STATUS OF THE WIDOW ROCKFISH RESOURCE IN Y2K

Erik H. Williams, Alec D. MacCall, Stephen V. Ralston, and Donald E. Pearson

National Marine Fisheries Service
Southwest Fisheries Science Center
Santa Cruz/Tiburon Laboratory
3150 Paradise Drive
Tiburon, CA 94920

Appendix to

STATUS OF THE PACIFIC COAST GROUNDFISH FISHERY THROUGH 2000 AND RECOMMENDED ACCEPTABLE BIOLOGICAL CATCHES FOR 2001

STOCK ASSESSMENT AND FISHERY EVALUATION

Pacific Fishery Management Council
2130 SW Fifth Avenue, Suite 224
Portland, OR 97201

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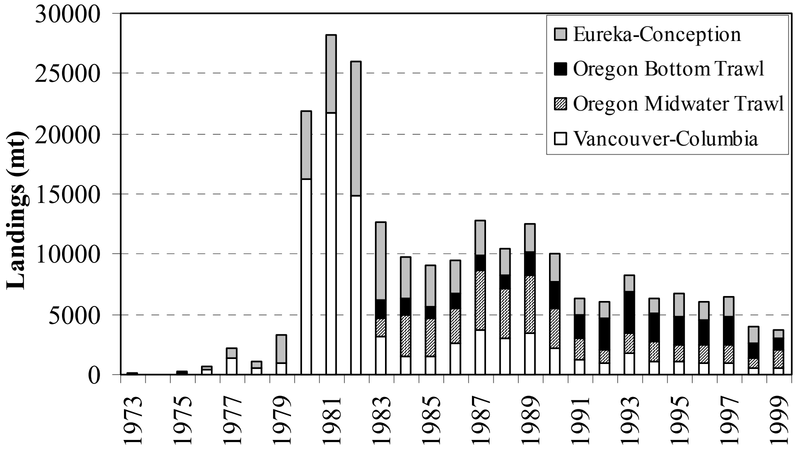
Executive Summary

Stock: This assessment applies to widow rockfish (*Sebastes entomelas*) located in the territorial waters of the U.S., including the Vancouver, Columbia, Eureka, Monterey, and Conception areas designated by the International North Pacific Fishery Commission (INPFC).

Catches: U.S. commercial catches of widow rockfish began in 1973 (117 mt), peaking soon afterwards in 1981 (28,146 mt). Since the 1981 peak there has been a steady decline in the landings of widow rockfish to 3,761 mt in 1999 (Figure 1). The dominant gear type historically has been the midwater trawl, but in recent years bottom trawl catches have nearly matched the midwater trawl catches.

