36	0.3	0.19	0.12	0.13	0.31	0.06	0.26	0.07	0.07	0.29
1999	0.82	0.56	0.6	1.3	0.44	0.4	0.41	0.62	0.24	0.18	0.3	0.25	0.15	0.1	0.11	0.25	0.05	0.22	0.06	0.3
2000	1.18	0.73	0.5	0.54	1.16	0.39	0.35	0.37	0.55	0.21	0.16	0.26	0.21	0.13	0.08	0.09	0.22	0.04	0.18	0.31
2001	0.76	1.04	0.65	0.44	0.47	1.03	0.35	0.31	0.32	0.48	0.18	0.13	0.21	0.18	0.11	0.07	0.07	0.18	0.03	0.41
2002	1.08	0.68	0.92	0.57	0.39	0.42	0.91	0.31	0.28	0.28	0.42	0.15	0.11	0.18	0.15	0.09	0.06	0.06	0.15	0.37
2003	1.16	0.95	0.6	0.82	0.51	0.35	0.37	0.8	0.27	0.24	0.24	0.35	0.13	0.09	0.15	0.13	0.08	0.05	0.05	0.44
2004	2.26	1.03	0.85	0.53	0.73	0.45	0.31	0.33	0.7	0.23	0.2	0.2	0.3	0.11	0.08	0.13	0.11	0.07	0.04	0.42
2005	0.99	2	0.91	0.75	0.47	0.64	0.4	0.27	0.29	0.6	0.2	0.17	0.17	0.25	0.09	0.07	0.11	0.09	0.06	0.39
2006	1.55	0.88	1.77	0.81	0.67	0.42	0.57	0.35	0.23	0.24	0.51	0.16	0.14	0.14	0.21	0.08	0.06	0.09	0.08	0.37
2007	1.42	1.37	0.78	1.57	0.72	0.59	0.37	0.49	0.29	0.2	0.2	0.42	0.14	0.12	0.12	0.17	0.06	0.05	0.08	0.37
2008	1.07	1.26	1.22	0.69	1.4	0.63	0.52	0.32	0.41	0.24	0.16	0.17	0.35	0.11	0.1	0.1	0.14	0.05	0.04	0.37
2009	1.11	0.95	1.11	1.08	0.61	1.23	0.56	0.45	0.27	0.34	0.2	0.13	0.13	0.28	0.09	0.08	0.08	0.11	0.04	0.32
2010	1.12	0.98	0.84	0.99	0.96	0.54	1.09	0.49	0.39	0.23	0.28	0.16	0.11	0.11	0.22	0.07	0.06	0.06	0.09	0.3

Table 4.19—Model estimates of the number of female spawners (millions) 1964-2010.

year/age	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1964	4.4	5.9	26.8	71.5	31.3	48.8	70.7	53.2	20.2	8.3	2.2	0.5	0.2	0.1	0.1	1.4
1965	2.6	5.6	20.1	52.1	121.0	41.7	51.4	61.3	40.5	14.3	5.7	1.5	0.3	0.1	0.1	1.0
1966	4.9	3.3	19.0	39.9	95.0	188.0	51.2	49.0	49.4	30.0	10.2	4.0	1.0	0.2	0.1	0.8
1967	2.4	6.2	11.1	37.6	72.1	143.0	213.1	42.7	33.5	30.7	17.9	6.0	2.3	0.6	0.1	0.5
1968	2.3	3.1	21.2	22.0	67.0	103.6	146.2	155.1	25.3	18.1	15.9	9.1	3.0	1.2	0.3	0.3
1969	3.0	2.9	10.4	40.0	35.2	85.2	105.6	123.1	114.6	17.5	12.1	10.4	5.9	2.0	0.8	0.4
1970	3.0	3.8	9.7	19.9	63.0	38.4	65.0	63.2	63.9	55.3	8.1	5.5	4.8	2.7	0.9	0.5
1971	6.2	3.8	12.3	13.4	19.3	51.1	26.1	37.0	31.7	29.9	25.1	3.6	2.5	2.1	1.2	0.6
1972	9.3	7.8	12.0	15.4	13.2	16.5	36.8	15.8	19.7	15.8	14.4	11.9	1.7	1.2	1.0	0.9
1973	9.5	11.8	26.6	23.8	28.5	21.1	20.3	32.6	11.8	13.7	10.6	9.5	7.8	1.1	0.8	1.2
1974	12.4	12.0	40.3	52.3	42.2	40.9	22.1	15.7	20.8	6.9	7.6	5.8	5.2	4.2	0.6	1.1
1975	13.7	15.7	40.9	79.9	95.5	65.9	51.6	22.4	13.6	16.8	5.3	5.8	4.4	3.9	3.2	1.3
1976	10.7	17.3	53.4	79.9	139.2	139.0	78.9	51.4	19.6	11.2	13.3	4.2	4.5	3.4	3.0	3.4
1977	7.4	13.5	59.0	105.0	143.2	212.0	172.2	80.1	45.4	16.1	8.9	10.4	3.2	3.5	2.6	5.0
1978	9.9	9.3	45.5	114.2	186.5	221.2	274.1	185.7	76.0	40.2	13.8	7.5	8.7	2.7	2.9	6.3
1979	11.7	12.5	31.4	87.5	197.1	274.0	269.2	277.6	165.4	63.1	32.3	10.9	5.9	6.8	2.1	7.2
1980	7.7	14.7	42.5	61.1	155.4	302.0	350.2	286.9	260.4	144.8	53.4	26.9	9.0	4.8	5.6	7.7
1981	9.6	9.7	50.0	83.2	110.1	241.9	390.1	374.4	268.4	226.5	121.5	44.1	22.1	7.4	4.0	10.8
1982	6.3	12.1	32.8	98.0	149.8	171.6	314.2	421.1	354.8	237.0	193.2	102.0	36.8	18.4	6.1	12.3
1983	4.0	8.0	41.1	64.2	176.1	233.9	224.4	342.9	404.8	318.2	205.5	164.9	86.5	31.1	15.5	15.5
1984	7.8	5.1	26.9	79.8	114.3	273.0	304.5	244.3	329.0	362.4	275.5	175.1	139.7	73.1	26.2	26.2
1985	5.8	9.9	17.3	52.7	142.3	175.2	347.9	323.0	228.0	286.4	305.0	228.2	144.2	114.8	59.9	42.9

Table 4.19 (continued).

year/age	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1986	16.6	7.3	33.5	33.8	93.2	214.5	217.3	356.7	290.4	190.9	231.7	242.9	180.6	113.9	90.4	81.0
1987	3.1	21.0	24.8	64.8	58.5	137.6	263.8	223.1	322.5	245.0	155.8	186.1	193.9	143.9	90.4	136.1
1988	13.6	3.9	71.6	48.8	117.2	90.7	174.8	275.0	203.0	272.8	200.1	125.1	148.6	154.4	114.3	179.9
1989	4.7	17.3	13.3	140.9	87.2	176.3	110.7	175.4	241.7	166.2	215.9	155.9	96.9	114.8	119.0	226.6
1990	3.6	5.9	59.0	26.3	256.8	136.2	224.5	115.4	159.6	204.7	136.0	173.8	124.7	77.4	91.4	275.1
1991	4.8	4.5	20.3	117.0	48.0	405.8	179.2	245.9	111.2	143.5	178.0	116.4	147.9	105.9	65.5	310.2
1992	6.6	6.1	15.5	40.2	213.3	75.8	533.6	195.8	236.0	99.5	124.1	151.5	98.4	124.8	89.1	316.2
1993	6.5	8.3	20.9	30.4	72.3	329.9	97.0	565.4	182.0	204.4	83.3	102.2	124.0	80.4	101.7	330.1
1994	3.2	8.2	28.3	41.2	55.5	114.6	435.3	106.0	540.5	161.6	174.9	70.1	85.4	103.3	66.8	358.7
1995	3.5	4.0	27.8	55.4	73.6	85.1	146.3	462.9	99.2	471.9	136.4	145.4	57.9	70.4	84.9	349.6
1996	7.7	4.4	13.7	54.3	98.7	113.1	109.3	156.8	437.2	87.4	402.1	114.4	121.2	48.1	58.4	360.5
1997	4.5	9.7	15.1	26.7	97.1	152.6	145.6	117.1	147.6	383.4	74.1	335.4	94.8	100.2	39.7	345.4
1998	3.8	5.6	32.9	29.2	47.2	147.6	191.8	151.4	106.5	124.9	313.3	59.5	267.8	75.6	79.6	305.9
1999	3.7	4.8	19.0	64.2	52.2	73.0	190.6	206.6	143.5	94.2	106.8	263.6	49.8	223.5	62.9	320.8
2000	9.7	4.7	16.3	37.7	117.8	83.2	96.6	209.1	198.9	128.7	81.6	91.1	223.5	42.1	188.6	323.7
2001	4.0	12.3	16.0	32.4	69.1	186.9	109.2	105.0	199.2	176.4	110.3	68.9	76.4	187.0	35.2	427.4
2002	3.3	5.0	42.0	31.6	58.9	109.0	246.0	119.8	101.4	179.3	153.6	94.5	58.7	64.9	158.5	391.9
2003	4.3	4.2	17.2	83.3	57.9	93.5	143.5	268.8	115.1	90.8	155.2	130.8	80.1	49.6	54.7	463.7
2004	6.1	5.4	14.2	34.1	151.7	91.3	122.8	156.9	258.5	103.2	78.7	132.5	111.0	67.8	41.8	437.6
2005	4.0	7.7	18.4	28.1	62.1	239.5	120.3	134.7	151.3	232.6	89.8	67.4	112.7	94.3	57.4	405.9
2006	5.6	5.0	26.3	36.2	50.8	97.1	311.7	130.1	128.0	134.1	199.2	75.7	56.4	94.2	78.5	386.0
2007	6.0	7.0	16.8	50.2	63.4	77.8	125.1	336.3	123.8	113.7	115.1	168.3	63.6	47.3	78.8	388.3
2008	11.7	7.6	24.0	32.9	89.8	97.4	99.1	132.5	313.0	107.4	95.4	95.0	138.1	52.0	38.6	381.3
2009	5.1	14.8	25.8	46.7	58.0	134.8	121.0	102.3	120.2	265.0	87.9	76.8	76.1	110.4	41.5	334.5
2010	8.0	6.5	50.5	50.8	83.5	88.5	170.7	127.6	95.0	104.2	222.0	72.5	63.0	62.3	90.0	306.7

Table 4.20. Model estimates of yellowfin sole age 5 recruitment (millions) from the 2009 and 2010 stock assessments. Average from the 2010 assessment is 1,482 million.

Year class	2009 Assessment	2010 Assessment
1964	719	721
1965	728	714
1966	1,418	1,470
1967	2,132	2,224
1968	2,120	2,253
1969	2,749	2,948
1970	3,109	3,256
1971	2,471	2,546
1972	1,735	1,764
1973	2,383	2,369
1974	2,862	2,781
1975	1,907	1,825
1976	2,391	2,285
1977	1,554	1,501
1978	988	962
1979	1,891	1,859
1980	1,378	1,375
1981	3,930	3,957
1982	724	732
1983	3,205	3,251
1984	1,103	1,118
1985	848	853
1986	1,159	1,153
1987	1,580	1,563
1988	1,548	1,537
1989	754	757
1990	800	837
1991	1,776	1,839
1992	1,013	1,060
1993	853	901
1994	832	880
1995	2,225	2,313
1996	913	949
1997	768	784
1998	1,082	1,016
1999	1,640	1,455
2000	946	942
2001	1,219	1,331
2002	1,265	1,431
2003	2,186	2,790
2004	1,040	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)	-0.08	0.04	1970	total biomass	713.96	17.87
	beta (q-temp model)	0.09	0.02	1971	total biomass	726.83	19.55
	mean_log_rec	0.80	0.10	1972	total biomass	743.72	21.76
	sel_slope_fsh (females)	1.21	0.09	1973	total biomass	920.98	26.18
	sel50_fsh (females)	8.58	0.26	1974	total biomass	1106.90	31.25
	sel_slope_fsh_males	1.41	0.11	1975	total biomass	1369.70	37.15
	sel50_fsh_males	8.15	0.25	1976	total biomass	1622.80	43.26
	sel_slope_srv (females)	1.59	0.10	1977	total biomass	1887.50	49.25
	sel50_srv (females)	5.14	0.07	1978	total biomass	2138.10	54.90
	sel_slope_srv_males	-0.04	0.08	1979	total biomass	2281.00	59.79
	sel50_srv_males	0.02	0.02	1980	total biomass	2443.50	64.28
	F40	0.11	0.03	1981	total biomass	2591.80	68.10
	F35	0.13	0.04	1982	total biomass	2718.30	71.54
	F30	0.16	0.05	1983	total biomass	2810.20	74.32
	Ricker SR logalpha	-4.16	0.51	1984	total biomass	2872.50	76.71
	Ricker SR logbeta	-6.11	0.29	1985	total biomass	2859.40	78.52
	log (Fmsy)	-1.57	0.54	1986	total biomass	2777.80	80.12
	Fmsyr	0.13	0.04	1987	total biomass	2710.70	81.66
	log(Fmsyr)	-2.06	0.30	1988	total biomass	2688.40	83.62
	ABC_biomass 2010	1963.90	144.27	1989	total biomass	2608.50	85.02
	ABC_biomass 2011	1990.70	173.37	1990	total biomass	2599.60	86.71
	msy	345.75	118.55	1991	total biomass	2632.70	87.82
	Bmsy	379.18	64.20	1992	total biomass	2635.10	88.57
1954	total biomass	1999.40	101.80	1993	total biomass	2565.20	89.12
1955	total biomass	1981.90	89.34	1994	total biomass	2523.10	89.26
1956	total biomass	1956.90	77.88	1995	total biomass	2434.30	89.13
1957	total biomass	1941.10	67.78	1996	total biomass	2370.10	89.47
1958	total biomass	1944.20	60.22	1997	total biomass	2297.40	89.84
1959	total biomass	1941.90	54.88	1998	total biomass	2168.40	89.87
1960	total biomass	1810.90	49.33	1999	total biomass	2121.80	90.50
1961	total biomass	1435.30	38.71	2000	total biomass	2134.40	92.27
1962	total biomass	1025.30	25.13	2001	total biomass	2130.90	94.22
1963	total biomass	716.19	14.47	2002	total biomass	2133.30	95.66
1964	total biomass	754.89	15.02	2003	total biomass	2135.60	97.77
1965	total biomass	757.03	15.65	2004	total biomass	2144.00	100.38
1966	total biomass	815.19	16.97	2005	total biomass	2154.40	103.25
1967	total biomass	811.71	17.31	2006	total biomass	2142.30	106.90
1968	total biomass	745.11	16.60	2007	total biomass	2143.60	112.53
1968	total biomass	765.68	17.69	2008	total biomass	2141.40	120.80
1969	total biomass	784.74	16.84	2009	total biomass	2115.70	131.45
				2010	total biomass	2146.00	146.18

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. 2009 ABC is highlighted.

