4. Assessment of the yellowfin sole stock in the Bering Sea and Aleutian Islands

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Executive Summary

Summary of Changes in Assessment Inputs

Changes to the input data

1) 2017 fishery age composition.
2) 2017 survey age composition.
3) 2018 trawl survey biomass point estimate and standard error.
4) Estimate of the discarded and retained portions of the 2017 catch.
5) Estimate of total catch made through the end of 2018. Catch of 150,000 t assumed for 2019 and 2020 projection.

Changes to the assessment methodology

Explored incorporating survey start date and its interaction term with annual bottom water temperature in the survey catchability equation.

Summary of Results

The assessment updates last year's with results and management quantities that are lower than the 2017 assessment primarily due to 1) the 2018 survey biomass point estimate is 32% lower than the 2017 estimate and 2) the assessment model estimated a slightly lower survey catchability. Yellowfin sole continue to be well-above B_{MSY} and the annual harvest remains below the ABC level. The female spawning stock is in a slow downward trend. Management quantities are given below for the current base model (Model 14_1) and a new base model (Model 18_1).

Current base model (Model 14_1)

Quantity	As estimated or *specified last* year for: 2018	2019	As estimated or *recommended this* year for: 2019	2020
M (natural mortality rate)	0.12	0.12	0.12	0.12
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	2,553,100	2,460,700	2,388,000	2,331,500
Female spawning biomass (t)				
Projected	895,600	890,000	827,900	796,600
B_0	1,204,000		1,236,000	
B_{MSY}	456,000		451,600	
F_{OFL}	0.12	0.12	0.118	0.118
$maxF_{ABC}$	0.109	0.109	0.107	0.107
F_{ABC}	0.109	0.109	0.107	0.107
OFL (t)	306,700	295,600	281,800	275,100
maxABC (t)	277,500	267,500	255,100	249,100
ABC (t)	277,500	267,500	255,100	249,100
Status	As determined *last* year for: 2016	2017	As determined *this* year for: 2017	2018
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

New proposed base model (Model 18_1)

Quantity	As estimated or *specified last* year for: 2018	2019	As estimated or *recommended this* year for: 2019	2020
M (natural mortality rate)	0.12	0.12	0.12	0.12
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	2,553,100	2,460,700	2,462,400	2,411,700
Female spawning biomass (t)				
Projected	895,600	890,000	850,600	821,500
B_0	1,204,000		1,245,400	
B_{MSY}	456,000		460,800	
F_{OFL}	0.12	0.12	0.118	0.118
$maxF_{ABC}$	0.109	0.109	0.107	0.107
F_{ABC}	0.109	0.109	0.107	0.107
OFL (t)	306,700	295,600	290,000	284,000
maxABC (t)	277,500	267,500	263,200	257,800
ABC (t)	277,500	267,500	263,200	257,800
Status	As determined *last* year for: 2016	2017	As determined *this* year for: 2017	2018
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Projections are based on estimated catches of 150,000 t used in place of maximum ABC for 2019 and 2020.

Responses to SSC and Plan Team Comments on Assessments in General

In this section, we list new or outstanding comments on assessments in general from the last full assessment in 2017.

"The SSC recommends that, for those sets of environmental and fisheries observations that support the inference of an impending severe decline in stock biomass, the issue of concern be brought to the SSC, with an integrated analysis of the indices in future stock assessment cycles. To be of greatest value, to the extent possible, this information should be presented at the October Council meeting so that there is sufficient time for the Plan Teams and industry to react to the possible reduction in fishing opportunity." (SSC October 2017)

To facilitate a coordinated response to this request, the co-chairs and coordinators of the BSAI and GOA Groundfish Plan Teams, with concurrence from stock assessment program leadership at the AFSC, have suggested that authors address it by using the previous year's Ecosystem Status Report (ESR) as follows:

> "No later than the summer of each year, the lead author of each assessment should review the previous year's ESR and determine whether any factor or set of factors described in that ESR implies an impending severe decline in stock/complex biomass, where "severe decline" means a decline of at least 20% (or any alternative value that may be established by the SSC), and where biomass is measured as spawning biomass for Tiers 1-3 and survey biomass as smoothed by the standard Tier 5 random effects model for Tiers 4-5. If an author determines that an impending severe decline is likely and if that decline was not anticipated in the most recent stock assessment, he or she should summarize that evidence in a document that will be reviewed by the respective Team in September of that year and by the SSC in October of that year, including a description of at least one plausible mechanism linking the factor or set of factors to an impending severe decline in biomass, and also including an estimate or range of estimates regarding likely impacts on ABC. In the event that new survey or relevant ESR data become available after the document is produced but prior to the October Council meeting of that year, the document should be amended to include those data prior to its review by the SSC, and the degree to which they corroborate or refute the predicted severe decline should be noted, with the estimate or range of estimates regarding likely impacts on ABC modified in light of the new data as necessary."

"Stock assessment authors are encouraged to work with ESR analysts to identify a small subset of indicators prior to analysis, and preferably based on mechanistic hypotheses." (SSC October 2018)

It has been demonstrated that annual bottom water temperature is at least a partial determinate of yellowfin sole late spring/summertime distribution. However it is unclear how temperature is related to the productivity of the stock. This species does not rely on ocean/atmosphere advective properties but instead migrates directly to nursery areas to spawn, so may be more resilient to changing ocean conditions. We also know that somatic growth is positively related to bottom temperature that may result in increased fecundity. Stock assessment authors would welcome the chance to work with an ESR analysist to think about indicators.

"The SSC also recommends explicit consideration and documentation of ecosystem and stock assessment status for each stock ... during the December Council meeting to aid in identifying stocks of concern." (SSC October 2017)

Clarification during December 2017 SSC meeting and then re-clarified during June 2018 SSC meeting. In the interest of efficiency, the clarification from the December 2017 minutes is not included here. The relevant portion of the clarification from the June 2018 minutes reads as follows:

"This request was recently clarified by the SSC by replacing the terms 'ecosystem status' and 'stock assessment status' with 'Ecosystem Status Report information' and 'Stock Assessment Information,'

where the potential determinations for each will consist of 'Okay' and 'Not Okay,' and by issuing the following guidance:

- *The SSC clarifies that 'stock assessment status' is a fundamental requirement of the SAFEs and is not really very useful to this exercise, because virtually all stocks are never overfished nor is overfishing occurring.*
- *Rather the SSC suggests that recent trends in recruitment and stock abundance could indicate warning signs well before a critical official status determination is reached. It may also be useful to consider some sort of ratio of how close a stock is to a limit or target reference point (e.g., B/B35). Thus, additional results for the stock assessments will need to be considered to make the 'Okay' or 'Not Okay' determinations.*
- *The SSC retracts its previous request for development of an ecosystem status for each stock/complex. Instead, while considering ecosystem status report information, it may be useful to attempt to develop thresholds for action concerning broad-scale ecosystem changes that are likely to impact multiple stocks/complexes.*
- *Implementation of these stock and ecosystem determinations will be an iterative process and will require a dialogue between the stock assessment authors, Plan Teams, ecosystem modelers, ESR editors, and the SSC."*

"The Teams recommend that the terms 'current and future ecosystem condition' and 'current and future stock condition' be used in place of 'ESR information' and 'stock assessment information'." (Plan Team September 2018)

"The SSC recognized that because formal criteria for these categorizations have not been developed by the PT, they will not be presented in December 2018." (SSC October 2018)

The iterative process described in the final bullet above was scheduled to begin at the September 2018 meeting of the Joint BSAI and GOA Plan Teams. However, no formal criteria for these categorizations were developed by the Plan Teams in September 2018. As specified by the SSC in October, we will not provide determinations for yellowfin sole at this time and will provide determinations when formal criteria are established.

"The Team recommended that the authors simply report in words or a table whether catches exceed ABC as an indicator for "partial update" stocks. (Plan Team November 2017)

Does not apply to yellowfin sole SAFE report since it is not a "partial update stock".

"The SSC reminds authors of the need to balance the desire to improve model fit with increased risk of model misspecification." (SSC December 2017)

Clarification: *"In the absence of strict objective guidelines, the SSC recommends that thorough documentation of model evaluation and the logical basis for changes in model complexity be provided in all cases."* (SSC June 2018)

Important point as the 2018 yellowfin sole assessment has increased the number of parameters estimated by 2 to improve fit to survey biomass. Hopefully our model evaluation is sound by providing a mechanism for the increased complexity from a new paper on availability/temperature correlations.

"Report a consistent metric (or set of metrics) to describe fish condition among assessments and ecosystem documents where possible." (SSC December 2017)

We do not yet report fish condition for yellowfin sole. However, if we do report this metric in the future then we will be consistent with the weight-length residual approach to report fish condition as described in the Ecosystem Status Report.

"Projections ... clearly illustrate the lack of uncertainty propagation in the 'proj' program used by assessment authors. The SSC encourages authors to investigate alternative methods for projection that incorporate uncertainty in model parameters in addition to recruitment deviations. Further, the SSC noted that projections made on the basis of fishing mortality rates (Fs) only will tend to underestimate the uncertainty (and perhaps introduce bias if the population distribution is skewed). Instead, a two-stage approach that first includes a projection using F to find the catch associated with that F and then a second projection using that fixed catch may produce differing results that may warrant consideration." (SSC December 2017)

Please see model evaluation section for alternative Tier 1 projection with uncertainty in F.

"The Teams recommend that the appropriate use, or non-use, of new model based estimates in this assessment cycle be left to individual authors' discretion. The Teams further recommend that, if an author chooses to incorporate these into the assessment, the assessment should also contain appropriate comparative models and a full set of diagnostics." (Plan Team September 2018)

"The SSC supports the PT recommendation to make the use of model-based survey estimates at the individual author's discretion for 2018." (SSC October 2018)

This assessment did not utilize any model based survey estimates. In the future, model-based estimates produced by the Groundfish Assessment Program (GAP) will be used to fit the assessment model as a contrast to the current use of survey estimates. A working group was formed to investigate criteria for use of the model-based estimates in a variety of groundfish life histories. We will consult the guidelines from this working group for determining the usefulness of the model-based estimates for yellowfin sole when they become available.

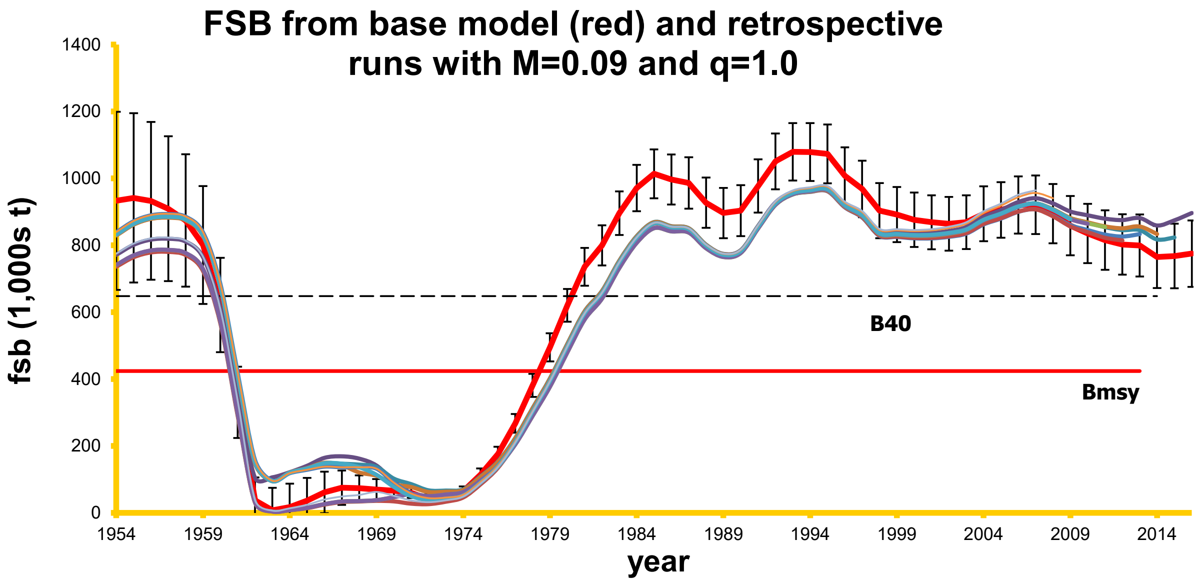
"The SSC also noted that, in order to save resources, authors should not conduct additional assessments beyond the prioritized schedule unless they specifically trigger one or more of the criteria identified." (SSC October 2018)

Yellowfin sole is a Tier 1 stock assessment conducted every year and as such it's frequency for completion is not determined by a specific external criteria.

Responses to SSC and Plan Team Comments Specific to this Assessment

The Team recommends plotting the estimated spawning biomass trajectory with a fixed pair of M and q values that reduces the retrospective pattern (e.g., M=0.09 and q=1.0) on top of the estimated spawning biomass trajectory, with confidence intervals, from the base model run. This comparison will help to determine if the different combination of M and q values is within the estimated uncertainty of the base model, or is describing a completely different population size.

Please see Retrospective Analysis section of this report.



The M=0.09 and q=1.0 retrospective model runs are outside the confidence intervals of the assessment model spawning biomass trajectory for about a 17 year period from 1978-1995. Otherwise it is generally within the uncertainty of the assessment model results.

The Team recommends continuing to explore the retrospective patterns in relation to values of M and q, with fixed values of M and fixed values of q, reporting values of Mohn's rho for each combination (range to be decided by the authors). Additionally, using those same model runs, report the total likelihood for each combination to create a bivariate likelihood profile for those parameters. Realizing that this will require a considerable number of model runs, the Team leaves it up to the authors to decide whether using the model runs done for the 2017 assessment will suffice, or if important differences arise from a 2018 model that warrant redoing those model runs.

One ongoing concern with the assessment is a strong retrospective pattern in female spawning biomass, whereby more recent assessments tend to yield higher biomass estimates (Figure 4.21). Pursuant to requests by the Plan Team and SSC, the authors explored the effects of M and q on these patterns. Lower values of q and M resulted in better retrospective patterns and lower Mohn's test statistics. The SSC supports the Plan Team's recommendation to select a parameterization (e.g., M=0.09 and q=1.0) that reduces the retrospective pattern and to determine whether spawning biomass projections from this parameterization fall within the uncertainty of the base model or if it describes different population trends. The SSC also endorses the Plan Team's recommendation to continue to explore effects of M and q on the retrospective patterns in biomass.

The M-q analysis of 2017 was repeated in 2018 but focused on the pattern of model fit (-log likelihood) instead of Mohn's test statistic and indicated that the best fit to the stock assessment model occurs at M and q values higher than where the best retrospective pattern occurs.

The SSC notes that potential improved performance of the model with lower values of M are interesting, given that M appears to have been well specified both outside the model (based on multiple methods of estimation, including analysis of old Japanese pair trawl effort data) as well as inside the model (profile of M over a range of values). A natural mortality value of 0.12 is used for both sexes in the base model. Pending the outcome of efforts to explore effects of M and q on the retrospective pattern, the SSC recommends that the authors reexamine alternative methods and data available to estimate M independent of the model in attempts to independently "validate" the plausibility of the results.

Natural mortality modeling was not attempted in 2018 but can be done in 2019, for both sex-specific M and also time-varying M.

The SSC notes that there appears to be a strong time trend in the proportion of fish in the final age bin (age 17+) in the fishery catch at age data for both males and females (Table 4.4). Prior to 1980, there were no fish in this category. This proportion has generally increased from the mid 1980s to a maximum of 19% for males in 2004 and 23% for females in 1999, and fluctuated at relatively high levels through 2016. Such a pattern could be consistent with time-varying M, although there may be other explanations. For next year's assessment, the SSC recommends that the assessment authors consider the evidence for time-varying M and evaluate the ability of time-varying M to address the retrospective biomass pattern in an alternative model.

The pattern of increasing proportion of fish in the plus group for our time-series can also be explained by overfishing the stock in the early 1960s by foreign fleets where the yellowfin sole stock was reduced to very low levels and the larger fish were mostly gone. By 1980 the age 15+ fish were beginning to accumulate in the population again and increased thereafter (to the present) with more prudent management.

Introduction

The yellowfin sole (*Limanda aspera*) is one of the most abundant flatfish species in the eastern Bering Sea (EBS) and currently 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. 49º N) to the Chukchi Sea (about lat. 70º N) and south along the Asian coast off the South Korean coast in the Sea of Japan (to about lat. 35º N). 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. The directed fishery historically occurred from winter through autumn (Wilderbuer et al. 1992). Yellowfin sole are managed as a single stock in the BSAI management area as there is presently no evidence of stock structure.

Fishery

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 (Fig 4.1, bottom panel) and the rate of target catch per bycatch ton. There is now a more even and slow attainment of the annual catch relative to the pre-Amendment 80 fishing behavior.

Yellowfin sole are usually headed and gutted, frozen at sea, and then shipped to Asian countries for further processing (AFSC 2016). The first wholesale value of Alaska yellowfin sole totaled $97.8 million in 2014. From 2016 to 2017 the first wholesale price of all Bering Sea flatfish fisheries increased 16% to $192.9 million t and yellowfin sole price increased 19% year over year. In 2010, following a compr,ehensive 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.

In 2011, federally permitted vessels using non-pelagic trawl gear whose harvest results in flatfish retained catch that is greater than any other retained fishery category were required to use modified trawl gear. The modifications required the use of elevating devices to raise the section of the trawl warps between the doors and the trawl wing tips by 2.5 inches off the seafloor. The purpose of the management action was to reduce damage of non-target animals, particularly those that form habitat structure or support other fisheries while not substantially reducing flatfish catch rates or causing gear handling problems (Rose et al. 2010).

The 1997 catch of 181,389 t (retained and discards) was the largest since the fishery became completely domestic but was at lower levels from 1998–2010, averaging 94,004 t (Table 4.2). From 2011-2014 the catch increased, averaging 155,000 t. The 2013 catch totaled 165,000 t (73% of the ABC), the highest annual catch in the past 19 years. For 2018, the catch distribution has been spread out from January through May with the majority coming from 4 BSAI management areas (509, 513, 514, 517). As of mid-September 2018, the fishing season is ongoing. In order to estimate the total 2018 catch for the stock assessment model, the average proportion of the 2010-2017 cumulative catch attained by the 35th week of the year (mid-September) was applied to the 2018 catch amount at the same time period and results in a 2018 catch estimate of 146,500 t (53% of the ABC). The size composition of the 2018 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 2018, by month (through mid-September), are shown in Figure 4.4. The average age of yellowfin sole in the 2017 catch is estimated at 12.6 and 13.5 years for females and males, respectively.

The time-series of catch in Table 4.1 also includes yellowfin sole that were discarded in domestic fisheries from 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 2% of the total catch in 2012 (and 2015) to 30% in 1992 and is estimated at 3% in the 2017 fishery. The trend has been toward fuller retention of the catch in recent years, and with the advent of the Amendment 80 harvest practices, discarding is at its lowest level since these estimates have become available. Historically, discarding primarily occurred in the yellowfin sole directed fishery, with lesser amounts in the Pacific cod, Pollock, rock sole, flathead sole, and “other flatfish” fisheries (Table 4.3).

Data

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

Data source	years
Fishery catch	1954-2018
Fishery age composition	1964-2017
Fishery weight-at-age	Avg wt at age from 2008-16 used for 2008-2018
Survey biomass and standard error, bottom temperature	1982-2018
Survey age composition	1979-2017
Annual length-at-age and weight-at-age from surveys	1979-2017
Age at Maturity	Combined 1992 and 2012 samples

Fishery Catch and Catch-at-Age

This assessment uses fishery catch data from 1955- 2018 (shown for 1964-2018 in Table 4.1), including an estimate of the 2018 catch, and fishery catch-at-age (proportions) from 1964-2017 (Table 4.4, 1975-2017). The 2017 fishery age composition was primarily composed of fish older than 9 years with a large amount of 20+ fish.

Survey Biomass Estimates and Population Age Composition Estimates

Indices of relative abundance available from AFSC surveys have 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 in 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 (Fig. 4.5). Biomass estimates for yellowfin sole from the annual bottom trawl survey on the eastern Bering Sea shelf are shown in Table 4.5 and Figure 4.6. The data show a doubling of survey 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. However, the 2012 estimate is a 19% decrease from 2011 and the 2013 and 2014 surveys have estimated a 17% increase over 2012. Similarly, there was a 24% decrease from 2014 to 2015 followed by a 48% increase from 2015 to 2016, the highest biomass estimate since 1984. Fluctuations of the magnitude shown between 1980 and 1990, 1998 and 1999, 2008 and 2009, 2011and 2012, 2014 and 2015 and 2015 and 2016 are unreasonable considering the elements of slow growth and long life span of yellowfin sole combined with low to moderate exploitation rate, characteristics which should produce more gradual changes in abundance.

Variability of yellowfin sole survey biomass 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 near shore 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 during early summer indicate that yellowfin sole concentrations can be greater in these shallower areas not covered by the standard AFSC survey than in the survey proper. 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 coastal areas are sufficiently large enough to offer a substantial refuge for yellowfin sole from the current survey.

Over the past 18 years, survey biomass estimates for yellowfin sole have shown a positive correlation with shelf bottom temperatures (Nichol, 1998); estimates have generally been lower during cold years. The 1999 survey, which was conducted in exceptionally cold waters, indicated a decline in biomass that was unrealistic. The bottom temperatures during the 2000 survey were much warmer than in 1999, and the biomass increased, but still did not approach estimates from earlier years. Average bottom temperature and biomass both increased again during the period 2001 – 2003, with the 2003 value the highest temperature and biomass observed over the 22 year time series up to that time. Given that both the 1999 and 2000 surveys were conducted two weeks earlier than previous surveys, it is possible that the time difference may also have also 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 pattern was observed again in 2009 and 2012 when the temperatures and the bottom trawl survey point estimates were lower. Summer shelf bottom temperatures in 2012 were the 2nd coldest recorded by the survey and the time-series and resulted in a 19% decline from 2011. In 2016 the Bering Sea had the highest recorded bottom temperature since measurements began in 1982 and the 2016 estimate of biomass was the highest in 32 years and 48% higher than the 2015 estimate. The 2017 survey estimate of 2,787,700 t was 3% lower than 2016, but the 2018 estimate of 1,892,925 (another warm year) was down 32% from 2017.

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 cold. 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 (Nichol et al. in review). 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 2016, a very warm year in the Bering Sea, it appears that a higher portion of the adult biomass was distributed on the shelf (outside of the spawning areas) relative to the average of all previous survey years, indicating earlier spawning migration (Fig 4.7).

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

Northern Bering Sea survey

Trawl survey sampling was extended to the northern Bering Sea in 2010, 2017 and 2018. The trawl surveys conducted in 2010 and 2017 occupied the same areas with similar sampling densities. The 2018 survey was a reduced effort and only sampled a subset of the northern Bering Sea. Stations in 2018 were 30 nautical miles apart (instead of 20 nm) and excluded Norton Sound and inshore areas north of Nunivak Island. For comparison among years (2010, 2017, 2018), biomass estimates were derived by truncating the areal coverage of the 2010 and 2017 surveys to include only the area covered in 2018 that was common to all three surveys, and this was treated as a single stratum (Table 4.5). This truncated area is 158,286 square kilometers (compared to 200,207 square kilometers in 2010 & 2017). There was a small increase in the estimate of yellowfin sole in the truncated survey area from the 3 surveys. Since yellowfin sole fishing is presently prohibited in the northern Bering Sea, the biomass from this area is not included in the stock assessment model.

Age Determination

Yellowfin sole ages have been determined at the AFSC by using the break and burn method on otoliths collected in surveys and from fisheries since 1979. In 2016 the age determination methods for yellowfin sole were validated using the bomb-produced uptake measurement of ^{14}C method (Kastelle et al. 2016).

Length and Weight-at-Age

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

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

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

A sex-specific length-weight relationship was also calculated from the survey database using the usual power function, weight (g) = a Length(cm)^b, where a and b are parameters estimated to provide the best fit to the data (Fig. 4.8).

	a	b	n
Males	0.00854	3.081	2,701
Females	0.0054	3.227	3,662

These estimates of weight at length were applied to the annual trawl survey estimates of population length at age, by sex, to calculate the weight at each age (Fig. 4.8). Since the resulting estimates of annual weight-at-age were highly variable for fish older than 11 years, ages 11-20 were smoothed using a five year average smoothing method for 1982-2018.

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

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

In order to incorporate time-varying (year effect on growth) and temperature-dependent growth functions into the age-structured stock assessment model we used the annual observed population mean weight-at-age (time-varying) from the trawl survey. These empirical data indicate good somatic growth correspondence with annual bottom temperature anomalies from 1982-2017 (Fig. 4.11). Fishery weight at age data available from 2008-2016 were averaged across years for each age to provide updated estimates for the fishery

Maturity-at-age

Maturity information collected from yellowfin sole females during the 1992 and 1993 eastern Bering Sea trawl surveys have been used in this assessment for the past 20 years (Table 4.10). Nichol (1995) estimated the age of 50% maturity at 10.5 years based on the histological examination of 639 ovaries. Maturity has recently been re-evaluated from a histological analysis of ovaries collected in 2012 (Table 4.10). Results were very similar to the earlier study with only a 2% difference in estimates of yellowfin sole female spawning biomass (TenBrink and Wilderbuer 2015). In addition, the SSC requested that the assessment use a maturity schedule that uses estimates derived from both the 1992 and the 2012 collections (Table 4.10). For yellowfin sole sexual maturity occurs well after the age of entry into the fishery. Yellowfin sole females are 82% selected to the fishery by age 10 whereas they have been found to be only 40% 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 (Fournier et al. 2012; Ianelli and Fournier 1998). The conceptual model is a separable catch-age analysis that uses survey estimates of biomass and age composition as auxiliary information (Fournier and Archibald 1982). The assessment model simulates the dynamics of the population and compares the expected values of the population characteristics to the characteristics observed from surveys and fishery sampling programs. This is accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the simulated values to the observable characteristics is optimized by maximizing a log(likelihood) function given some distributional assumptions about the observed data.

The model starts at age one and fish older than twenty are allowed to accumulate into a plus group. Since the sex-specific weight-at-age for yellowfin sole diverges after age of maturity (about age 10 for 40% 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 Outside the Assessment Model

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) occurred at a M value of 0.12 (Bakkala and Wespestad 1984). This was also the value which provided the best fit to the observable population characteristics when M was profiled over a range of values in the stock assessment model using data up to 1992 (Wilderbuer 1992). Since then, natural mortality has been estimated as a free parameter in some of the stock assessment model runs which have been evaluated the past five years. A natural mortality value of 0.12 is used for both sexes in the base model presented in this assessment.

Yellowfin sole maturity schedules were estimated from in-situ observations from two studies as discussed in a previous section (Table 4.10).

Parameters Estimated Inside the Assessment Model

The parameters estimated by the model are presented below:

Fishing mortality	Selectivity	Survey catchability	Year class strength	Spawner-recruit	Total
66	268	4	105	2	445

The increase in the number of parameters estimated in this assessment compared to last year (8) can be accounted for by the input of another year of fishery data and the entry of another year class into the observed population, four more sex-specific fishery selectivity parameters and 2 additional catchability parameters.

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, time-varying fishing selectivity curves were estimated. 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. The variance of the model estimates were then rounded up slightly and fixed for subsequent runs. The 2016 values were fixed as the average of the 3 most recent years.

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 (300) was placed on the catch likelihood component to force the model to closely 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 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 has resulted in an improved fit to the survey (shown in Figure 4.12 for the base model).

In this assessment we introduce a revised survey catchability model (Model 18_1) where survey start date (expressed as deviation in days (- and +) from the average survey start date of June 4th) and it's interaction with annual bottom water temperature is added to the catchability equation as:

$$q=e^{-\alpha+\beta T+\gamma S+\mu T:S}$$

where *T*=survey bottom temperature (averaged per year for all stations <100 m), *S*=survey start date, and *T:S*=interaction of *T* and *S*. Earlier survey start dates usually encounter colder water and since the timing of the survey start date is positively correlated with bottom water temperature, improvement in fitting the survey biomass estimates can be gained by estimating two new parameters (μ and ɤ). Akaike information criterion (AIC) were used to determine if the additional variables (*S* and *T:S*) improved the regression fit. The improvement in fit was more than offset by the additional two parameters (Nichol et al. In review).

Spawner-Recruit Estimation
Annual recruitment estimates from 1978-2012 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.

Results

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 sets of years to include for spawner-recruit fitting (increased from 1978-2010 to 1978-2012 in this assessment). The second step evaluated various hypothesized states of nature by fitting natural mortality and catchability estimates in various combinations.

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

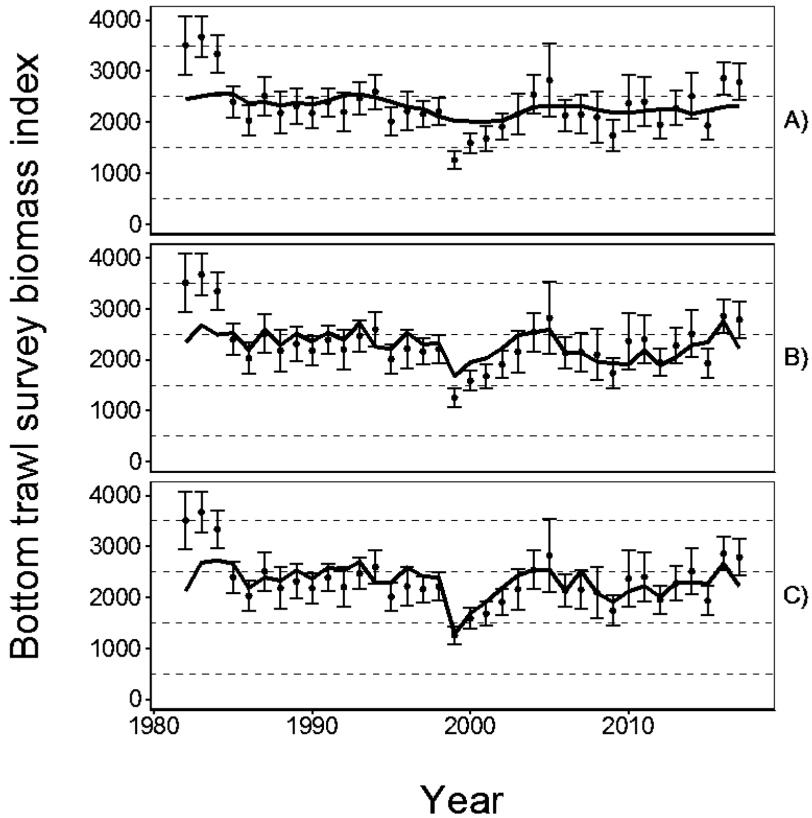
For this assessment, two different stock-recruitment time-series were investigated: the full time-series 1955-2012 (Model 14_2) and the post-regime shift era, 1978-2012 (Model 14_1) (Fig. 4.13) (see Joint Plan Team recommendations for September 2012). Very different estimates of the long-term sustainability of the stock (F_{MSY} and B_{MSY}) are obtained, depending on which years of stock-recruitment data are included in the fitting procedure (Table 4.13). When the entire time-series from 1955-2012 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} (0.208) is higher than $F_{35\%}$ ($F_{35\%}$ = 0.17) and B_{MSY} is 314,800 t (Model 14_2). If we limit the analysis to consider only recruitments which occurred after the well-documented regime shift in 1977 (Model 14_1), a lower value of F_{MSY} is obtained (0.118) and B_{MSY} is 451,600 t. Table 4.13 indicates that the ABC values from the Model 14_2 harvest scenario for 2019 would be 239,560 t higher than Model 14_1. Posterior distributions of F_{MSY} for these models indicate that this parameter is estimated with less uncertainty for Model 14_1 resulting in the reduced buffer between ABC and OFL relative to Model 14_2 (9% for Model 14_1 versus 1% for Model 14_2, Table 4.13 and Fig 4.14).