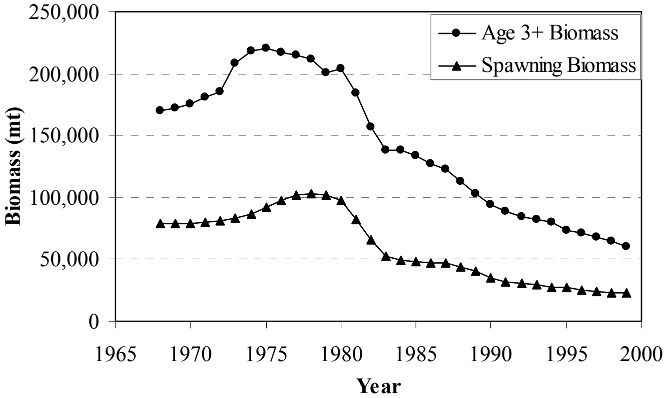


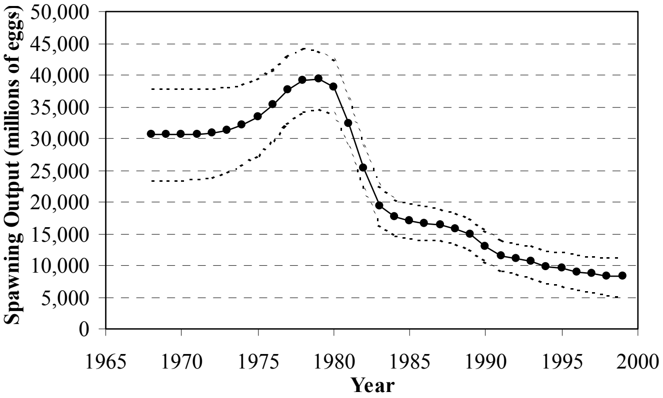
Data and Assessment: The last assessment of widow rockfish occurred in 1997 using the age-based version of the Stock Synthesis program (Ralston and Pearson 1997). For this assessment an age-based model, similar to Stock Synthesis, was programmed in the AD Model Builder 3.10 software (Otter Research, Ltd.; Fournier 1996). Data time series used in the 1997 assessment were updated for this assessment with the addition of the Alaska Fisheries Science Center triennial bottom trawl survey biomass estimates and a re-examination of the Pacific whiting bycatch information, as suggested by the 1997 widow rockfish stock assessment review panel.

Unresolved Problems and Major Uncertainties: The information for discards used in this assessment is highly uncertain and potentially could have great effects on model outcome. The primary sources of information on trends in abundance of widow rockfish come from the Oregon logbook data and the triennial trawl survey, both of which are questionable sources of information for widow rockfish. Natural mortality has been fixed at 0.15 based on previous assessments, but the validity of this estimate is uncertain.

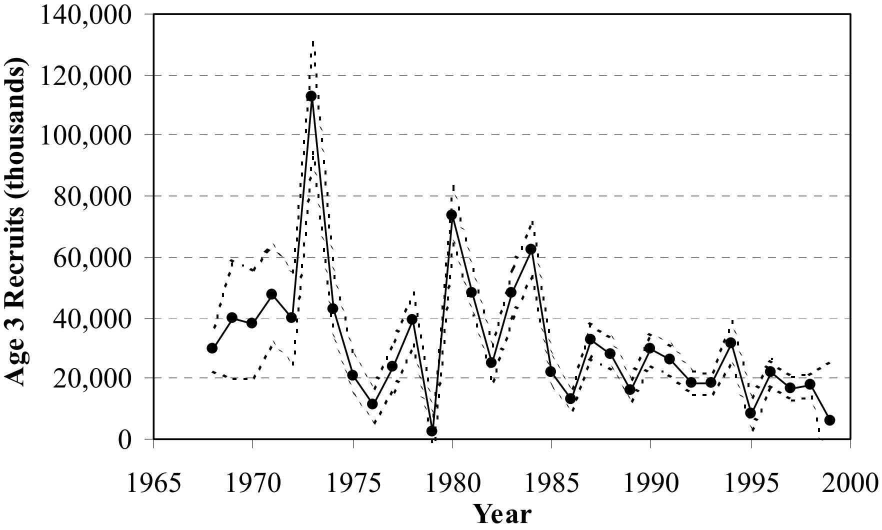
Reference Points: For widow rockfish the estimates of fishing mortality (F) corresponding to $F_{40\%}$, $F_{50\%}$, and $F_{65\%}$ are 0.171, 0.122, and 0.07, respectively. The spawning output-per-recruit (SPR) at F=0 is 1.062.

Stock Biomass: Stock biomass has shown a steady decline since 1975, soon after the fisheries for widow rockfish began. The current spawning output level (8,223) is at 23.6% of the unfished level (34,900), which was computed using the average recruitment from 1968-82 multiplied by the spawning output-per-recruit at *F*=0.