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2010	599.769	119.00	0.09
2011	585.126	128.56	0.10
2012	580.36	132.51	0.10
2013	584.601	135.68	0.10
2014	593.956	137.79	0.10
2015	607.512	139.43	0.10
2016	611.522	138.50	0.10
2017	609.724	136.55	0.10
2018	603.547	134.52	0.10
2019	595.911	133.17	0.10
2020	589.114	132.22	0.10
2021	582.226	130.98	0.10
2022	579.253	129.82	0.10
2023	579.636	129.24	0.10

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2010	599.769	119.00	0.09
2011	594.88	64.28	0.05
2012	618.537	70.12	0.05
2013	650.768	74.47	0.05
2014	688.214	78.12	0.05
2015	730.062	81.40	0.05
2016	759.384	83.07	0.05
2017	779.764	83.90	0.05
2018	792.447	84.39	0.05
2019	800.607	85.00	0.05
2020	806.921	85.59	0.05
2021	810.063	86.07	0.05
2022	816.259	86.70	0.05
2023	825.813	87.39	0.05

Scenario 4
Harvest at average F over the past 5 years

Year	Female spawning biomass	catch	F
2010	599.769	119.00	0.09
2011	587.324	114.23	0.09
2012	590.696	106.16	0.08
2013	606.479	110.50	0.08
2014	627.215	113.87	0.08
2015	652.02	116.74	0.08
2016	665.971	117.34	0.08
2017	672.722	116.91	0.08
2018	673.615	116.20	0.08
2019	671.707	115.87	0.08
2020	669.51	115.72	0.08
2021	665.943	115.57	0.08
2022	665.764	115.70	0.08
2023	668.702	115.97	0.08

Scenario 5
No fishing

Year	Female spawning biomass	catch	F
2010	599.769	119	0.09
2011	604.37	0	0
2012	657.828	0	0
2013	722.841	0	0
2014	796.023	0	0
2015	876.661	0	0
2016	943.787	0	0
2017	1000.26	0	0
2018	1046.65	0	0
2019	1085.95	0	0
2020	1120.75	0	0
2021	1148.71	0	0
2022	1179.22	0	0
2023	1214.07	0	0

Table 4.22—continued.

Scenario 6

Determination of whether yellowfin sole are currently overfished **B35=487.400**

Year	Female spawning biomass	catch	F
2010	599.769	119.00	0.09
2011	581.53	151.80	0.10
2012	566.704	154.09	0.10
2013	561.571	155.63	0.10
2014	562.087	156.18	0.10
2015	567.238	156.39	0.10
2016	564.228	153.87	0.10
2017	556.744	150.25	0.10
2018	546.588	144.47	0.10
2019	537.129	140.08	0.10
2020	530.21	137.17	0.10
2021	524.498	134.93	0.10
2022	522.823	134.17	0.10
2023	523.987	134.31	0.10

Scenario 7

Determination of whether the stock is approaching an overfished condition **B35=487.400**

Year	Female spawning biomass	catch	F
2010	599.769	119.00	0.09
2011	585.126	128.56	0.10
2012	580.36	132.51	0.10
2013	581.008	160.20	0.12
2014	579.891	160.15	0.12
2015	583.246	159.77	0.12
2016	578.065	156.69	0.12
2017	568.356	152.77	0.12
2018	555.819	148.48	0.12
2019	543.809	142.97	0.12
2020	534.914	139.10	0.11
2021	527.742	136.18	0.11
2022	525.033	134.97	0.11
2023	525.49	134.81	0.11

Table 4-23. Yellowfin catch and bycatch (t) from 1992-2008 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).

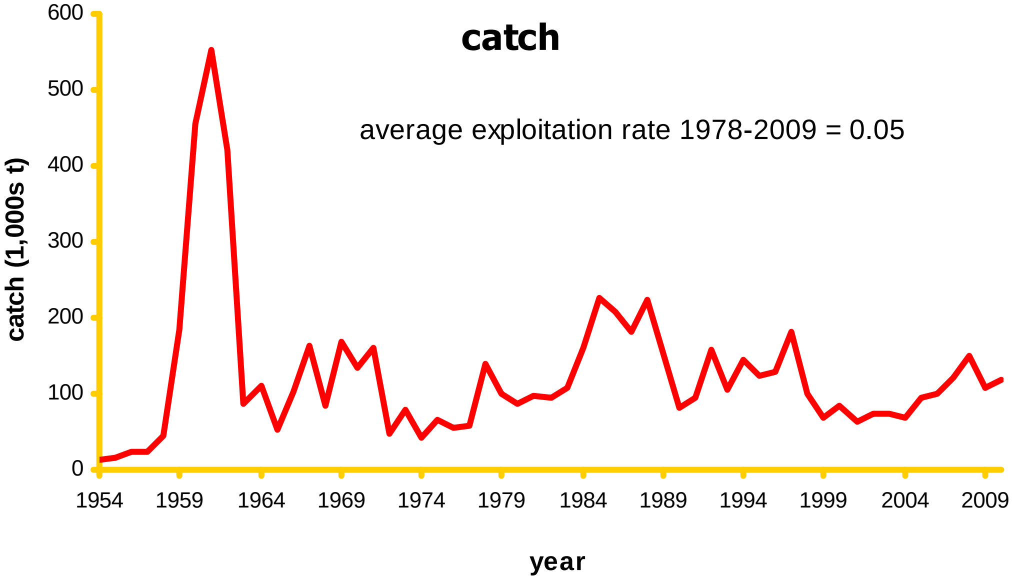
Species	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pollock	16,502	14,489	11,396	10,382	10,312	6,084	4,041	9,867	7,024
Arrowtooth Flounder	1,845	998	1,125	279	645	352	216	1,969	1,858
Pacific Cod	6,531	6,259	4,621	3,606	3,767	2,588	2,529	5,769	10,849
Groundfish, General	3,936	2,678	3,133	1,612	2,134	2,333	4003		
Rock Sole	5,810	10,665	8,419	10,068	10,086	8,113	8,218	10,487	9,109
Flathead Sole	3,231	2,190	2,899	1,102	1,246	2,039	1,744	5,581	3,525
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	
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
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
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, 2003-2010 (PSC not included).

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Benthic urochordata	1670.846	1695.563	674.7624	520.0914	114.4274	347.552	206.4775	67.27267
Birds	0	0	0.129	0	0	0	0.141	0.121
Bivalves	1.54282	1.11309	1.32744	0.34322	0.4477	1.48346	1.30055	1.24342
Brittle star unidentified	34.30287	32.27117	28.70562	19.96138	7.52649	19.04737	5.21187	2.31421
Capelin	0.00267	4.5185	0.04509	0.108	0.32147	0.1609	0.25149	0.71119
Corals Bryozoans	0.23986	0.0455	1.23163	9.37805	0.16167	8.30938	0.31258	0.28688
Eelpouts	19.04418	12.2563	7.72927	4.51426	2.34444	5.59793	5.20088	2.25799
Eulachon	0.01203	0.27755	0.03315	0.11504	5.07469	0.02184	0.08945	0.12897
Greenlings	0.64604	0.75319	0.2828	0.70314	0.47441	0.18273	0.0242	0.05348
Grenadier	0	0	0	0	0.3393	0	0.3578	0
Gunnels	0	0	0	0	0.00119	0	0	0
Hermit crab unidentified	87.93991	51.99948	82.99641	26.89809	35.8197	36.60232	15.6259	12.40632
Invertebrate unidentified	556.4948	625.5613	418.5124	177.1813	40.0089	70.40073	30.66689	11.8869
Large Sculpins	237.8308	830.6943	1056.932	1058.601	2279.104	2857.093	2506.388	1433.573
Misc crabs	14.43208	21.52378	11.77418	10.57058	27.96667	14.08331	11.05639	4.72173
Misc crustaceans	0.0138	0.18599	0.22541	2.32542	1.4018	0.71929	1.3349	0.81287
Misc fish	95.74469	91.46901	66.1643	42.47032	70.97052	66.42061	48.92667	23.37701
Misc inverts (worms etc)	0.02022	0.12325	0.02452	0.04977	0.04633	0.15228	0.17099	0.07722
Octopus	3.503	4.321	0	0	0.889	0.009	0.68	0.611
Other osmerids	4.25776	4.29177	0.49686	0.63364	35.77011	9.83296	0.84875	2.81941
Other Sculpins	1157.574	131.0271	105.1396	68.15323	194.3892	39.01741	74.21343	5.80024
Pacific Sand lance	0.00907	0.167	0.09705	0.03273	0.01712	0.03698	0.01486	0.0346
Pandalid shrimp	0.21569	0.91962	0.11492	0.77247	0.10127	0.3052	0.49346	0.57968
Polychaete unidentified	0.01604	0.06843	0.04204	0.36008	0.06918	0.17511	0.07477	0.096
Scypho jellies	111.9004	299.034	115.5504	46.78463	42.34558	146.1526	223.1044	106.5139
Sea anemone unidentified	6.08694	6.20228	2.58069	4.8956	8.79075	24.83441	25.57264	20.03461
Sea pens whips	0.00928	0.02805	0.1642	0.00301	0.01205	0.32394	0.18461	0.62297
Sea star	1939.624	1865.768	1606.948	1308.482	1456.62	1830.467	684.4507	430.79
Shark, pacific sleeper	2.227	0.08	1.407	0.05	0.646	0.398	0.017	0
Shark, salmon	0	0	0.08	0	0	0.508	1.531	0.381
Shark, spiny dogfish	0	0	0	0	0	0	0.546	0
Skate, Alaska	0	0	0	0	0	0	0	1470.717
Skate, Big	0	0	0	0.424	0	0.193	0.651	0.037
Skate, Longnose	0	1.138	0	0	0	0	0	0.015
Skate, Other	1513.092	594.621	942.31	1132.276	1405.223	1300.651	1801.29	10.297
Snails	118.257	191.0642	69.76944	141.5169	95.87579	139.7597	58.36212	44.78557
Sponge unidentified	11.43358	6.80734	12.20534	3.1182	0.4052	6.71651	69.49758	13.81009
Squid	1.396	0	0.007	0	0.008	0.275	0.006	0.005
Stichaeidae	0.07211	0.03178	0	0.00992	0.78432	0.2387	0.00955	0.17116
Surf smelt	0	0	0	0	0	0.00102	0	0
urchins dollars cucumbers	2.25373	0.31493	2.54864	0.84545	3.47735	4.89716	7.54771	0.91921
Grand Total	7591.041	6474.24	5210.337	4581.668	5831.86	6932.62	5782.633	3670.286

Table 4.25--Yellowfin sole TAC and ABC levels, 1980-2010

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



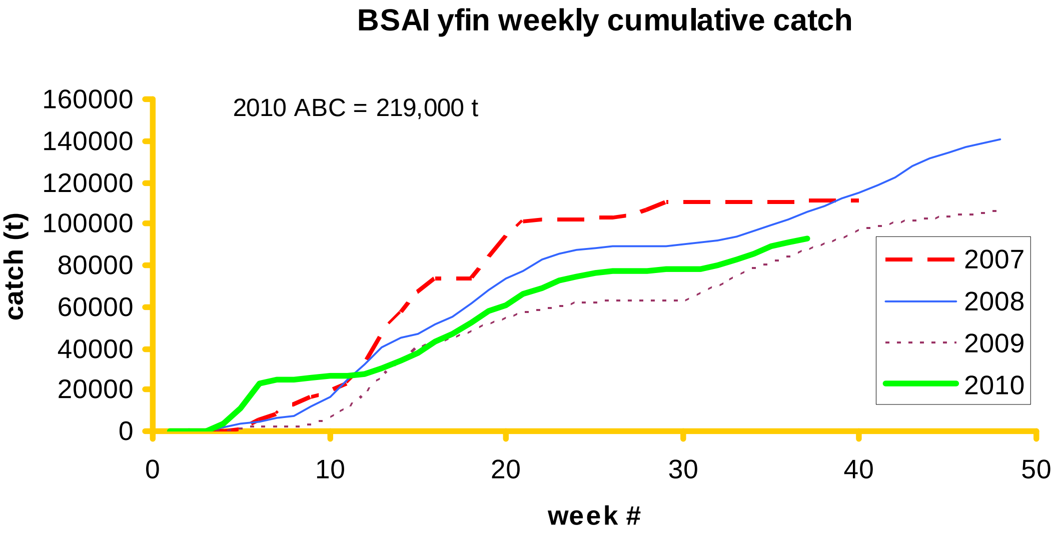


Figure 4.1—Yellowfin sole annual catch (1,000s t) in the Eastern Bering Sea from 1954-2009 (top panel) and catch by week from 2007 – September 2009 (bottom panel).