It is important for the Tier 1 calculations to identify which subset of the stock recruitment data is used. Using the full time series to fit the spawner recruit curve estimates that the stock is most productive at a small stock size. Thus MSY and F_{MSY} are relatively high values and B_{MSY} is a lower value. If the stock was productive in the past at a small stock size because of non density-dependent factors (environment), then reducing the stock size to low levels could be detrimental to the long-term sustainability of the stock if the environment, and thus productivity, have 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, and because the AFSC policy for reference point time-series selection is to use the post 1977 regime shift values unless there is a compelling reason to do otherwise, the productivity of yellowfin sole in this assessment is estimated by fitting the 1977-2012 spawner-recruit data in the model (Model 14_1).

The second step in the model evaluation for this assessment entails the use of a single structural model to consider the uncertainty in the key parameters M and catchability. This is the Model which has been the model of choice is the past 5 assessments (Model 14_1) and operates by fixing M at 0.12 for both sexes and then estimates q using the relationship between survey catchability and the annual average water temperature at the sea floor (from survey stations at less than 100 m). The other models used in the evaluation represented various combinations of estimating M or q as free parameters with different amounts of uncertainty in the parameter estimates (Wilderbuer et al. 2010). The results are detailed in those assessments and are not repeated here except for the following observations.

The introduction of survey start date as a variable within the *q* parameter calculation of the stock assessment model (Model 18_1), similarly improved overall model fits to the survey biomass data with the full model ($q=e^{-\alpha+\beta T+\gamma S+\mu T:S}$) providing the best fit to the survey biomass data compared to models where either annual bottom temperature or start date variable (i.e., constant *q* across years) were not included, or models with only a bottom temperature variable ($q=e^{-\alpha+\beta T}$) (Nichol et. al 2018). In particular, inclusion of the start date in the model improved model fits for years 1999 to 2003, years for which the more reduced models clearly overestimated survey biomass. (Panel A constant q, Panel B bottom temperature only, and Panel C survey start date, bottom temperature and interaction term.)



Given these results and the AIC evidence (Nichol et al. 2018), Model 18_1 is the model of choice for estimating the yellowfin sole stock size and management quantities for the 2019 fishing season.

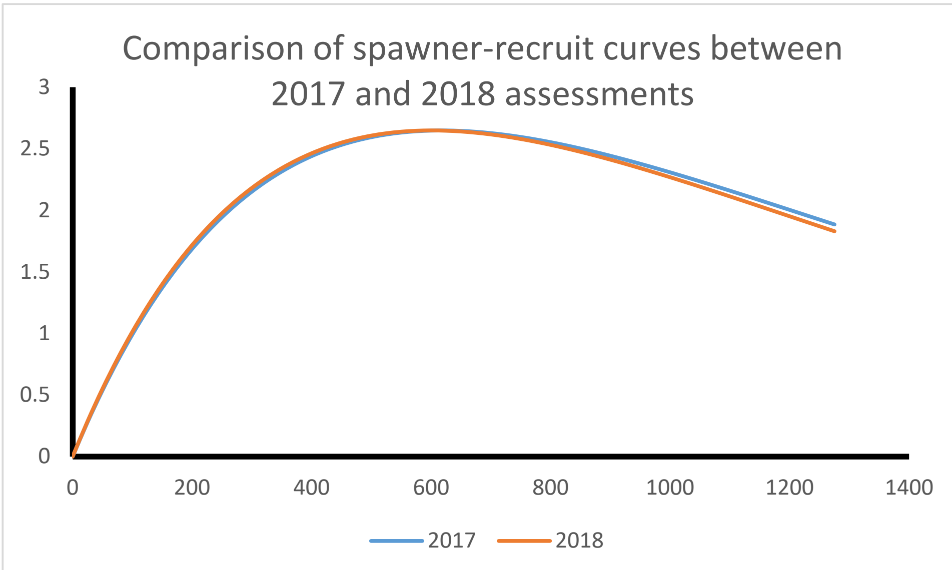
Experiments examining the bridle efficiency of the Bering Sea survey trawl indicate that yellowfin sole are herded into the trawl path from an area between the wing tips of the net and the point where the bridles contact the seafloor (Somerton and Munro 2001). The herding experiments suggest that the survey trawl vulnerability (a component of catchability) is greater than 1.0. The likelihood profile of q from the model indicated a small variance with a narrow range of likely values with a low probability of q being equal to the value of 1.0 in a past assessment (Wilderbuer and Nichol 2003).

A model that allows M to be estimated as a free parameter for males with females fixed at 0.12 provided a better fit to the sex ratio estimated from the annual trawl survey age compositions than did the base model (both sexes fixed at M = 0.12). However, since the population sex ratio annually observed at the time of the survey is a function of the timing of the annual spawning in adjacent inshore areas, it is questionable that providing the best fit to these observations is really fitting the population sex ratio better. Thus, the model configuration which utilizes the relationship between annual seafloor temperature and survey start date to estimate survey catchability with M fixed at 0.12 for both sexes (Model 18_1) is the preferred model used to base the assessment of the condition of the Bering Sea yellowfin sole resource for the 2018 fishing season.

Time Series Results

Before presenting the preferred model results, a brief consideration of the inputs and changes to the assessment methodology relative to last year (Model 14_1) is given. Primary updates in going from Model 14_1 to Model 18_1 were the 2018 catch, the fishery and survey age compositions from 2017 and the 2018 survey biomass (32% lower than 2017) and standard error estimates. The fishery and survey weights-at-age were also changed in a small amount to include the latest year of data. In their totality, these changes produced Model 18_1 ABC and OFL estimates for 2019 that were 2% lower than the 2017 assessment (Model 14_1) projections for 2019.

As expected, this small increase produced very similar spawner-recruit curves.



The 2018 overall estimate (1982 – 2018) of trawl survey catchability decreased from 0.9 to 0.88. This resulted in slightly higher model estimates of population numbers at age and biomass for the time-series back to 1992 relative to last year's assessment and increased the estimated level of female spawning biomass. The model results indicate the stock has been in a slowly declining condition since 1994. The estimates of total biomass and ABC are a bit lower than those used to manage the stock in 2018. Seven of the past 11 years have had negative bottom temperature anomalies in the Bering Sea but the last four years have been above the mean. The temperature-dependent q adjustment for 2017 was 0.92.

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 0.07 over the period of 1978-2018 with a maximum of 0.11 in 1978 and a minimum of 0.04 in 2001. Model estimated selectivities (Table 4.16, Fig. 4.15) 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 0.88 for the period 1982-2018 which results in the model estimate of the 2018 age 2+ total biomass at 2,786,300 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 (700,000-1,000,000 t) after a period of high exploitation (Table 4.17, Fig. 4.16, center left panel). Sustained above average recruitment from 1967-76 combined with light exploitation resulted in a biomass increase to a peak of 3.6 million t by 1985. 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, 1995 and

2003 year-classes at levels observed during the 1970s. The present biomass is estimated at 78% of the peak 1985 level.

The female spawning biomass has also declined since the peak in 1994, with a 2018 estimate of 854,800 t (27% decline). The spawning biomass has been in a gradual decline for the past 22 years and is 36% above the $B_{40\%}$ level and 1.9 times the B_{MSY} level (Fig. 4.16). The model estimate of yellowfin sole population numbers at age for all years is shown in Table 4.18 and the resulting fit to the observed fishery and survey age compositions input into the model are shown in the Figure 4.17. The fit to the trawl survey biomass estimates are shown in Figure 4.16. Allowing q to be correlated with annual bottom temperature and survey start date provides a better fit to the bottom trawl survey estimates than using a q fixed at the average value (Fig. 4.18). Table 4.19 lists the numbers of female spawners estimated by the model for all ages and years. The estimated average age of yellowfin sole in the population is 6.5 years for males and females.

Both the trawl survey and the stock assessment model indicate that the yellowfin sole resource (total biomass) increased during the 1970s and early 1980s to a peak level during the mid-1980s. The yellowfin sole population biomass slowly decreased over the 23 years since the mid-1990s as the majority of year-classes during those years were below average strength. Average to above average recruitment from 2006 to 2009 is expected to maintain the abundance of yellowfin sole at a level above B_{MSY} in the near future. The stock assessment projection model indicates a mildly decreasing trend in female spawning biomass through 2023 if the fishing mortality rate continues at the same level as the average of the past 5 years (Fig. 4.22).

Recruitment Trends
The primary reason for the sustained increase in abundance of yellowfin sole during the 1970s and early 1980s was the recruitment of a series of stronger than average year classes spawned in 1967-76 (Figure 4.19 and Table 4.20). The 1981 year class was the strongest observed (and estimated) during the 47 year period analyzed and the 1983 year class was also very strong. Survey age composition estimates and the assessment model also estimate that the 1987 and 1988 year classes were average and the 1991 and 1995 year classes were above average. With the exception of these 4 year classes, recruitment from 15 of the following 19 years estimated from 1984-2005 (since the strong 1983 year-class) were below the 48 year average, which caused the population to gradually decline. The 2003 year-class has now been observed multiple times in the age compositions and is clearly a strong year class, similar to some of the strong recruitment mentioned above and have contributed to the reservoir of spawning fish in the current population. In addition, recruitment from 2006-2009 appear also to be average to above average.

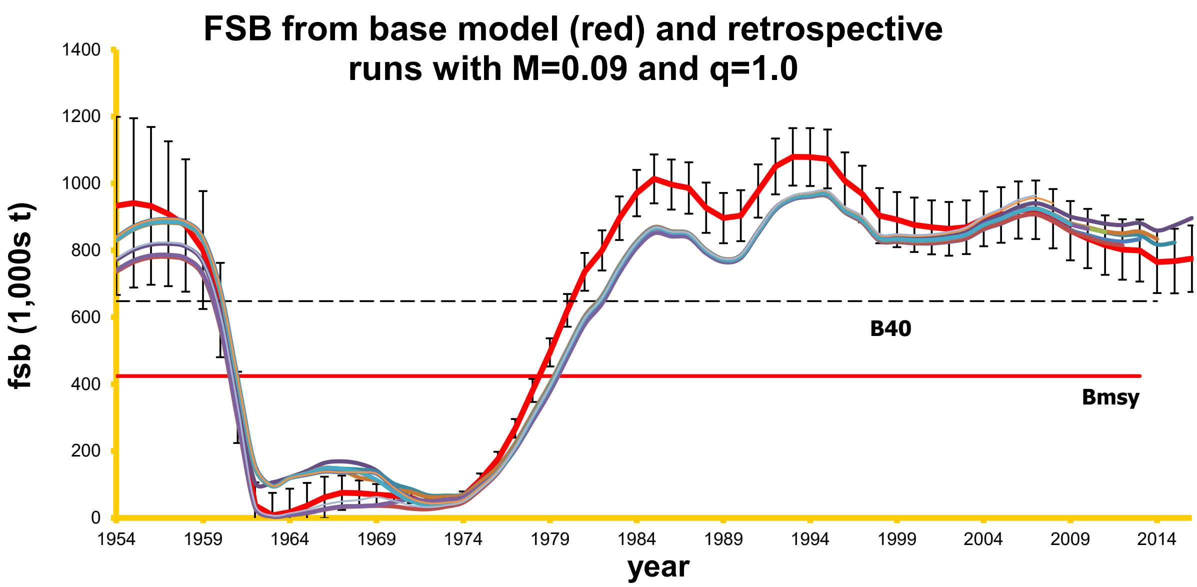
Historical Exploitation Rates
Based on results from the stock assessment model, annual average exploitation rates of yellowfin sole since 1977 ranged from 3 to 7% of the total biomass, and have averaged 4% (Table 4.15). Posterior distributions of selected parameters from the preferred stock assessment model used in the assessment are shown in Figure 4.20. The values and standard deviations of some selected model parameters are listed in Table 4.21.

Retrospective Analysis

A within-model retrospective analysis is also included for the recommended assessment model (Model 18_1) where retrospective female spawning biomass is calculated by working backwards in time dropping data one year at a time and then comparing the “peeled” estimate to the reference stock assessment model used in the assessment (Fig. 4.21). The resulting pattern from the current assessment model was less than desirable.

Peculiar to the yellowfin sole assessment, in comparison to the northern rock sole and Alaska plaice assessments (that have nice patterns), is the large amount of variability in the annual survey biomass assessments for this stock due to the temperature-influenced availability to the survey. This large variability in the annual estimates can contribute to undesirable patterns since the earlier years are not fitting the same highly variable information as the current year.

In the 2017 assessment it was demonstrated that low values of Mohn's rho and desirable retrospective patterns of female spawning biomass were obtainable if lower values of M and q were used relative to the base model. The Plan Team (and SSC concurred) requested a plot of the model-estimated female spawning biomass trajectory that reduces the retrospective pattern using M fixed at 0.09 and q =1.0 on top of the estimated female spawning biomass trajectory with confidence interval from the assessment. This comparison is plotted below and indicates the retrospective model runs are outside the confidence intervals of the assessment model spawning biomass trajectory for about a 17 year period from 1978-1995. Otherwise it is within the uncertainty of the assessment model estimate of female spawning biomass.



The Plan Team recommended that the assessment continue to explore the retrospective patterns in relation to M and q by profiling over a range of combinations of M and q and recording the resulting values of Mohn's roe and also total likelihood. This was accomplished using data through 2018 and yielded the following results.

		q				
		0.8	**0.9**	**1.0**	**1.1**	**1.2**
M	**0.08**	0.11	0.01	0.02	0.05	0.08
	0.09	0.04	0.03	0.06	0.08	0.11
	0.10	0.02	0.06	0.09	0.12	0.14
	0.11	0.07	0.09	0.12	0.14	0.16
	0.12	0.12	0.12	0.14	0.16	0.19
	0.13	0.12	0.14	0.16	0.19	0.21
	0.14	0.14	0.16	0.18	0.20	0.22

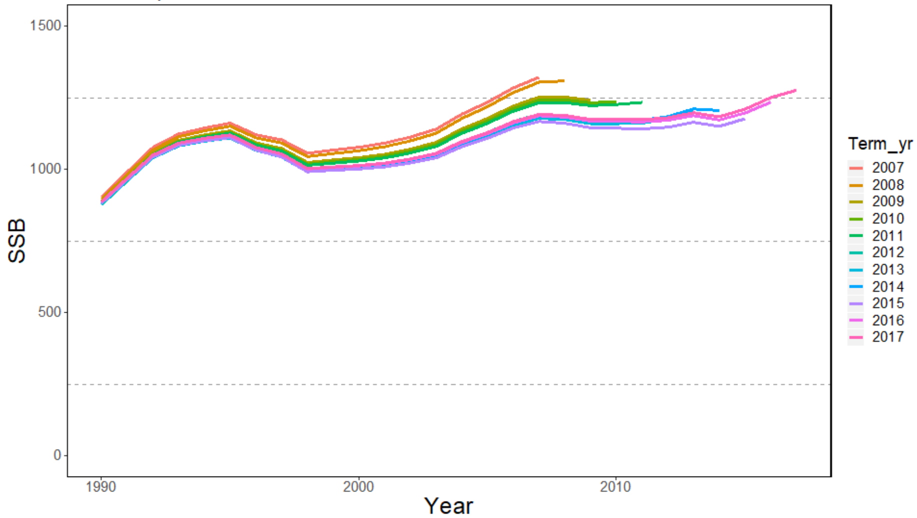
		q				
		0.8	**0.9**	**1.0**	**1.1**	**1.2**
M	**0.08**	303	73	48	28	14
	0.09	230	44	26	13	4
	0.10	177	24	13	4	0
	0.11	142	13	5	2	1
	0.12	121	7	3	3	6
	0.13	8	6	6	9	14
	0.14	8	8	11	16	23

Natural mortality (M) and catchability (q) profile. Top panel is Mohn's roe values and bottom panel is log(likelihood).

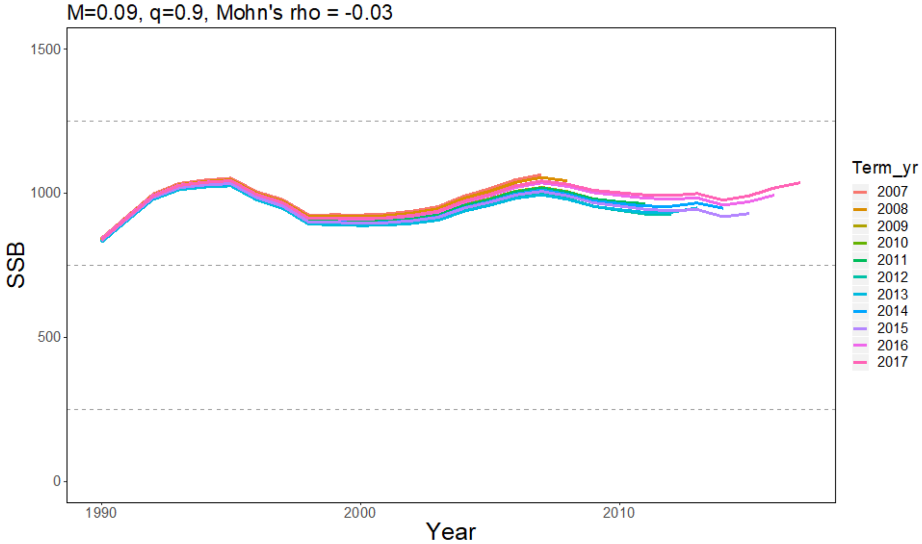
Best retrospective patterns (lower values of M and q in top panel) did not occur at corresponding best model fit values (single digit numbers in the bottom panel) of M and q (higher values). The retrospective technique may not always be the best tool for model selection, at least for BSAI yellowfin sole as there is tension between model fit and good retrospective pattern over the range of parameterization examined.

Figures of yellowfin sole spawning biomass for selected retrospective M-q combinations:

M=0.08, q=0.8, Mohn's rho = 0.11



M=0.09, q=0.9, Mohn's rho = -0.03



M=0.14, q=1.2, Mohn's rho = -0.22

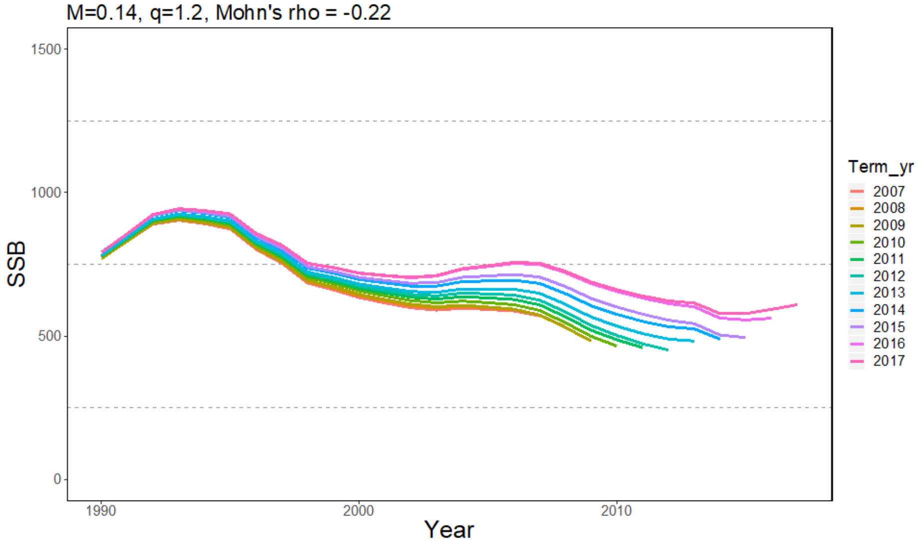
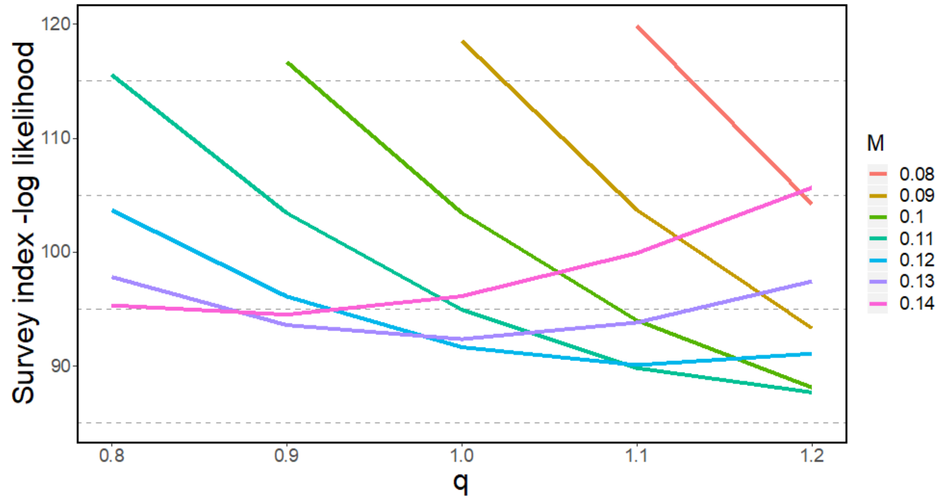
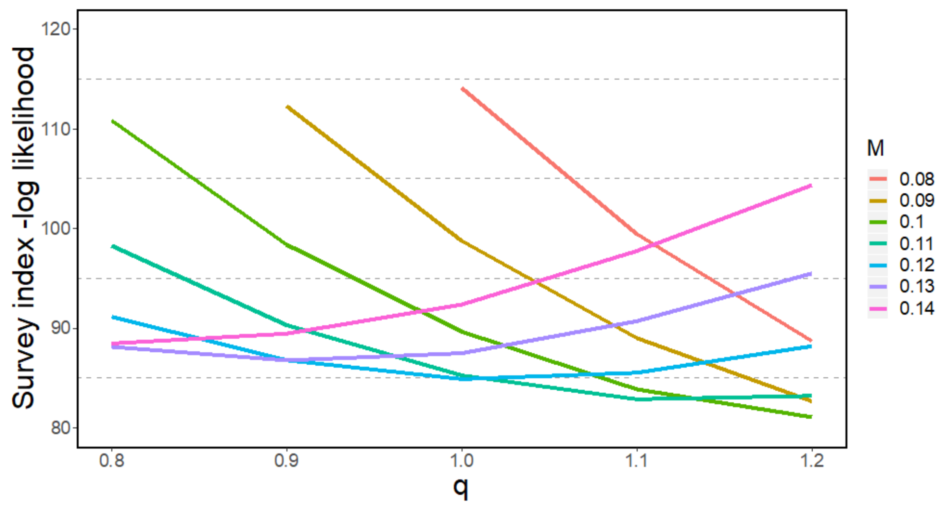


Figure on tradeoffs between M and q relative to negative log likelihood for the survey index for yellowfin sole.



Temperature/date and male M estimated



Harvest Recommendations

The SSC has determined that yellowfin sole qualify as a Tier 1 stock and therefore the 2019 ABC is calculated using Tier 1 methodology. The Tier 1 harvest level is calculated as the product of the harmonic mean of F_{MSY} and the geometric mean of the 2019 biomass estimate, as follows:

$B_{gm} = e^{\ln \hat{B} - \frac{cv^2}{2}}$, where B_{gm} is the geometric mean of the 2019 biomass estimate, $\hat{B}$ is the point estimate of the 2019 biomass from the stock assessment model and cv^2 is the coefficient of variation of the point estimate (a proxy for sigma);

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.

In 2006 the SSC selected the 1978-2001 data set for the Tier 1 harvest recommendation. Using this approach again for the 2019 harvest (now the 1978-2012 time-series) recommendation (Model 18_1 in Table 4.13), the $F_{ABC} = F_{harmonic\ mean} = 0.107$. The estimate of age 6+ total biomass for 2019 is 2,462,440 t. The calculations outlined above give a Tier 1 ABC harvest recommendation of **263,200 t** and an OFL of 289,900 t for 2019. This results in a 9% (26,200 t) buffer between ABC and OFL. The ABC value is 5% lower than last year, primarily due to the 32% decline in the survey estimate from 2017 to 2018.

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

Harvest level	F value	2019 Yield
Tier 1 $F_{OFL} = F_{MSY}$	**0.117**	**289,900 t**
Tier 1 $F_{ABC} = F_{harmonic\ mean}$	**0.107**	**263,200 t**

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 2018 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2019 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2018. 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 2019, 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 2019 recommended in the assessment to the *max* F_{ABC} for 2019. (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 the 2014-2018 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 4: In all future years, the upper bound on F_{ABC} is set at $F_{60\%}$. (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.)

0*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 2016 and above its MSY level in 2030 under this scenario, then the stock is not overfished.)

Scenario 7: In 2019 and 2020, 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 2031 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 2031 is shown in Figure 4.22 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 4.23.

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 2018 numbers at age from the stock assessment model are projected to 2019 given the 2018 catch and then a 2019 catch of 150,000 t is applied to the projected 2019 population biomass to obtain the 2020 OFL.

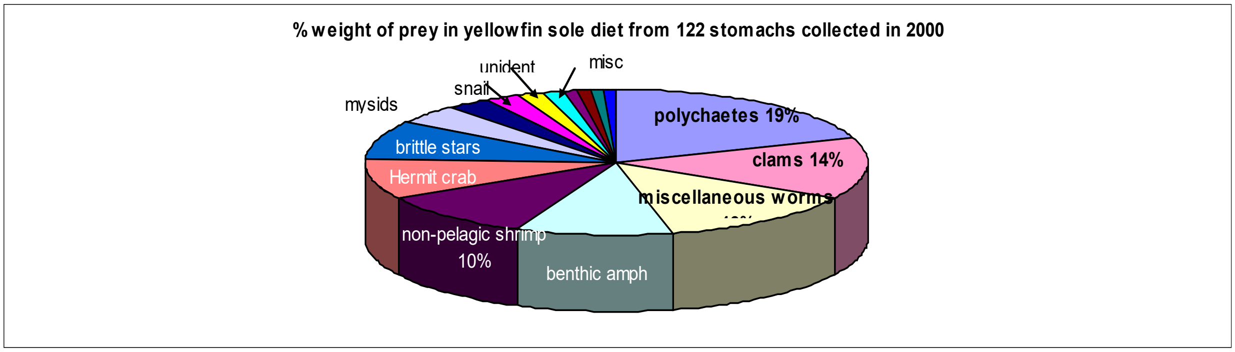
	Tier 1 Projection				
Year	Catch	SSB	Geometric mean 6+ total biomass	ABC	OFL
2019	150,000	850,600	2,462,400	263,200	290,000
2020	150,000	821,500	2,411,700	257,800	284,000

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 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 Report 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 1992-2017in Table 4.23. The catch of non-target species from 2003-2016 is shown in Table 4.24. The yellowfin sole target fishery contribution to the total bycatch of prohibited species is shown for 2014 and 2015 in Table 13 of the Economic SAFE (Appendix C) and is summarized for 2015 as follows:

Prohibited species	Yellowfin sole fishery % of total bycatch
Halibut mortality	30
Herring	2
Red King crab	5
C. bairdi	25.5
Other Tanner crab	78.2
Salmon	<1

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

3) The target fishery is not perceived to have an effect on the amount of large size target fish in the population due to its history of light to moderate exploitation (6%) over the past 30 years. Population age composition data indicate a large 20+ age group.

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, but based on two maturity studies conducted 20 years apart, it is expected to be minimal.

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

Data Gaps and Research Priorities

Isolation by distance genetic study to define stock structure in the planning stage. NPRB proposal to collect maturity in the northern Bering Sea for comparison with recent SE Bering Sea shelf samples.

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Tables

Table 4.1 Catch (t) of yellowfin sole 1964-2018. Catch for 2018 is an estimate through the end of the year.

		Domestic		
Year	Foreign	JVP	DAP	Total
1964	111,777			111,777
1965	53,810			53,810
1966	102,353			102,353
1967	162,228			162,228
1968	84,189			84,189
1969	167,134			167,134
1970	133,079			133,079
1971	160,399			160,399
1972	47,856			47,856
1973	78,240			78,240
1974	42,235			42,235
1975	64,690			64,690
1976	56,221			56,221
1977	58,373			58,373
1978	138,433			138,433
1979	99,019			99,019
1980	77,768	9,623		87,391
1981	81,255	16,046		97,301
1982	78,331	17,381		95,712
1983	85,874	22,511		108,385
1984	126,762	32,764		159,526
1985	100,706	126,401		227,107
1986	57,197	151,400		208,597
1987	1,811	179,613	4	181,428
1988		213,323	9,833	223,156
1989		151,501	1,664	153,165
1990		69,677	14,293	83,970
1991			115,842	115,842
1992			149,569	149,569
1993			106,101	106,101
1994			144,544	144,544
1995			124,740	124,740
1996			129,659	129,659
1997			181,389	181,389
1998			101,201	101,201
1999			67,320	67,320
2000			83,850	83,850
2001			63,395	63,395
2002			73,000	73,000
2003			74,418	74,418
2004			69,046	69,046
2005			94,383	94,383
2006			99,068	99,068
2007			121,029	121,029
2008			148,894	148,894
2009			107,528	107,528
2010			118,624	118,624
2011			151,164	151,164
2012			147,183	147,183
2013			164,944	164,944
2014			156,778	156,778
2015			126,933	126,933
2016			135,353	135,353
2017			132,297	132,297
2018			146,500	146,500

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

Year	Retained	Discarded
1987	3	1
1988	7,559	2,274
1989	1,279	385
1990	10,093	4,200
1991	89,054	26,788
1992	103,989	45,580
1993	76,798	26,838
1994	107,629	36,948
1995	96,718	28,022
1996	101,324	28,334
1997	149,570	31,818
1998	80,365	20,836
1999	55,202	12,118
2000	69,788	14,062
2001	54,759	8,635
2002	62,050	10,950
2003	63,732	10,686
2004	57,378	11,668
2005	85,321	9,062
2006	90,570	8,498
2007	109,084	11,945
2008	141,253	7,659
2009	92,488	5,733
2010	113,244	5,380
2011	146,419	4,745
2012	143,737	3,446
2013	158,781	6,163
2014	152,164	4,614
2015	123,065	3,871
2016	131,205	4,148
2017	128,699	3,598

Table 4.3. Discarded and retained catch of non-CDQ yellowfin sole, by fishery, in 2017. Source: AKFIN.