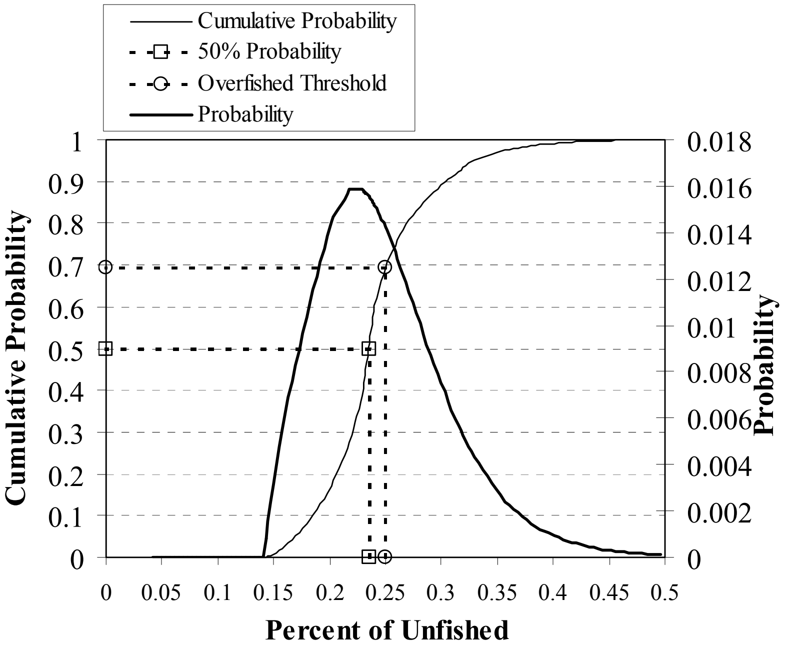


Recruitment: Recruitment is variable in the early years of the time series, but in recent times has been fairly stable with a slight decreasing trend which seems to be following the decreasing trend in biomass.



<u>Exploitation Status</u>: Three methods are used to evaluate whether widow rockfish abundance is below the minimum stock size threshold (MSST) and warrants determination of an overfished condition.

Default definition: The estimated spawning output in 1999 is 8223 units, which is 23.6% of the estimated unfished level (34900 units) as computed by average recruitment from 1968-82 multiplied by SPR at *F*=0, and is below the default MSST value of 25% established by FMP Amendment 11.



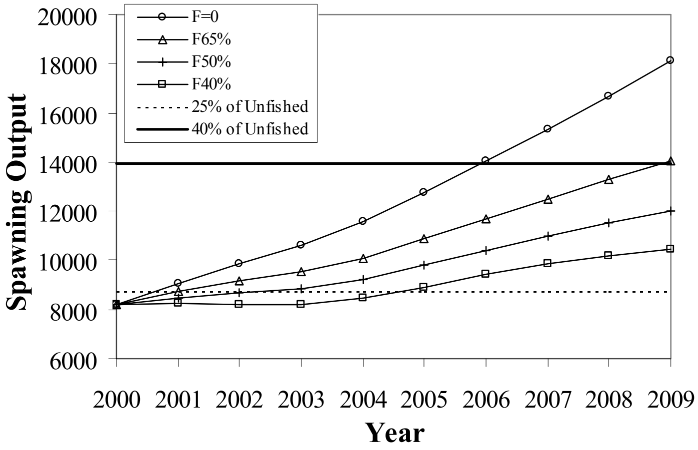
National Standard Guideline approach: The MSST is 50% of the abundance producing maximum sustainable yield (Bmsy). A first approximation uses the biomass producing maximum surplus recruitment (Bmsr) as a proxy for Bmsy. The Beverton-Holt SRR indicates that the stock is healthy (near Bmsr), while the Ricker SRR indicates that the stock is near the MSST of 0.5Bmsr. A second approximation uses an equilibrium relationship between yield per recruit and spawning output per recruit to convert stock-recruitment relationships to equilibrium yield curves. Results are similar to those from the first approximation. The following table summarizes estimates of stock status (values of B1999/Bmsy) for alternative stock-recruitment models and alternative methods of estimation. A value below 0.5 qualifies as overfished.

	Beverton-Holt		Ricker	
Approach:	MSR	MSY	MSR	MSY
MinSSQ (Best fit)	0.63	0.63	0.53	0.54
Maximum Posterior Likelihood	1.19	1.11	0.51	0.53
SPR=50% at Fmsy	0.84	0.82	0.62	0.61

Management Performance: See below.