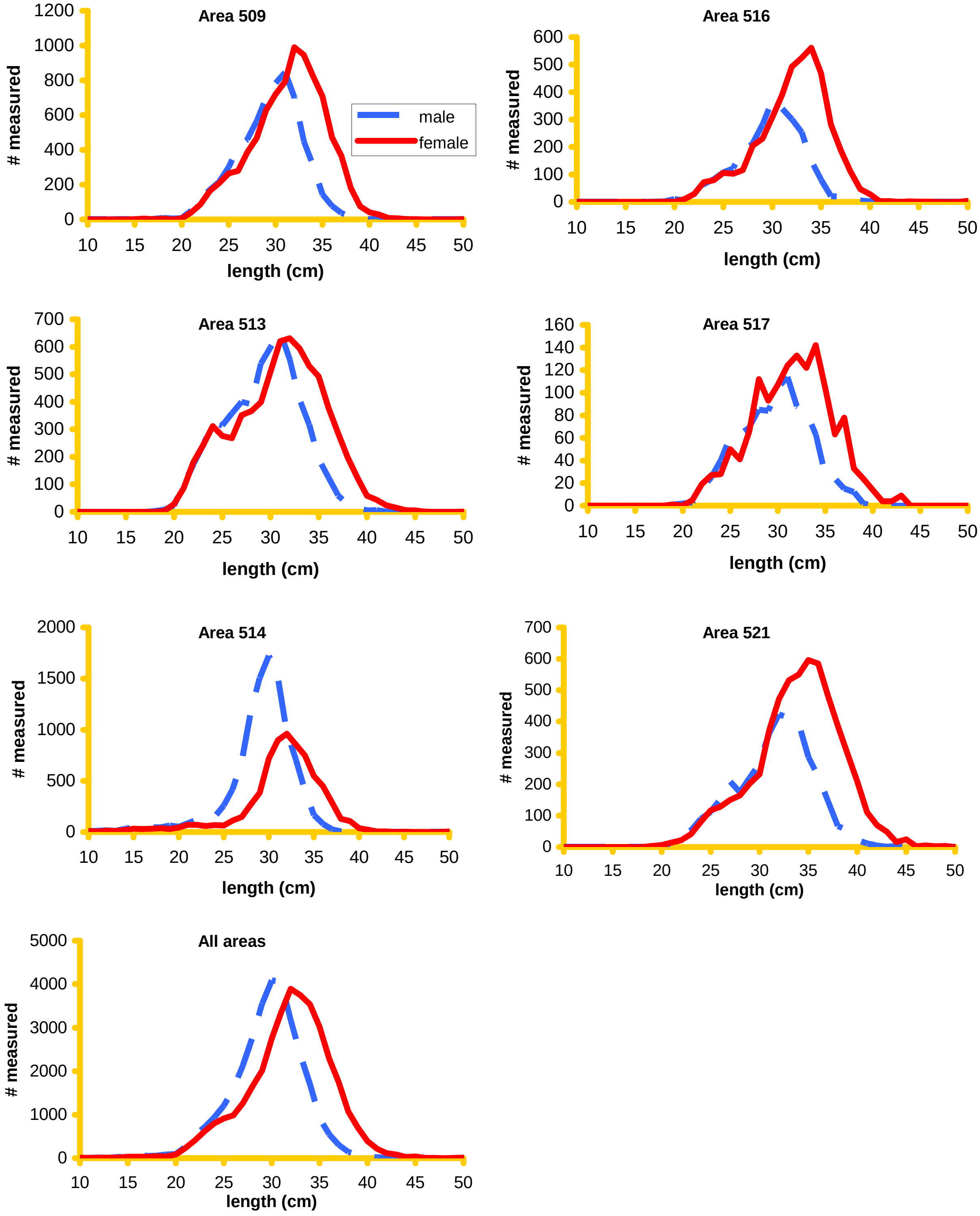
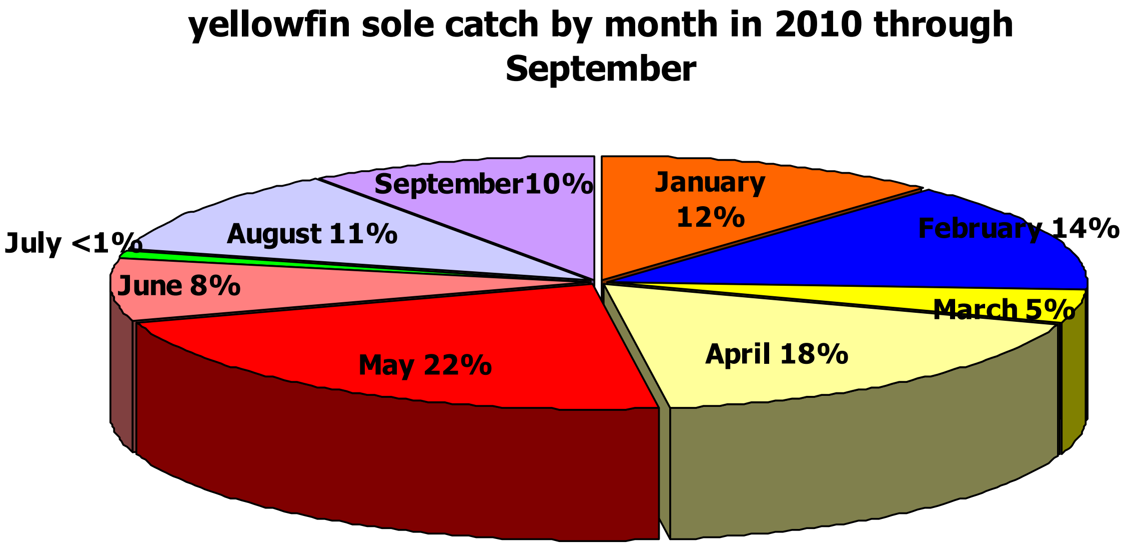


Figure 4.2—Size composition of the yellowfin sole catch in 2010 (through September), by subarea and total.



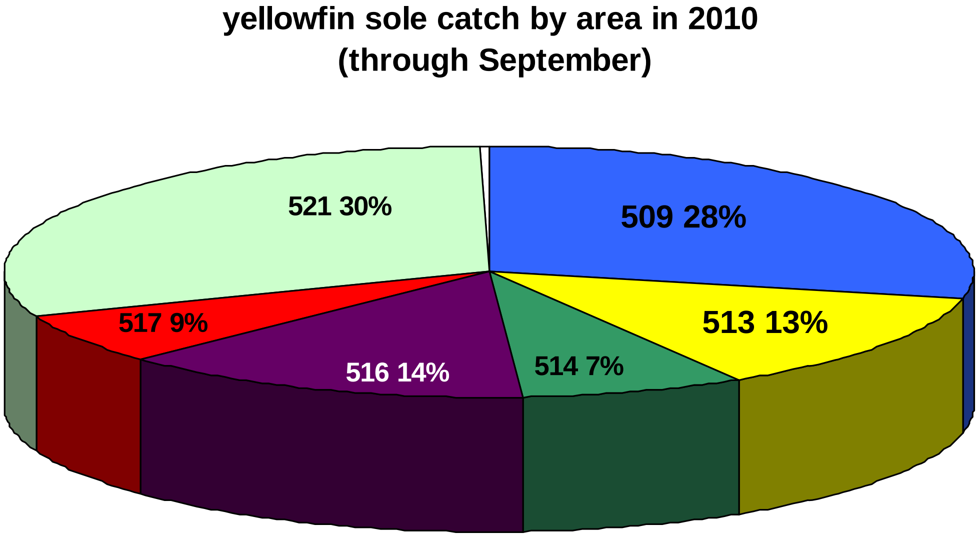
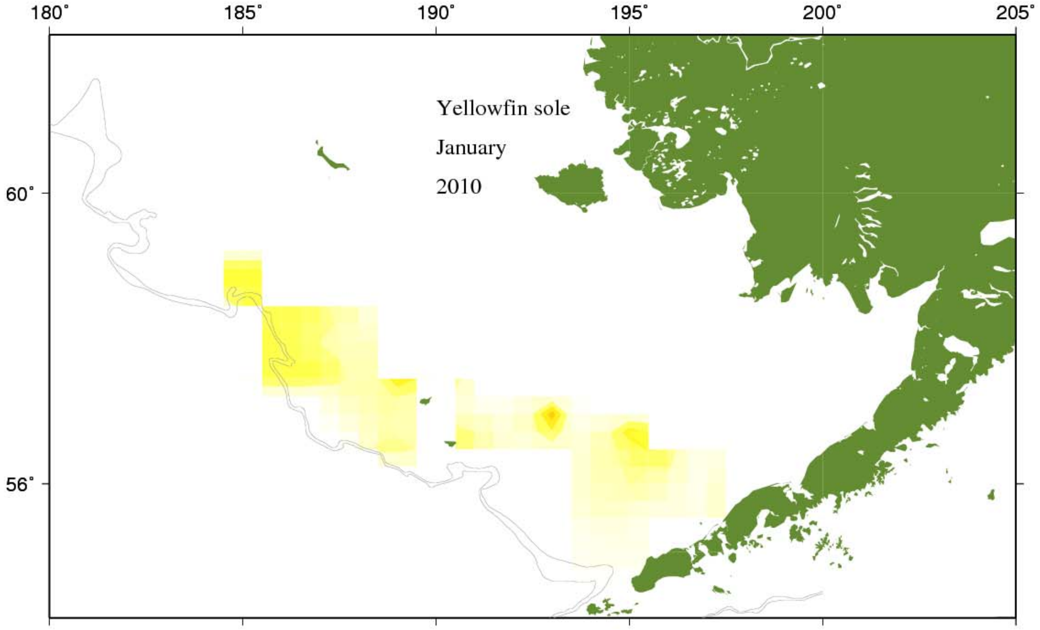


Figure 4.3—Yellowfin sole catch by month and area in the Eastern Bering Sea in 2009.



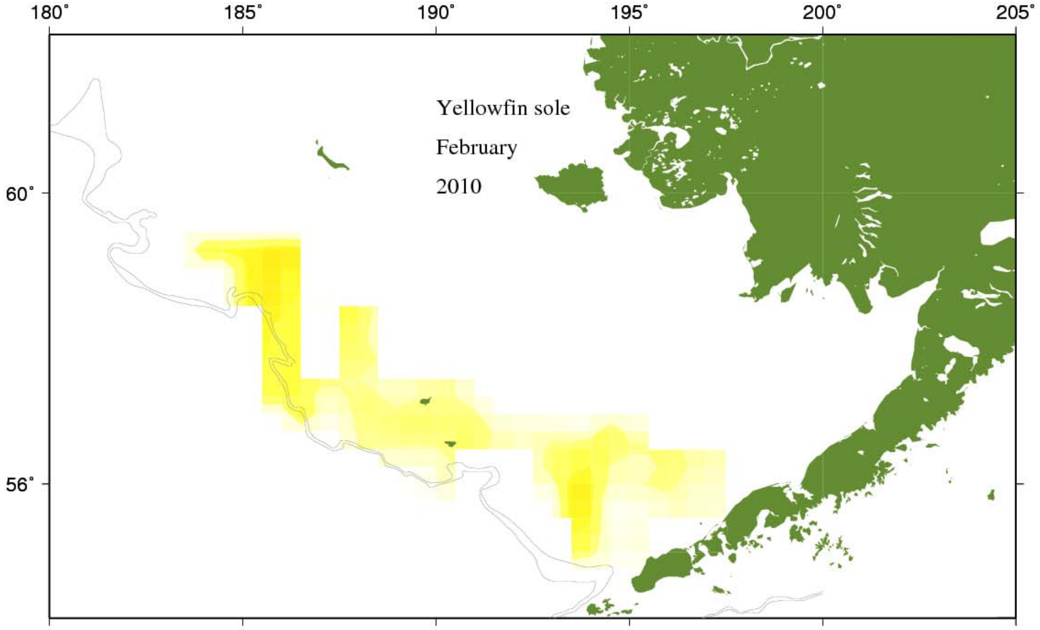
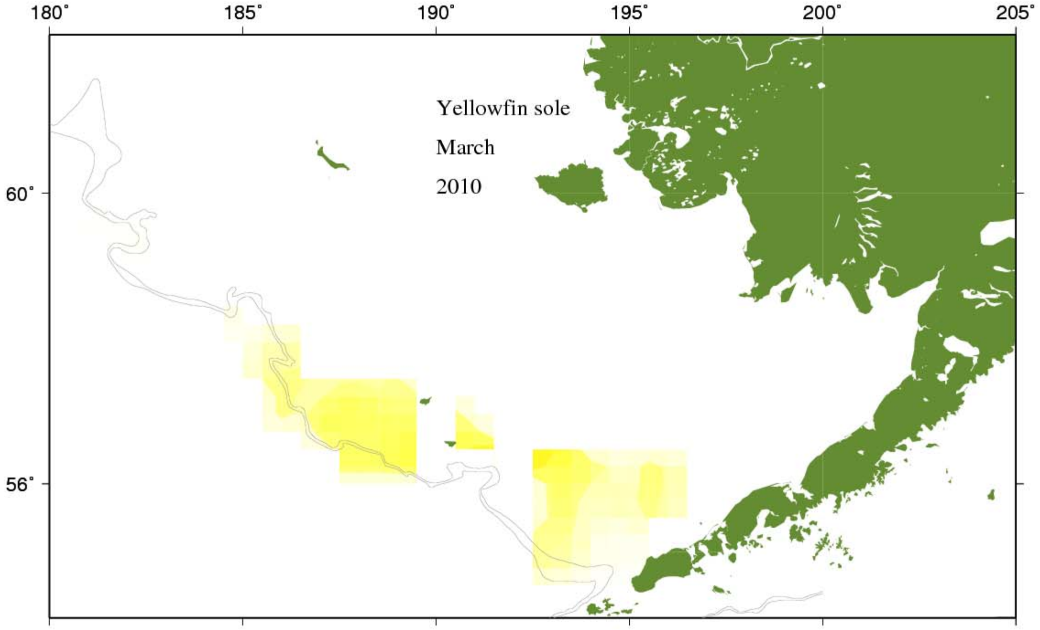


Figure 4.4—Yellowfin sole catch locations, by month, in 2010.