Trip Target Name	Discarded	Retained
Atka Mackerel	<1	<1
Pollock - bottom	1	194
Pacific Cod	1,504	289
Alaska Plaice - BSAI	<1	83
Other Flatfish - BSAI	<1	1
Halibut		
Rockfish	<1	<1
Flathead Sole	42	2,832
Kamchatka Flounder - BSAI	<1	<1
Pollock - midwater	148	265
Rock Sole - BSAI	353	16,087
Sablefish		
Greenland Turbot - BSAI	<1	1
Arrowtooth Flounder	2	2
Yellowfin Sole - BSAI	1,542	108,909

Table 4.4. Yellowfin sole fishery catch-at-age (proportions), 1975-2017.

	Males										
	7	8	9	10	11	12	13	14	15	16	17+
1975	0.09	0.24	0.12	0.02	0.01	0.01	0.02	0.00	0.00	0.00	0.00
1976	0.05	0.04	0.14	0.11	0.04	0.02	0.02	0.00	0.01	0.00	0.00
1977	0.03	0.08	0.07	0.12	0.09	0.04	0.01	0.00	0.00	0.00	0.00
1978	0.05	0.09	0.07	0.07	0.07	0.03	0.02	0.01	0.00	0.00	0.00
1979	0.03	0.06	0.11	0.07	0.06	0.04	0.02	0.00	0.00	0.00	0.00
1980	0.04	0.02	0.03	0.05	0.05	0.05	0.03	0.01	0.01	0.01	0.01
1981	0.04	0.04	0.03	0.05	0.07	0.06	0.04	0.02	0.01	0.00	0.00
1982	0.04	0.06	0.05	0.05	0.07	0.07	0.04	0.02	0.01	0.00	0.00
1983	0.06	0.03	0.06	0.05	0.04	0.06	0.05	0.03	0.02	0.01	0.01
1984	0.01	0.06	0.04	0.08	0.04	0.05	0.05	0.10	0.04	0.02	0.01
1985	0.02	0.03	0.06	0.06	0.07	0.06	0.07	0.06	0.03	0.02	0.02
1986	0.03	0.02	0.05	0.06	0.04	0.04	0.04	0.02	0.04	0.04	0.05
1987	0.02	0.05	0.04	0.05	0.04	0.05	0.06	0.04	0.02	0.03	0.13
1988	0.03	0.04	0.09	0.02	0.04	0.04	0.02	0.05	0.04	0.01	0.08
1989	0.00	0.04	0.04	0.06	0.02	0.02	0.04	0.03	0.03	0.03	0.16
1990	0.05	0.01	0.18	0.02	0.05	0.02	0.03	0.04	0.00	0.04	0.07
1991	0.01	0.09	0.01	0.19	0.03	0.06	0.01	0.01	0.02	0.02	0.07
1992	0.01	0.03	0.10	0.03	0.14	0.02	0.02	0.02	0.01	0.01	0.04
1993	0.02	0.01	0.01	0.08	0.01	0.10	0.02	0.02	0.01	0.02	0.09
1994	0.02	0.04	0.03	0.02	0.11	0.01	0.09	0.01	0.03	0.01	0.05
1995	0.03	0.06	0.03	0.01	0.02	0.10	0.00	0.10	0.01	0.01	0.05
1996	0.02	0.06	0.04	0.02	0.01	0.03	0.10	0.02	0.07	0.01	0.06
1997	0.02	0.02	0.05	0.04	0.03	0.04	0.02	0.10	0.02	0.05	0.09
1998	0.02	0.02	0.02	0.05	0.04	0.03	0.01	0.02	0.03	0.01	0.12
1999	0.00	0.02	0.01	0.02	0.04	0.05	0.03	0.02	0.03	0.04	0.11
2000	0.00	0.02	0.05	0.01	0.02	0.05	0.03	0.03	0.02	0.05	0.13
2001	0.01	0.02	0.01	0.03	0.03	0.01	0.02	0.03	0.03	0.02	0.16
2002	0.00	0.02	0.03	0.04	0.09	0.03	0.02	0.05	0.01	0.01	0.14
2003	0.01	0.08	0.04	0.03	0.02	0.04	0.02	0.02	0.03	0.02	0.15
2004	0.01	0.02	0.09	0.02	0.02	0.02	0.03	0.01	0.01	0.02	0.19
2005	0.01	0.04	0.02	0.08	0.02	0.02	0.03	0.04	0.02	0.01	0.14
2006	0.06	0.05	0.03	0.05	0.06	0.02	0.01	0.02	0.03	0.01	0.09
2007	0.02	0.06	0.03	0.03	0.05	0.06	0.02	0.02	0.03	0.02	0.12
2008	0.02	0.03	0.06	0.02	0.03	0.02	0.07	0.01	0.02	0.02	0.11
2009	0.01	0.04	0.03	0.05	0.03	0.01	0.02	0.04	0.02	0.02	0.13
2010	0.06	0.03	0.06	0.02	0.05	0.04	0.02	0.01	0.02	0.01	0.10
2011	0.02	0.07	0.03	0.03	0.03	0.04	0.01	0.01	0.01	0.03	0.14
2012	0.02	0.04	0.08	0.04	0.03	0.03	0.04	0.04	0.01	0.02	0.16
2013	0.02	0.00	0.03	0.08	0.05	0.06	0.04	0.04	0.03	0.01	0.09
2014	0.02	0.04	0.03	0.04	0.06	0.02	0.04	0.04	0.04	0.01	0.13
2015	0.01	0.03	0.04	0.02	0.02	0.05	0.02	0.05	0.02	0.04	0.16
2016	0.02	0.03	0.03	0.05	0.04	0.02	0.05	0.03	0.02	0.01	0.17
2017	0.02	0.08	0.07	0.05	0.04	0.03	0.03	0.11	0.05	0.05	0.25

Table 4.4. continued.

	females										
	7	8	9	10	11	12	13	14	15	16	17+
1975	0.05	0.14	0.09	0.05	0.02	0.02	0.02	0.00	0.01	0.00	0.00
1976	0.04	0.07	0.17	0.10	0.07	0.01	0.01	0.00	0.01	0.00	0.00
1977	0.07	0.16	0.11	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1978	0.05	0.13	0.12	0.09	0.09	0.03	0.01	0.01	0.00	0.00	0.00
1979	0.03	0.07	0.12	0.12	0.08	0.06	0.03	0.01	0.01	0.00	0.00
1980	0.06	0.04	0.06	0.11	0.10	0.07	0.07	0.04	0.02	0.01	0.03
1981	0.06	0.06	0.03	0.05	0.09	0.11	0.07	0.05	0.02	0.01	0.01
1982	0.03	0.07	0.06	0.05	0.09	0.09	0.05	0.03	0.02	0.01	0.00
1983	0.07	0.05	0.08	0.04	0.05	0.07	0.06	0.05	0.03	0.02	0.01
1984	0.03	0.04	0.05	0.09	0.04	0.06	0.05	0.06	0.03	0.01	0.02
1985	0.02	0.02	0.06	0.05	0.07	0.06	0.05	0.06	0.05	0.01	0.01
1986	0.03	0.03	0.04	0.09	0.07	0.06	0.04	0.03	0.04	0.03	0.06
1987	0.01	0.03	0.02	0.04	0.05	0.05	0.06	0.05	0.03	0.03	0.09
1988	0.02	0.03	0.07	0.02	0.04	0.05	0.04	0.06	0.05	0.02	0.12
1989	0.00	0.04	0.05	0.05	0.03	0.03	0.05	0.02	0.05	0.05	0.15
1990	0.02	0.01	0.13	0.03	0.06	0.03	0.02	0.01	0.01	0.08	0.09
1991	0.01	0.07	0.01	0.11	0.04	0.04	0.01	0.03	0.04	0.02	0.09
1992	0.01	0.02	0.09	0.02	0.14	0.04	0.04	0.01	0.03	0.02	0.12
1993	0.02	0.01	0.02	0.09	0.01	0.12	0.03	0.03	0.02	0.03	0.18
1994	0.02	0.03	0.03	0.03	0.16	0.00	0.10	0.01	0.04	0.02	0.13
1995	0.04	0.06	0.02	0.01	0.02	0.10	0.00	0.16	0.01	0.03	0.12
1996	0.01	0.04	0.06	0.02	0.03	0.03	0.07	0.01	0.11	0.01	0.11
1997	0.02	0.02	0.06	0.03	0.02	0.03	0.03	0.10	0.01	0.06	0.10
1998	0.02	0.03	0.08	0.04	0.02	0.04	0.04	0.12	0.01	0.07	0.13
1999	0.01	0.02	0.03	0.02	0.08	0.05	0.03	0.04	0.04	0.07	0.23
2000	0.00	0.01	0.05	0.03	0.03	0.07	0.08	0.05	0.02	0.04	0.22
2001	0.01	0.02	0.05	0.08	0.05	0.04	0.07	0.05	0.04	0.02	0.16
2002	0.01	0.02	0.03	0.04	0.06	0.04	0.03	0.04	0.05	0.02	0.21
2003	0.00	0.05	0.04	0.03	0.04	0.08	0.03	0.02	0.02	0.03	0.19
2004	0.01	0.01	0.10	0.05	0.03	0.02	0.05	0.02	0.01	0.05	0.19
2005	0.02	0.03	0.03	0.08	0.03	0.03	0.04	0.06	0.03	0.01	0.19
2006	0.07	0.05	0.03	0.04	0.14	0.02	0.00	0.01	0.03	0.01	0.10
2007	0.01	0.04	0.03	0.02	0.04	0.08	0.03	0.03	0.03	0.03	0.17
2008	0.02	0.04	0.04	0.05	0.03	0.03	0.07	0.04	0.02	0.03	0.17
2009	0.02	0.03	0.06	0.06	0.03	0.05	0.04	0.05	0.03	0.03	0.17
2010	0.04	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.06	0.03	0.17
2011	0.02	0.05	0.04	0.05	0.04	0.06	0.03	0.03	0.03	0.04	0.16
2012	0.02	0.03	0.05	0.04	0.05	0.02	0.05	0.02	0.01	0.02	0.16
2013	0.01	0.02	0.04	0.07	0.06	0.07	0.05	0.04	0.02	0.03	0.14
2014	0.01	0.02	0.04	0.05	0.05	0.06	0.04	0.03	0.04	0.03	0.18
2015	0.01	0.02	0.02	0.04	0.03	0.08	0.04	0.04	0.03	0.04	0.18
2016	0.02	0.04	0.04	0.03	0.04	0.03	0.06	0.03	0.02	0.01	0.21
2017	0.02	0.18	0.13	0.10	0.13	0.06	0.03	0.08	0.05	0.04	0.09

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

Year	Total	Lower CI	Upper CI
1982	3,377,800	2,571,000	4,184,600
1983	3,535,300	2,958,100	4,112,400
1984	3,141,200	2,636,800	3,645,600
1985	2,443,700	1,563,400	3,324,000
1986	1,909,900	1,480,700	2,339,000
1987	2,613,100	2,051,800	3,174,400
1988	2,402,400	1,808,400	2,996,300
1989	2,316,300	1,836,700	2,795,800
1990	2,183,800	1,886,200	2,479,400
1991	2,393,300	2,116,000	2,670,700
1992	2,172,900	1,898,900	2,690,600
1993	2,465,400	2,151,500	2,779,300
1994	2,610,500	2,266,800	2,954,100
1995	2,009,700	1,724,800	2,294,600
1996	2,298,600	1,749,900	2,847,300
1997	2,163,400	1,907,900	2,418,900
1998	2,329,600	2,033,130	2,626,070
1999	1,306,470	1,118,800	1,494,150
2000	1,581,900	1,382,000	1,781,800
2001	1,863,700	1,605,000	2,122,300
2002	2,016,700	1,740,700	2,292,700
2003	2,239,600	1,822,700	2,656,600
2004	2,530,600	2,147,900	2,913,300
2005	2,823,500	2,035,800	3,499,800
2006	2,133,070	1,818,253	2,447,932
2007	2,152,738	1,775,191	2,530,285
2008	2,099,521	1,599,100	2,600,000
2009	1,739,238	1,435,188	2,043,288
2010	2,367,830	1,807,430	2,928,230
2011	2,403,021	1,926,371	2,879,671
2012	1,951,400	1,675,982	2,226,819
2013	2,279,004	1,934,134	2,623,874
2014	2,512,250	2,058,018	2,966,482
2015	1,932,347	1,644,043	2,220,651
2016	2,859,811	2,532,202	3,187,421
2017	2,787,688	2,310,198	3,265,178
2018	1,892,925	1,664,586	2,121,264

Northern Bering Sea surveys

	Biomass (t)	lower CI	upper CI	Haul count	hauls with catch	number count	length count
2010	310,617	215,238	405,997	108	88	88	88
2017	368,156	254,797	481,515	110	98	98	97
2018	373,373	240,861	505,885	49	49	49	49

Table 4.6. Yellowfin sole population numbers-at-age (millions) estimated from the annual EBS bottom trawl surveys, 1982-2017.

Females

year/age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17+
1979	21	113	150	442	616	386	555	801	626	528	219	274	59	35	29	15
1980	1	92	342	518	800	1055	413	661	880	651	765	285	113	33	23	23
1981	0	20	195	839	692	1321	1155	261	477	744	527	311	168	55	23	45
1982	38	183	349	1211	1485	1424	1619	843	829	832	704	409	246	159	51	84
1983	0	5	59	154	751	1413	843	1065	936	753	1155	866	295	160	60	54
1984	0	53	278	264	427	745	841	1111	1080	941	541	583	480	239	174	133
1985	0	3	105	442	587	406	632	915	441	518	545	384	298	321	205	127
1986	0	8	24	219	349	666	279	574	519	377	284	318	196	250	136	259
1987	0	0	70	120	803	458	843	259	376	599	356	449	243	270	247	688
1988	0	0	7	370	71	1495	560	557	184	239	351	208	360	273	219	886
1989	0	0	14	98	718	234	1337	593	446	74	179	308	234	238	183	565
1990	0	0	70	102	325	1066	192	1257	408	482	101	72	107	78	231	605
1991	0	10	127	248	123	405	896	151	1263	213	525	63	128	87	123	807
1992	0	19	247	485	520	213	286	938	94	825	75	309	129	137	170	715
1993	0	24	100	357	634	434	269	224	1314	78	866	157	165	69	68	674
1994	0	54	95	223	518	905	555	482	284	1170	516	44	274	142	42	588
1995	0	19	153	288	181	889	627	274	135	25	634	21	561	104	80	512
1996	0	16	154	809	288	279	434	517	206	146	151	602	116	637	47	619
1997	0	18	324	502	725	256	239	506	228	114	176	184	500	44	314	533
1998	0	10	83	479	420	900	260	203	370	413	369	170	176	265	67	1167
1999	0	3	65	198	175	185	727	104	107	245	190	186	72	102	175	425
2000	0	11	54	248	208	304	444	537	189	198	237	219	65	117	145	572
2001	0	1	71	239	522	248	403	415	654	374	83	191	154	127	189	617
2002	0	16	123	170	255	778	346	290	229	457	221	91	307	116	152	805
2003	0	15	115	241	251	287	1143	225	279	286	251	103	115	170	168	943
2004	10	33	192	430	560	441	217	966	221	212	218	219	106	20	167	1020
2005	0	53	167	194	602	433	213	487	834	196	144	191	324	170	53	1332
2006	0	67	302	376	276	634	470	176	325	738	133	133	71	156	175	514
2007	0	37	515	348	376	277	504	308	124	227	504	119	137	127	105	724
2008	0	24	115	736	621	546	359	355	198	117	259	350	153	79	85	732
2009	5	38	204	204	1187	609	488	259	210	218	129	138	196	88	43	444
2010	0	33	328	386	438	895	554	517	329	335	155	166	135	173	99	684
2011	0	14	243	539	707	463	769	410	457	204	226	149	142	145	186	619
2012	10	50	229	394	503	293	243	752	256	334	106	156	37	150	128	547
2013	0	4	88	269	420	531	256	221	409	406	358	119	135	133	133	770
2014	0	0	37	421	384	248	420	231	228	523	341	160	144	228	34	819
2015	0	23	3	167	467	350	308	287	249	149	282	258	135	99	80	592
2016	1	32	71	45	164	743	565	403	364	300	144	245	230	140	163	1027
2017	17	79	381	379	122	318	1001	482	336	377	228	149	203	200	148	911

Table 4.6.(continued)

	males															
year/age	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17+
1979	21	115	143	390	381	303	583	847	604	406	349	247	54	76	29	36
1980	20	78	306	632	853	1221	457	558	616	568	444	370	147	18	8	8
1981	0	50	200	1047	640	1280	858	394	372	546	534	266	66	83	55	12
1982	89	193	428	1780	1781	1059	1673	644	774	463	471	482	302	8	24	8
1983	0	1	65	183	724	1729	808	1049	676	699	722	566	425	550	77	51
1984	0	68	246	323	497	734	830	612	788	718	358	379	201	316	122	106
1985	0	41	172	419	559	263	652	527	401	451	360	224	260	157	112	65
1986	0	13	47	108	373	652	262	327	284	335	211	205	115	210	82	252
1987	0	5	41	106	838	467	673	445	328	277	210	147	106	142	185	600
1988	0	2	10	435	49	1163	553	443	85	187	28	177	336	189	28	599
1989	0	2	23	181	788	177	1306	513	357	135	50	103	54	204	35	478
1990	0	11	47	121	316	888	195	1144	318	263	40	65	67	24	55	389
1991	0	0	103	354	139	275	1046	68	1137	328	244	74	64	60	53	420
1992	0	0	146	445	566	262	226	812	114	907	193	213	12	12	61	607
1993	0	20	52	233	646	393	279	247	1096	69	842	53	53	50	0	341
1994	4	22	71	166	427	953	656	308	191	822	26	622	46	132	11	303
1995	0	0	169	120	270	667	565	94	179	75	478	13	603	49	24	418
1996	0	76	95	837	244	227	425	344	331	141	139	399	61	449	125	495
1997	0	10	214	425	798	181	184	446	245	194	214	108	514	79	264	416
1998	0	48	70	351	569	832	159	226	204	272	346	140	157	191	113	814
1999	0	5	100	142	225	243	575	146	94	309	269	75	53	28	119	425
2000	0	0	36	219	259	143	509	583	78	215	133	77	92	78	66	547
2001	0	0	87	141	652	341	375	357	562	208	87	158	65	73	140	432
2002	0	58	72	158	309	758	318	333	262	442	194	120	220	161	133	507
2003	0	24	95	178	258	251	1074	238	363	53	284	173	10	71	57	682
2004	4	63	114	469	447	199	395	993	263	81	195	223	103	47	249	456
2005	0	49	166	187	474	476	204	288	972	123	142	121	133	69	93	726
2006	0	101	173	348	332	505	393	288	298	384	116	155	89	39	11	590
2007	0	58	481	352	405	284	545	209	166	252	338	101	133	72	59	620
2008	0	10	99	662	462	483	344	453	225	144	185	329	63	66	35	581
2009	0	65	144	289	946	462	555	248	249	217	78	31	195	30	29	363
2010	0	78	199	418	371	1032	462	510	171	189	159	53	117	151	78	678
2011	1	7	150	385	482	358	792	398	224	176	77	81	136	103	157	440
2012	0	69	274	352	344	273	238	425	297	179	98	67	91	34	100	2
2013	0	7	92	366	384	481	211	268	445	200	200	33	89	100	118	612
2014	0	0	0	9	366	396	286	338	310	251	400	206	193	20	192	841
2015	1	29	36	131	426	332	301	312	318	48	180	131	80	1	80	492
2016	0	43	85	20	142	704	544	402	367	125	117	227	180	88	35	859
2017	0	10	120	231	396	107	260	880	498	310	275	195	107	216	155	599

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

Year	Total Hauls	Hauls w/Len	Number lengths	Hauls w/otoliths	Hauls w/ages	Number otoliths	Number ages
1982	334	246	37023	35	35	744	744
1983	353	256	33924	37	37	709	709
1984	355	271	33894	56	56	821	796
1985	357	261	33824	44	43	810	802
1986	354	249	30470	34	34	739	739
1987	357	224	31241	16	16	798	798
1988	373	254	27138	14	14	543	543
1989	374	236	29672	24	24	740	740
1990	371	251	30257	28	28	792	792
1991	372	248	27986	26	26	742	742
1992	356	229	23628	16	16	606	606
1993	375	242	26651	20	20	549	549
1994	375	269	24448	14	14	526	522
1995	376	254	22116	20	20	654	647
1996	375	247	27505	16	16	729	721
1997	376	262	26034	11	11	470	466
1998	375	310	34509	15	15	575	570
1999	373	276	28431	31	31	777	770
2000	372	255	24880	20	20	517	511
2001	375	251	26558	25	25	604	593
2002	375	246	26309	32	32	738	723
2003	376	241	27135	37	37	699	695
2004	375	251	26103	26	26	725	712
2005	373	251	24658	34	34	644	635
2006	376	246	28470	39	39	428	426
2007	376	247	24790	66	66	779	772
2008	375	238	25848	65	65	858	830
2009	376	235	22018	70	70	784	752
2010	376	228	20619	77	77	841	827
2011	376	228	21665	65	64	784	753
2012	376	242	23519	72	72	993	973
2013	376	232	23261	70	70	821	803
2014	376	219	20229	52	52	799	790
2015	376	223	20830	73	73	878	875
2016	376	242	26674	69	69	884	876
2017	376	258	25767	78		896	
2018	376	255	1830				

Table 4.8—Total tonnage of yellowfin sole caught in resource assessment surveys in the eastern Bering Sea from 1977-2018.

Year	Research catch (t)
1977	60
1978	71
1979	147
1980	92
1981	74
1982	158
1983	254
1984	218
1985	105
1986	68
1987	92
1988	138
1989	148
1990	129
1991	118
1992	60
1993	95
1994	91
1995	95
1996	72
1997	76
1998	79
1999	61
2000	72
2001	75
2002	76
2003	78
2004	114
2005	94
2006	74
2007	74
2008	69
2009	60
2010	79
2011	77
2012	64
2013	75
2014	81
2015	64
2016	98
2017	98
2018	67

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

	average mean length at age (cm)																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
males	7	11	12	14	17	20	22	24	26	27	28	29	30	30	31	31	31	32	32	32
females		10	13	15	17	20	22	25	27	29	30	31	32	33	33	33	34	34	33	34
	weight at age (g)			males																
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1964	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1965	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1966	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1967	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1968	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1969	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1970	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1971	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1972	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1973	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1974	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1975	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1976	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1977	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1978	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1979	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1980	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1981	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1982	4	11	25	50	83	112	133	142	158	182	196	212	218	249	403	386	386	455	532	408
1983	4	5	5	23	57	95	156	156	155	176	212	227	227	254	262	287	271	370	370	408
1984	4	10	20	31	57	121	150	181	202	193	202	213	246	252	257	262	282	415	290	370
1985	4	11	23	32	51	84	148	186	214	227	228	246	277	267	283	305	407	389	532	387
1986	4	9	18	27	34	61	98	176	217	233	239	229	271	263	258	324	265	318	300	370
1987	4	8	14	17	27	53	97	157	211	226	260	267	311	309	276	291	307	296	329	394
1988	4	7	10	18	45	75	76	138	207	242	261	304	301	297	339	304	308	315	326	386
1989	4	7	10	27	47	72	142	130	179	244	270	351	338	352	317	302	391	309	361	348
1990	4	9	16	22	44	64	98	120	175	197	273	323	341	326	337	286	348	353	343	388
1991	4	9	17	29	51	75	100	132	180	212	266	267	325	355	326	359	352	304	532	381
1992	4	9	17	28	53	86	97	125	174	208	239	264	306	508	407	395	344	360	406	360
1993	4	9	18	45	56	93	135	145	206	209	238	265	387	303	349	363	376	349	342	384
1994	4	23	32	53	76	92	116	182	198	207	259	336	311	345	345	407	356	479	349	424
1995	4	10	19	32	59	88	110	154	177	207	249	258	336	294	319	377	367	383	401	448
1996	4	10	19	32	54	107	134	163	184	215	221	264	281	295	314	326	333	418	326	435
1997	4	8	14	37	64	75	149	174	185	239	231	248	261	303	349	336	384	370	346	444
1998	4	10	20	27	49	79	113	156	208	207	259	262	289	301	291	332	330	354	350	392
1999	4	6	7	18	37	63	95	123	170	171	245	281	269	269	347	330	395	350	350	450
2000	4	10	20	36	32	64	88	133	161	284	233	271	302	255	291	331	351	349	373	385
2001	4	9	16	27	38	51	91	152	161	198	268	240	280	299	292	320	343	357	430	434
2002	4	9	18	21	57	59	81	134	188	204	241	248	269	306	303	343	336	304	368	414
2003	4	11	22	39	53	83	109	161	179	251	248	304	263	468	330	339	305	339	352	405
2004	4	7	20	40	64	94	157	157	213	266	334	310	297	356	360	338	387	414	443	446
2005	4	11	24	44	77	110	136	170	201	262	278	332	366	308	328	350	375	347	349	434
2006	4	10	19	36	71	124	139	180	207	237	233	315	330	380	385	446	369	335	382	390
2007	4	10	19	36	63	107	140	181	208	248	291	286	311	340	375	342	353	369	422	430
2008	4	8	13	29	50	91	113	181	194	252	262	289	306	364	366	369	372	374	417	481
2009	4	7	11	20	39	74	112	133	194	273	270	302	348	321	379	320	405	370	391	460
2010	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
2011	4	14	17	25	47	81	134	164	174	305	283	330	291	346	332	344	389	364	375	400
2012	4	14	12	27	48	83	126	181	214	249	274	296	295	341	342	382	380	388	396	400
2013	4	14	13	21	40	72	122	179	227	259	278	320	273	379	357	379	407	390	366	400
2014	4	8	11	44	34	75	150	195	246	296	313	314	330	273	385	387	400	478	436	400
2015	4	8	11	44	34	75	150	195	246	296	313	314	330	273	385	387	400	478	436	400
2016	4	8	43	57	63	82	116	171	253	319	318	331	338	346	381	383	408	434	413	460
2017	4	9	26	58	76	94	103	149	207	291	314	356	370	352	397	363	501	389	398	500
2018	4	9	26	58	76	94	103	149	207	291	314	356	370	352	397	363	501	389	398	500

Table 4.9—(continued)

	females																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1954	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1955	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1956	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1957	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1958	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1959	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1960	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1961	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1962	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1963	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1964	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1965	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1966	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1967	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1968	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1969	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1970	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1971	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1972	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1973	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1974	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1975	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1976	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1977	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1978	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1979	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1980	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1981	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1982	8	20	42	75	98	139	176	214	233	235	289	300	339	336	406	490	417	386	568	590
1983	10	14	26	60	103	162	185	201	243	255	280	329	395	477	539	583	578	630	685	590
1984	14	26	33	57	110	156	177	222	246	294	338	332	325	422	436	458	497	665	654	590
1985	11	16	28	46	77	177	202	251	286	302	323	371	370	421	425	499	624	600	620	590
1986	14	27	23	41	71	103	173	239	284	338	342	350	402	351	391	422	440	455	611	590
1987	10	14	20	47	55	127	179	256	317	324	373	373	385	384	422	412	458	436	523	590
1988	9	12	16	34	66	85	159	237	286	307	378	396	404	388	415	437	429	485	578	590
1989	12	21	33	67	71	112	133	197	279	339	402	430	449	456	456	456	578	476	516	590
1990	11	17	24	38	65	99	126	197	243	321	449	450	416	446	464	455	471	523	569	590
1991	11	16	23	58	56	100	142	156	238	310	370	457	446	473	474	490	492	484	598	590
1992	12	21	29	55	85	121	177	176	283	305	284	352	435	516	459	484	519	459	547	590
1993	15	28	35	64	93	155	165	232	244	301	333	368	442	452	497	499	471	538	586	590
1994	20	46	53	86	87	125	155	235	276	284	337	396	351	461	464	480	476	514	553	590
1995	12	20	28	60	84	123	160	217	284	332	340	443	384	414	454	439	619	482	589	590
1996	11	16	36	51	108	137	167	202	222	311	318	334	405	399	432	534	462	523	558	590
1997	16	34	33	72	85	157	200	236	260	292	353	373	401	469	440	490	431	515	600	590
1998	10	14	36	51	90	104	177	237	278	279	318	370	416	405	403	448	407	532	581	590
1999	9	12	18	37	67	103	131	239	284	296	328	348	384	396	416	461	502	477	639	590
2000	11	16	33	33	91	81	158	175	237	306	310	373	401	440	422	494	506	483	636	590
2001	6	6	32	41	57	83	148	179	255	305	357	372	447	415	420	422	476	522	598	590
2002	11	18	27	48	65	87	120	224	243	261	337	346	374	408	434	452	505	489	585	590
2003	9	12	31	53	86	124	156	213	289	303	344	407	425	399	434	365	438	457	536	590
2004	9	18	43	63	101	168	172	245	299	346	380	407	483	543	450	461	464	500	604	590
2005	14	26	44	78	114	152	213	238	277	337	347	397	439	461	531	522	438	539	629	590
2006	9	13	40	82	125	153	204	245	319	314	375	370	533	460	476	865	480	537	691	590
2007	11	16	36	66	115	173	198	244	316	311	362	358	417	461	462	497	491	611	640	590
2008	13	24	28	54	98	129	199	226	286	320	355	384	442	434	471	530	530	552	630	590
2009	6	9	18	45	69	127	163	239	306	322	375	416	381	413	473	736	539	491	679	590
2010	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
2011	8	18	25	56	80	126	188	205	327	332	372	403	415	440	426	369	491	542	590	590
2012	8	12	26	49	81	144	169	256	313	341	349	445	459	471	476	444	527	525	590	590
2013	8	12	21	35	92	125	182	261	305	364	410	426	464	456	451	507	494	532	590	590
2014	6	8	11	18	34	74	145	203	260	305	376	367	405	410	488	519	483	581	548	590
2015	6	8	11	18	34	74	145	203	260	305	376	367	405	410	488	519	483	581	548	590
2016	6	8	32	50	66	74	112	186	338	372	412	408	455	456	485	508	515	532	555	590
2017	6	9	18	56	65	155	129	156	250	351	372	432	484	491	516	507	543	560	548	590
2017	6	9	18	56	65	155	129	156	250	351	372	432	484	491	516	507	543	560	548	590

Table 4.10. Female yellowfin sole proportion mature at age from Nichol (1995) and TenBrink and Wilderbuer (2015).