Year	Harvest Guideline	Allowable Biological Catch	Landings	Catch
1989	12100	12400	12515	14518
1990	12400	8900	10062	11671
1991	7000	7000	6350	7366
1992	7000	7000	6054	7023
1993	7000	7000	8242	9561
1994	6500	6500	6397	7420
1995	6500	7700	6712	7786
1996	6500	7700	6079	7052
1997	6500	7700	6500	7541
1998	5090	5750	3940	4571
1999	5090	5750	3761	4363
2000	5090	5750		

Forecasts: The forecasts indicate that widow rockfish spawning output is likely to remain below 25% of the unfished level, the overfished threshold, through 2000 under any of the exploitation levels examined here. At *F*=0 it appears that the widow rockfish spawning output will increase fairly rapidly, exceeding 40% of the unfished level by 2006. The fishing rate corresponding to $F_{65\%}$ results in the population status reaching 40% of the unfished level by 2009.



Decision Table: A decision table was not deemed necessary since the status of the population is uncertain. Alternate levels of unfished population size are presented as well as forecasts of yield at various harvest policies. The choices seem to be to declare the population overfished, which then would require a rebuilding schedule following future harvest rates similar to those shown for the $F_{65\%}$ harvest policy, or to not declare the population overfished, which results in an array of possible harvest rates, ranging from the default policy of $F_{50\%}$ to zero fishing mortality.

Recommendations: The assessment generally seems to indicate the population is slightly below the overfished threshold (23.6% of unfished). All the forecasts indicate the population will begin to rebuild and rise above the overfished threshold. The most conservative approach would be to declare the population overfished and proceed with an $F_{65\%}$ harvest rate for the next 10 years, which would achieve a population status over 40% in 2009. If the population is not declared overfished, then the harvest rate is not set for the next 10 years. The $F_{50\%}$ is likely too aggressive given the forecast indications that the population will only reach 25.3% of unfished by 2003. One possible compromise is to choose a conservative harvest rate that is highly likely to get the population over the 25% of unfished mark in the next 3 years and allow the next widow rockfish assessment to dictate a more appropriate long term harvest policy.

Sources of Additional Information: The California logbook index was examined in this analysis, but ultimately removed from the final model based on concerns about different gear types going into the index calculations. Fishery data from Soviet Union vessels operating off the U.S. West Coast from 1970-78 were examined, but poor record keeping and low catches in some years limited the utility of this data.

Introduction

Widow rockfish (*Sebastes entomelas*) is an important commercial groundfish species belonging to the scorpionfish family (Scorpaenidae). It ranges from southeastern Alaska to northern Baja California, where it frequents rocky banks at depths of 25-370m (Eschemeyer et al. 1983). In those habitats it feeds on small pelagic crustaceans and fishes, including especially *Sergentes similis*, myctophids, and euphausiids (Adams 1987). There is no evidence that separate genetic stocks of widow rockfish occur along the Pacific coast and the species has been treated as one stock with four separate fisheries (Hightower and Lenarz 1990; Rogers and Lenarz 1993; Ralston and Pearson 1997).

A midwater trawl fishery for widow rockfish developed rapidly in the late 1970’s and increased rapidly in 1980-82 (Gunderson 1984). Large concentrations of widow rockfish had evidently gone undetected because aggregations of this species form at night and disperse at dawn, an atypical pattern for rockfish. Since the fishery first developed, substantial landings of widow rockfish have been made in all three west coast states.

Management of the fishery began in 1982 when 75,000 lbs trip limits were introduced in an effort to curb the rapid expansion of the fishery (Tables 2-3). These were reduced to 30,000 lbs in 1983 and the fishery was managed by alteration of trip limits within the fishing season. A 10,500 mt/yr Allowable Biological Catch (ABC) for widow rockfish was instituted in 1983 (Table 3), but no harvest guideline was established. This form of management continued with alterations in ABC and trip limits until 1989 when a 12,100 mt/yr harvest guideline was implemented (Tables 2-3). From 1994-1997 the harvest guideline was changed to 6,500 mt and then further reduced to 5090 mt/yr in 1998, where it remains to this day. The current ABC is 5750 mt/yr, based on the last stock assessment (Ralston and Pearson 1997).