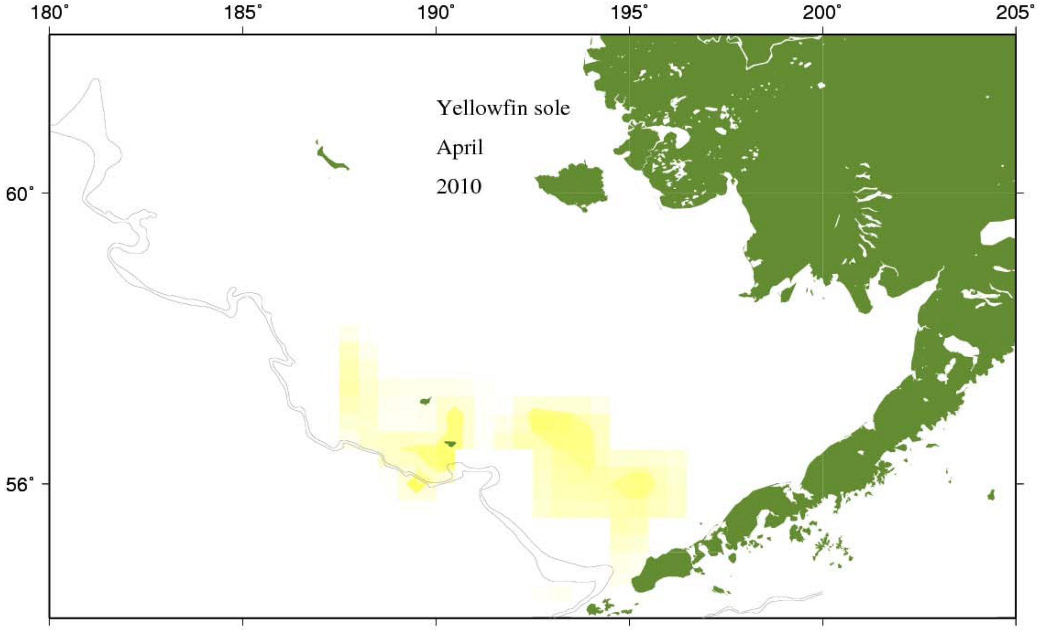
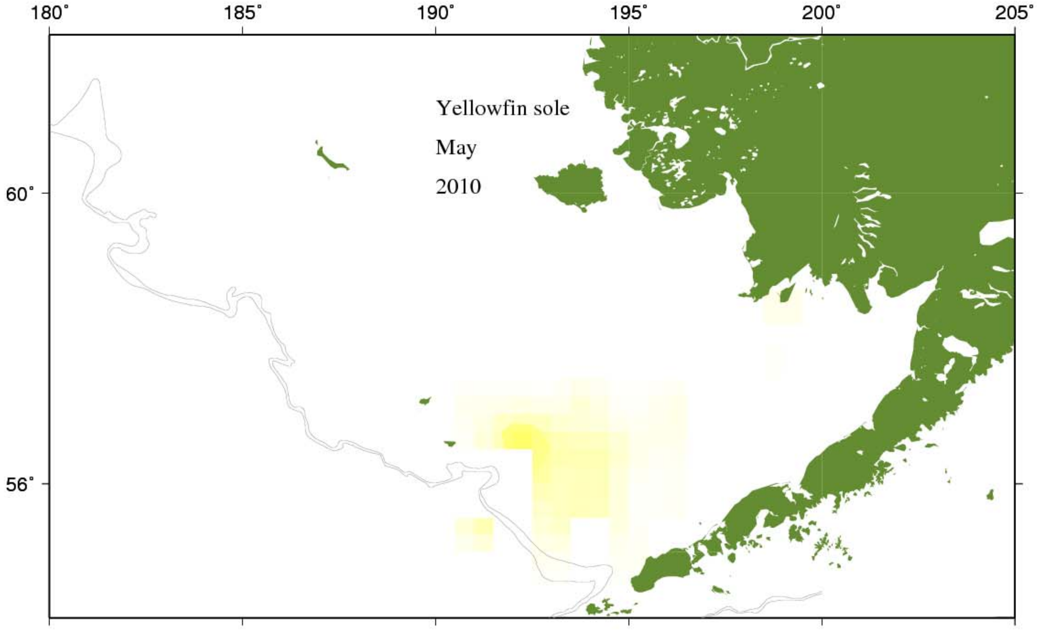


Figure 4.4— (continued).



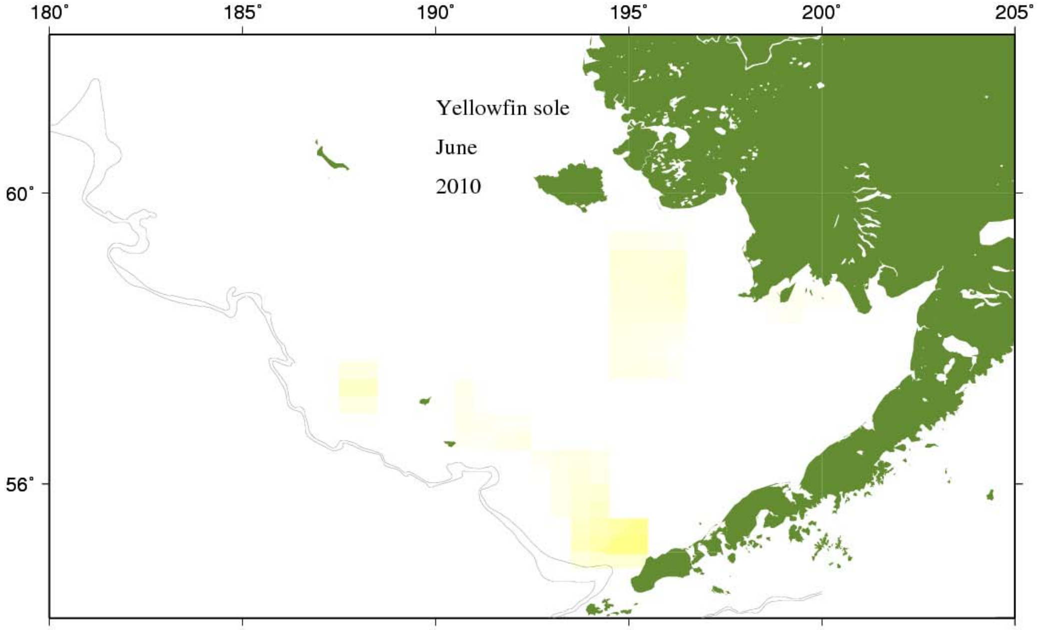
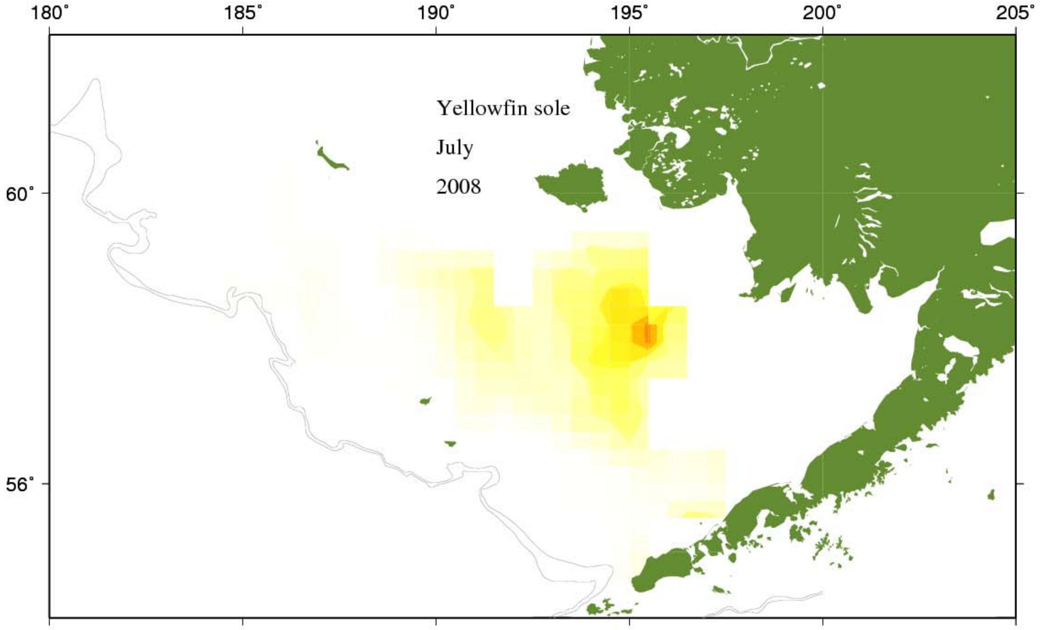


Figure 4.4— (continued).



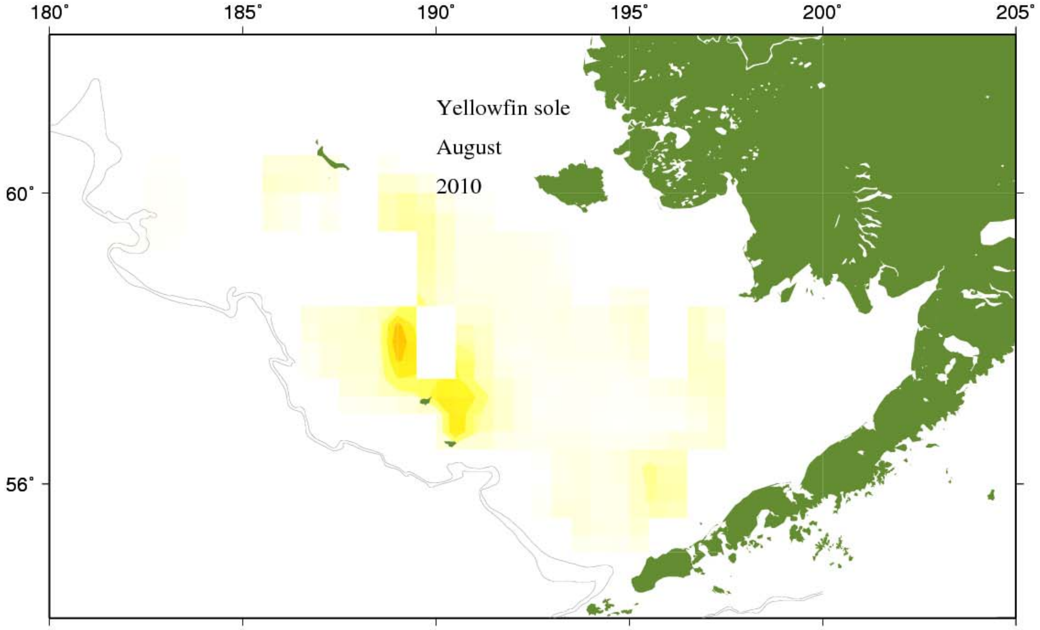


Figure 4.4— (continued).

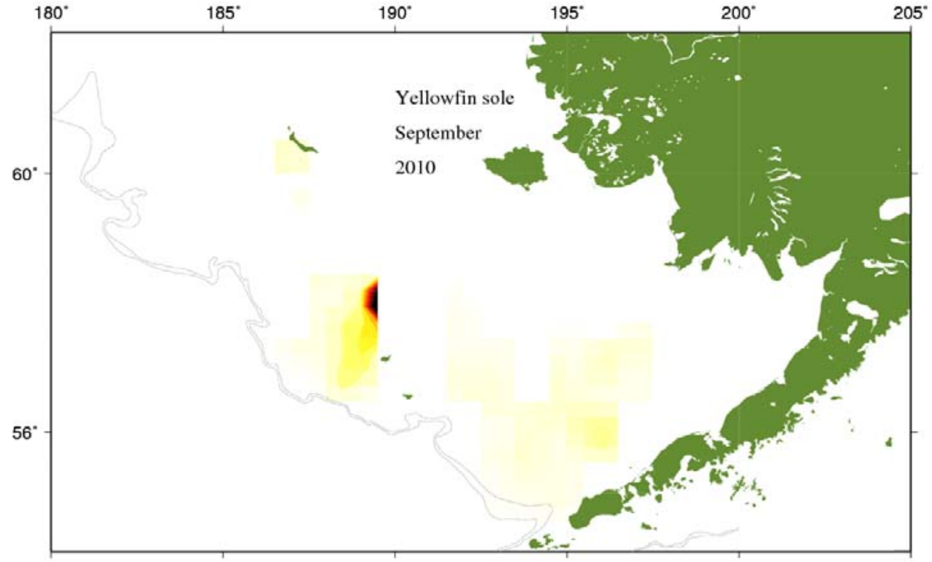


Figure 4.4— (continued).

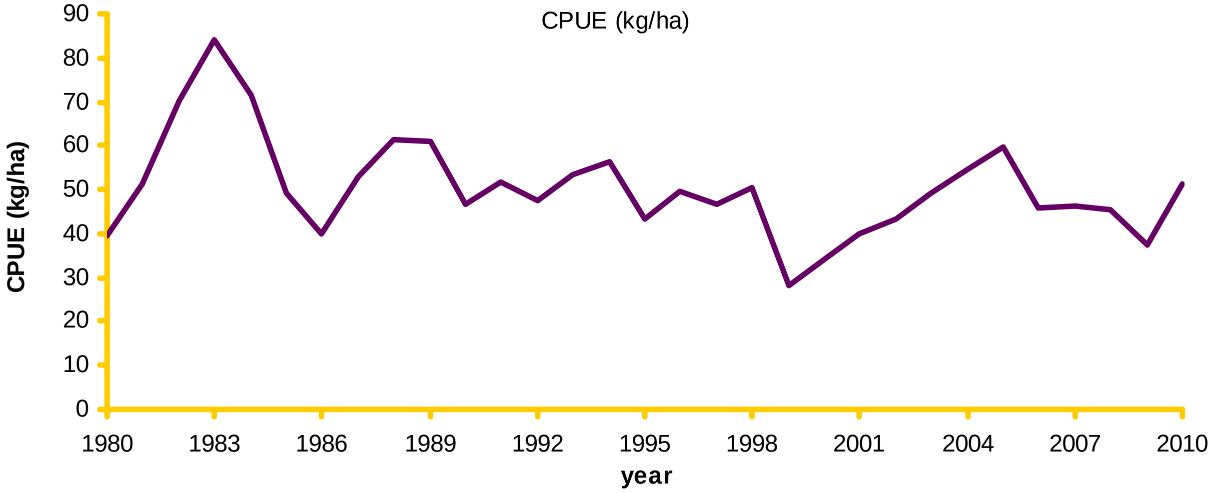


Figure 4.5. Yellowfn sole CPUE (catch per unit effort in kg/ha) from the annual Bering Sea shelf trawl surveys, 1982-2010.

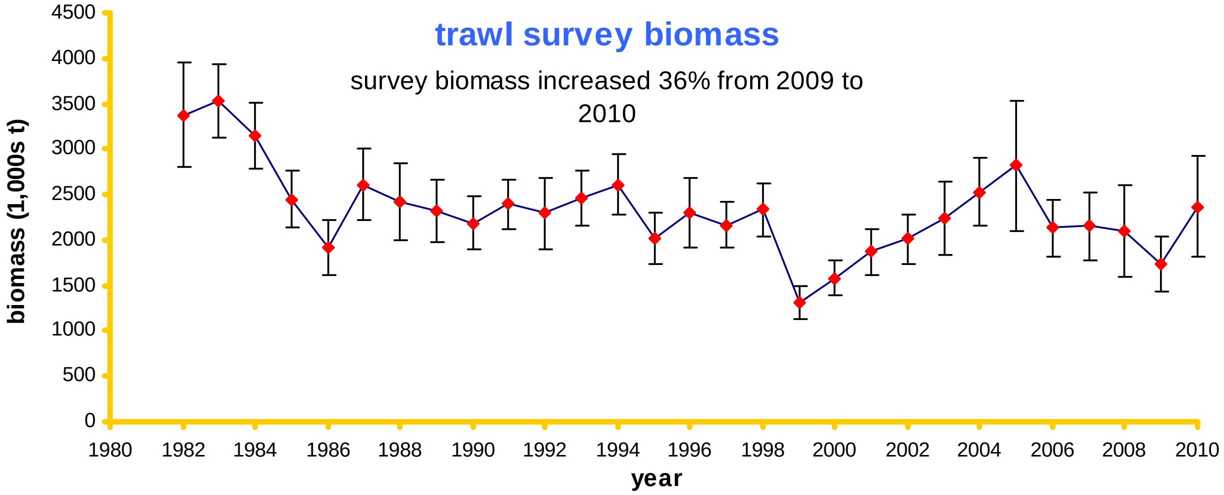


Figure 4.6. Annual bottom trawl survey biomass point-estimates and 95% confidence intervals for yellowfin sole, 1982-2010.