Age	1992, 1993 samples	2012 samples	Combined
1	0.00	0	0
2	0.00	0	0
3	.001	0	0
4	.004	0	0
5	.008	0	0
6	.020	.01	0.01
7	.046	.03	0.04
8	.104	.09	0.10
9	.217	.21	0.21
10	.397	.43	0.41
11	.612	.68	0.65
12	.790	.86	0.83
13	.899	.94	0.92
14	.955	.98	0.97
15	.981	.99	0.99
16	.992	1.0	1.0
17	.997	1.0	1.0
18	1.0	1.0	1.0
19	1.0	1.0	1.0
20	1.0	1.0	1.0

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
$C_{t,a} = \dfrac{F_{t,a}}{Z_{t,a}}\left(1-e^{-z_{t,a}}\right)N_{t,a}$	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
$s_a = \dfrac{1}{1+\left(e^{-\alpha+\beta a}\right)}$	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
$qprior = \lambda \dfrac{0.5(\ln q_{est,t} - \ln q_{prior})^2}{\sigma_q^2}$	survey catchability prior (when estimated)
$mprior = \lambda \dfrac{0.5(\ln m_{est} - \ln m_{prior})^2}{\sigma_m^2}$	natural mortality prior (when estimated)
$reclike = \lambda(\sum_{i=1965}^{endyear} \bar{R} - R_i)^2 + \sum_{a=1}^{20}(\bar{R}_{init} - R_{init,a})^2 + \dfrac{1}{2((\sum_{i=1965}^{endyear} \bar{R} - R_i)\frac{1}{n+1})})$	recruitment likelihood
$catchlike = \lambda \sum_{i=startyear}^{endyear}(\ln C_{obs,i} - \ln C_{est,i})^2$	catch likelihood
$surveylike = \lambda \dfrac{(\ln B - \ln \hat{B})^2}{2\sigma^2}$	survey likelihood
$SurvAgelike = \sum_{i,t} m_t P_{t,a} \ln \dfrac{\hat{P}_{t,a}}{P_{t,a}}$	survey age composition likelihood
$FishAgelike = \sum_{i,t} m_t P_{t,a} \ln \dfrac{\hat{P}_{t,a}}{P_{t,a}}$	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, 1976-2014
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
v_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 stock productivity in the 2018 stock assessment of yellowfin sole.

	Model 14_2	Model 14_1
Years included	1955-2012	1978-2012
Fmsy	0.21	0.12
Bmsy (t)	314,800	451,600
ABC (t)	494,700	255,100
OFL (t)	500,000	281,800
Buffer between ABC and OFL	1%	9%

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	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277
1965	0.002	0.006	0.022	0.067	0.143	0.201	0.223	0.230	0.232	0.232	0.232	0.232	0.232	0.232
1966	0.003	0.012	0.044	0.132	0.273	0.376	0.417	0.430	0.433	0.434	0.434	0.434	0.434	0.434
1967	0.003	0.012	0.056	0.199	0.416	0.535	0.568	0.575	0.577	0.577	0.577	0.577	0.577	0.577
1968	0.001	0.003	0.011	0.035	0.102	0.223	0.343	0.407	0.431	0.439	0.441	0.441	0.441	0.441
1969	0.016	0.073	0.260	0.520	0.646	0.678	0.685	0.686	0.686	0.686	0.686	0.686	0.686	0.686
1970	0.000	0.003	0.016	0.087	0.332	0.618	0.720	0.740	0.743	0.744	0.744	0.744	0.744	0.744
1971	0.480	0.620	0.628	0.628	0.628	0.628	0.628	0.628	0.628	0.628	0.628	0.628	0.628	0.628
1972	0.000	0.000	0.003	0.083	0.306	0.332	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333
1973	0.015	0.056	0.164	0.315	0.407	0.440	0.448	0.451	0.451	0.451	0.451	0.451	0.451	0.451
1974	0.004	0.012	0.035	0.078	0.119	0.140	0.147	0.149	0.150	0.150	0.150	0.150	0.150	0.150
1975	0.018	0.056	0.101	0.122	0.128	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130
1976	0.011	0.028	0.058	0.090	0.111	0.120	0.123	0.125	0.125	0.125	0.125	0.125	0.125	0.125
1977	0.026	0.037	0.046	0.051	0.054	0.056	0.057	0.057	0.057	0.057	0.058	0.058	0.058	0.058
1978	0.032	0.063	0.091	0.106	0.111	0.113	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114
1979	0.019	0.037	0.053	0.061	0.064	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
1980	0.014	0.025	0.038	0.051	0.061	0.068	0.071	0.073	0.074	0.075	0.075	0.075	0.075	0.075
1981	0.014	0.024	0.036	0.046	0.053	0.056	0.058	0.058	0.059	0.059	0.059	0.059	0.059	0.059
1982	0.015	0.026	0.035	0.040	0.043	0.043	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
1983	0.022	0.035	0.041	0.044	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1984	0.016	0.034	0.052	0.063	0.068	0.069	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
1985	0.019	0.041	0.067	0.087	0.097	0.102	0.103	0.104	0.104	0.104	0.104	0.104	0.104	0.104
1986	0.025	0.058	0.084	0.093	0.095	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096
1987	0.009	0.021	0.042	0.066	0.082	0.089	0.092	0.093	0.094	0.094	0.094	0.094	0.094	0.094
1988	0.011	0.032	0.068	0.099	0.113	0.118	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
1989	0.004	0.013	0.035	0.064	0.081	0.087	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089
1990	0.004	0.011	0.024	0.033	0.037	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1991	0.006	0.013	0.025	0.035	0.040	0.042	0.043	0.043	0.043	0.044	0.044	0.044	0.044	0.044
1992	0.011	0.025	0.043	0.058	0.066	0.069	0.070	0.071	0.071	0.071	0.071	0.071	0.071	0.071
1993	0.007	0.013	0.022	0.032	0.040	0.046	0.050	0.052	0.053	0.053	0.053	0.053	0.053	0.053
1994	0.013	0.030	0.048	0.058	0.062	0.063	0.063	0.063	0.064	0.064	0.064	0.064	0.064	0.064
1995	0.015	0.033	0.046	0.052	0.054	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
1996	0.016	0.028	0.041	0.050	0.055	0.058	0.059	0.059	0.059	0.060	0.060	0.060	0.060	0.060
1997	0.021	0.036	0.055	0.070	0.079	0.084	0.087	0.088	0.088	0.089	0.089	0.089	0.089	0.089
1998	0.016	0.028	0.039	0.046	0.049	0.050	0.050	0.051	0.051	0.051	0.051	0.051	0.051	0.051
1999	0.002	0.006	0.015	0.026	0.034	0.037	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
2000	0.003	0.008	0.019	0.032	0.041	0.046	0.047	0.048	0.048	0.048	0.048	0.048	0.048	0.048
2001	0.005	0.013	0.022	0.030	0.033	0.035	0.035	0.036	0.036	0.036	0.036	0.036	0.036	0.036
2002	0.003	0.008	0.018	0.030	0.036	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
2003	0.005	0.012	0.022	0.031	0.035	0.037	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
2004	0.005	0.013	0.022	0.029	0.033	0.034	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
2005	0.010	0.019	0.029	0.038	0.042	0.045	0.046	0.046	0.047	0.047	0.047	0.047	0.047	0.047
2006	0.032	0.041	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
2007	0.013	0.027	0.042	0.052	0.057	0.059	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
2008	0.017	0.035	0.053	0.063	0.067	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
2009	0.010	0.026	0.042	0.049	0.051	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
2010	0.011	0.024	0.039	0.049	0.053	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
2011	0.013	0.030	0.050	0.063	0.069	0.071	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
2012	0.014	0.031	0.049	0.061	0.067	0.069	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
2013	0.006	0.021	0.050	0.074	0.084	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087
2014	0.006	0.020	0.047	0.071	0.082	0.086	0.086	0.087	0.087	0.087	0.087	0.087	0.087	0.087
2015	0.004	0.011	0.025	0.045	0.064	0.075	0.080	0.081	0.082	0.082	0.082	0.082	0.082	0.082
2016	0.008	0.018	0.035	0.055	0.070	0.078	0.081	0.082	0.083	0.083	0.083	0.083	0.083	0.083
2017	0.016	0.035	0.056	0.069	0.074	0.076	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077
2018	0.010	0.027	0.052	0.070	0.078	0.080	0.081	0.081	0.082	0.082	0.082	0.082	0.082	0.082

Table 4.14 continued.

	Males													
year/age	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1964	0.020	0.092	0.210	0.264	0.275	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277	0.277
1965	0.018	0.082	0.182	0.223	0.231	0.232	0.232	0.232	0.232	0.232	0.232	0.232	0.232	0.232
1966	0.029	0.105	0.254	0.374	0.419	0.430	0.433	0.434	0.434	0.434	0.434	0.434	0.434	0.434
1967	0.133	0.344	0.507	0.562	0.574	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577	0.577
1968	0.052	0.176	0.339	0.416	0.436	0.441	0.441	0.442	0.442	0.442	0.442	0.442	0.442	0.442
1969	0.041	0.175	0.444	0.623	0.673	0.684	0.686	0.686	0.686	0.686	0.686	0.686	0.686	0.686
1970	0.370	0.688	0.739	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744
1971	0.256	0.552	0.620	0.627	0.628	0.628	0.628	0.628	0.628	0.628	0.628	0.628	0.628	0.628
1972	0.116	0.274	0.325	0.332	0.332	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333
1973	0.118	0.366	0.443	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451
1974	0.084	0.128	0.144	0.149	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
1975	0.047	0.102	0.125	0.129	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130	0.130
1976	0.010	0.028	0.061	0.095	0.114	0.122	0.124	0.125	0.125	0.125	0.125	0.125	0.125	0.125
1977	0.009	0.026	0.045	0.054	0.057	0.057	0.057	0.058	0.058	0.058	0.058	0.058	0.058	0.058
1978	0.025	0.050	0.079	0.098	0.108	0.112	0.113	0.114	0.114	0.114	0.114	0.114	0.114	0.114
1979	0.018	0.035	0.051	0.060	0.064	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
1980	0.007	0.011	0.018	0.027	0.038	0.048	0.057	0.064	0.068	0.071	0.073	0.073	0.073	0.073
1981	0.012	0.019	0.028	0.038	0.046	0.051	0.055	0.057	0.058	0.058	0.058	0.058	0.058	0.058
1982	0.021	0.031	0.038	0.042	0.043	0.043	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
1983	0.023	0.035	0.041	0.044	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1984	0.022	0.044	0.061	0.067	0.069	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
1985	0.034	0.071	0.094	0.101	0.103	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104
1986	0.032	0.069	0.089	0.094	0.095	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096
1987	0.015	0.048	0.081	0.091	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
1988	0.015	0.053	0.097	0.115	0.118	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
1989	0.004	0.015	0.042	0.071	0.084	0.088	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089
1990	0.008	0.021	0.033	0.037	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1991	0.008	0.023	0.037	0.042	0.043	0.043	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
1992	0.016	0.037	0.056	0.066	0.070	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
1993	0.008	0.015	0.023	0.033	0.041	0.046	0.050	0.052	0.053	0.053	0.053	0.053	0.053	0.053
1994	0.017	0.037	0.053	0.060	0.063	0.063	0.063	0.064	0.064	0.064	0.064	0.064	0.064	0.064
1995	0.018	0.035	0.048	0.053	0.054	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
1996	0.024	0.038	0.049	0.055	0.058	0.059	0.059	0.059	0.060	0.060	0.060	0.060	0.060	0.060
1997	0.024	0.044	0.064	0.078	0.084	0.087	0.088	0.089	0.089	0.089	0.089	0.089	0.089	0.089
1998	0.007	0.019	0.036	0.046	0.049	0.050	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
1999	0.002	0.004	0.009	0.018	0.027	0.034	0.037	0.038	0.039	0.039	0.039	0.039	0.039	0.039
2000	0.002	0.007	0.016	0.028	0.039	0.044	0.047	0.047	0.048	0.048	0.048	0.048	0.048	0.048
2001	0.001	0.003	0.007	0.014	0.022	0.029	0.033	0.034	0.035	0.035	0.035	0.035	0.035	0.035
2002	0.002	0.008	0.020	0.032	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
2003	0.005	0.016	0.029	0.035	0.037	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
2004	0.005	0.011	0.020	0.028	0.032	0.034	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
2005	0.011	0.022	0.034	0.041	0.045	0.046	0.046	0.047	0.047	0.047	0.047	0.047	0.047	0.047
2006	0.027	0.041	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
2007	0.019	0.038	0.052	0.058	0.059	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
2008	0.018	0.037	0.055	0.064	0.067	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
2009	0.008	0.019	0.033	0.044	0.049	0.051	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
2010	0.017	0.035	0.049	0.054	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
2011	0.018	0.037	0.056	0.066	0.070	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
2012	0.020	0.043	0.060	0.067	0.069	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
2013	0.008	0.024	0.052	0.074	0.083	0.086	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087
2014	0.010	0.026	0.052	0.073	0.082	0.085	0.086	0.087	0.087	0.087	0.087	0.087	0.087	0.087
2015	0.005	0.012	0.024	0.041	0.059	0.071	0.077	0.080	0.082	0.082	0.082	0.082	0.082	0.082
2016	0.007	0.017	0.033	0.052	0.068	0.077	0.081	0.082	0.083	0.083	0.083	0.083	0.083	0.083
2017	0.007	0.015	0.027	0.042	0.056	0.066	0.072	0.075	0.076	0.077	0.077	0.077	0.077	0.077
2018	0.011	0.031	0.057	0.073	0.079	0.081	0.081	0.082	0.082	0.082	0.082	0.082	0.082	0.082

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

Year	Full selection F	Exploitation Rate
1975	0.13	0.04
1976	0.13	0.03
1977	0.06	0.02
1978	0.11	0.05
1979	0.07	0.03
1980	0.07	0.03
1981	0.06	0.03
1982	0.04	0.03
1983	0.05	0.03
1984	0.07	0.05
1985	0.10	0.06
1986	0.10	0.06
1987	0.09	0.06
1988	0.12	0.07
1989	0.09	0.05
1990	0.04	0.03
1991	0.04	0.03
1992	0.07	0.05
1993	0.05	0.03
1994	0.06	0.04
1995	0.06	0.04
1996	0.06	0.04
1997	0.09	0.06
1998	0.05	0.04
1999	0.04	0.03
2000	0.05	0.03
2001	0.04	0.02
2002	0.04	0.03
2003	0.04	0.03
2004	0.04	0.02
2005	0.05	0.03
2006	0.04	0.03
2007	0.06	0.04
2008	0.07	0.05
2009	0.05	0.04
2010	0.06	0.04
2011	0.07	0.05
2012	0.07	0.05
2013	0.09	0.06
2014	0.09	0.06
2015	0.08	0.05
2016	0.08	0.05
2017	0.08	0.05
2018	0.05	

Table 4.16. Model estimates of yellowfin sole age-specific selectivities for the survey and fishery (ages 4 to 20 from left to right).

Age	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
					survey	females											
1982-2018	0.2	0.5	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
					survey males												
	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
					fishery females												
1964	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1965	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1966	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1967	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1968	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0
1969	0.0	0.0	0.0	0.0	0.1	0.4	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1971	0.0	0.0	0.1	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1973	0.0	0.0	0.0	0.0	0.1	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1974	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1975	0.0	0.0	0.0	0.1	0.4	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1976	0.0	0.0	0.0	0.1	0.2	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1977	0.1	0.2	0.3	0.5	0.6	0.8	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1978	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1979	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1980	0.0	0.0	0.1	0.2	0.3	0.5	0.7	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1981	0.0	0.1	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1982	0.0	0.1	0.2	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1983	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1984	0.0	0.0	0.1	0.2	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1985	0.0	0.0	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1986	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1987	0.0	0.0	0.0	0.1	0.2	0.4	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1988	0.0	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1989	0.0	0.0	0.0	0.0	0.1	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1990	0.0	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1991	0.0	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1992	0.0	0.0	0.1	0.2	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1993	0.0	0.0	0.1	0.1	0.3	0.4	0.6	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1994	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1995	0.0	0.0	0.1	0.3	0.6	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1996	0.0	0.1	0.1	0.3	0.5	0.7	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1997	0.0	0.1	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1998	0.0	0.1	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1999	0.0	0.0	0.0	0.1	0.2	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2000	0.0	0.0	0.0	0.1	0.2	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2001	0.0	0.0	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2002	0.0	0.0	0.0	0.1	0.2	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2003	0.0	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2004	0.0	0.0	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2005	0.0	0.0	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2006	0.0	0.1	0.3	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2007	0.0	0.0	0.1	0.2	0.4	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2008	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2009	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2010	0.0	0.0	0.1	0.2	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2011	0.0	0.0	0.1	0.2	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2012	0.0	0.0	0.1	0.2	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2013	0.0	0.0	0.0	0.1	0.2	0.6	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2014	0.0	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2015	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2016	0.0	0.0	0.0	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2017	0.0	0.0	0.1	0.2	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2018	0.0	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 4.16. Continued

				fishery males													
1964	0.0	0.0	0.0	0.1	0.3	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1965	0.0	0.0	0.0	0.1	0.4	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1966	0.0	0.0	0.0	0.1	0.2	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1967	0.0	0.0	0.1	0.2	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1968	0.0	0.0	0.0	0.1	0.4	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1969	0.0	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1970	0.0	0.0	0.1	0.5	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1971	0.0	0.0	0.1	0.4	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1972	0.0	0.0	0.1	0.3	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1973	0.0	0.0	0.0	0.3	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1974	0.0	0.1	0.2	0.6	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1975	0.0	0.0	0.1	0.4	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1976	0.0	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1977	0.0	0.0	0.0	0.2	0.4	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1978	0.0	0.0	0.1	0.2	0.4	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1979	0.0	0.0	0.1	0.3	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1980	0.0	0.0	0.1	0.1	0.1	0.2	0.4	0.5	0.6	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0
1981	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.8	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1982	0.0	0.1	0.3	0.5	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1983	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1984	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1985	0.0	0.0	0.1	0.3	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1986	0.0	0.0	0.1	0.3	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1987	0.0	0.0	0.0	0.2	0.5	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1988	0.0	0.0	0.0	0.1	0.4	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1989	0.0	0.0	0.0	0.0	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1990	0.0	0.0	0.1	0.2	0.5	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1991	0.0	0.0	0.0	0.2	0.5	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1992	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1993	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1994	0.0	0.0	0.1	0.3	0.6	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1995	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1996	0.0	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1997	0.0	0.1	0.1	0.3	0.5	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1998	0.0	0.0	0.0	0.1	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1999	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2000	0.0	0.0	0.0	0.1	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2001	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2002	0.0	0.0	0.0	0.1	0.2	0.5	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2003	0.0	0.0	0.0	0.1	0.4	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2004	0.0	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2005	0.0	0.0	0.1	0.2	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2006	0.0	0.0	0.2	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2007	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2008	0.0	0.0	0.1	0.3	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2009	0.0	0.0	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2010	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2011	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2012	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2013	0.0	0.0	0.0	0.1	0.3	0.6	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2014	0.0	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2015	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2016	0.0	0.0	0.0	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2017	0.0	0.0	0.0	0.1	0.2	0.4	0.5	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2018	0.0	0.0	0.0	0.1	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 4.17. Model estimates of yellowfin sole age 2+ total biomass (t) and begin-year female spawning biomass (t) from the 2017 and 2018 stock assessments.

	2018 Assessment						2017 Assessment	
Year	**Female spawning biomass**	**lower 95% C.I.**	**upper 95% C.I.**	**Total biomass**	**lower 95% C.I.**	**upper 95% C.I.**	**Female spawning biomass**	**Total biomass**
1964	22,250	0	59,282	841,880	806,912	876,848	142,369	926,625
1965	38,507	0	77,880	820,938	786,415	855,461	169,571	901,174
1966	67,959	26,274	109,643	871,549	835,070	908,028	207,104	936,828
1967	94,819	57,304	132,334	863,697	827,217	900,177	218,877	911,246
1968	114,791	71,356	158,226	794,386	758,216	830,556	213,928	823,838
1969	121,790	79,341	164,239	830,955	792,701	869,209	197,480	850,296
1970	99,015	70,977	127,053	806,942	766,650	847,234	135,238	813,647
1971	89,577	68,462	110,691	871,887	825,019	918,755	87,750	862,710
1972	74,935	53,393	96,477	942,508	885,669	999,347	71,363	936,838
1973	77,867	58,416	97,318	1,195,960	1,126,742	1,265,178	78,284	1,188,580
1974	87,741	70,192	105,289	1,445,090	1,361,783	1,528,397	84,991	1,433,880
1975	139,767	117,680	161,854	1,803,350	1,704,279	1,902,421	134,520	1,786,070
1976	200,423	175,202	225,644	2,112,780	1,997,601	2,227,959	194,457	2,091,310
1977	292,690	261,774	323,606	2,426,040	2,295,246	2,556,834	285,756	2,400,420
1978	408,575	371,057	446,093	2,724,040	2,580,019	2,868,061	400,220	2,694,380
1979	525,835	481,484	570,186	2,886,920	2,732,763	3,041,077	515,975	2,853,520
1980	656,348	604,733	707,963	3,072,050	2,908,060	3,236,040	644,788	3,034,890
1981	776,651	718,285	835,017	3,240,970	3,069,225	3,412,715	763,587	3,200,280
1982	844,000	782,823	905,177	3,356,750	3,182,315	3,531,185	830,159	3,312,110
1983	945,364	879,380	1,011,348	3,334,910	3,159,350	3,510,470	930,442	3,289,120
1984	1,025,040	955,833	1,094,247	3,563,600	3,377,392	3,749,808	1,009,100	3,509,840
1985	1,072,100	999,044	1,145,156	3,575,020	3,383,117	3,766,923	1,054,930	3,516,680
1986	1,058,570	983,815	1,133,325	3,288,330	3,100,625	3,476,035	1,040,470	3,228,140
1987	1,051,670	974,941	1,128,399	3,250,640	3,058,490	3,442,790	1,032,280	3,183,200
1988	993,831	917,868	1,069,794	3,155,220	2,962,121	3,348,319	973,826	3,082,600
1989	966,298	888,361	1,044,235	3,214,980	3,009,267	3,420,693	944,673	3,130,950
1990	977,078	898,165	1,055,991	3,080,450	2,878,440	3,282,460	953,446	2,993,920
1991	1,057,870	975,454	1,140,286	3,201,010	2,992,554	3,409,466	1,030,640	3,106,100
1992	1,140,200	1,053,763	1,226,637	3,411,440	3,192,444	3,630,436	1,108,300	3,303,480
1993	1,175,190	1,085,247	1,265,133	3,446,950	3,221,879	3,672,021	1,139,450	3,328,080
1994	1,178,190	1,087,730	1,268,650	3,490,570	3,262,673	3,718,467	1,139,730	3,362,290
1995	1,177,170	1,085,827	1,268,513	3,262,000	3,041,972	3,482,028	1,135,560	3,135,510
1996	1,110,800	1,023,039	1,198,561	3,178,180	2,961,784	3,394,576	1,068,660	3,047,450
1997	1,074,290	987,535	1,161,045	3,194,460	2,974,324	3,414,596	1,029,840	3,056,250
1998	1,010,000	926,068	1,093,932	2,917,550	2,708,522	3,126,578	964,342	2,782,490
1999	1,001,710	918,311	1,085,109	2,730,790	2,530,236	2,931,344	953,817	2,599,520
2000	988,414	905,857	1,070,971	2,778,860	2,577,448	2,980,272	939,002	2,645,900
2001	984,205	901,952	1,066,458	2,702,270	2,504,408	2,900,132	932,963	2,571,130
2002	982,406	900,256	1,064,556	2,742,240	2,543,114	2,941,366	929,799	2,612,290
2003	991,226	908,958	1,073,494	2,953,970	2,742,059	3,165,881	937,347	2,820,560
2004	1,021,790	937,760	1,105,820	3,161,400	2,936,559	3,386,241	966,374	3,028,200
2005	1,037,570	952,434	1,122,706	3,264,880	3,033,172	3,496,588	981,900	3,138,190
2006	1,057,690	970,445	1,144,935	3,239,190	3,006,581	3,471,799	1,001,710	3,121,280
2007	1,062,390	973,571	1,151,209	3,237,760	3,001,604	3,473,916	1,007,020	3,131,800
2008	1,037,330	948,015	1,126,645	3,093,160	2,861,474	3,324,846	984,018	3,002,470
2009	1,001,180	912,475	1,089,885	2,913,730	2,687,163	3,140,297	950,705	2,834,320
2010	976,282	888,116	1,064,448	2,954,900	2,723,626	3,186,174	928,940	2,903,440
2011	953,167	865,681	1,040,653	2,967,530	2,732,028	3,203,032	910,298	2,936,040
2012	935,293	847,370	1,023,216	2,930,120	2,691,609	3,168,631	897,681	2,927,810
2013	924,882	835,264	1,014,500	2,858,950	2,618,904	3,098,996	894,342	2,883,080
2014	881,893	791,941	971,845	2,647,610	2,414,228	2,880,992	858,579	2,680,370
2015	873,451	780,881	966,021	2,651,310	2,407,193	2,895,427	861,299	2,699,440
2016	875,385	779,950	970,820	2,812,320	2,541,253	3,083,387	876,687	2,852,570
2017	857,224	760,631	953,817	2,738,450	2,448,186	3,028,714	884,750	2,878,150
2018	854,807	755,497	954,117	2,786,330	2,447,731	3,124,929		

Table 4.18—Model estimates of yellowfin sole population numbers at age (billions) for 1954-2018.

	Females																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1954	1.00	0.43	0.30	0.27	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
1955	0.72	0.89	0.38	0.26	0.24	0.23	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.43
1956	0.49	0.63	0.79	0.33	0.23	0.21	0.21	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.57
1957	1.61	0.44	0.56	0.70	0.30	0.21	0.19	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.67
1958	1.17	1.43	0.39	0.50	0.62	0.26	0.18	0.17	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.73
1959	0.90	1.04	1.27	0.34	0.44	0.55	0.23	0.16	0.15	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.76
1960	0.85	0.80	0.92	1.13	0.30	0.39	0.48	0.20	0.14	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.69
1961	0.50	0.75	0.71	0.82	1.00	0.27	0.34	0.40	0.16	0.09	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.47
1962	0.94	0.44	0.67	0.63	0.72	0.87	0.23	0.26	0.25	0.07	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.18
1963	0.50	0.84	0.39	0.59	0.55	0.61	0.65	0.12	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.46	0.44	0.74	0.35	0.52	0.48	0.53	0.54	0.09	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.59	0.41	0.39	0.65	0.25	0.35	0.32	0.36	0.37	0.06	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.61	0.53	0.36	0.35	0.58	0.22	0.31	0.29	0.31	0.32	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	1.27	0.54	0.47	0.32	0.31	0.51	0.20	0.27	0.25	0.27	0.25	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	1.94	1.12	0.48	0.41	0.28	0.27	0.45	0.18	0.24	0.21	0.19	0.14	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1969	1.98	1.72	1.00	0.42	0.37	0.25	0.24	0.40	0.15	0.21	0.18	0.16	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1970	2.61	1.76	1.52	0.88	0.37	0.32	0.22	0.21	0.33	0.11	0.11	0.08	0.07	0.05	0.00	0.00	0.00	0.00	0.00	0.00
1971	2.90	2.31	1.56	1.35	0.78	0.33	0.29	0.20	0.19	0.29	0.09	0.07	0.04	0.03	0.02	0.00	0.00	0.00	0.00	0.00
1972	2.28	2.57	2.05	1.38	1.20	0.69	0.27	0.16	0.09	0.09	0.14	0.04	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00
1973	1.58	2.02	2.28	1.82	1.23	1.06	0.61	0.24	0.14	0.08	0.07	0.09	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.00
1974	2.12	1.40	1.79	2.02	1.61	1.09	0.94	0.54	0.20	0.11	0.05	0.04	0.05	0.01	0.01	0.01	0.01	0.00	0.00	0.00
1975	2.49	1.88	1.24	1.59	1.79	1.43	0.96	0.83	0.47	0.17	0.09	0.04	0.03	0.04	0.01	0.01	0.01	0.00	0.00	0.00
1976	1.64	2.21	1.67	1.10	1.41	1.59	1.26	0.84	0.70	0.38	0.14	0.07	0.03	0.03	0.03	0.01	0.01	0.00	0.00	0.00
1977	2.07	1.46	1.96	1.48	0.98	1.25	1.40	1.11	0.72	0.58	0.31	0.11	0.05	0.03	0.02	0.02	0.01	0.01	0.00	0.00
1978	1.35	1.83	1.29	1.74	1.31	0.86	1.09	1.21	0.95	0.61	0.49	0.26	0.09	0.04	0.02	0.02	0.02	0.01	0.00	0.01
1979	0.86	1.20	1.62	1.14	1.54	1.15	0.75	0.94	1.01	0.77	0.49	0.39	0.20	0.07	0.04	0.02	0.01	0.02	0.00	0.01
1980	1.67	0.77	1.06	1.44	1.01	1.36	1.02	0.65	0.80	0.85	0.64	0.41	0.32	0.17	0.06	0.03	0.01	0.01	0.01	0.01
1981	1.25	1.48	0.68	0.94	1.27	0.89	1.20	0.89	0.57	0.68	0.72	0.53	0.34	0.27	0.14	0.05	0.02	0.01	0.01	0.02
1982	3.61	1.11	1.31	0.60	0.83	1.13	0.79	1.05	0.77	0.48	0.58	0.60	0.45	0.28	0.22	0.12	0.04	0.02	0.01	0.02
1983	0.67	3.20	0.98	1.17	0.53	0.74	0.99	0.69	0.90	0.66	0.41	0.49	0.51	0.38	0.24	0.19	0.10	0.03	0.02	0.03
1984	2.99	0.59	2.84	0.87	1.03	0.47	0.65	0.86	0.59	0.77	0.56	0.35	0.42	0.43	0.32	0.20	0.16	0.08	0.03	0.04
1985	1.03	2.65	0.53	2.52	0.77	0.91	0.42	0.57	0.74	0.50	0.64	0.46	0.29	0.34	0.36	0.27	0.17	0.13	0.07	0.06
1986	0.79	0.92	2.35	0.47	2.23	0.68	0.80	0.36	0.48	0.61	0.40	0.52	0.37	0.23	0.28	0.29	0.21	0.13	0.11	0.10
1987	1.08	0.70	0.81	2.08	0.41	1.98	0.60	0.70	0.30	0.39	0.49	0.33	0.42	0.30	0.19	0.22	0.23	0.17	0.11	0.17
1988	1.48	0.96	0.62	0.72	1.85	0.37	1.75	0.53	0.60	0.26	0.33	0.40	0.26	0.34	0.24	0.15	0.18	0.19	0.14	0.22
1989	1.48	1.32	0.85	0.55	0.64	1.64	0.32	1.53	0.45	0.50	0.21	0.26	0.32	0.21	0.26	0.19	0.12	0.14	0.15	0.28
1990	0.74	1.32	1.17	0.76	0.49	0.57	1.45	0.29	1.34	0.39	0.42	0.17	0.21	0.26	0.17	0.21	0.15	0.10	0.11	0.35
1991	0.83	0.66	1.17	1.04	0.67	0.44	0.50	1.28	0.25	1.16	0.33	0.36	0.14	0.18	0.22	0.14	0.18	0.13	0.08	0.40
1992	1.85	0.74	0.58	1.04	0.92	0.59	0.39	0.44	1.12	0.22	1.00	0.28	0.30	0.12	0.15	0.19	0.12	0.16	0.11	0.41
1993	1.10	1.64	0.66	0.52	0.92	0.81	0.52	0.34	0.38	0.95	0.18	0.83	0.23	0.25	0.10	0.13	0.15	0.10	0.13	0.43
1994	0.93	0.98	1.45	0.58	0.46	0.81	0.72	0.46	0.30	0.33	0.82	0.15	0.70	0.20	0.21	0.09	0.11	0.13	0.08	0.47
1995	0.94	0.82	0.87	1.29	0.52	0.41	0.72	0.63	0.40	0.25	0.28	0.68	0.13	0.58	0.16	0.18	0.07	0.09	0.11	0.46
1996	2.30	0.83	0.73	0.77	1.14	0.46	0.36	0.63	0.54	0.34	0.21	0.23	0.57	0.11	0.49	0.14	0.15	0.06	0.07	0.48
1997	0.99	2.04	0.74	0.65	0.68	1.01	0.40	0.31	0.54	0.46	0.28	0.18	0.20	0.48	0.09	0.41	0.12	0.12	0.05	0.46
1998	0.82	0.88	1.81	0.65	0.57	0.60	0.89	0.35	0.27	0.45	0.38	0.23	0.14	0.16	0.39	0.07	0.33	0.09	0.10	0.41
1999	1.01	0.73	0.78	1.61	0.58	0.51	0.53	0.77	0.30	0.23	0.38	0.32	0.20	0.12	0.13	0.33	0.06	0.28	0.08	0.43
2000	1.43	0.90	0.65	0.69	1.42	0.51	0.45	0.47	0.68	0.26	0.20	0.33	0.27	0.17	0.10	0.11	0.28	0.05	0.24	0.44
2001	0.91	1.27	0.79	0.58	0.62	1.26	0.45	0.40	0.41	0.59	0.23	0.17	0.28	0.23	0.14	0.09	0.10	0.24	0.04	0.57
2002	1.25	0.81	1.12	0.70	0.51	0.55	1.12	0.40	0.35	0.36	0.51	0.19	0.14	0.24	0.20	0.12	0.07	0.08	0.20	0.53
2003	1.22	1.11	0.71	1.00	0.62	0.45	0.48	0.99	0.35	0.30	0.31	0.44	0.17	0.12	0.20	0.17	0.10	0.06	0.07	0.62
2004	1.93	1.08	0.98	0.63	0.88	0.55	0.40	0.43	0.87	0.31	0.26	0.26	0.37	0.14	0.10	0.17	0.14	0.09	0.05	0.59
2005	0.84	1.71	0.96	0.87	0.56	0.78	0.49	0.35	0.37	0.75	0.26	0.22	0.23	0.32	0.12	0.09	0.15	0.12	0.08	0.55
2006	1.02	0.75	1.52	0.85	0.77	0.50	0.69	0.43	0.31	0.32	0.64	0.22	0.19	0.19	0.27	0.10	0.08	0.13	0.10	0.53
2007	1.30	0.90	0.66	1.35	0.75	0.68	0.43	0.59	0.37	0.26	0.27	0.55	0.19	0.16	0.16	0.23	0.09	0.06	0.11	0.54
2008	1.17	1.15	0.80	0.59	1.19	0.66	0.60	0.38	0.51	0.31	0.22	0.23	0.46	0.16	0.13	0.14	0.19	0.07	0.05	0.54
2009	1.34	1.04	1.02	0.71	0.52	1.06	0.59	0.53	0.33	0.43	0.26	0.18	0.19	0.38	0.13	0.11	0.11	0.16	0.06	0.49
2010	1.80	1.19	0.92	0.91	0.63	0.46	0.93	0.51	0.45	0.28	0.36	0.22	0.15	0.16	0.32	0.11	0.09	0.09	0.13	0.47
2011	0.59	1.60	1.06	0.82	0.80	0.56	0.41	0.82	0.45	0.39	0.23	0.31	0.18	0.13	0.13	0.27	0.09	0.08	0.08	0.50
2012	0.37	0.52	1.42	0.94	0.72	0.71	0.49	0.36	0.71	0.38	0.32	0.19	0.25	0.15	0.11	0.11	0.22	0.08	0.06	0.48
2013	1.03	0.33	0.47	1.26	0.83	0.64	0.63	0.43	0.31	0.60	0.31	0.27	0.16	0.21	0.13	0.09	0.09	0.18	0.06	0.45
2014	1.90	0.92	0.29	0.41	1.12	0.74	0.57	0.55	0.37	0.26	0.49	0.26	0.22	0.13	0.17	0.10	0.07	0.07	0.15	0.42
2015	1.70	1.68	0.81	0.26	0.37	0.99	0.65	0.50	0.48	0.32	0.21	0.40	0.21	0.18	0.11	0.14	0.08	0.06	0.06	0.46
2016	1.19	1.51	1.49	0.72	0.23	0.32	0.88	0.58	0.44	0.42	0.27	0.18	0.33	0.17	0.14	0.09	0.11	0.07	0.05	0.43
2017	1.17	1.05	1.34	1.32	0.64	0.20	0.29	0.77	0.50	0.38	0.35	0.22	0.15	0.27	0.14	0.12	0.07	0.09	0.06	0.39
2018	1.18	1.03	0.93	1.19	1.17	0.56	0.18	0.25	0.66	0.42	0.31	0.29	0.18	0.12	0.22	0.11	0.10	0.06	0.08	0.36