Data

Biological Information

Growth in length for widow rockfish has been described using von Bertalanffy growth equations in two papers by Lenarz (1987) and Pearson and Hightower (1991). In their analyses it was determined that females attain a larger size compared to males and fish from the northern part of the range tend to be larger at age compared to those in the south. For these reasons we chose to use the sex specific and area specific estimates for length-at-age. Furthermore, we chose to use the estimates listed in Pearson and Hightower (1991), shown below and in Figure 2, because they are from a more recent and comprehensive analysis of widow rockfish growth compared to the analysis by Lenarz (1987). In order to match the fisheries, we used the Columbia-Eureka INPFC area border (43^{o} Lat.) to delineate north from south.

Parameter	Females (north)	Males (north)	Females (south)	Males (south)
L_{inf} (cm)	50.54	44.0	47.55	41.5
K	0.14	0.18	0.2	0.25
t_0	-2.68	-2.81	-0.17	-0.28

Sex specific weight-at-age estimates were computed using the length-at-age estimates above with sex specific length-weight regressions for widow rockfish developed by Barss and Echeverria (1987) (Figure 2). The length-weight regression equation is $W = \alpha L^{\beta}$, where W is the weight (g) and L is the length (cm). The sex specific parameter values used in this assessment are listed below:

Parameter	Females	Males
α	0.00545	0.01188
β	3.28781	3.06631

Estimates of maturity and fecundity of female widow rockfish were obtained from Barss and Echeverria (1987) and Boehlert et al. (1982), respectively. Age specific maturity estimates were taken directly from the literature instead of fitting a parametric model (Figure 3), while age specific fecundity was computed using the weight-fecundity regression,

$F = 605.71\ W - 261830.7$, where F is fecundity (# eggs) and W is weight (g),

with the weight-at-age estimates from above. The weight-fecundity regression applied to the southern weight-at-age estimates resulted in negative values for ages 3 and 4. The weight-fecundity regression developed by Boehlert et al. (1982) was based on fish captured from Oregon and apparently does not apply to widow rockfish in the south. The maturity estimates shown in Figure 3 indicate a substantial difference in maturity-at-age between the north and south, with the northern fish maturing at an older age. Lacking any other estimate of fecundity for the south, we applied the weight-fecundity regression from the north and modified the estimates for ages 3-5 to approximate an asymptote to 0 (Figure 3).

Landings

For the period 1980-99, landings statistics used in this assessment were derived from four sources. In particular, State of Washington commercial trawl landings by year and INPFC area were provided by the Washington Department of Fish and Wildlife from expansions of port sampled data. Secondly, Oregon commercial landings by year, area, and gear type were extracted from the PacFIN database. California commercial landings by year, area, and gear type were obtained from expansions described by Pearson and Erwin (1997). Lastly, the very small annual recreational take of widow rockfish was extracted from the Marine Recreational Fishing Statistics Survey (MRFSS) database. As in the last two assessments of widow rockfish, the data were pooled over states into INPFC area blocks. These in turn were collapsed into northern and southern areas, representing the U.S. Vancouver and Columbia areas and the Eureka, Monterey, and Conception areas, respectively. The northern and southern areas are conveniently delineated by the 43^{o} latitude line. Within the southern area, widow rockfish landings were further condensed by summing over gears (i.e., trawl, other commercial, and recreational), providing annual estimates of landings from the southern area fishery. In the northern area, however, landings were partitioned into three separate fisheries; the Oregon midwater trawl fishery, the Oregon bottom trawl fishery, and the remaining catch of widow rockfish, referred to as the Vancouver-Columbia fishery. Because identification of gear types in

Oregon (midwater or bottom trawl) did not begin until 1983, all landings in the northern area prior to that time were assigned to the Vancouver-Columbia "trawl" fishery.