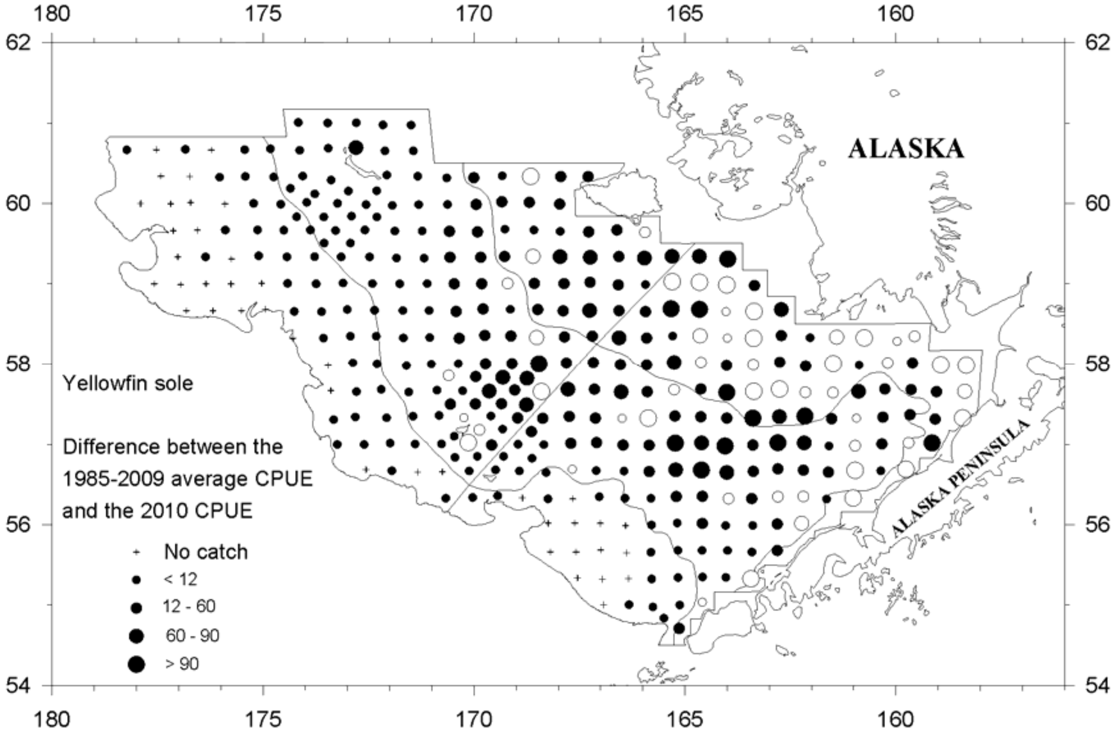


Figure 4.7. Difference between the 1985-2009 average trawl survey CPUE for yellowfin sole and the 2010 survey CPUE. Open circles indicate that the magnitude of the catch was greater in 2010 than the long-term average, closed circles indicate the catch was greater in the long-term average than in 2010.

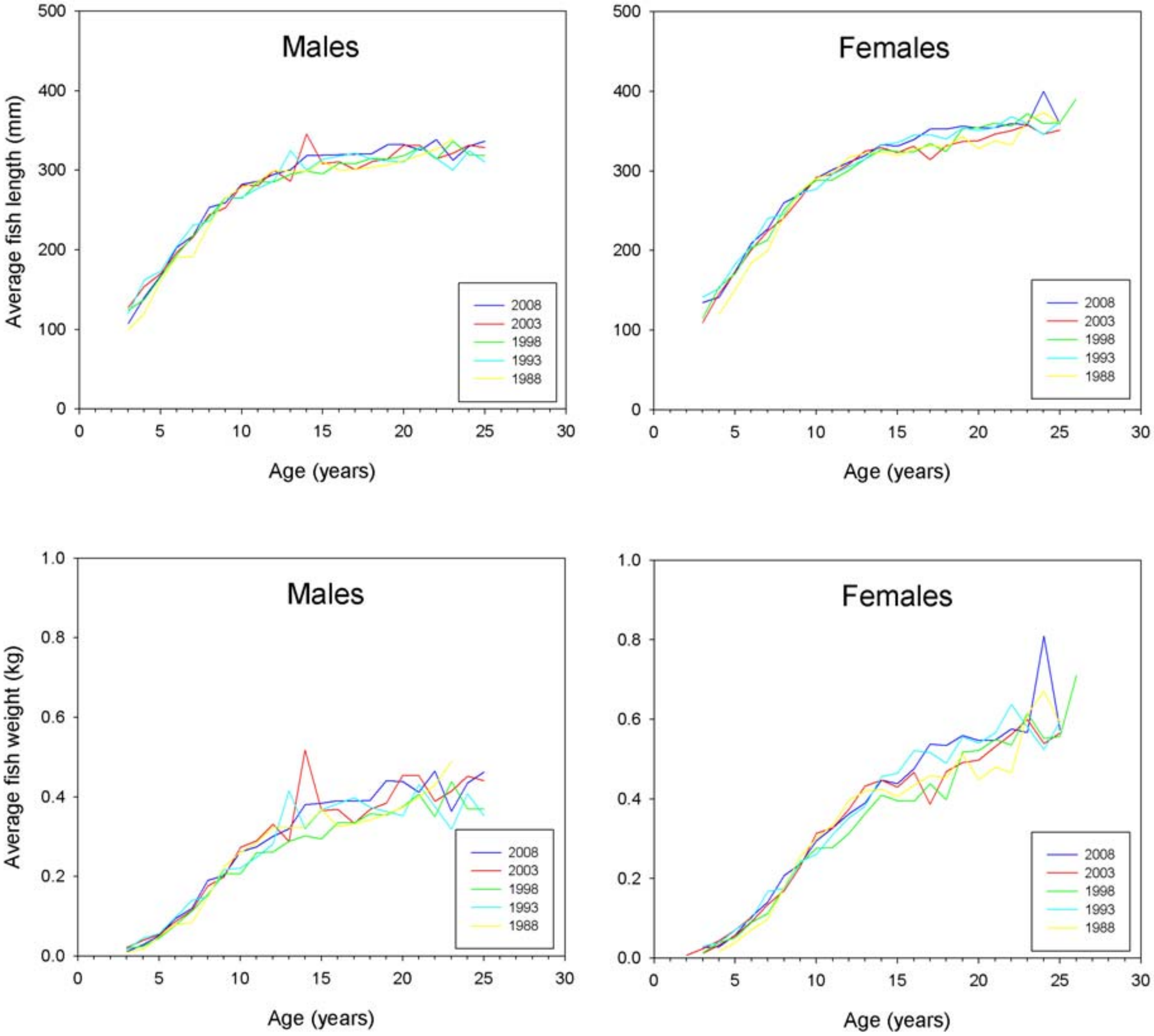


Figure 4.8. Comparison of yellowfin sole length at age (top panel) and weight at age (bottom panel) from biological samples collected in 1988, 1993, 1998, 2003 and 2008.

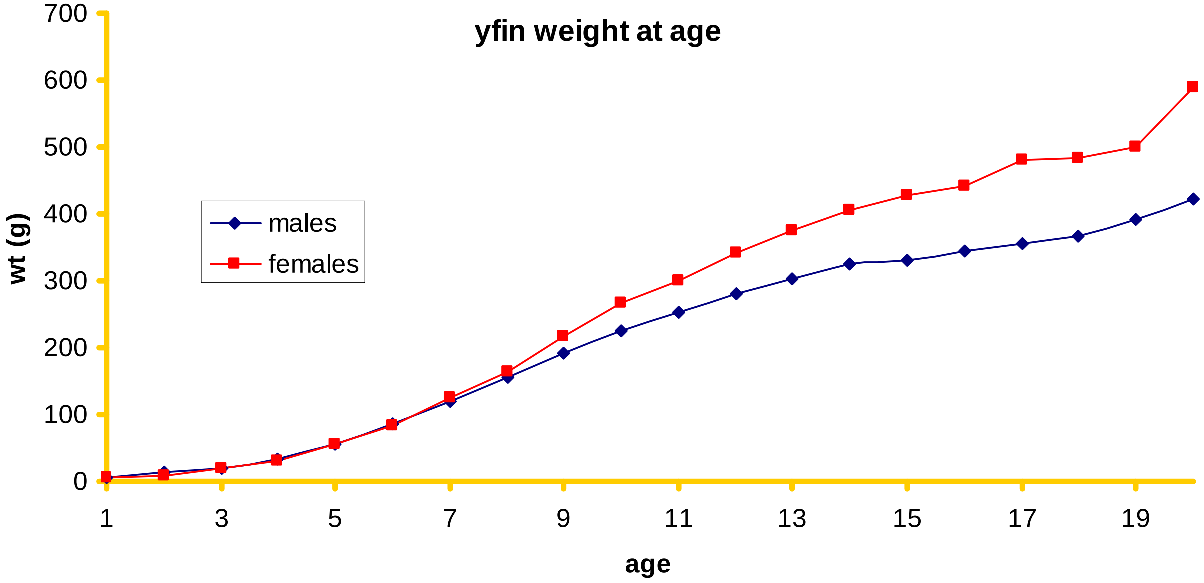


Figure 4.9--Estimates of yellowfin sole weight-at-age (g) from trawl survey observations.

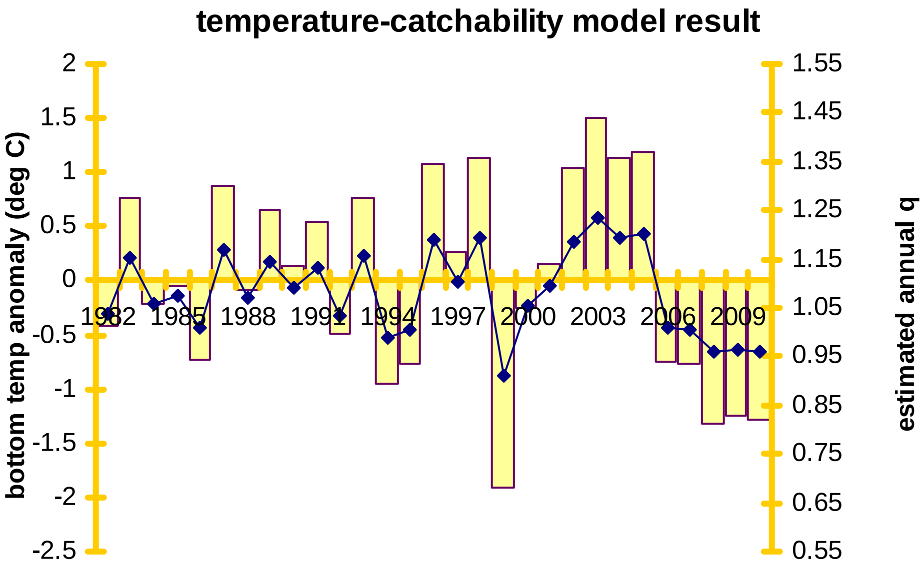


Figure 4.10.--Average bottom water temperature from stations less than or equal to 100 m in the Bering Sea trawl survey (bars) and the stock assessment model estimate of q for each year 1982-2010.

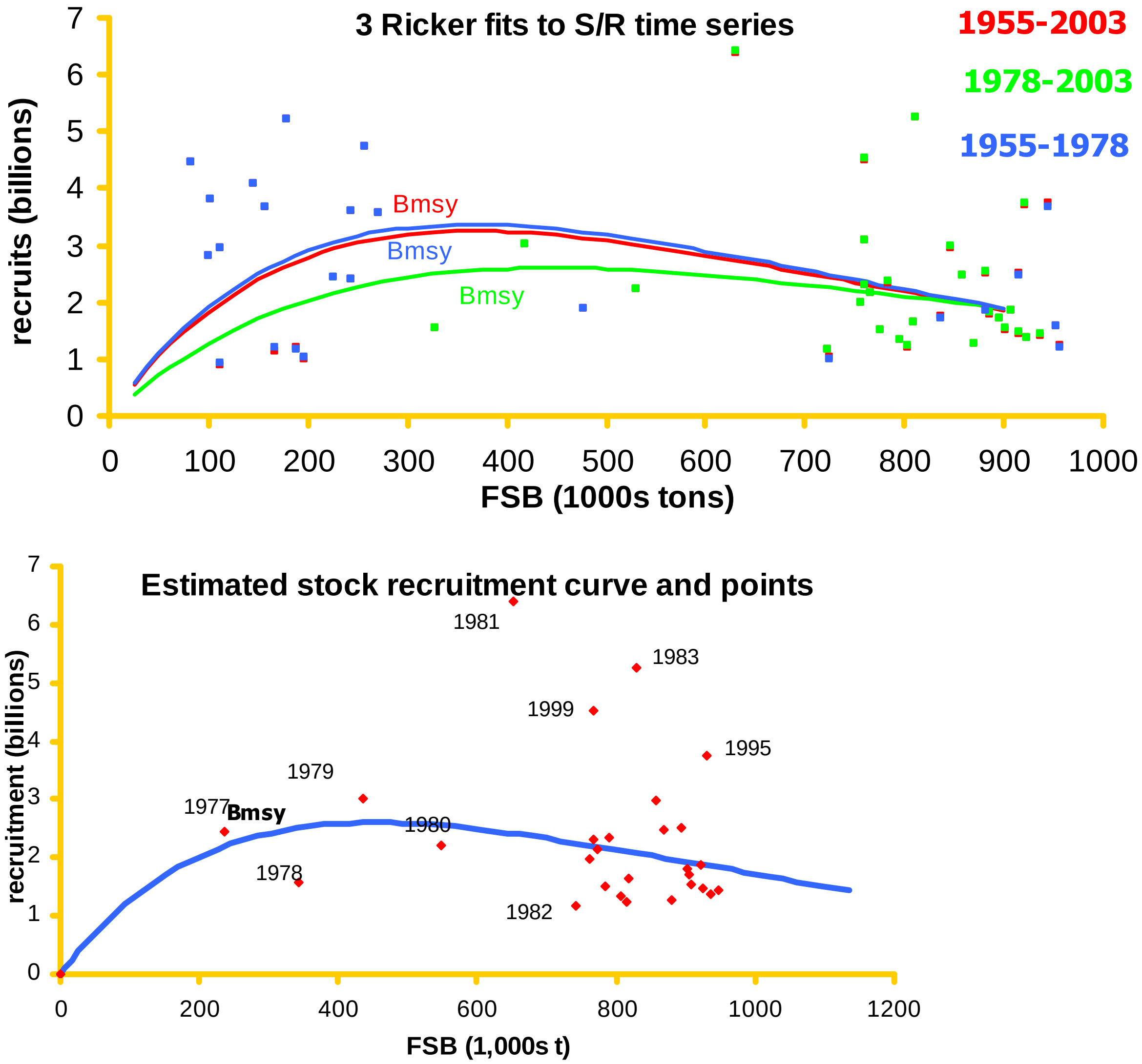


Figure 4.11--Fit of the Ricker (1958) stock recruitment model to three distinct stock recruitment time-series data sets (top panel), and the fit to the assessment preferred model (model 2, lower panel).