Table 4.18 (continued).

	Males																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1954	1.00	0.72	0.34	0.28	0.27	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
1955	0.72	0.89	0.64	0.31	0.25	0.24	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.43
1956	0.49	0.63	0.79	0.56	0.27	0.22	0.21	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.57
1957	1.61	0.44	0.56	0.70	0.50	0.24	0.20	0.19	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.67
1958	1.17	1.43	0.39	0.50	0.62	0.44	0.21	0.17	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.73
1959	0.90	1.04	1.27	0.34	0.44	0.55	0.39	0.19	0.15	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.76
1960	0.85	0.80	0.92	1.13	0.30	0.39	0.48	0.34	0.16	0.13	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.69
1961	0.50	0.75	0.71	0.82	1.00	0.27	0.35	0.42	0.29	0.12	0.08	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.47
1962	0.94	0.44	0.67	0.63	0.73	0.89	0.24	0.31	0.37	0.24	0.09	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.18
1963	0.50	0.84	0.39	0.59	0.56	0.64	0.79	0.21	0.27	0.33	0.21	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.46	0.44	0.74	0.35	0.52	0.49	0.55	0.63	0.15	0.18	0.21	0.13	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.59	0.41	0.39	0.66	0.31	0.46	0.43	0.48	0.51	0.11	0.12	0.14	0.09	0.03	0.01	0.00	0.00	0.00	0.00	0.00
1966	0.61	0.53	0.36	0.35	0.58	0.27	0.41	0.38	0.39	0.38	0.08	0.09	0.10	0.06	0.02	0.01	0.00	0.00	0.00	0.00
1967	1.27	0.54	0.47	0.32	0.31	0.52	0.24	0.35	0.30	0.27	0.23	0.04	0.05	0.06	0.04	0.01	0.00	0.00	0.00	0.00
1968	1.94	1.12	0.48	0.41	0.28	0.27	0.44	0.19	0.22	0.16	0.14	0.11	0.02	0.02	0.03	0.02	0.01	0.00	0.00	0.00
1969	1.98	1.72	1.00	0.42	0.37	0.25	0.24	0.37	0.14	0.14	0.09	0.08	0.07	0.01	0.01	0.02	0.01	0.00	0.00	0.00
1970	2.61	1.76	1.52	0.88	0.37	0.32	0.22	0.20	0.28	0.08	0.07	0.04	0.04	0.03	0.01	0.01	0.01	0.00	0.00	0.00
1971	2.90	2.31	1.56	1.35	0.78	0.33	0.27	0.14	0.09	0.12	0.03	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1972	2.28	2.57	2.05	1.38	1.20	0.69	0.28	0.19	0.07	0.04	0.06	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
1973	1.58	2.02	2.28	1.82	1.23	1.06	0.60	0.22	0.13	0.04	0.03	0.04	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1974	2.12	1.40	1.79	2.02	1.61	1.09	0.93	0.47	0.14	0.07	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1975	2.49	1.88	1.24	1.59	1.79	1.42	0.93	0.76	0.37	0.11	0.05	0.02	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
1976	1.64	2.21	1.67	1.10	1.41	1.58	1.24	0.79	0.61	0.29	0.08	0.04	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
1977	2.07	1.46	1.96	1.48	0.98	1.25	1.40	1.09	0.68	0.51	0.23	0.06	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00
1978	1.35	1.83	1.29	1.74	1.31	0.86	1.10	1.23	0.94	0.58	0.42	0.20	0.05	0.03	0.01	0.01	0.01	0.00	0.00	0.00
1979	0.86	1.20	1.62	1.14	1.54	1.16	0.76	0.96	1.04	0.77	0.46	0.34	0.16	0.04	0.02	0.01	0.00	0.01	0.00	0.00
1980	1.67	0.77	1.06	1.44	1.01	1.36	1.02	0.66	0.82	0.87	0.65	0.39	0.28	0.13	0.04	0.02	0.01	0.00	0.01	0.01
1981	1.25	1.48	0.68	0.94	1.28	0.90	1.20	0.90	0.58	0.71	0.76	0.55	0.33	0.24	0.11	0.03	0.02	0.01	0.00	0.01
1982	3.61	1.11	1.31	0.60	0.83	1.13	0.79	1.06	0.78	0.50	0.61	0.64	0.47	0.27	0.20	0.09	0.02	0.01	0.00	0.01
1983	0.67	3.20	0.98	1.17	0.53	0.74	0.99	0.69	0.91	0.67	0.43	0.52	0.54	0.40	0.23	0.17	0.08	0.02	0.01	0.01
1984	2.99	0.59	2.84	0.87	1.03	0.47	0.65	0.86	0.59	0.77	0.57	0.36	0.44	0.46	0.34	0.20	0.14	0.06	0.02	0.02
1985	1.03	2.65	0.53	2.52	0.77	0.91	0.41	0.56	0.73	0.49	0.64	0.47	0.30	0.36	0.38	0.28	0.16	0.12	0.05	0.03
1986	0.79	0.92	2.35	0.47	2.23	0.68	0.80	0.36	0.46	0.59	0.39	0.51	0.38	0.24	0.29	0.30	0.22	0.13	0.09	0.07
1987	1.08	0.70	0.81	2.09	0.41	1.98	0.60	0.69	0.29	0.38	0.47	0.32	0.41	0.30	0.19	0.23	0.25	0.18	0.10	0.13
1988	1.48	0.96	0.62	0.72	1.85	0.37	1.75	0.52	0.58	0.24	0.30	0.38	0.26	0.33	0.24	0.16	0.19	0.20	0.14	0.19
1989	1.48	1.32	0.85	0.55	0.64	1.64	0.32	1.53	0.44	0.47	0.19	0.24	0.30	0.20	0.26	0.19	0.12	0.15	0.16	0.26
1990	0.74	1.32	1.17	0.76	0.49	0.57	1.45	0.29	1.33	0.37	0.39	0.16	0.19	0.24	0.16	0.21	0.16	0.10	0.12	0.34
1991	0.83	0.66	1.17	1.04	0.67	0.44	0.50	1.28	0.25	1.15	0.32	0.33	0.13	0.17	0.21	0.14	0.18	0.13	0.08	0.39
1992	1.85	0.74	0.58	1.04	0.92	0.59	0.39	0.44	1.11	0.21	0.97	0.27	0.28	0.11	0.14	0.18	0.12	0.15	0.11	0.41
1993	1.10	1.64	0.66	0.52	0.92	0.81	0.52	0.34	0.38	0.93	0.18	0.81	0.22	0.23	0.09	0.12	0.15	0.10	0.13	0.43
1994	0.93	0.98	1.45	0.58	0.46	0.81	0.72	0.46	0.29	0.33	0.80	0.15	0.68	0.19	0.20	0.08	0.10	0.12	0.08	0.47
1995	0.94	0.82	0.87	1.29	0.52	0.41	0.72	0.63	0.39	0.25	0.27	0.66	0.13	0.57	0.16	0.16	0.07	0.08	0.10	0.46
1996	2.30	0.83	0.73	0.77	1.14	0.46	0.36	0.62	0.54	0.33	0.21	0.23	0.56	0.10	0.48	0.13	0.14	0.05	0.07	0.47
1997	0.99	2.04	0.74	0.65	0.68	1.01	0.40	0.31	0.53	0.45	0.28	0.17	0.19	0.47	0.09	0.40	0.11	0.11	0.05	0.45
1998	0.82	0.88	1.81	0.65	0.57	0.60	0.88	0.35	0.26	0.44	0.37	0.23	0.14	0.16	0.38	0.07	0.32	0.09	0.09	0.40
1999	1.01	0.73	0.78	1.61	0.58	0.51	0.53	0.78	0.30	0.22	0.38	0.31	0.19	0.12	0.13	0.32	0.06	0.27	0.08	0.42
2000	1.43	0.90	0.65	0.69	1.43	0.51	0.45	0.47	0.69	0.26	0.20	0.32	0.27	0.16	0.10	0.11	0.27	0.05	0.23	0.42
2001	0.91	1.27	0.79	0.58	0.62	1.26	0.45	0.40	0.41	0.60	0.23	0.17	0.28	0.23	0.14	0.09	0.09	0.23	0.04	0.55
2002	1.25	0.81	1.12	0.70	0.51	0.55	1.12	0.40	0.35	0.37	0.52	0.20	0.14	0.24	0.20	0.12	0.07	0.08	0.20	0.51
2003	1.22	1.11	0.71	1.00	0.62	0.45	0.48	0.99	0.35	0.31	0.31	0.45	0.17	0.12	0.20	0.17	0.10	0.06	0.07	0.60
2004	1.93	1.08	0.98	0.63	0.88	0.55	0.40	0.43	0.87	0.31	0.26	0.27	0.38	0.14	0.10	0.17	0.14	0.09	0.05	0.57
2005	0.84	1.71	0.96	0.87	0.56	0.78	0.49	0.35	0.37	0.75	0.26	0.23	0.23	0.33	0.12	0.09	0.15	0.12	0.07	0.54
2006	1.02	0.75	1.52	0.85	0.77	0.50	0.69	0.43	0.31	0.32	0.64	0.22	0.19	0.19	0.28	0.10	0.08	0.12	0.10	0.52
2007	1.30	0.90	0.66	1.35	0.75	0.69	0.44	0.60	0.37	0.26	0.27	0.54	0.19	0.16	0.16	0.24	0.09	0.06	0.11	0.53
2008	1.17	1.15	0.80	0.59	1.19	0.67	0.60	0.38	0.51	0.31	0.22	0.23	0.45	0.16	0.14	0.14	0.20	0.07	0.05	0.53
2009	1.34	1.04	1.02	0.71	0.52	1.06	0.59	0.53	0.33	0.43	0.26	0.18	0.19	0.38	0.13	0.11	0.11	0.16	0.06	0.48
2010	1.80	1.19	0.92	0.91	0.63	0.46	0.93	0.52	0.46	0.28	0.36	0.22	0.15	0.16	0.32	0.11	0.09	0.10	0.14	0.46
2011	0.59	1.60	1.06	0.82	0.80	0.56	0.41	0.82	0.44	0.39	0.23	0.30	0.18	0.13	0.13	0.27	0.09	0.08	0.08	0.50
2012	0.37	0.52	1.42	0.94	0.72	0.71	0.49	0.35	0.70	0.37	0.32	0.19	0.25	0.15	0.11	0.11	0.22	0.08	0.07	0.48
2013	1.03	0.33	0.47	1.26	0.83	0.64	0.63	0.43	0.30	0.58	0.31	0.27	0.16	0.21	0.12	0.09	0.09	0.18	0.06	0.45
2014	1.90	0.92	0.29	0.41	1.12	0.74	0.57	0.55	0.37	0.25	0.48	0.25	0.22	0.13	0.17	0.10	0.07	0.07	0.15	0.42
2015	1.70	1.68	0.81	0.26	0.37	0.99	0.65	0.50	0.48	0.31	0.21	0.39	0.20	0.18	0.11	0.14	0.08	0.06	0.06	0.46
2016	1.19	1.51	1.49	0.72	0.23	0.32	0.87	0.58	0.44	0.41	0.26	0.18	0.32	0.17	0.14	0.09	0.11	0.07	0.05	0.42
2017	1.17	1.05	1.34	1.32	0.64	0.20	0.29	0.77	0.50	0.37	0.35	0.22	0.14	0.26	0.14	0.12	0.07	0.09	0.05	0.38
2018	1.18	1.03	0.93	1.19	1.17	0.57	0.18	0.25	0.67	0.43	0.32	0.29	0.18	0.12	0.22	0.11	0.10	0.06	0.08	0.36

Table 4.19. Model estimates of the number of female spawners (millions) 1964-2018.

year/age	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1964	5.3	20.2	52.7	19.2	15.4	5.0	0.6	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.9
1965	3.9	12.4	34.5	77.9	24.9	16.1	4.3	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.7
1966	2.5	11.9	27.8	66.9	131.0	32.3	15.9	3.5	0.3	0.1	0.1	0.0	0.0	0.0	0.5
1967	5.6	7.6	26.6	53.6	110.0	159.1	27.9	10.8	2.2	0.2	0.1	0.0	0.0	0.0	0.3
1968	3.0	17.4	17.0	51.3	87.1	125.0	118.9	16.1	5.7	1.1	0.1	0.0	0.0	0.0	0.2
1969	2.8	9.2	39.1	33.0	87.2	116.5	127.9	94.1	10.7	3.4	0.6	0.1	0.0	0.0	0.1
1970	3.6	8.5	20.4	70.8	43.8	71.8	69.2	64.2	44.3	4.9	1.5	0.3	0.0	0.0	0.1
1971	3.7	11.0	19.1	39.8	119.8	55.6	58.4	36.9	29.2	19.1	2.1	0.7	0.1	0.0	0.0
1972	7.6	10.4	15.3	20.1	36.5	88.6	33.6	30.8	18.4	14.1	9.1	1.0	0.3	0.1	0.0
1973	11.7	23.5	23.5	29.9	34.4	46.5	73.9	23.9	20.6	11.9	9.0	5.8	0.6	0.2	0.0
1974	11.9	35.8	52.1	43.4	43.6	34.8	35.1	47.1	14.2	11.9	6.8	5.1	3.3	0.4	0.1
1975	15.7	36.8	80.4	100.4	71.9	55.9	35.0	30.1	37.9	11.1	9.2	5.2	3.9	2.5	0.4
1976	17.5	48.2	81.3	148.5	156.0	88.2	55.7	30.4	24.7	30.1	8.7	7.1	4.1	3.0	2.2
1977	13.7	53.6	107.4	154.1	240.6	197.6	89.5	48.9	25.1	19.7	23.8	6.8	5.6	3.2	4.1
1978	9.4	41.6	117.6	202.1	253.0	316.8	211.9	83.6	43.1	21.4	16.7	20.0	5.7	4.7	6.1
1979	12.7	28.7	90.8	215.5	317.0	315.4	321.1	187.1	69.7	34.7	17.1	13.2	15.8	4.5	8.6
1980	15.0	38.8	63.4	170.8	351.2	413.2	335.0	297.2	163.5	58.9	29.1	14.2	11.0	13.1	10.9
1981	9.8	45.7	86.2	120.8	282.5	462.4	440.2	309.5	258.3	137.3	49.0	24.1	11.7	9.1	19.8
1982	12.4	30.1	101.6	164.1	200.1	373.7	497.0	411.5	272.7	220.1	116.0	41.1	20.1	9.8	24.1
1983	8.1	37.9	66.8	193.1	272.2	266.3	405.7	470.5	367.6	235.8	188.9	98.7	34.9	17.1	28.8
1984	5.2	24.8	83.5	125.9	318.3	361.0	288.5	383.4	419.7	317.5	202.0	160.5	83.8	29.6	38.9
1985	10.1	15.9	54.9	157.5	205.3	414.1	382.2	266.1	333.7	353.6	265.3	167.5	133.0	69.3	56.7
1986	7.5	30.7	35.1	102.8	252.9	260.7	425.6	341.3	224.0	271.8	285.7	212.6	134.1	106.3	100.7
1987	21.7	22.9	67.5	64.6	162.4	319.5	268.6	382.4	289.5	183.9	221.4	230.8	171.6	108.1	166.8
1988	4.0	66.7	51.2	129.0	106.3	210.7	333.5	242.8	325.4	238.2	150.1	179.2	186.6	138.6	221.9
1989	18.0	12.4	148.7	96.8	206.9	133.4	213.2	293.1	201.2	260.9	189.5	118.4	141.3	146.9	283.8
1990	6.2	55.4	27.7	286.3	160.5	269.1	139.4	193.2	250.4	166.3	213.9	154.1	96.2	114.6	349.4
1991	4.8	19.2	124.4	53.5	480.3	215.1	293.7	132.6	173.5	217.6	143.4	183.0	131.7	82.1	395.9
1992	6.5	14.7	42.9	239.5	89.7	643.0	234.1	278.3	118.5	150.1	186.8	122.1	155.6	111.8	405.9
1993	8.9	20.0	32.8	81.8	394.2	117.4	682.1	216.0	242.1	99.8	125.3	154.7	101.0	128.6	427.7
1994	8.9	27.4	44.8	63.1	137.4	529.3	127.8	643.9	191.8	207.7	84.9	105.7	130.3	84.9	467.7
1995	4.5	27.4	61.0	84.8	103.3	179.7	563.6	118.6	564.0	162.6	174.7	70.8	88.1	108.4	460.0
1996	5.0	13.7	60.8	115.2	139.1	135.8	192.8	527.4	104.7	482.3	137.9	147.0	59.5	73.9	477.1
1997	11.1	15.3	30.3	115.3	190.1	183.4	145.6	179.9	464.1	89.2	407.3	115.6	123.0	49.7	460.5
1998	6.6	33.8	33.8	57.1	187.6	245.7	191.9	132.3	153.9	384.0	73.2	331.5	93.9	99.9	414.1
1999	5.6	20.2	75.0	64.2	94.3	248.3	265.0	180.4	117.4	132.2	327.2	61.8	279.9	79.2	433.3
2000	5.6	17.2	45.4	145.5	108.6	127.2	271.9	252.4	162.0	102.0	113.9	279.8	52.8	238.7	437.1
2001	13.9	17.3	38.6	87.9	245.3	145.7	138.3	256.8	224.7	139.6	87.1	96.6	236.9	44.7	571.4
2002	6.0	42.7	38.8	74.3	147.7	330.0	159.6	132.0	231.3	195.9	120.7	74.8	82.8	202.8	527.3
2003	5.0	18.5	96.0	75.2	125.4	198.7	360.6	151.9	118.5	200.9	168.8	103.2	63.9	70.6	622.5
2004	6.1	15.3	41.4	185.1	126.3	168.5	217.3	343.5	136.5	103.1	173.4	144.5	88.3	54.5	591.9
2005	8.6	18.7	34.3	79.7	311.0	170.0	184.7	207.6	309.6	119.1	89.2	148.9	124.0	75.6	553.6
2006	5.5	26.4	41.7	65.6	133.0	415.1	184.6	174.6	185.0	267.1	101.9	75.7	126.2	104.9	532.6
2007	7.5	16.6	57.6	78.1	107.9	176.4	449.9	174.6	155.9	159.9	229.0	86.7	64.3	107.1	540.9
2008	7.3	23.0	36.9	109.4	128.8	141.9	188.8	419.3	153.5	132.6	135.0	191.7	72.5	53.7	541.2
2009	11.6	22.4	51.0	69.5	178.4	167.6	150.4	174.4	365.5	129.5	111.0	112.1	159.1	60.0	492.8
2010	5.1	35.7	49.9	97.0	114.6	235.3	180.3	141.2	154.5	313.4	110.2	93.7	94.5	133.9	465.4
2011	6.1	15.6	79.5	95.1	160.3	151.2	252.8	168.8	124.7	132.0	265.8	92.7	78.7	79.3	502.9
2012	7.8	18.8	34.6	150.6	155.5	208.5	159.9	232.7	146.6	104.8	110.1	219.8	76.6	65.0	480.3
2013	7.0	24.0	41.7	65.5	246.3	202.6	220.9	147.5	202.5	123.5	87.6	91.3	182.1	63.3	450.9
2014	8.1	21.7	53.7	79.7	107.1	316.9	211.1	200.2	126.1	167.7	101.4	71.4	74.3	148.0	417.9
2015	10.9	24.9	48.5	102.6	130.7	138.2	330.7	191.5	171.4	104.5	137.8	82.7	58.1	60.4	460.1
2016	3.6	33.5	55.9	93.5	172.1	173.1	146.8	303.3	165.1	142.7	86.3	112.8	67.6	47.5	425.2
2017	2.2	11.0	74.8	107.2	155.1	225.6	182.8	134.3	261.0	137.3	117.7	70.6	92.2	55.2	385.7
2018	6.2	6.8	24.3	140.9	174.1	200.6	237.3	167.5	116.0	218.3	114.0	96.9	58.1	75.7	362.0

Table 4.20. Model estimates of yellowfin sole age 5 recruitment (millions) from the 2017 and 2018 stock assessments.

Year class	2017 assessment	2018 assessment
1964	733	733
1965	734	749
1966	1,520	1,568
1967	2,316	2,395
1968	2,361	2,451
1969	3,100	3,227
1970	3,432	3,581
1971	2,691	2,817
1972	1,862	1,951
1973	2,496	2,620
1974	2,932	3,078
1975	1,929	2,027
1976	2,424	2,551
1977	1,584	1,670
1978	1,008	1,067
1979	1,937	2,065
1980	1,435	1,541
1981	4,138	4,464
1982	765	827
1983	3,407	3,697
1984	1,173	1,278
1985	897	982
1986	1,219	1,341
1987	1,659	1,837
1988	1,646	1,836
1989	817	917
1990	908	1,030
1991	2,004	2,285
1992	1,191	1,361
1993	1,002	1,148
1994	1,010	1,156
1995	2,489	2,850
1996	1,076	1,231
1997	910	1,020
1998	1,103	1,249
1999	1,553	1,767
2000	1,013	1,124
2001	1,419	1,547
2002	1,401	1,503
2003	2,431	2,388
2004	1,201	1,042
2005	1,352	1,258
2006	1,726	1,607
2007	1,414	1,446
2008	1,529	1,550
2009	1,662	1,947
2010	618	1,482
2011		595

Table 4.21. Selected parameter estimates and their standard deviation from the preferred stock assessment model in 2018.

	parameter	value	std dev		parameter	value	std dev
	alpha (q-temp model)	-0.013	0.036	1976	total biomass	2,112.800	56.400
	beta (q-temp model)	0.060	0.013	1977	total biomass	2,426.000	63.419
	beta (survey start date	0.014	0.003	1978	total biomass	2,724.000	69.995
	beta (start date/temp interaction)	-0.010	0.003	1979	total biomass	2,886.900	75.460
	mean_log_rec	0.86	0.09	1980	total biomass	3,072.000	80.398
	mean sel_slope_fsh (females)	1.24	0.09	1981	total biomass	3,241.000	84.599
	mean sel50_fsh (females)	8.52	0.24	1982	total biomass	3,356.700	86.666
	mean sel_slope_fsh_males	1.33	0.09	1983	total biomass	3,334.900	87.367
	mean sel50_fsh_males	8.32	0.23	1984	total biomass	3,563.600	93.071
	sel_slope_srv (females)	1.64	0.09	1985	total biomass	3,575.000	96.065
	sel50_srv (females)	5.00	0.07	1986	total biomass	3,288.300	93.155
	sel_slope_srv_males	-0.06	0.08	1987	total biomass	3,250.600	95.545
	sel50_srv_males	0.02	0.02	1988	total biomass	3,155.200	95.552
	Ricker SR logalpha	-4.43	0.51	1989	total biomass	3,215.000	100.320
	Ricker SR logbeta	-6.42	0.32	1990	total biomass	3,080.400	98.702
	Fmsy	0.11	0.03	1991	total biomass	3,201.000	101.930
	log (Fmsy)	-2.19	0.31	1992	total biomass	3,411.400	107.500
	ABC_biomass 2018	2467.10	151.84	1993	total biomass	3,447.000	110.400
	ABC_biomass 2019	2418.80	185.47	1994	total biomass	3,490.600	112.040
	msy	396.19	146.92	1995	total biomass	3,262.000	108.220
	Bmsy	460.77	81.26	1996	total biomass	3,178.200	106.760
1954	total biomass	2473.80	156.64	1997	total biomass	3,194.500	108.400
1955	total biomass	2441.50	141.94	1998	total biomass	2,917.600	103.120
1956	total biomass	2400.10	125.63	1999	total biomass	2,730.800	98.823
1957	total biomass	2349.70	108.03	2000	total biomass	2,778.900	99.256
1958	total biomass	2311.00	89.47	2001	total biomass	2,702.300	97.420
1959	total biomass	2267.10	71.08	2002	total biomass	2,742.200	97.872
1960	total biomass	2090.90	54.49	2003	total biomass	2,954.000	103.760
1961	total biomass	1650.90	38.63	2004	total biomass	3,161.400	109.950
1962	total biomass	1142.30	25.10	2005	total biomass	3,264.900	113.250
1963	total biomass	800.95	17.03	2006	total biomass	3,239.200	113.740
1964	total biomass	841.88	16.90	2007	total biomass	3,237.800	115.500
1965	total biomass	820.94	16.54	2008	total biomass	3,093.200	113.450
1966	total biomass	871.55	17.35	2009	total biomass	2,913.700	110.650
1967	total biomass	863.70	17.83	2010	total biomass	2,954.900	113.030
1968	total biomass	794.39	17.75	2011	total biomass	2,967.500	115.500
1969	total biomass	830.95	19.49	2012	total biomass	2,930.100	117.540
1970	total biomass	806.94	21.13	2013	total biomass	2,858.900	118.560
1971	total biomass	871.89	24.39	2014	total biomass	2,647.600	115.280
1972	total biomass	942.51	28.51	2015	total biomass	2,651.300	120.780
1973	total biomass	1196.00	34.43	2016	total biomass	2,812.300	135.260
1974	total biomass	1445.10	40.89	2017	total biomass	2,738.400	142.440
1975	total biomass	1803.40	49.08	2018	total biomass	2,786.300	164.110

Table 4.22. Projections of yellowfin sole female spawning biomass (1,000s t), catch (1,000s t) and full selection fishing mortality rate for seven future harvest scenarios.