To extend the time series of Eureka-Conception and Vancouver-Columbia earlier in time, three sources of information were utilized. First, results presented in Quirollo (1987) provided estimates of widow rockfish in the vicinity of Eureka and Crescent City, California for the period 1973-1980. Second, supplemental State of California landings statistics for the years 1978 and 1979 were obtained from expansions of unpublished historical sample data present at the Tiburon Laboratory, Southwest Fisheries Science Center. For the years held in common (1978-79), the ratio of those landings to the data in Quirollo (1987) was calculated. This expansion factor (1.55) was then used to expand upwards the earlier (1973-77) Eureka data, providing an estimate of California landings for the earlier period. In combination, these data were used to estimate landings of widow rockfish from 1973-79 in the Eureka-Conception area. Next, results presented in Gunderson (1984) provided estimates of coastwide widow rockfish landings for the period 1978-81, which by difference, were used to determine the Vancouver-Columbia landings for 1978-79. Finally, the ratio of Vancouver-Columbia landings to Eureka-Conception landings for the period 1978-81 (1.49) was used to estimate the northern area catch from southern area statistics for the period 1973-77. Due to the low amount of landings estimated for the year 1973 (117 mt), zero landings were assumed for the period 1968-72 (Table 1, Figure 1). Bycatch estimates of widow rockfish in the whiting fishery were not included in the total landings.

Age Composition Data

Widow rockfish otolith samples collected coastwide since 1989 have been aged at the Tiburon Laboratory using the break and burn aging method (Pearson and Hightower 1991). Prior to 1989, the ages of all Vancouver-Columbia fish were obtained by researchers in the State of Washington, who used surface readings. Prior to 1987, Oregon widow rockfish were aged by investigators in Oregon, who used the break and burn aging method. All California fish were aged by Tiburon personnel using the break and burn aging technique.

Washington provided age expansions from samples collected during commercial market sampling (Sampson and Crone 1997). Oregon provided raw sample data which was expanded using methods described in Sampson and Crone (1997). California age data was extracted and expanded from the CALCOM database. Summaries of the numbers of fish aged and the number of trips sampled by year were also obtained. The sex specific age composition data and sample size information for the four west coast widow rockfish fisheries is presented in Tables 4-8 and Figures 4-7.

Age validation of widow rockfish was conducted by marginal increment analysis (Lenarz 1987). Hyaline-zone formation, the measure of annual growth, appears to occur between December and April (Pearson 1996). For convenience all widow rockfish are assumed to be born on January 1. Variation in the timing of the hyaline-zone formation occurs between fish from Washington and California, which could affect age determination. Knowledge of the timing variation can be used to avoid mis-ageing and ultimately the variation in hyaline-zone formation is not likely to result in major age discrepancies (Pearson 1996).

Oregon Bottom Trawl Logbook

Logbook index measures from the last assessment spanned 1984-1995 (Ralston and Pearson 1997). In their analysis an extract of data provided by the Oregon Department of Fish and Wildlife was performed, wherein all records meeting the following criteria were accepted: (1) actual widow rockfish landings were greater than or equal to 100 lbs., (2) hauls were conducted during the months of January, February, or March, (3) the fishing gear code corresponded to bottom trawl or roller gear, and (4) the location of the reported haul fell in the range of 42o30'N to 46o30'N latitude and 124o36'W to 124o54'W longitude. Their data set amounted to 2,682 hauls spanning the 1984-95.

Ralston and Pearson (1997) applied a General Linear Model (GLM) to their data in an attempt to account for interannual variability in catch-per-unit-effort (CPUE). Specifically, *CPUE* was computed as:

$$CPUE_{ijkl} = (lbs.\ widow\ rockfish)_{ijkl} \,/\, (hours\ trawled)_{ijkl}$$

where *CPUE* is the observed *CPUE* in year *i* by vessel *j* at location *k* in haul *l*. This statistic was then log transformed and fitted to a GLM model of the form:

$$\ln(CPUE) = \mu + Y_i + V_j + L_k + \varepsilon_{ijkl}$$

where μ is the average log(*CPUE*), Y_i is a year effect, V_j is a vessel effect, L_k is a location effect and ε_{ijkl} is a normal error term with mean zero and variance σ^2.