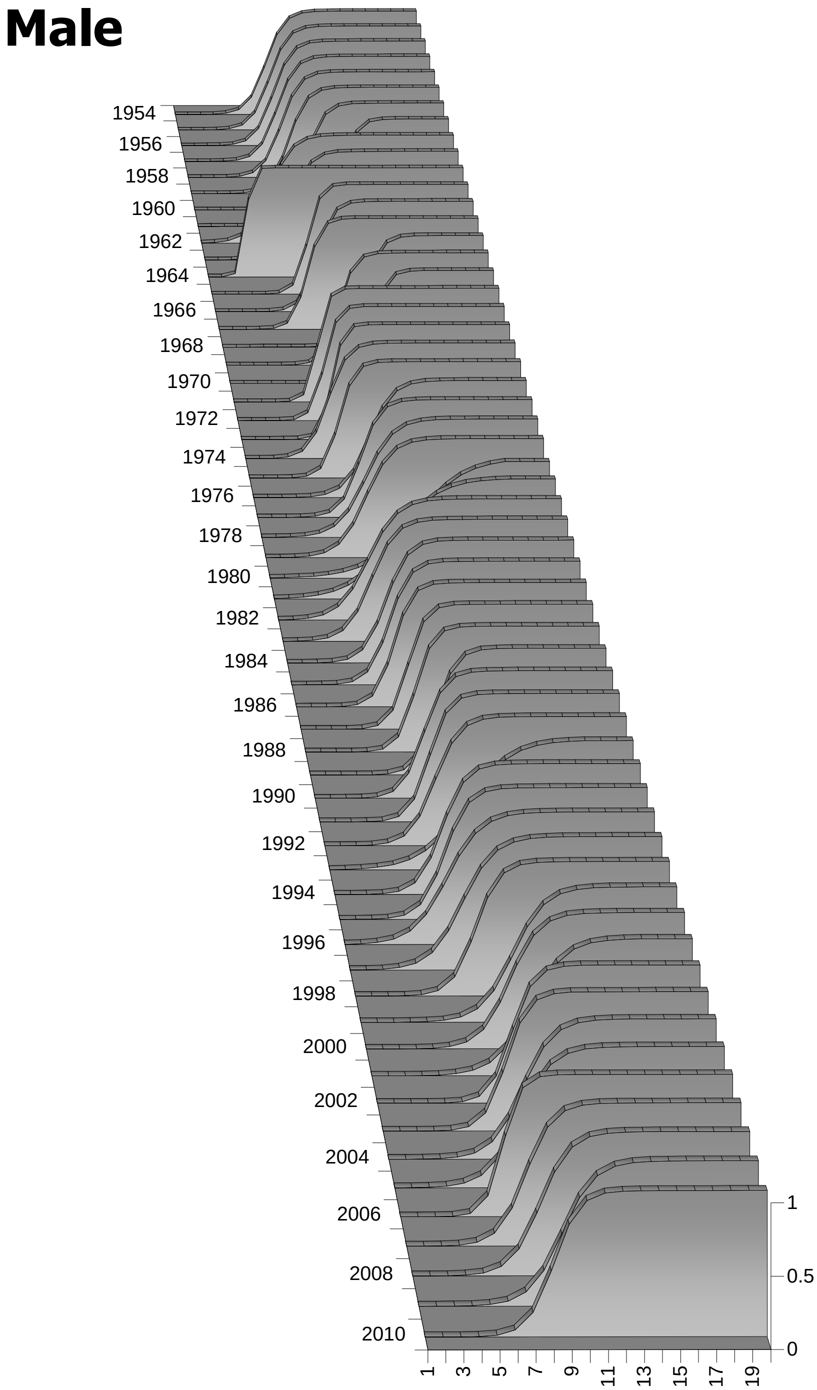


Figure 4.12—Estimated male fishery selectivity by age and year.

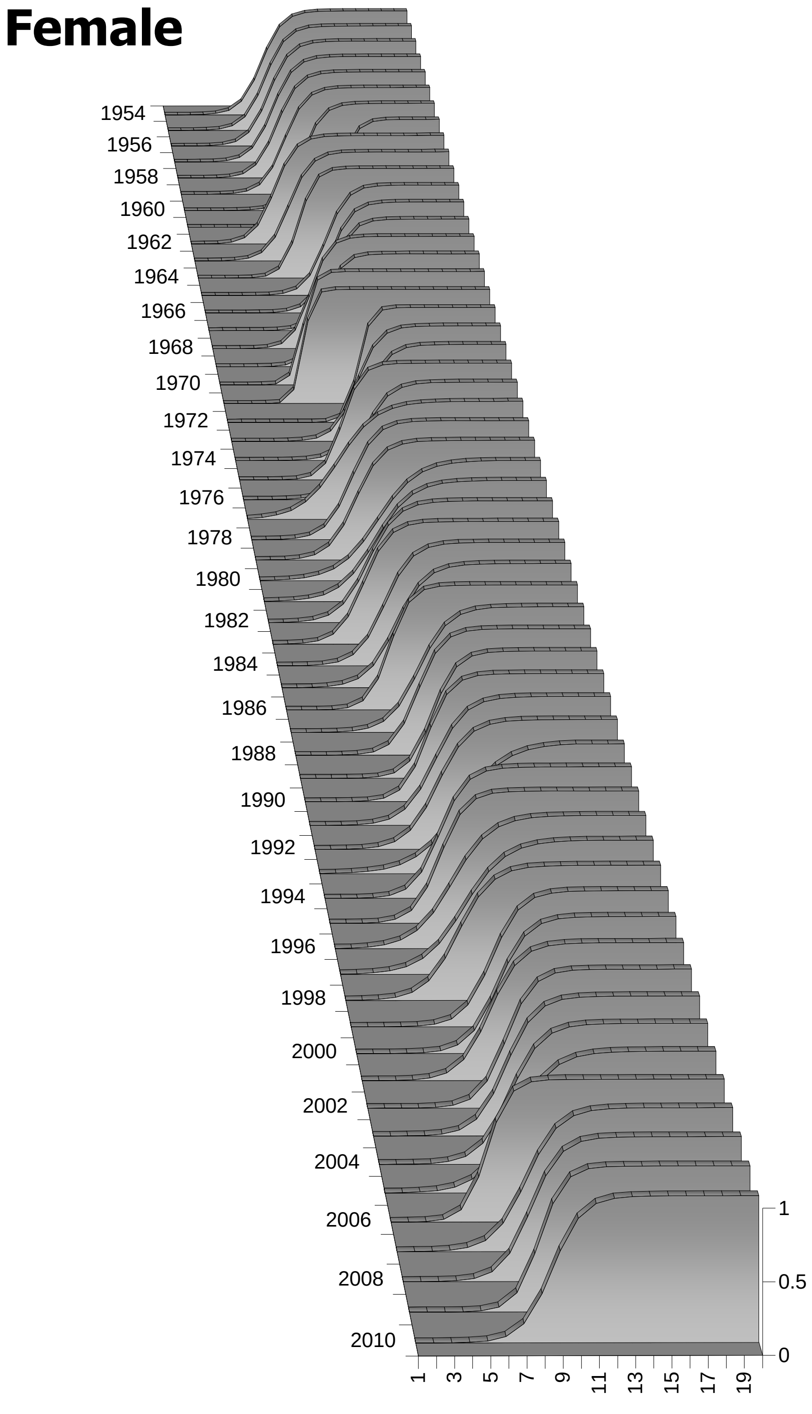


Figure 4.12—Estimated female fishery selectivity by age and year.

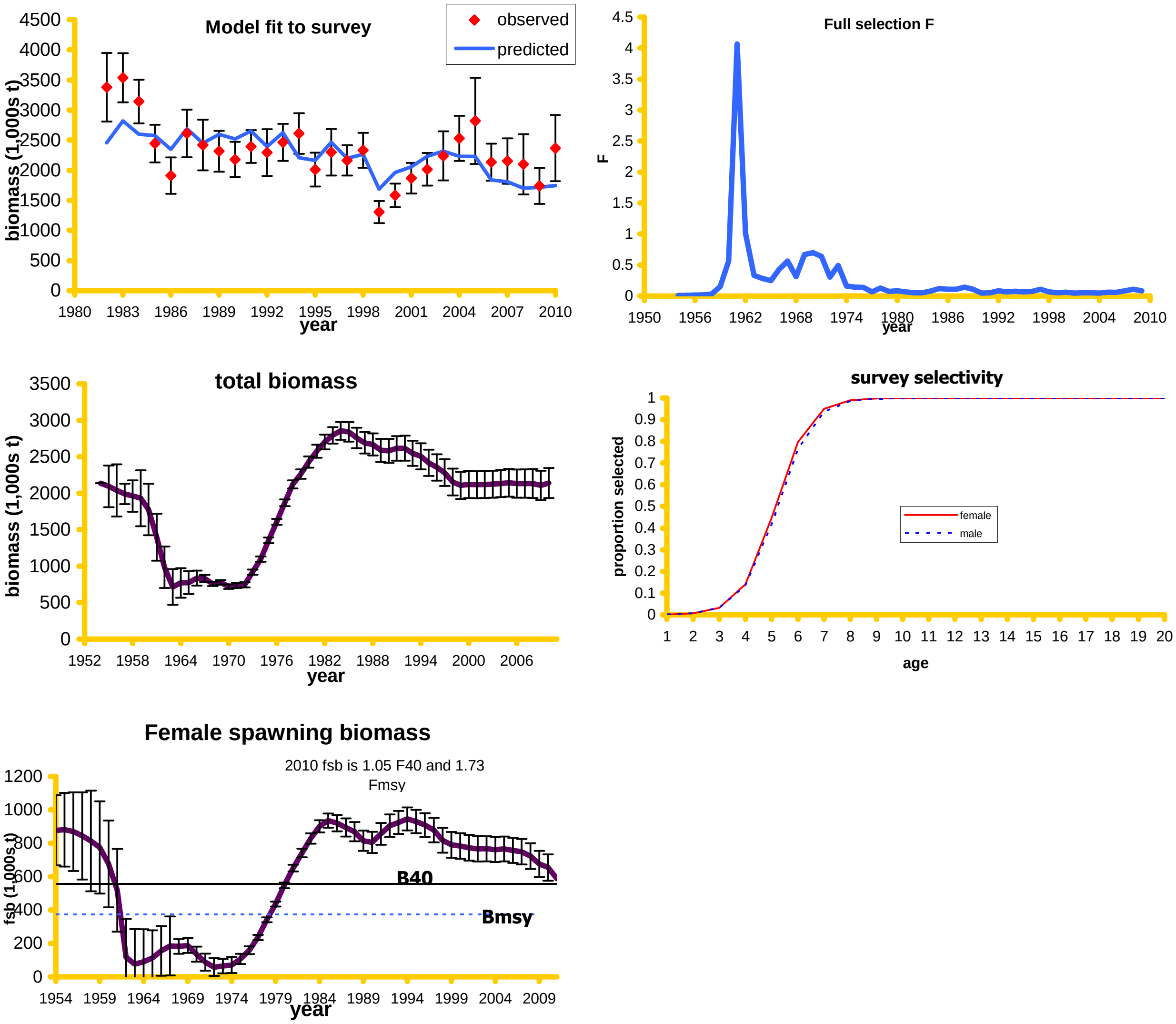


Figure 4.13. Model fit to the survey biomass estimates (top left panel), model estimate of the full selection fishing mortality rate throughout the time-series (top right panel), model estimate of total biomass (middle left panel), the model estimate of survey selectivity (middle right panel) and the estimate of female spawning biomass (bottom left panel).