Scenarios 1 and 2
Maximum Tier 3 ABC harvest permissible

Year	Female spawning biomass	catch	F
2018	851.556	146.487	0.09
2019	834.841	213.331	0.14
2020	783.016	198.284	0.14
2021	725.257	185.544	0.14
2022	684.279	180.081	0.14
2023	676.956	180.277	0.14
2024	687.010	181.741	0.14
2025	694.249	181.354	0.14
2026	689.230	179.757	0.14
2027	678.391	177.647	0.14
2028	669.827	175.750	0.14
2029	665.427	173.869	0.14
2030	661.479	171.523	0.14
2031	658.479	170.071	0.14

Scenario 3
Maximum Tier 3 ABC harvest permissible set at F60

Year	Female spawning biomass	catch	F
2018	851.556	146.487	0.09
2019	852.696	106.494	0.07
2020	846.564	119.589	0.08
2021	822.320	116.982	0.08
2022	807.327	117.484	0.08
2023	821.281	120.494	0.08
2024	850.041	123.868	0.08
2025	874.975	125.899	0.08
2026	884.795	126.992	0.08
2027	885.468	127.432	0.08
2028	886.439	127.655	0.08
2029	890.392	128.036	0.08
2030	891.741	128.102	0.08
2031	891.792	128.248	0.08

Scenario 4
Harvest at average F over the past 5 years

Year	Female spawning biomass	catch	F
2018	851.556	146.487	0.09
2019	846.244	145.568	0.09
2020	831.645	99.308	0.07
2021	817.456	98.273	0.07
2022	811.596	99.753	0.07
2023	833.817	103.250	0.07
2024	870.300	106.987	0.07
2025	902.553	109.516	0.07
2026	918.913	111.179	0.07
2027	925.181	112.196	0.07
2028	931.041	112.938	0.07
2029	939.386	113.745	0.07
2030	944.255	114.189	0.07
2031	947.129	114.638	0.07

Scenario 5
No fishing

Year	Female spawning biomass	catch	F
2018	851.556	146.487	0.09
2019	869.851	0	0
2020	916.577	0	0
2021	947.265	0	0
2022	982.135	0	0
2023	1042.770	0	0
2024	1116.490	0	0
2025	1186.460	0	0
2026	1238.260	0	0
2027	1276.510	0	0
2028	1312.500	0	0
2029	1350.060	0	0
2030	1379.400	0	0
2031	1403.320	0	0

Scenario 6
Determination of whether yellowfin sole are currently overfished **B35=555.1**

Year	Female spawning biomass	catch	F
2018	851.556	146.487	0.09
2019	827.488	256.166	0.17
2020	757.035	232.455	0.17
2021	685.260	212.931	0.17
2022	634.527	203.408	0.17
2023	620.444	198.556	0.17
2024	625.490	200.508	0.17
2025	627.569	199.325	0.17
2026	618.821	193.503	0.17
2027	606.880	186.834	0.16
2028	599.180	182.139	0.16
2029	596.438	179.756	0.16
2030	594.543	178.100	0.16
2031	593.404	177.373	0.16

Scenario 7
Determination of whether the stock is approaching an overfished condition **B35=555.1**

Year	Female spawning biomass	catch	F
2018	851.556	146.487	0.09
2019	834.839	213.343	0.14
2020	783.010	198.283	0.14
2021	718.776	222.773	0.17
2022	661.852	211.418	0.17
2023	642.013	207.928	0.17
2024	641.569	206.592	0.17
2025	639.633	203.537	0.17
2026	627.508	198.464	0.17
2027	612.515	190.060	0.17
2028	602.752	184.040	0.16
2029	598.677	180.879	0.16
2030	595.901	178.753	0.16
2031	594.207	177.749	0.16

Table 4-23. Catch and bycatch (t) of other BSAI target species in the yellowfin sole directed fishery from 1992-2016 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	
Other flatfish									
Squid	0	0	1					<1	
Dover Sole									
Thornyhead									
Shortraker/Rougheye	1								
Butter Sole		7							
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								
Kamchatka flounder									

Table 4.23 (continued).

Table 4.23 (continued).

	2010	2011	2012	2013	2014	2015	2016	2017
Pollock	3,749	8,685	11,226	20,246	24,712	21,282	22,324	23,433
Arrowtooth Flounder	868	2,338	995	2,012	2,216	1,686	3,252	1,263
Pacific Cod	8,649	16,300	19,230	24,382	15,217	12,169	11,988	14,649
Groundfish, General	3,048							
Rock Sole	9,030	9,762	8,959	7,737	7,031	9,773	7,948	12,194
Flathead Sole	1,895	3,236	2,109	4,191	3,999	3,337	4,105	3,107
Sablefish		<1			<1	<1	<1	<1
Atka Mackerel		<1	<1	<1	<1	<1	<1	<1
Pacific ocean Perch		<1		17	<1	<1	3	<1
Rex Sole								
Other flatfish			1,201	388	2,887	1,041	1,136	1,734
Squid		<1						
Dover Sole								
Thornyhead								
Shortraker/Rougheye								
Butter Sole								
Starry Flounder								
Northern Rockfish			<1					<1
Dusky Rockfish								
Yellowfin Sole	90,008	136,905	133,719	147,777	139,480	107,955	107,505	110,452
English Sole								
Unsp.demersal rockfish								
Greenland Turbot		6	6	335	56	42	8	9
Alaska Plaice							8,165	12,783
Sculpin, General						1,083		1,309
Skate, General	10,749	18,340	13,613	16,006	14,347	1,073	1,295	1,932
Sharpchin Rockfish								<1
Bocaccio		1,808	1,924	1,922	1,261			7
Rockfish, General		1,969	2,270	2,686	1,969			
Octopus								<1
Smelt, general								
Chilipepper				<1				
eels			1.3					
Lingcod								
Jellyfish (unspecified)								
Snails								
Sea cucumber								
Korean horsehair crab								
Kamchatka flounder			110	147		427	285	165
Sharks						1	11	2

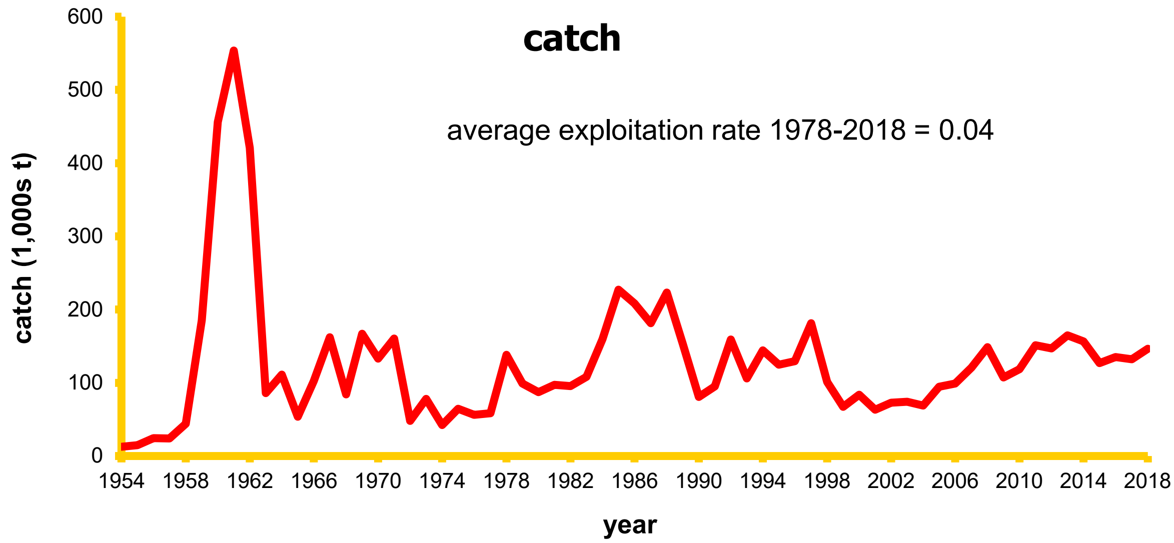
Table 4-24. Estimated non-target species catch (t) in the yellowfin sole fishery, 2003-2018 (PSC not included).

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Benthic urochordata	520.1	114.5	347.6	204.7	156.0	133.0	140.8	197.4	116.1	260.8	226.0	319.6	155.9
Birds													
Bivalves	0.3	0.5	1.5	1.3	1.8	1.7	0.7	1.2	0.9	1.7	1.0	0.9	0.6
Brittle star unidentified	20.0	7.6	19.0	5.2	4.2	14.0	13.1	5.9	11.6	11.5	6.4	2.4	2.4
Capelin	0.1	0.3	0.2	0.3	0.7	3.8	2.3	0.2	1.3	1.8	0.2	0.1	0.0
Corals Bryozoans	9.4	0.2	8.3	0.3	0.5	0.9	0.7	3.0	0.9	0.6	0.4	0.1	1.5
Deep sea smelts (bathylagidae)											0.0		
Eelpouts	4.5	2.3	5.6	5.2	5.1	29.3	14.3	51.6	69.8	30.1	56.7	8.2	22.0
Eulachon	0.1	5.1	0.0	0.1	0.1	0.5	0.1	0.0	0.7	0.2	2.9	0.1	0.0
Giant Grenadier													11.9
Greenlings	0.7	0.5	0.2	0.0	0.1	0.0	0.1		0.0	0.2	0.6	0.1	0.1
Gunnels		0.0						0.0		0.0	0.0		
Hermit crab unidentified	26.9	35.8	36.6	15.4	16.9	15.9	9.9	6.3	8.6	4.8	2.7	2.8	0.8
Invertebrate unidentified	177.2	40.0	70.4	30.6	25.9	65.4	121.3	25.2	44.4	6.2	7.5	11.3	1.7
Large Sculpins		2269.8											
Misc crabs	10.6	28.0	14.1	11.0	12.5	20.5	19.8	39.7	20.8	22.1	14.0	15.1	4.8
Misc crustaceans	2.3	1.4	0.7	1.3	0.9	0.5	0.4	0.6	0.2	0.6	0.1	0.2	0.2
Misc fish	42.5	71.2	66.3	48.8	29.2	39.4	54.8	46.8	26.9	36.2	30.2	42.9	20.6
Misc inverts (worms etc)	0.0	0.0	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.0	0.0	0.0	0.0
Other osmerids	0.6	35.8	9.8	0.8	2.8	2.2	4.7	1.0	9.2	4.8	5.1	2.7	0.5
Other Sculpins	68.2	195.2	38.6	74.6									
Pacific Sand lance	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.1	0.1	0.1	0.1
Pacific Sandfish					0.0	0.0	0.0	0.0	0.1	0.1	0.0		0.0
Pandalid shrimp	0.8	0.1	0.3	0.5	0.7	2.3	0.6	2.1	1.0	0.2	0.5	0.2	0.3
Polychaete unidentified	0.4	0.1	0.2	0.1	0.1	0.2	0.1	2.0	0.1	0.1	0.1	0.1	2.7
Scypho jellies	46.8	42.4	145.8	223.2	152.2	307.1	179.3	463.0	805.0	381.7	68.0	93.6	60.8
Sea anemone unidentified	4.9	8.8	24.8	25.5	20.0	14.7	6.2	23.4	5.7	4.3	1.6	2.5	2.0
Sea pens whips	0.0	0.0	0.3	0.2	0.6	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1
Sea star	1309	1462	1829	684	795	1674	1733	1372	2106	2247	2051	1617	1247
Snails	141.5	95.3	139.6	57.7	57.4	74.7	33.7	46.4	33.7	36.0	24.2	25.0	10.5
Sponge unidentified	3.1	0.4	6.8	69.4	16.5	15.1	14.1	16.6	1.5	2.5	1.3	2.0	2.8
Stichaeidae	0.0	0.8	0.2	0.0	0.2	0.4	0.1	0.1	0.4	0.5	0.3	0.0	0.1
Surf smelt			0.0										
urchins dollars cucumbers	0.8	3.4	4.9	7.5	1.3	1.0	0.7	0.8	0.5	0.6	0.3	2.2	0.3

Table 4.25. Yellowfin sole TAC and ABC levels, 1980- 2018.

Year	TAC	ABC	Total catch
1980	117,000	169,000	87,391
1981	117,000	214,500	97,301
1982	117,000	214,500	95,712
1983	117,000	214,500	108,385
1984	230,000	310,000	159,526
1985	229,900	310,000	227,107
1986	209,500	230,000	208,597
1987	187,000	187,000	181,428
1988	254,000	254,000	223,156
1989	182,675	241,000	153,170
1990	207,650	278,900	80,584
1991	135,000	250,600	95,000
1992	235,000	372,000	159,038
1993	220,000	238,000	106,101
1994	150,325	230,000	144,544
1995	190,000	277,000	124,740
1996	200,000	278,000	129,659
1997	230,000	233,000	181,389
1998	220,000	220,000	101,201
1999	207,980	212,000	67,320
2000	123,262	191,000	83,850
2001	113,000	176,000	63,395
2002	86,000	115,000	72,999
2003	83,750	114,000	74,418
2004	86,075	114,000	69,046
2005	90,686	124,000	94,683
2006	95,701	121,000	99,068
2007	136,000	225,000	121,029
2008	225,000	248,000	148,894
2009	210,000	210,000	107,528
2010	219,000	219,000	118,624
2011	196,000	239,000	151,164
2012	202,000	203,000	147,183
2013	198,000	206,000	164,944
2014	184,000	239,800	156,778
2015	149,000	248,800	126,933
2016	144,000	211,700	130,500
2017	154,000	260,800	132,297
2018	154,000	277,500	146,500

Figures



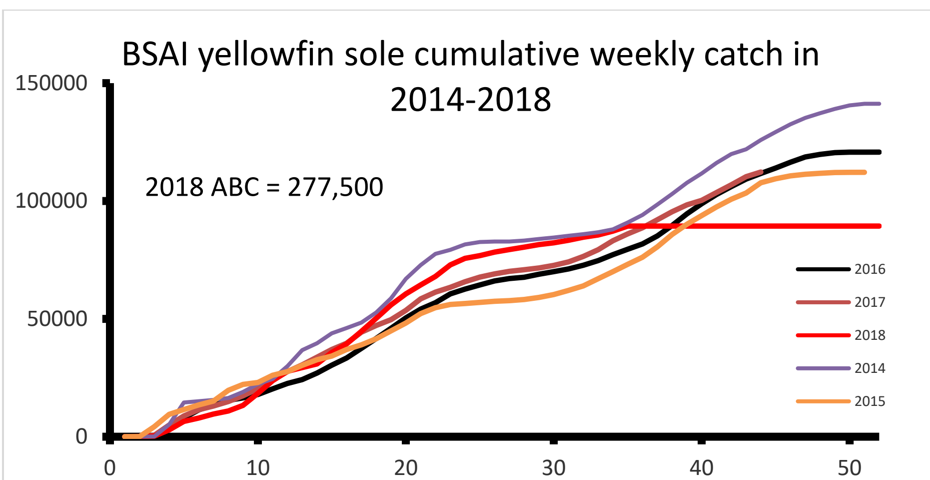


Figure 4.1. Yellowfin sole annual catch (1,000s t) in the Eastern Bering Sea from 1954-2018 (top panel) and catch by week (non CDQ) in 2018 through mid-September (bottom panel).

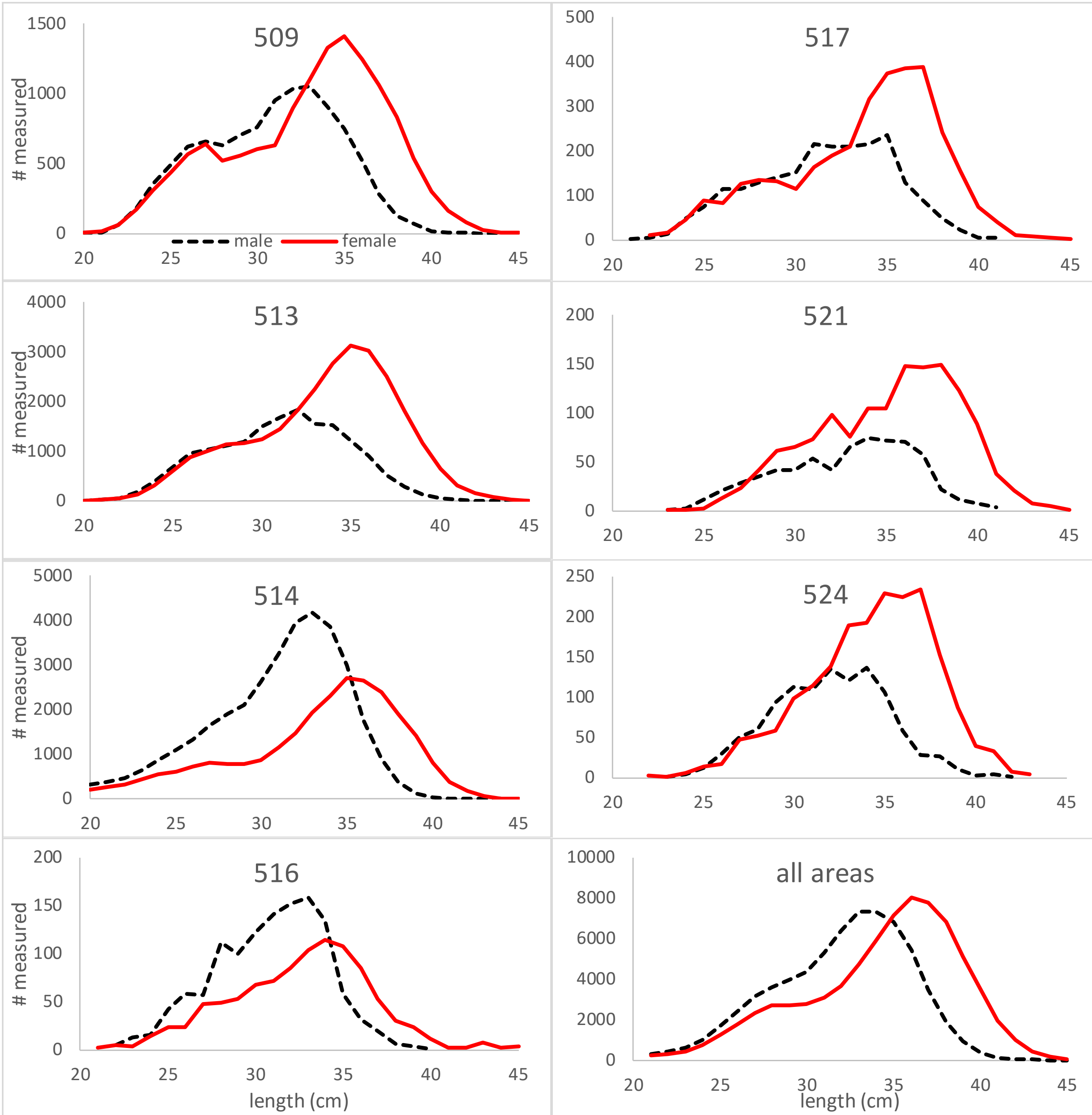
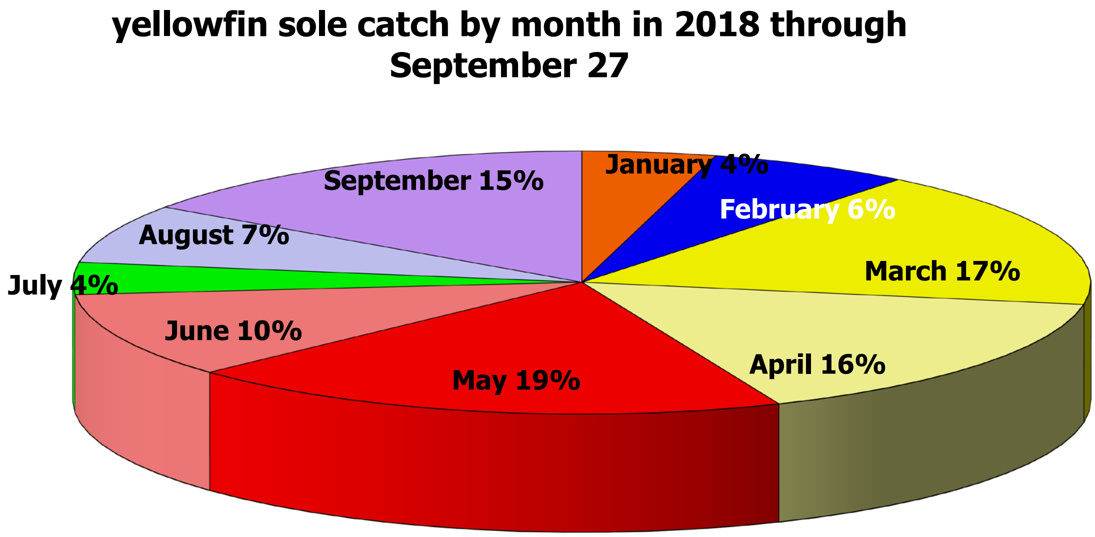


Figure 4.2. Size composition of the yellowfin sole catch in 2018(through mid-September), by subarea and total.



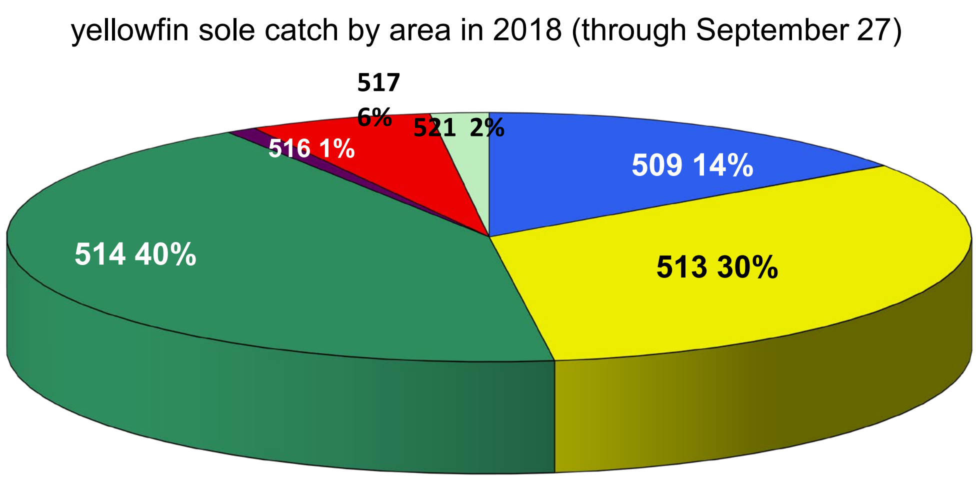
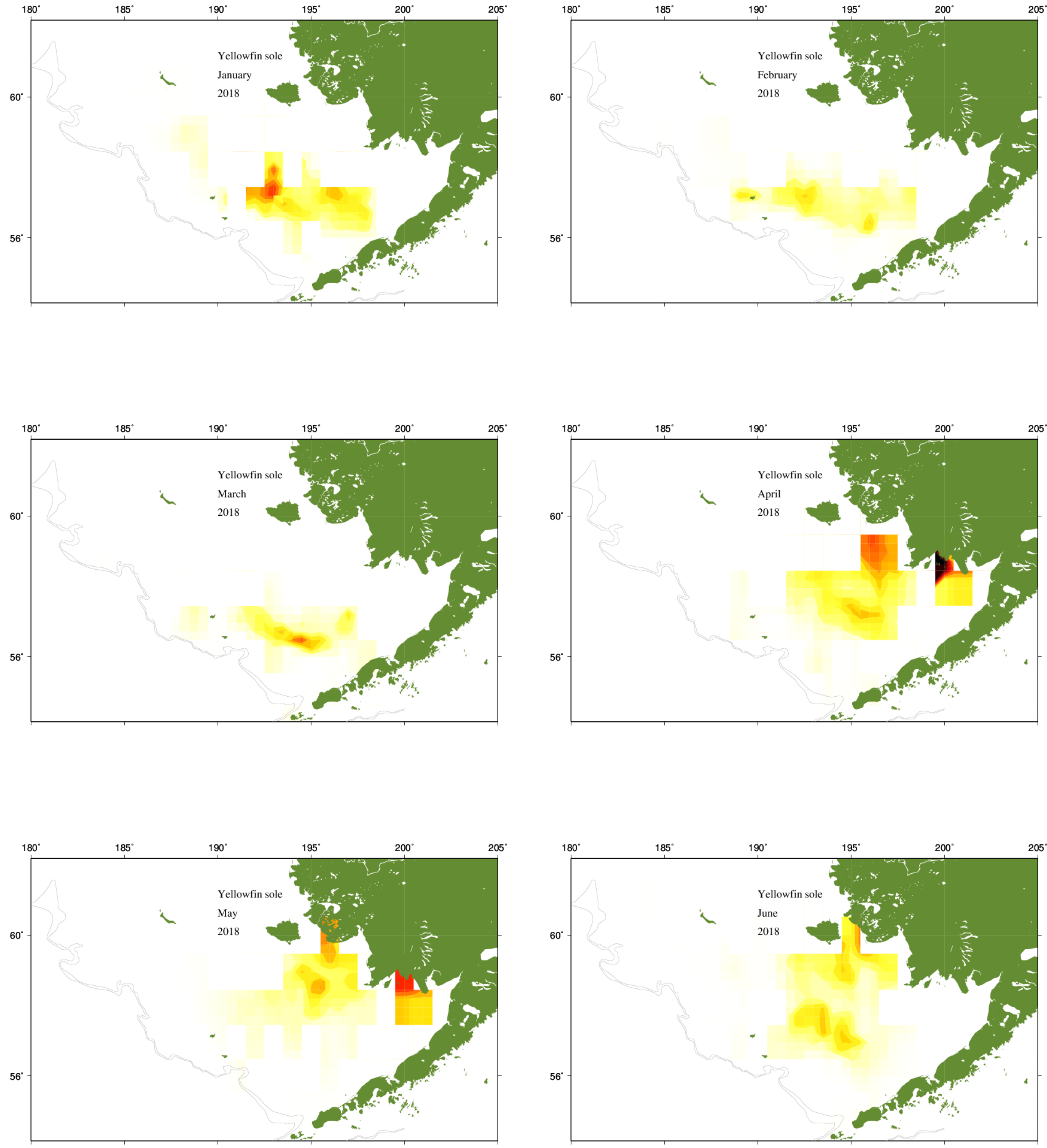


Figure 4.3 Yellowfin sole catch by month and area in the Eastern Bering Sea in 2018.


Yellowfin sole
January
2018
Yellowfin sole
February
2018
Yellowfin sole
March
2018
Yellowfin sole
April
2018
Yellowfin sole
May
2018
Yellowfin sole
June
2018
180°
185°
190°
195°
200°
205°
60°
56°

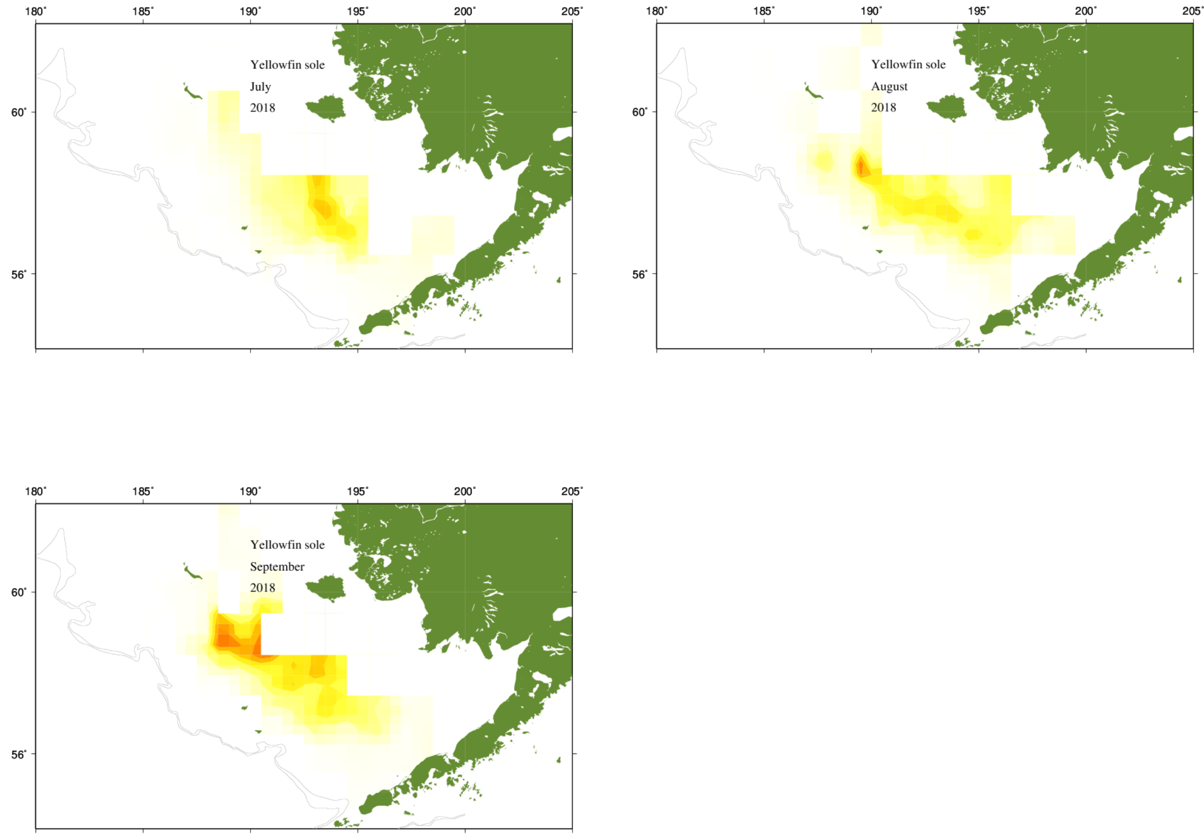


Figure 4.4 (Fishery locations by month).

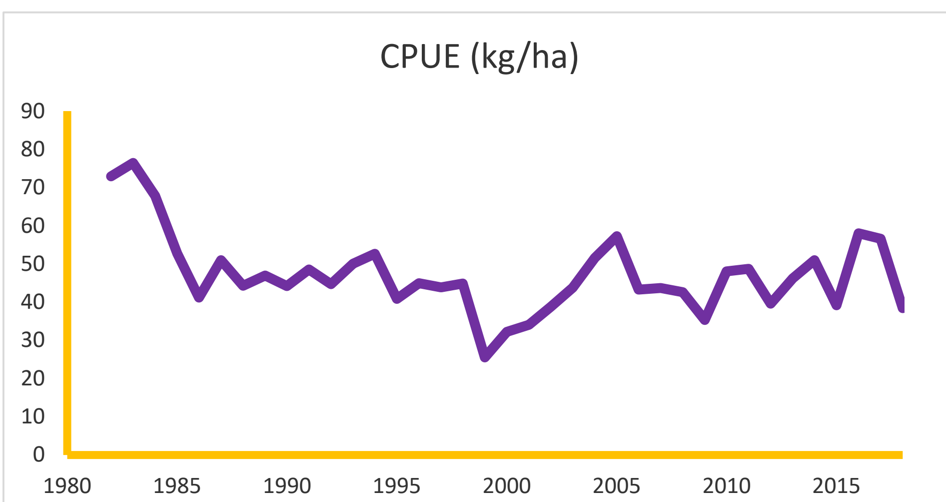


Figure 4.5. Yellowfn sole CPUE (catch per unit effort in kg/ha) from the annual Bering Sea shelf trawl surveys, 1982-2018.