An analysis of variance of the model indicated that all terms were highly significant (P<0.0001), with an overall model $r^2 = 0.36$. The back-transformed year-specific model prediction of *CPUE*, with bias-correction, was then calculated as:

$$CPUE_i = \exp\left[\mu + Y_i + \overline{V}_j + \overline{L}_k + \frac{\sigma_\varepsilon^2}{2}\right]$$

where $\overline{V}_j$ is the mean of 91 vessel effects, $\overline{L}_k$ is the mean of 64 spatial effects, and σ_ε^2 is the model mean-squared error.

We attempted to update this time series to 1998 by making an extraction of the same data as in Ralston and Pearson (1997) from the PacFIN database. For unknown reasons we could only extract the years 1988-1998. We performed the above mentioned analysis on the 1988-1998 data, which resulted in 3,264 hauls. The resulting GLM model contained 90 vessel effects and 68 spatial effects. The analysis of variance of the model indicated that all terms were highly significant (P<0.0001), with an overall model $r^2 = 0.35$. In order to make use of the earlier data in Ralston and Pearson's (1997) analysis we regressed our model results against their model results for the years of overlap (1988-1995) and used this relationship to predict the 1984-87 time period (Table 9, Figure 8). The regression was highly significant (P<0.0002), with an $r^2 = 0.89$.

Pacific Whiting Bycatch Index

As in the previous assessments (Rogers and Lenarz 1993, Ralston and Pearson 1997), a bycatch statistic was computed that measured the incidental catch rate of widow rockfish in the at-sea pacific whiting fishery. Data from the foreign fishery, joint-venture fishery and recent processor ship fisheries were extracted from the whiting observer databases and were provided by Martin Dorn (AFSC).

Two alternative approaches to an abundance index were examined. The first is a new direct estimate of catch per minute, and the second is an indirect index based on the ratio of widow bycatch to targeted hake catch as was done in previous assessments. Widow catch rates are highest near the 100-fathom curve, and the database was restricted to whiting hauls from a 3-mile-wide strip extending from one mile shoreward to two miles seaward of the 100 fathom isobath. Also, hauls of less than 15 minutes duration were excluded from the analysis. The data base was divided into three segments corresponding to the foreign fishery (FOR), the joint venture (JV) fishery and the recent domestic at-sea fishery (DOM). Due to changes in the fishery, the 1999 estimate was dropped from the analysis. The abundance indexes are ratio estimators of the form sum(y)/sum(x), but the coefficients of variation are derived from the standard deviation of individual (y/x) ratio values. Results are summarized in Table 10.

The direct abundance index (Figure 9) shows a much higher catch rate by the recent domestic offshore fishery relative to the foreign and joint venture fisheries. Because widow rockfish were almost certainly not more abundant after 1990, this suggests that the widow rockfish catchability coefficients were substantially different among the three fisheries. Accordingly, widow rockfish abundance indexes derived from the whiting bycatch are treated as three independent time series, rather than as a single time series as was done in previous assessments.

The indirect index was calculated as I=Whiting biomass*sum(Widow)/sum(whiting), using age 3+ whiting biomasses taken from Dorn et al. (1999, Table 12). Much of the decline in the JV and recent domestic periods is due to the influence of the declining whiting biomass; the raw ratios of widow catch to whiting catch were relatively constant over the time period.

Initial model fits use only the indirect index, in keeping with our preference to retain the previous model configuration as an initial starting point. However the present treatment does depart from the previous assessments in maintaining the independence of the indexes derived from the three separate fisheries.

Midwater Trawl Pelagic Juvenile Survey

Every year since 1983 the Groundfish Analysis Branch at the Southwest Fisheries Science Center's Santa Cruz/Tiburon Laboratory has fielded a midwater trawl survey, which is designed to assess the reproductive success of a group of rockfishes, including widow rockfish. The survey is conducted during May-June, the time of year when the pelagic juvenile stage is most susceptible to capture. Studies have shown that abundance statistics summarized from the survey gauge impending recruitment (Adams 1995; Ralston and Howard 1995; Ralston et al. 1996).