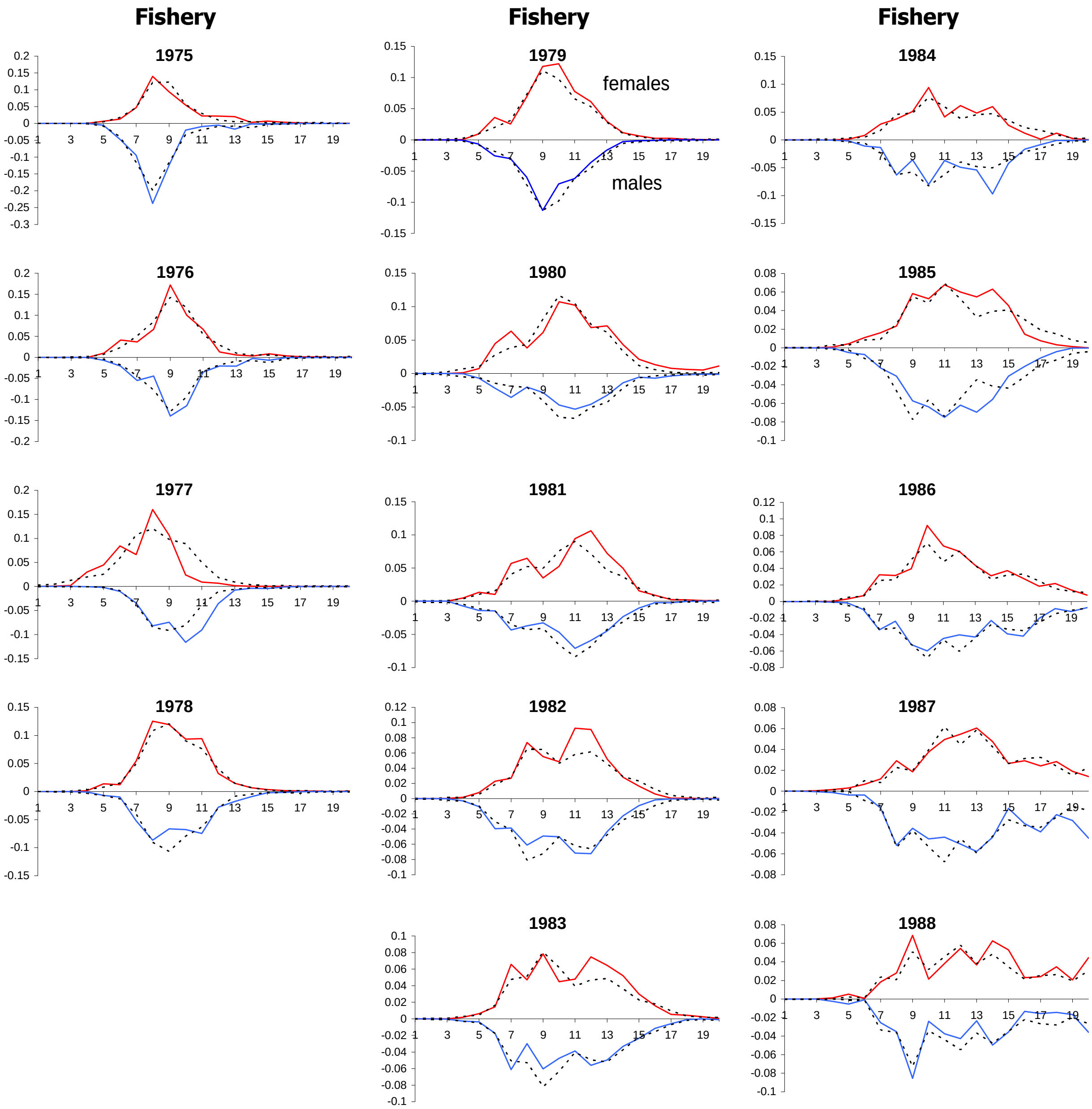


Figure 4.14—Stock assessment model fit to the time-series of fishery and survey age composition, by sex.

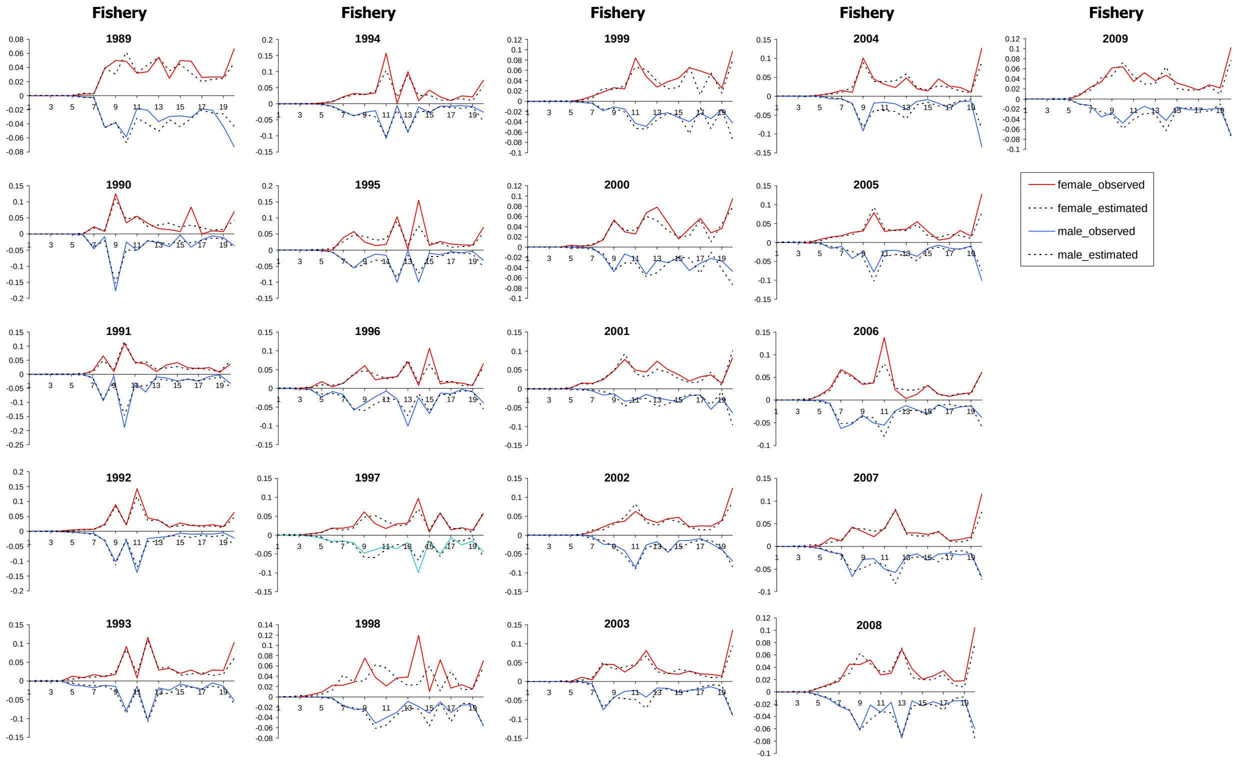


Figure 4.14 (continued).

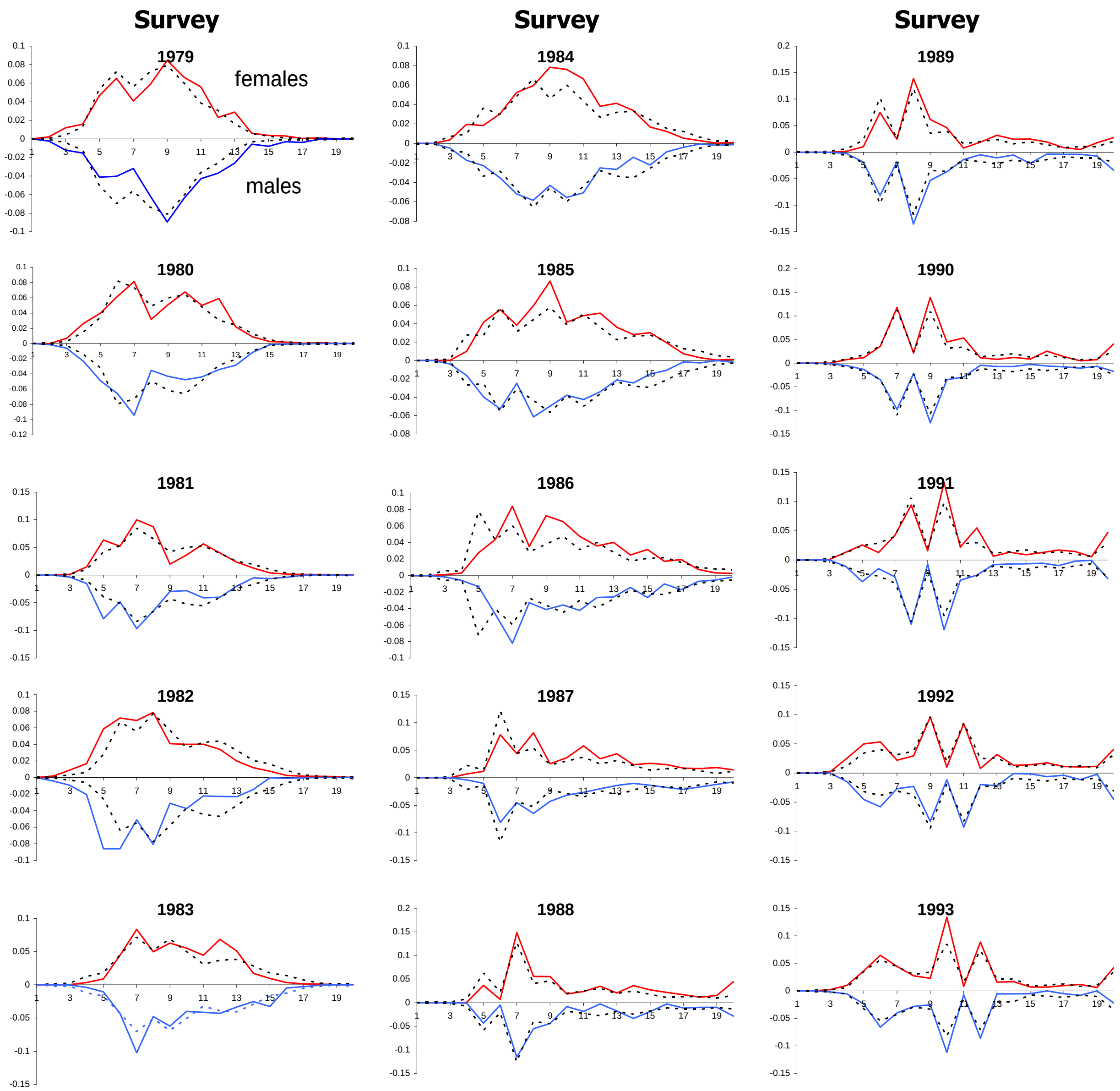


Figure 4.14 (continued).

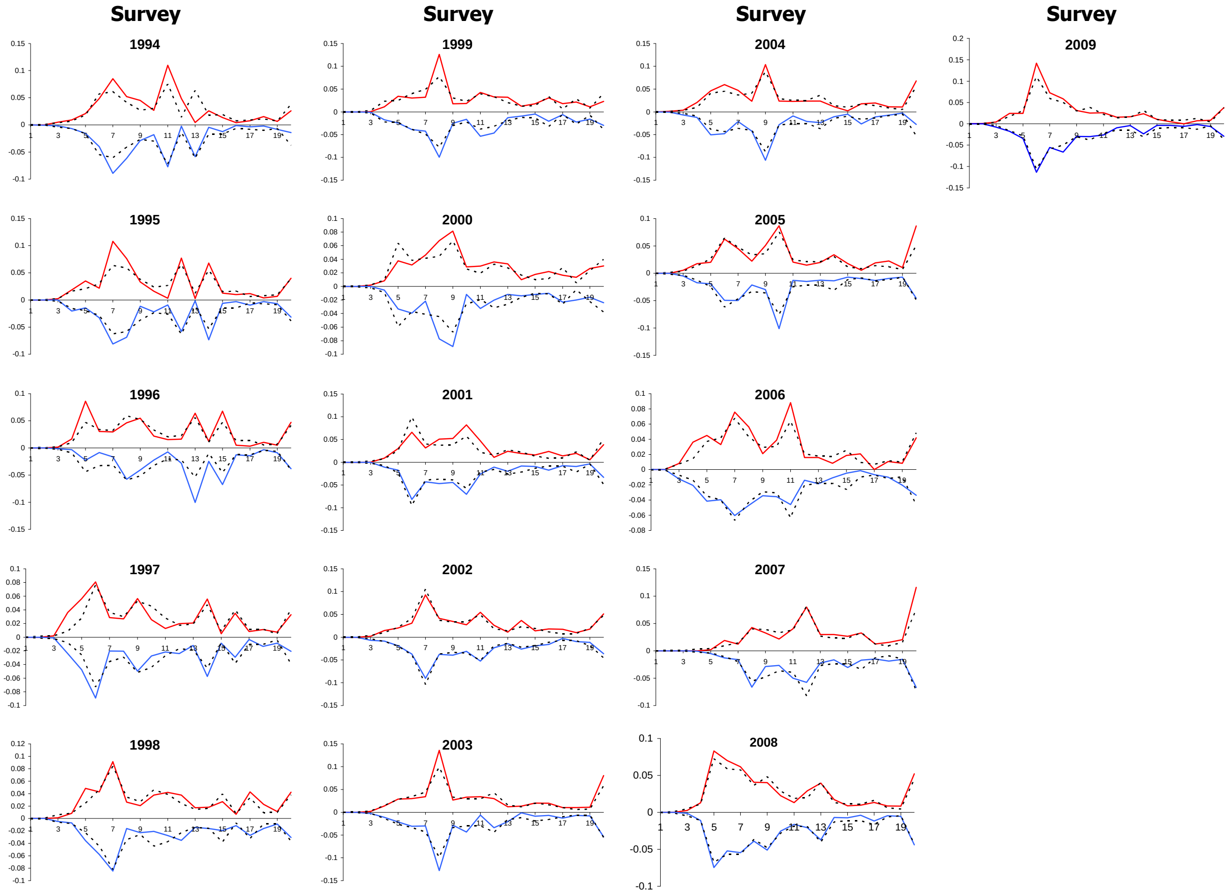


Figure 4.14 (continued).

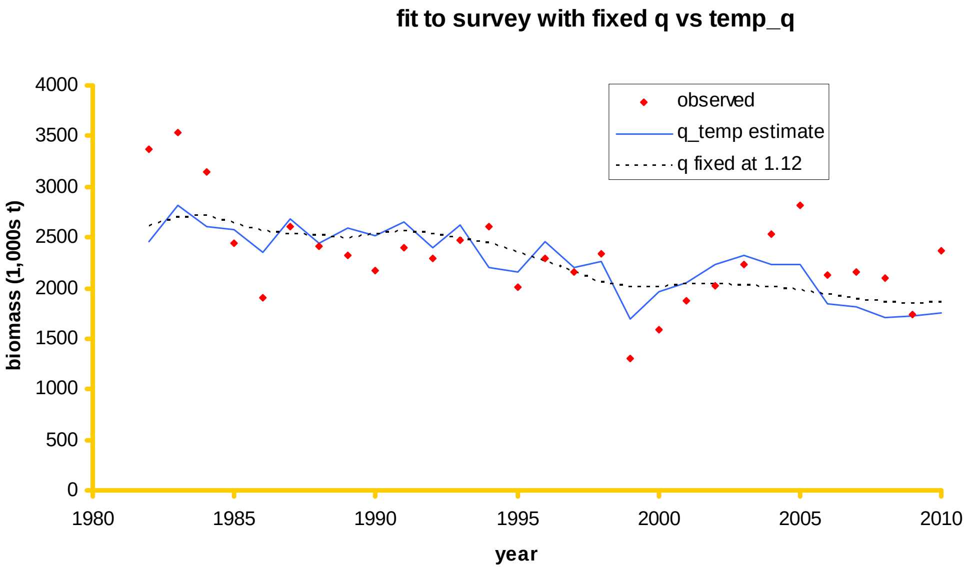


Figure 4.15--Comparison of the fit to the survey biomass using a fixed q and the q-bottom temperature relationship.