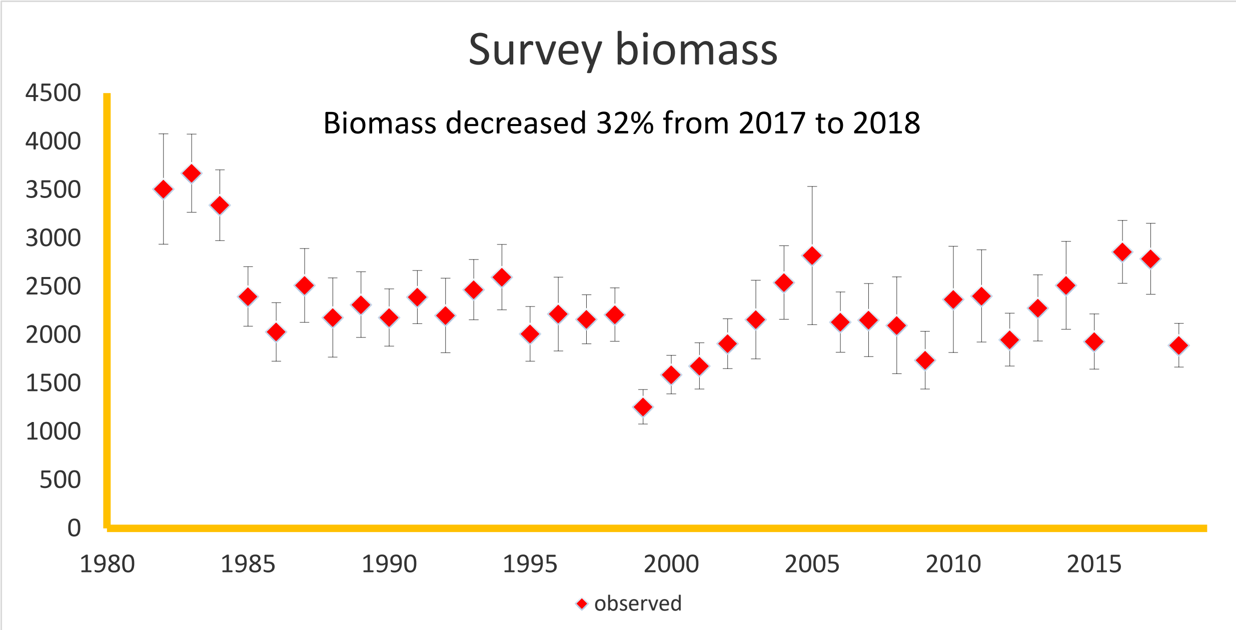


Figure 4.6. Annual bottom trawl survey biomass point-estimates and 95% confidence intervals for yellowfin sole, 1982-2018.

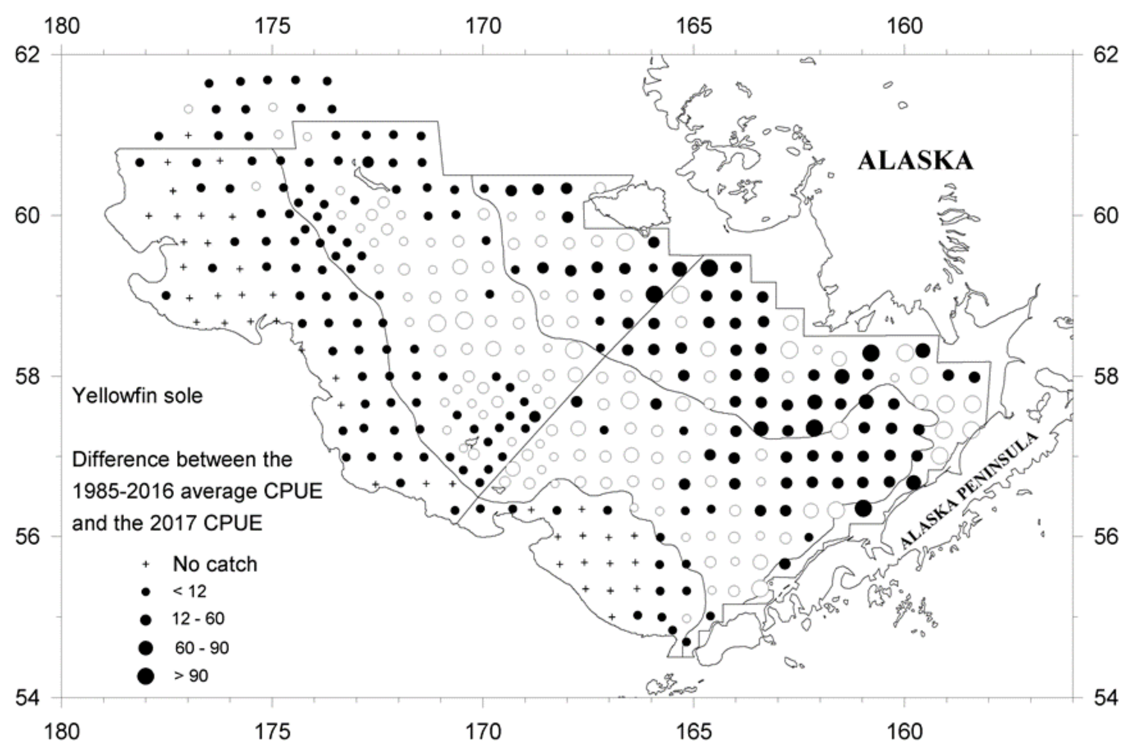


Figure 4.7. Difference between the 1985-2016 average trawl survey CPUE for yellowfin sole and the 2017 survey CPUE. Open circles indicate that the magnitude of the catch was greater in 2017 than the long-term average, closed circles indicate the catch was greater in the long-term average than in 2017.

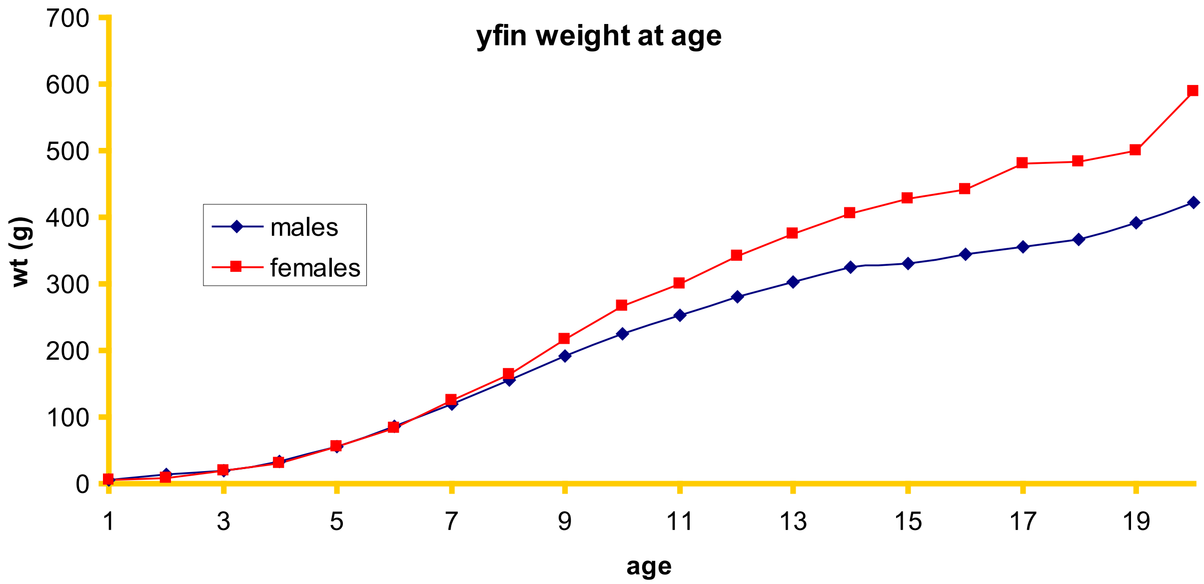


Figure 4.8 Estimates of average yellowfin sole weight-at-age (g) from trawl survey observations.

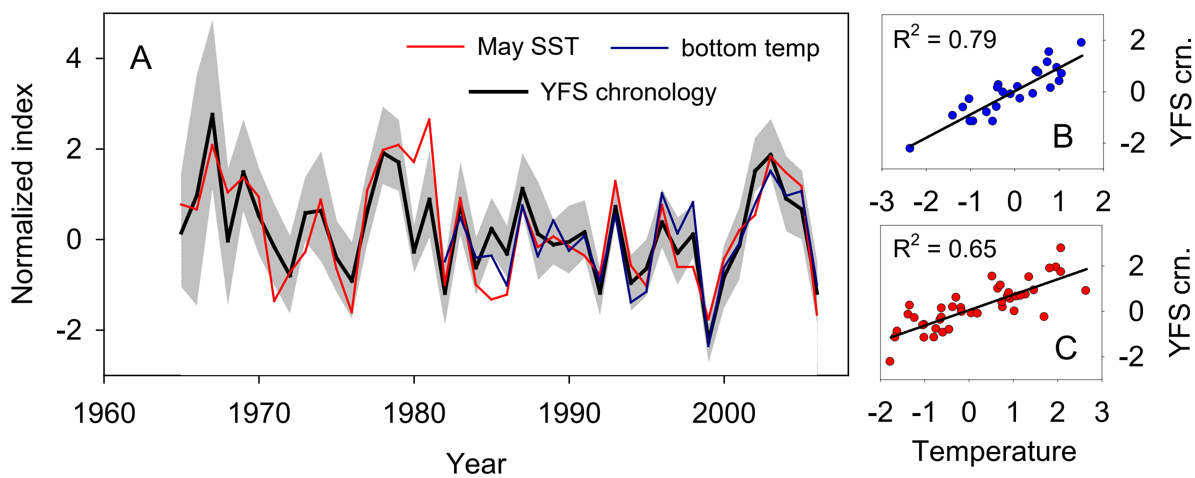


Figure 4.9. Master chronology for yellowfin sole and time series of mean summer bottom temperature and May sea surface temperature for the southeastern Bering Sea (Panel A). All data re normalized to a mean of 0 and standard deviation of 1. Correlations of chronologies with bottom temperature and sea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

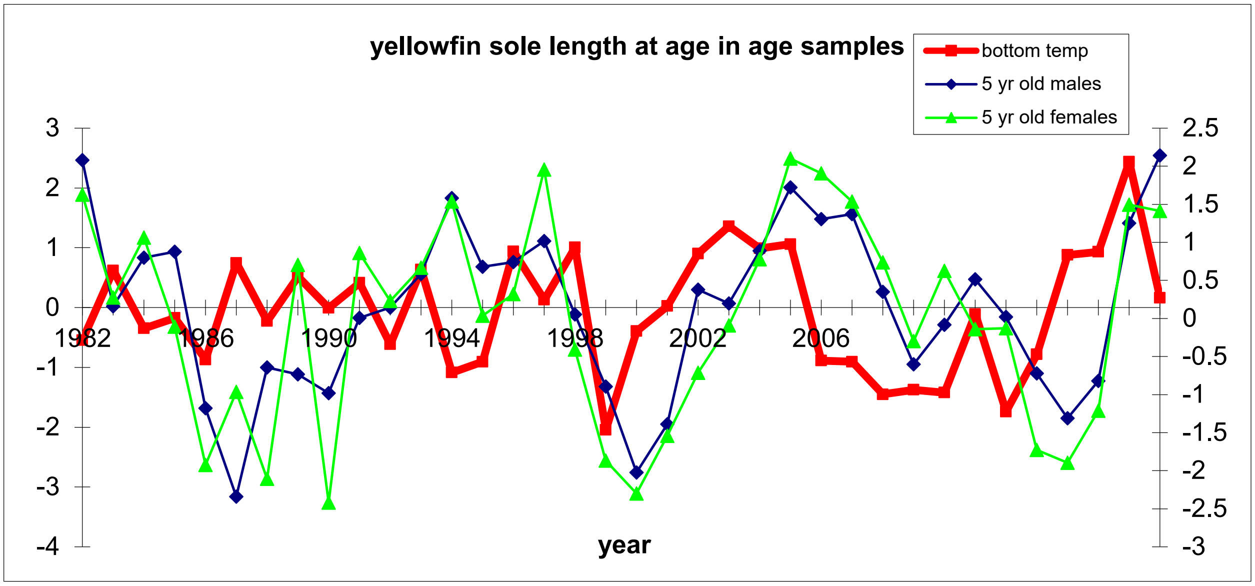


Figure 4.10—Yellowfin sole length-at-age anomalies, for males and females, and bottom temperature anomalies. Correspondence in these residuals is apparent with a 2-3 year lag effect from the mid-1990s to 2017. Late 1980s and early 1990s pattern may be a density-dependent response in growth from the large 1981 and 1983 year-classes.

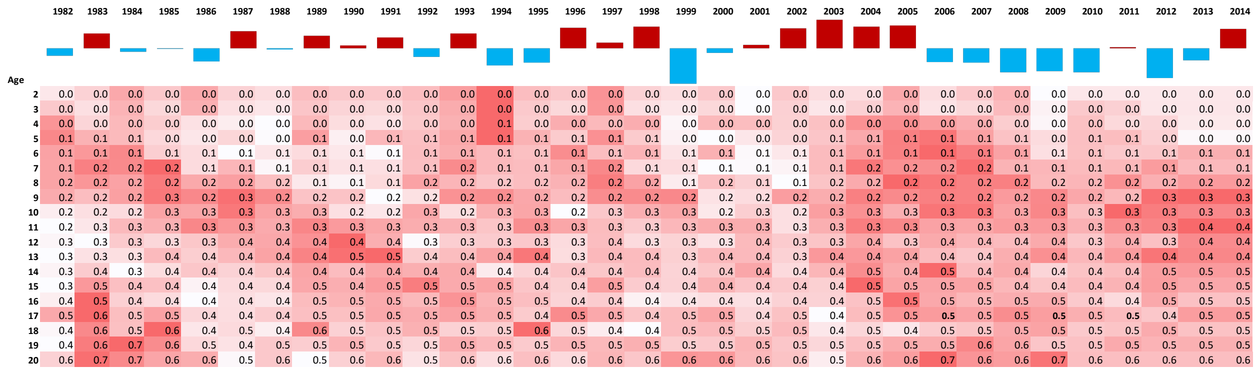


Figure 4.11—Results show the temperature anomalies (second row at top as bars) and observed values by age and year. Shadings within the matrix reflects relative weight-at-age (within a row) with darker red being heavier than average.

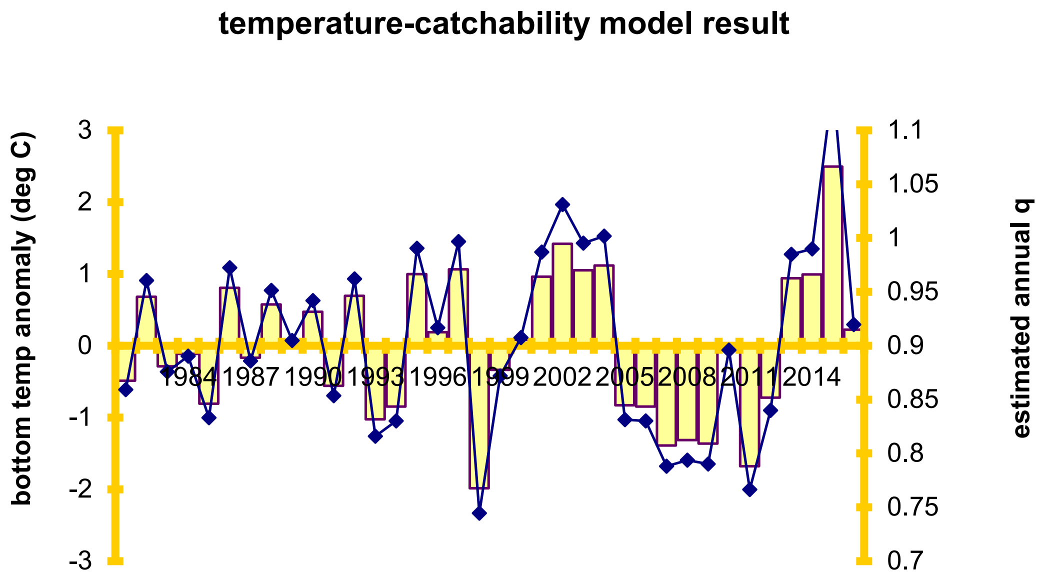


Figure 4.12. Average bottom water temperature from stations less than or equal to 100 m in the Bering Sea trawl survey (bars) and the stock assessment model estimate of q for each year 1982-2017.

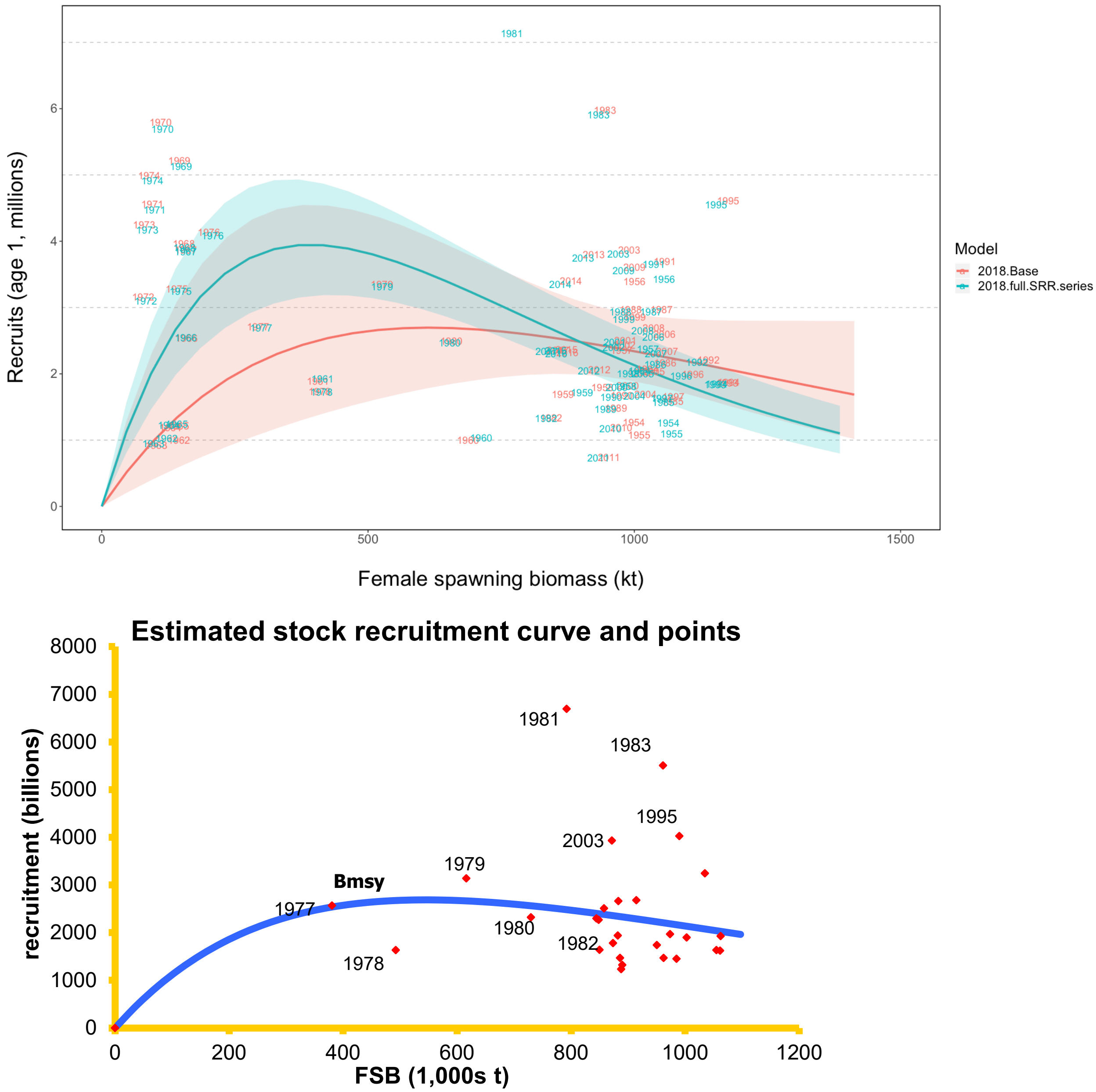


Figure 4.13. Fit of the Ricker (1958) stock recruitment model to two distinct stock recruitment time-series data sets, blue line full data set and red line 1978-2012 data set (top panel), and the fit to the assessment preferred model (model 18_1), lower panel).

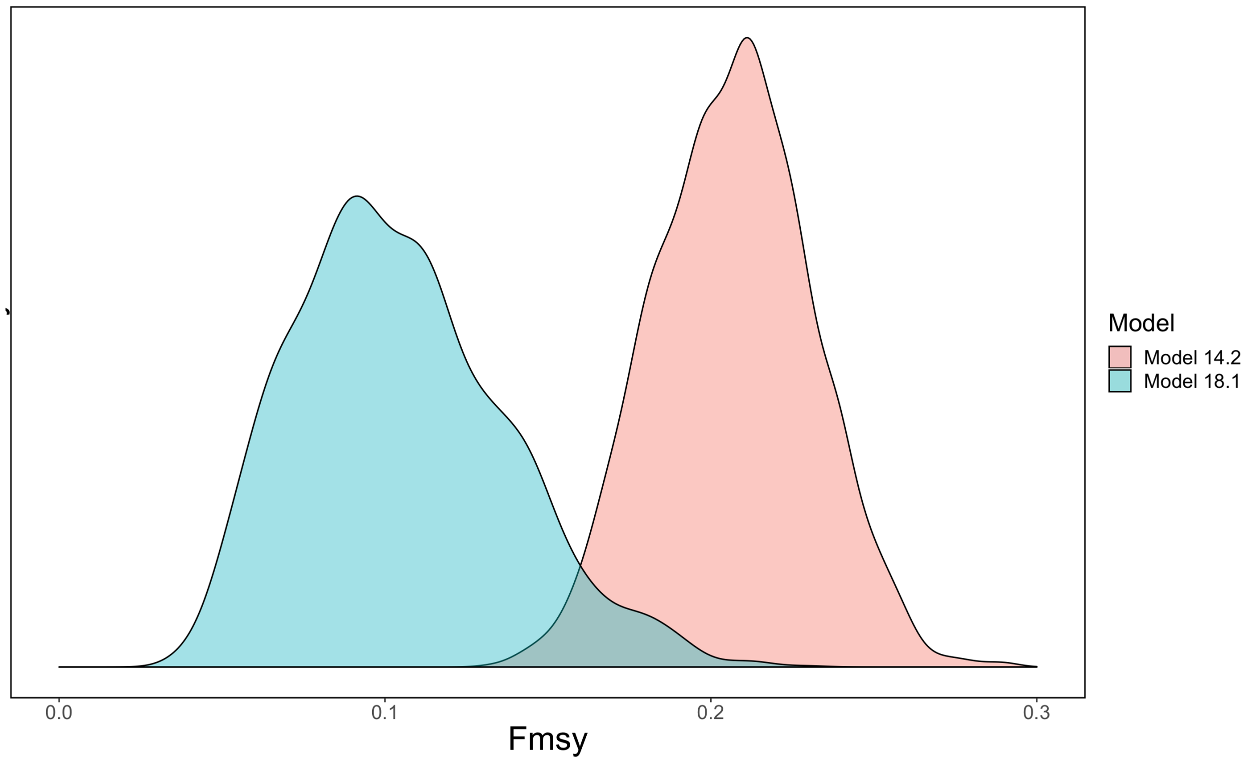


Figure 4.14. Posterior distributions of F_{msy} for the two models considered in the stock productivity analysis.

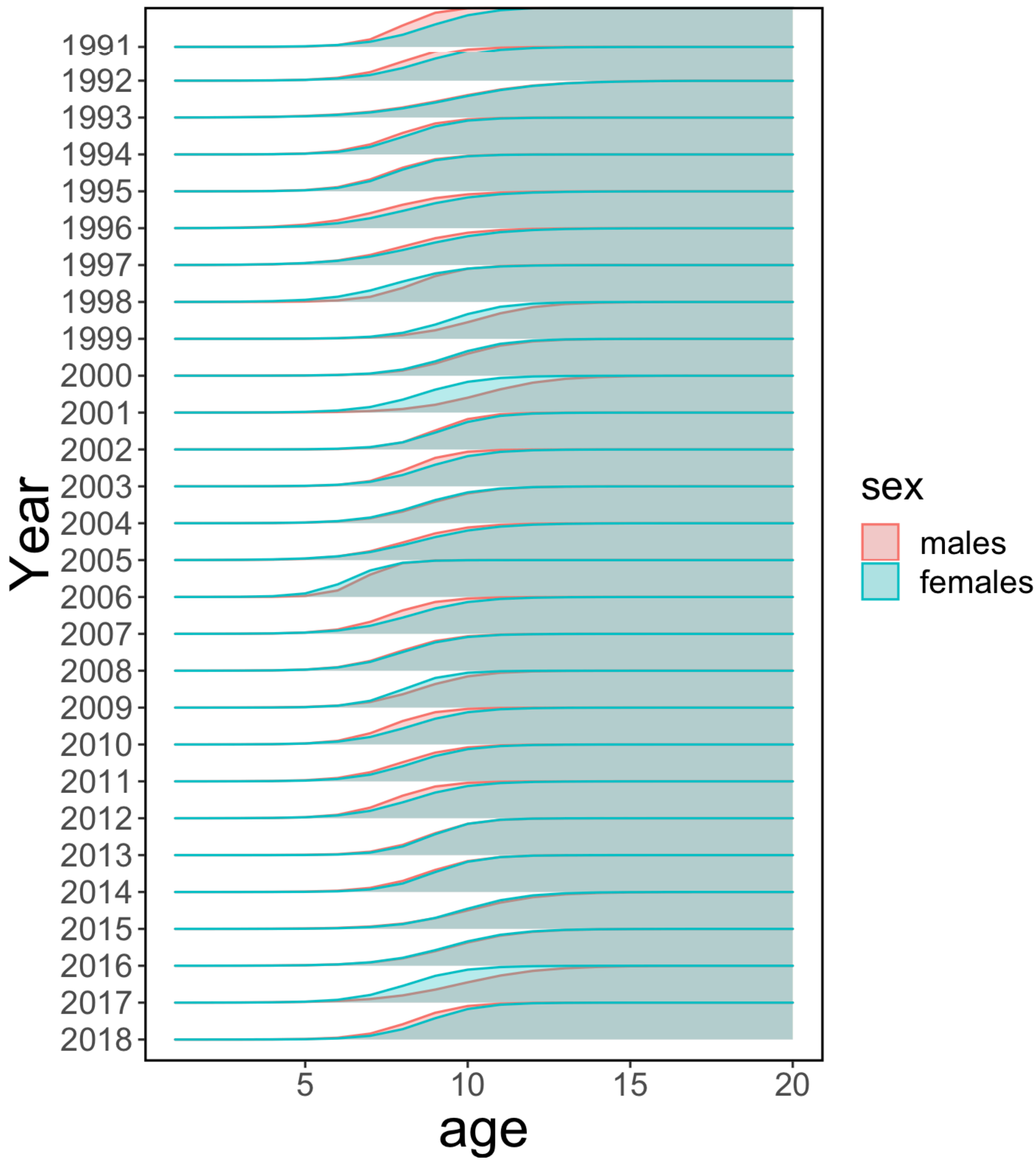


Figure 4.15a.Estimated male and female fishery selectivity by age and year.