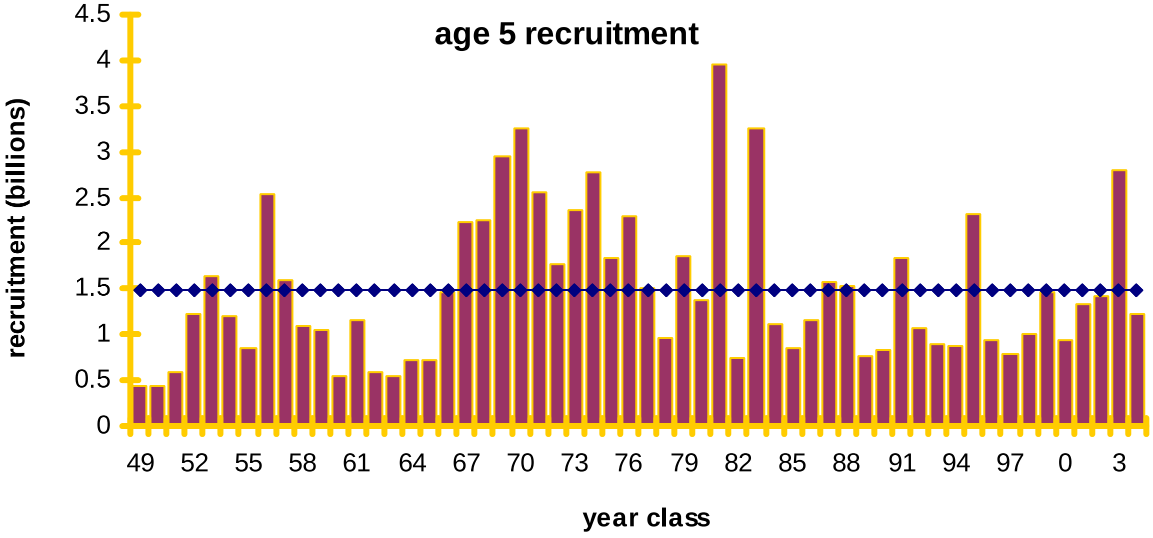


Figure 4.16 Year class strength of age 5 yellowfin sole estimated by the stock assessment model. The dotted line is the average of the estimates from 56 years of recruitment.

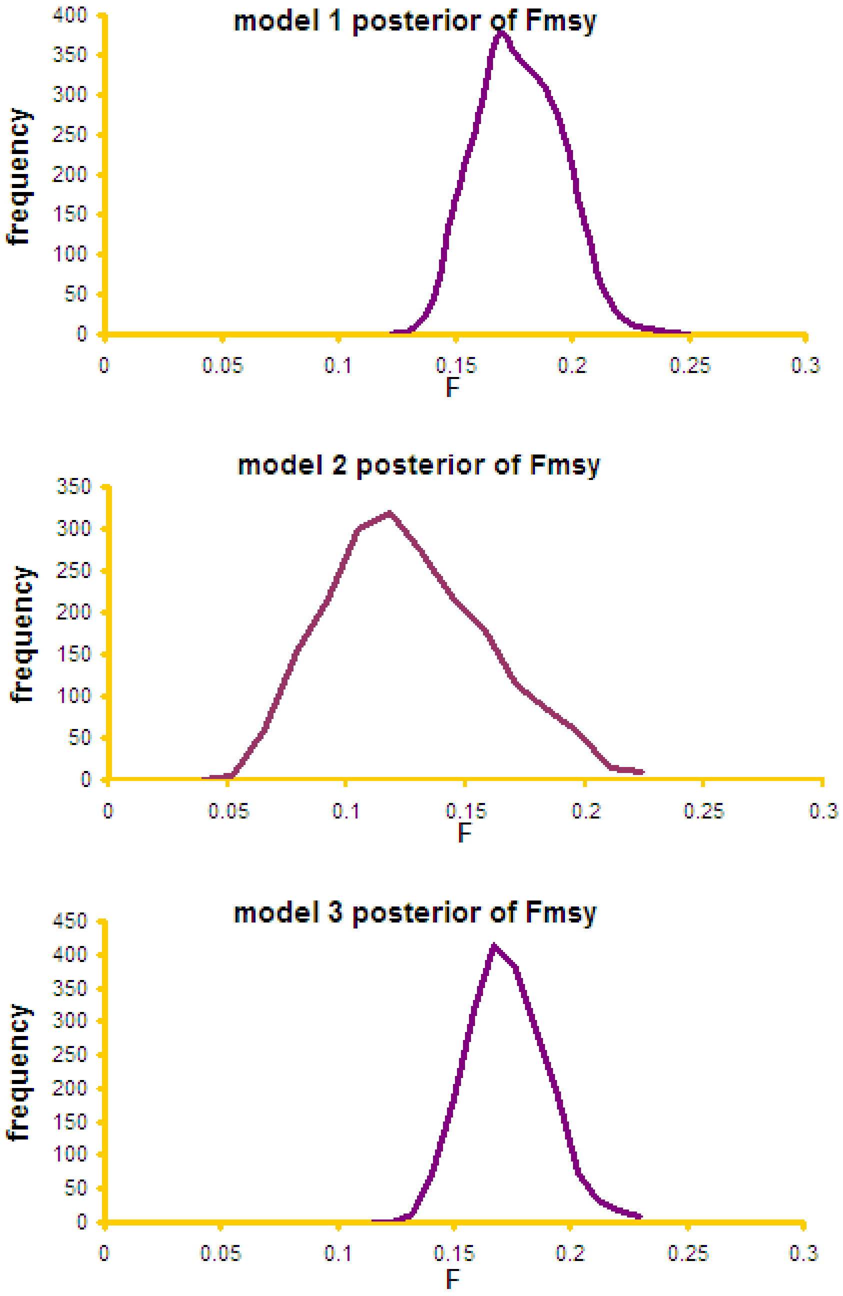


Figure 4.17—Posterior distributions of F_{MSY} for three models considered in the stock productivity analysis.

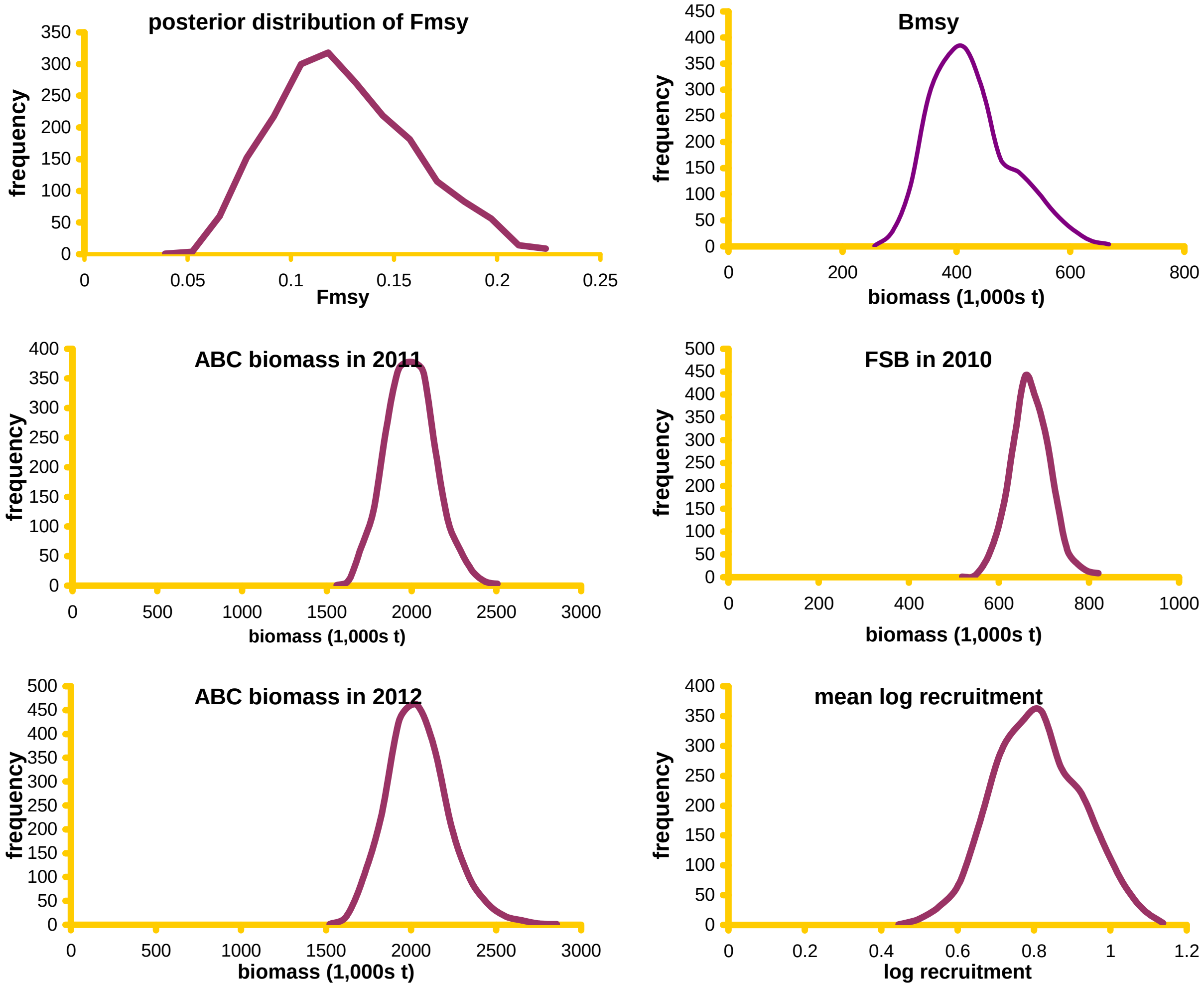


Figure 4.18—Posterior distributions of some important parameters estimated by the preferred stock assessment model (from mcmc integration).

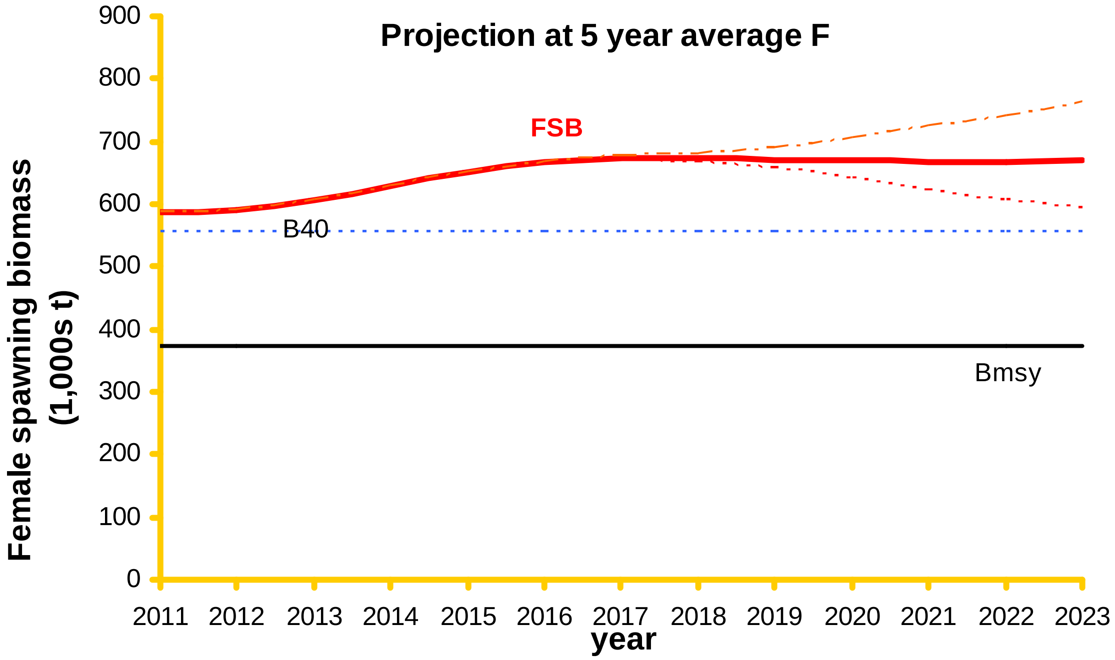


Figure 4.19. Projection of yellowfin sole female spawning biomass (1,000s t) at the average F from the past 5 years (0.055) through 2022 with $B_{40\%}$ and B_{msy} levels indicated.

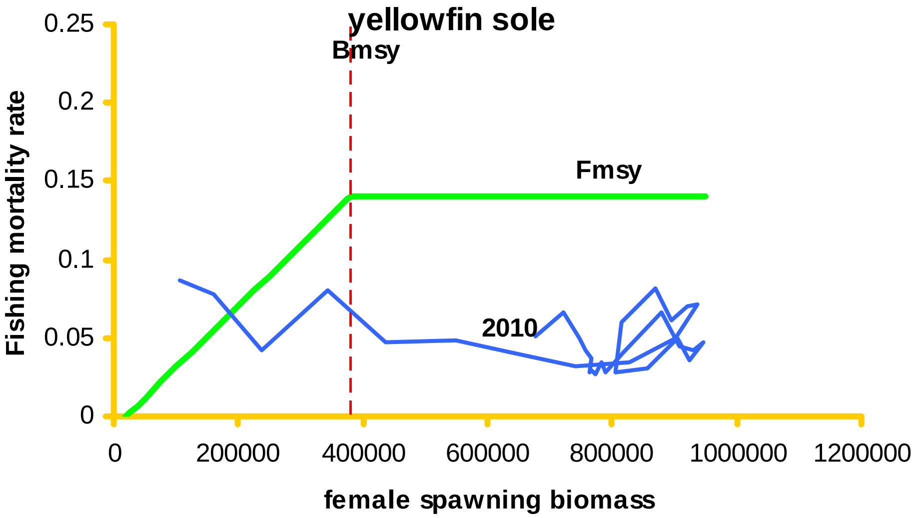


Figure 4.20—Phase plane figure of the time-series of yellowfin sole female spawning biomass relative to the harvest control rule with 1970 and 2008 indicated.