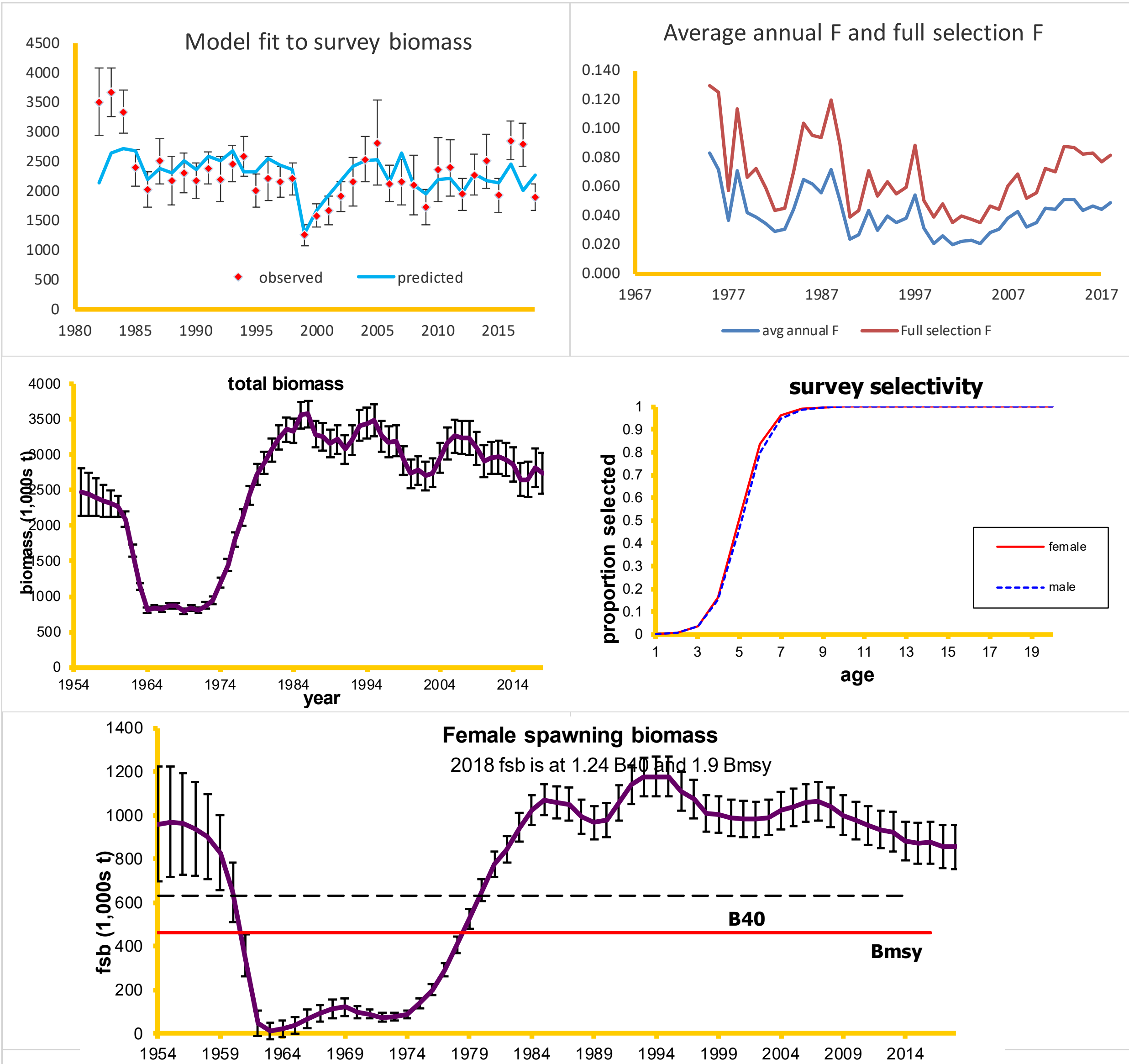


Figure 4.16. Model fit to the survey biomass estimates (top left panel), model estimate of the full selection fishing mortality rate throughout the time-series (top right panel), model estimate of total biomass (middle left panel), the model estimate of survey selectivity (middle right panel) and the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

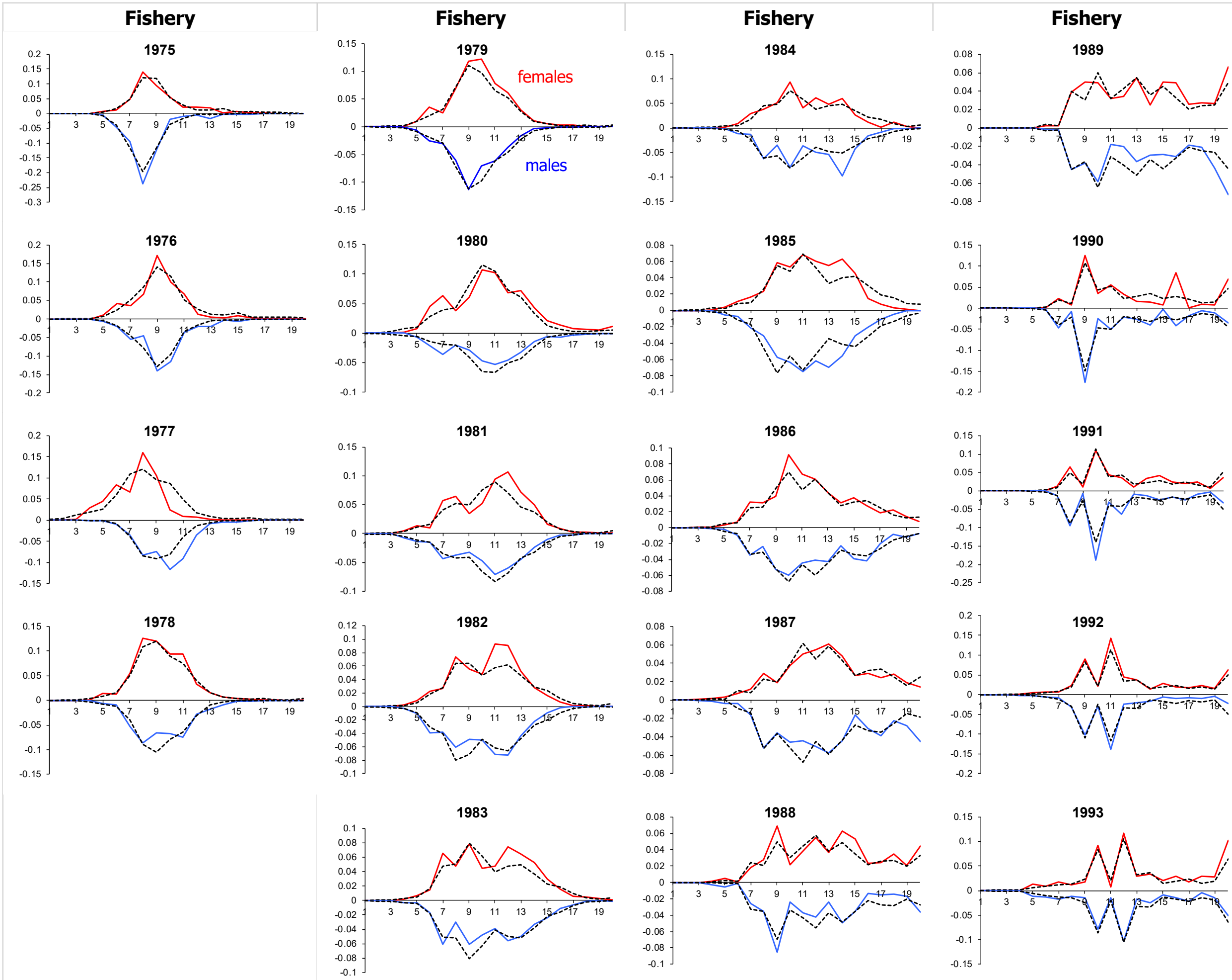


Figure 4.17. Stock assessment model fit to the time-series of fishery and survey age composition, by sex.

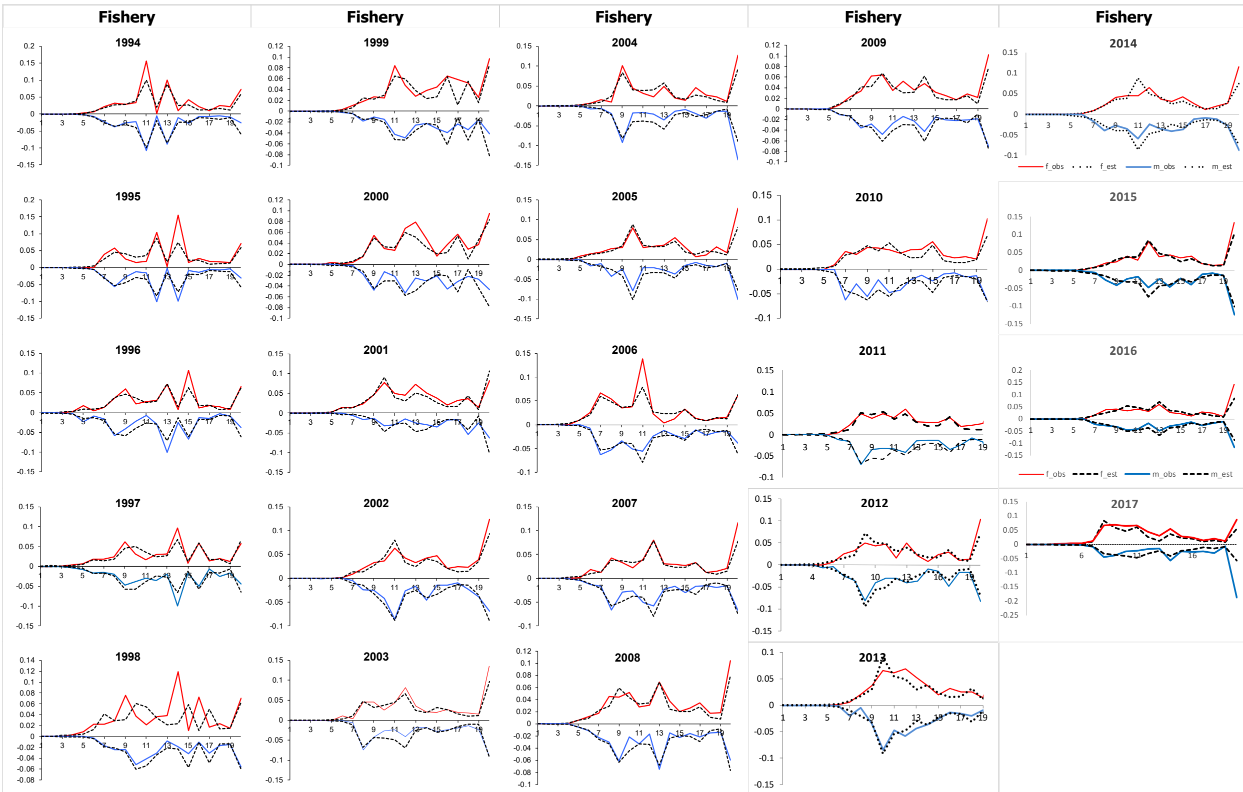


Figure 4.17 (continued).

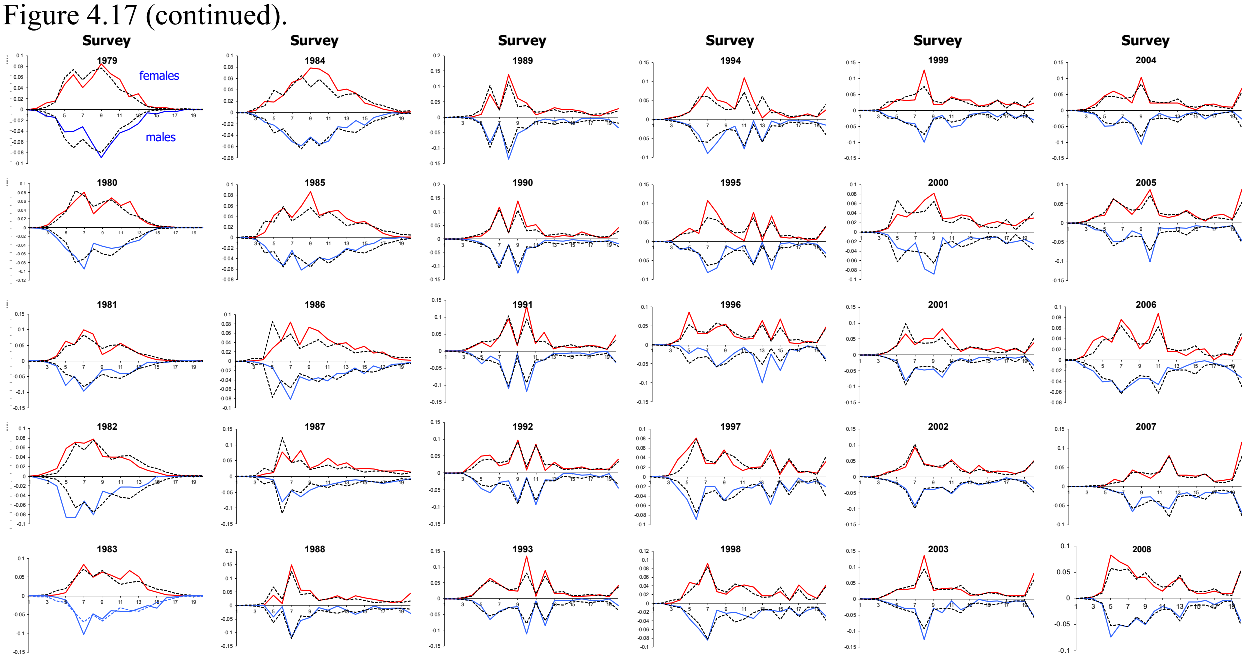


Figure 4.17 (continued).

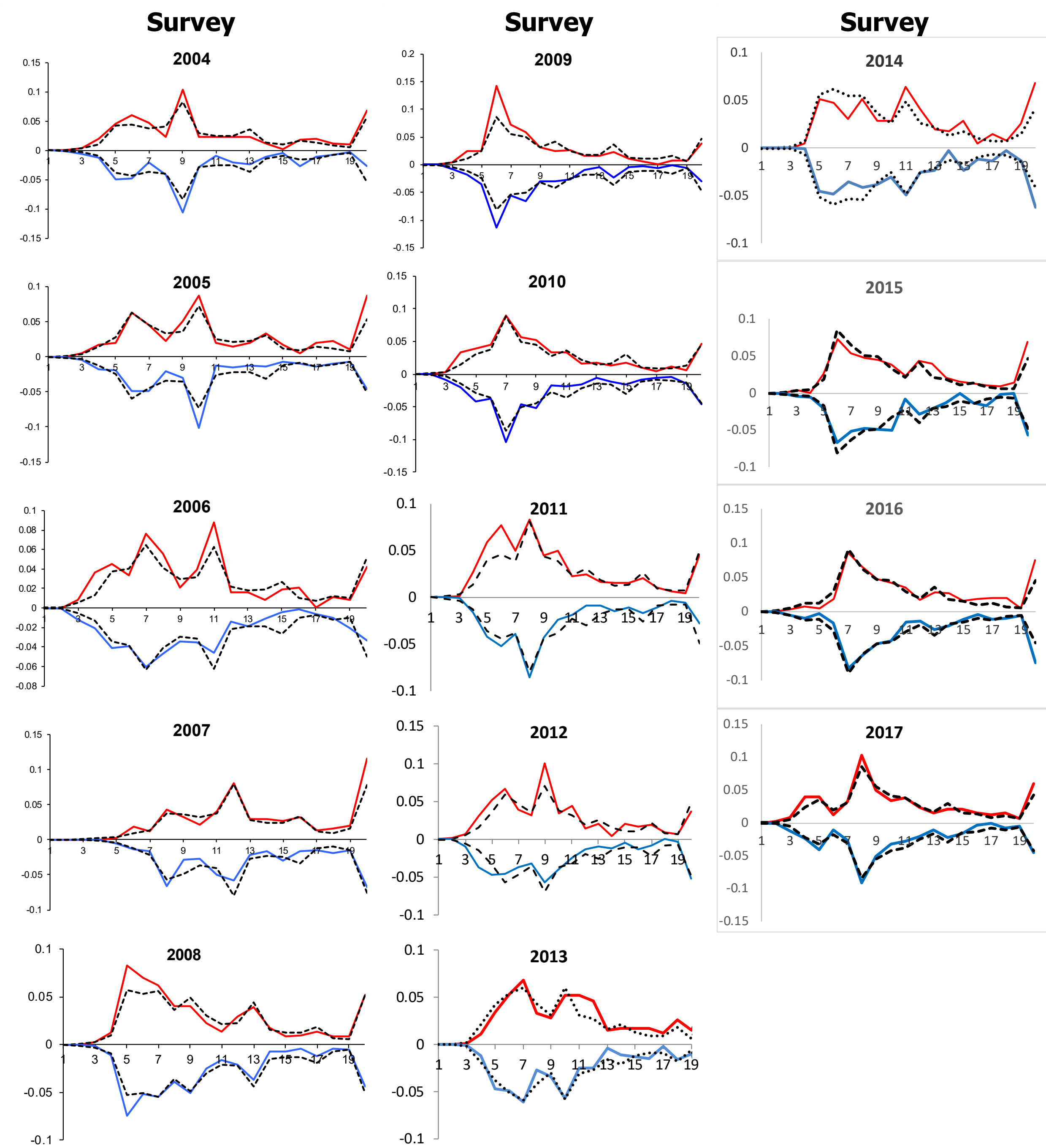


Figure 4.17 (continued).

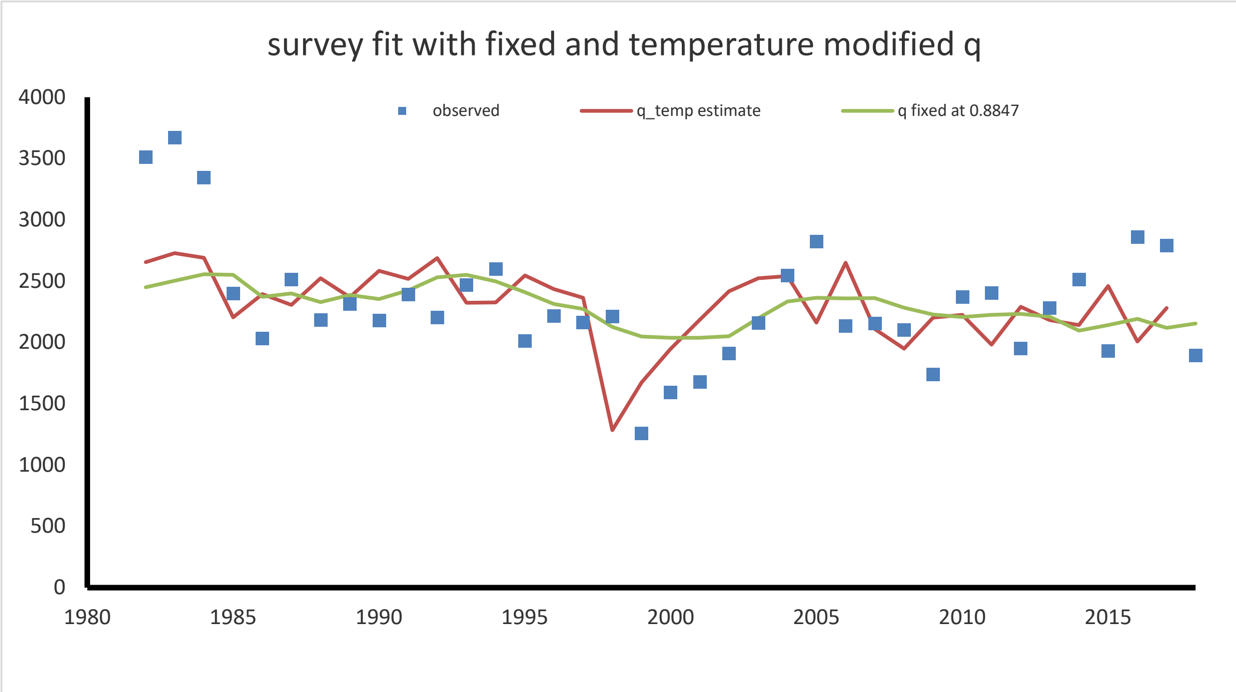


Figure 4.18. Comparison of the fit to the survey biomass using a fixed q and the q-bottom temperature relationship.

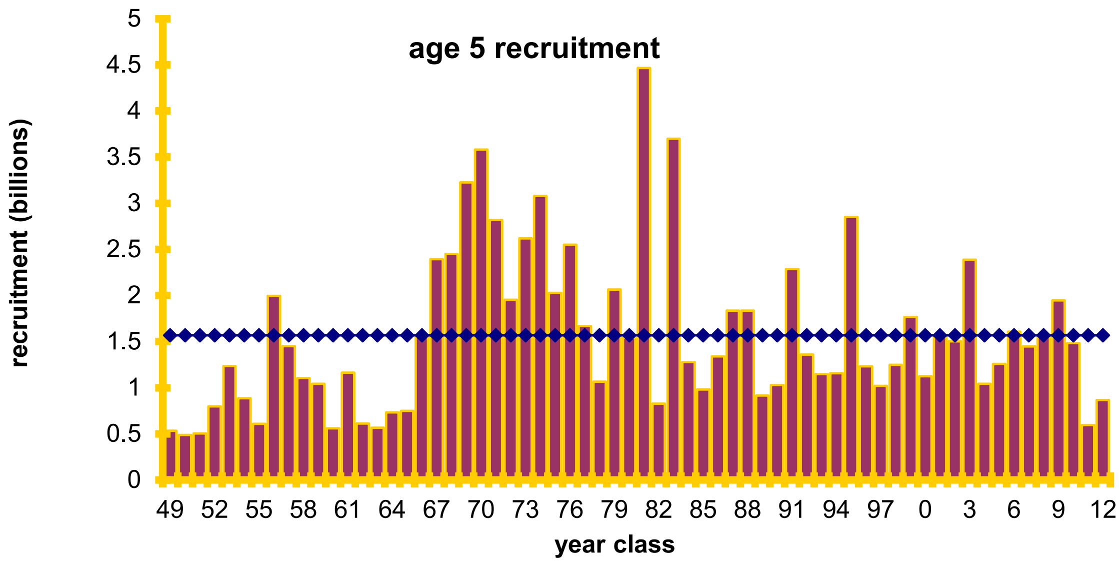


Figure 4.19. Year class strength of age 5 yellowfin sole estimated by the stock assessment model. The dotted line is the average of the estimates from 62 years of recruitment.

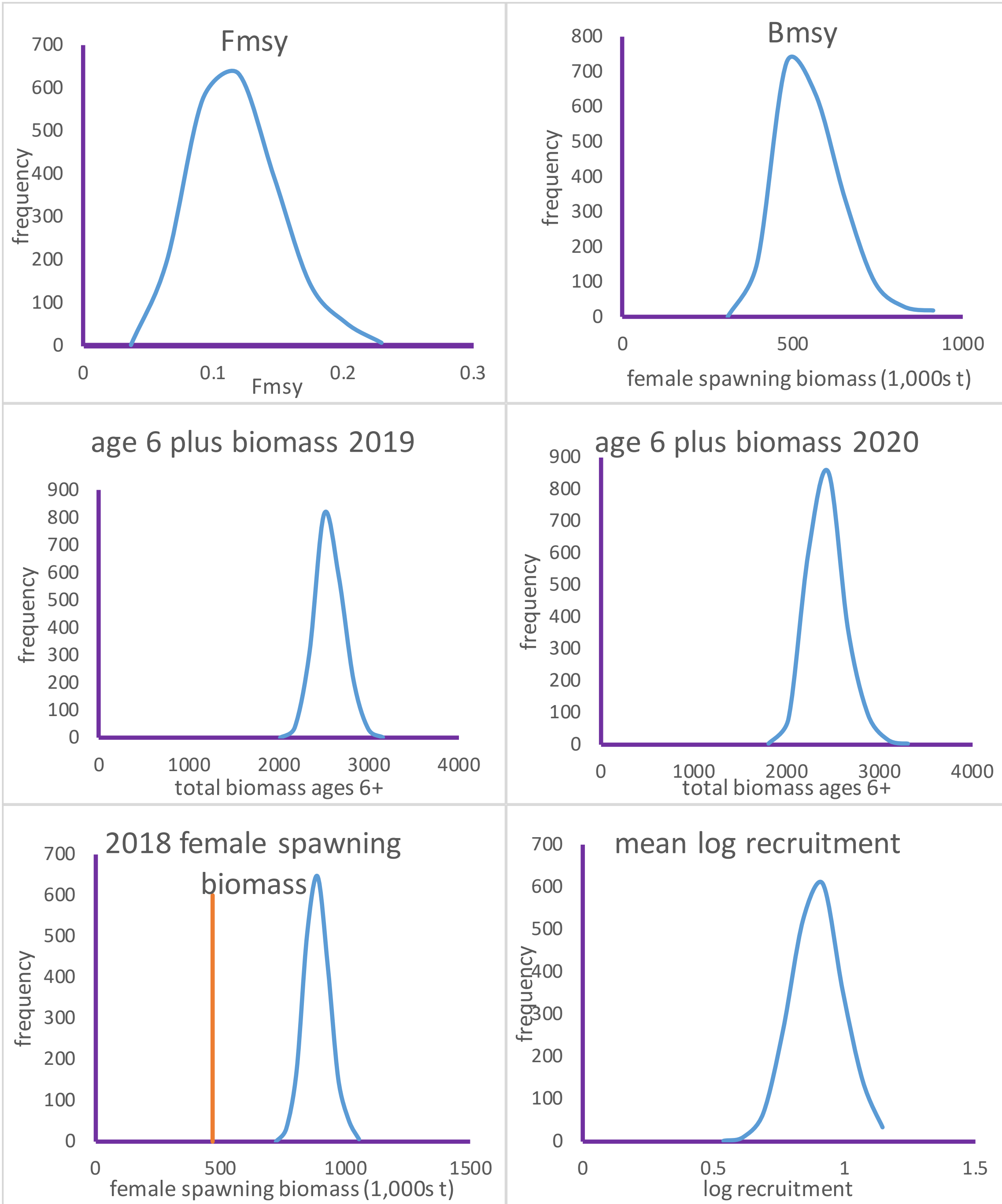


Figure 4.20. Posterior distributions of some important parameters estimated by the preferred stock assessment model (from mcmc integration).

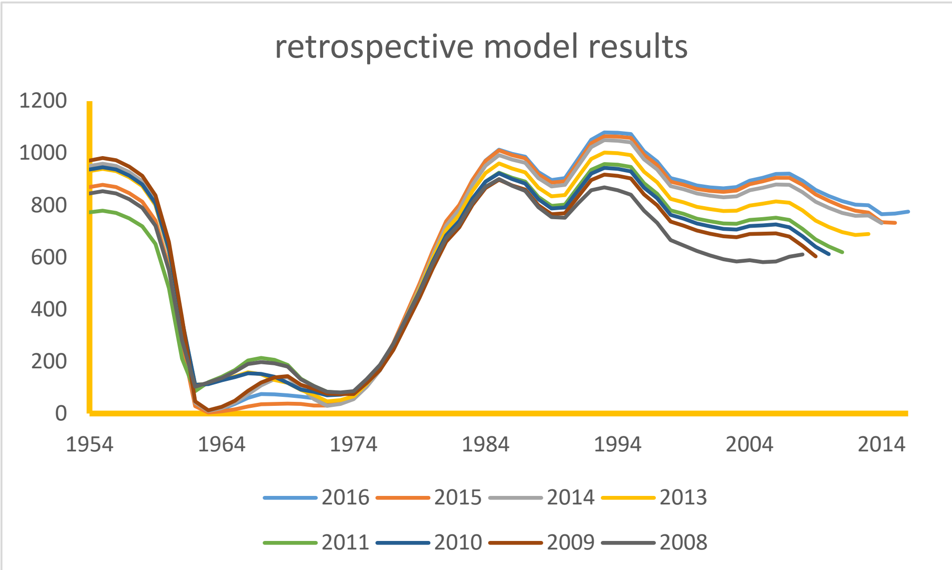


Figure 4.21—Retrospective plot of yellowfin sole female spawning biomass estimates (1,000s t), 2008-2016, from the recommended assessment model.

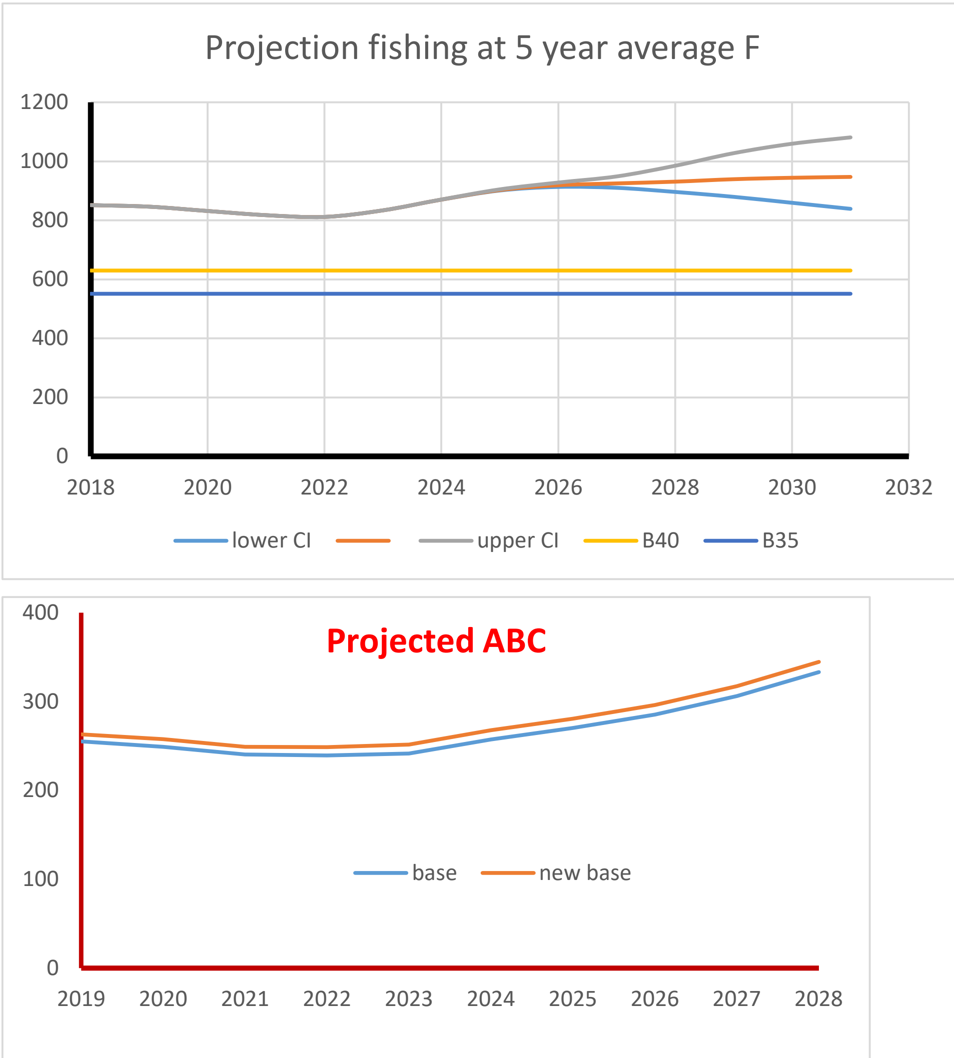


Figure 4.22. Projection of yellowfin sole female spawning biomass (1,000s t) at the average full-selection F from the past 5 years (0.104) through 2032 with $B_{40\%}$ and B_{msy} levels indicated (top panel). Tier 1 projection of yellowfin sole ABC assuming 150,000 t catch in each future year for models 14_1 (base model) and 18_1 (new base model) (bottom panel).

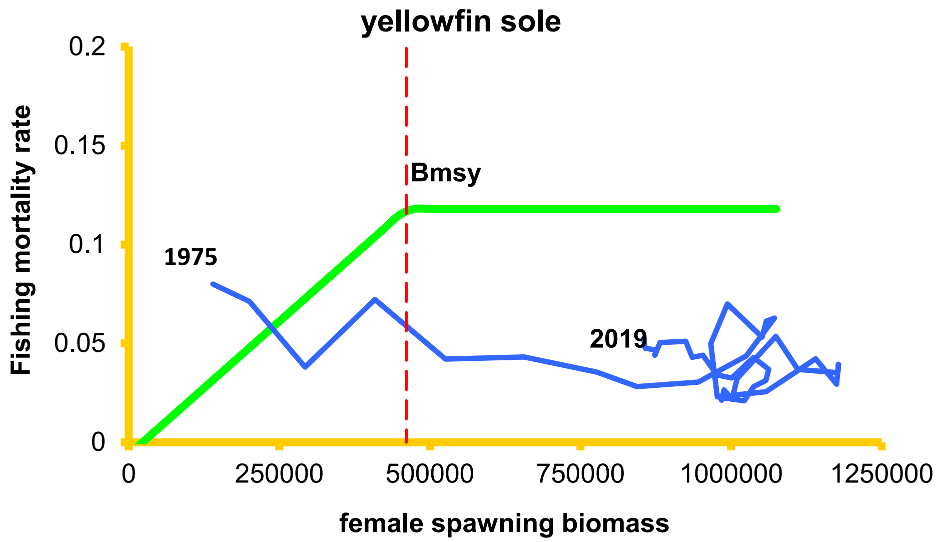


Figure 4.23. Phase plane figure of the time-series of yellowfin sole female spawning biomass relative to the harvest control rule with 1975 and 2019 indicated.

Appendix

	weight (kg)
2010	118576
2011	100900
2012	83380
2013	75044
2014	82574
2015	64837
2016	97794