The Tiburon recruitment index is calculated after the raw catch data are adjusted to a common age of 100-d to account for interannual differences in age structure. The abundance data are gathered during three consecutive sweeps of a series of 36 fixed stations that are arrayed over 7 spatial strata that extend from Carmel (36°30'N) to Bodega (38°20'N). The final index is calculated as the bias-corrected antilog of the largest stratified mean observed among the three consecutive sweeps of the survey grid (catch of 100-d fish/15 min.trawl). The resulting statistic was entered into the model as a relative index of abundance (Table 11, Figure 10). The survey time series (1983-1999) was shifted forward three years (1986-2002) to represent the abundance of age-3 widow rockfish, the age of recruitment in the model.

California Trawl Logbook

Commercial trawl logbook data have been recorded and collected by fishermen in California from 1978 to 1996 by the California Department of Fish and Game (CDF&G). Widow rockfish catches were recorded as a nominal category within this database. However, the incidence of positive occurrences of nominal widow rockfish in the logbook data set did not stabilize until 1982, after the fishery went through dramatic expansion (Gunderson 1984). For this reason, the analysis of the California logbook data set only involved the years 1982 to 1996. The data were analyzed on a port-specific basis using a general linear analysis of variance procedure, which is fully described in Ralston (1999). The model included year, vessel, CDF&G reporting block, and month effects. Due to the reduced number of records positive for nominal widow rockfish, the criterion for inclusion in the analysis was set at 100 records per block and 100 observations per vessel. Back-transformation of the year effects from the model, with bias-correction, then yielded port-specific standardized time series of nominal widow rockfish catch rates, expressed as CPUE. These port-specific CPUE's were then combined as a weighted average based on an area weighting scheme (Ralston 1999) (Table 12, Figure 11). The utility of this index as an appropriate measure of abundance is uncertain since it is a composite of bottom and midwater trawl gears.

AFSC Triennial Bottom Trawl Survey

Past assessments of widow rockfish have not used the AFSC triennial trawl survey because it is a demersal trawl survey and widow rockfish are a pelagic species of rockfish which are less available to bottom trawl gear than to midwater trawl gear. Because of this decreased availability of widow rockfish to bottom trawls, other methods of sampling have been proposed for determining widow rockfish abundances (Wilkins 1986). However, this data source is being introduced into this assessment for evaluation based on requests at the pre-assessment meeting held in March, 2000 at the Pacific States Marine Fisheries Commission office in Gladstone, Oregon. The biomass and corresponding CV estimates were obtained from Mark Wilkins at the Alaska Fisheries Science Center, Seattle and are shown in Table 13 and Figure 12. An immediate concern is warranted by examination of the biomass estimates relative to the landings in the same years (Tables 1 and 13). In several cases the landings exceed the biomass estimate from the survey, suggesting the survey is not accurately assessing the population.

History of Modeling Approaches

Previous assessments for widow rockfish have been performed in 1989, 1990, 1993, and 1997 (Hightower and Lenarz 1989, 1990; Rogers and Lenarz 1993; Ralston and Pearson 1997). In 1989 the assessment involved the use of cohort analysis and the stock synthesis program. In 1993 and 1997, the age-based version of the stock synthesis program was used to assess the status of widow rockfish. This assessment of widow rockfish utilizes the AD Model Builder

(ADMB) software (Otter Research, Ltd.) to apply an age-based analysis of the population with very similar methods as are used in the stock synthesis program. The differences between the ADMB model and stock synthesis are minor. The ADMB model estimates landings with a very low coefficient of variation (0.05), while stock synthesis treats landings in a slightly different manner and the initial age composition estimation process is slightly different in the two models. A full description of the ADMB model follows and should clarify any further differences between this model and the stock synthesis program used in past assessments of widow rockfish.

Model Description

General

This assessment of widow rockfish utilizes a statistical age-structured model similar to the one used in the stock synthesis program (Methot 1998). The model is written in a C++ software language extension, AD Model Builder (ADMB) (Otter Research, Ltd.), which utilizes automatic differentiation programming (Greiwank and Corliss 1991; Fournier 1996). The ADMB software allows for more rapid and accurate computation of derivative calculations used in the quasi-Newton optimization routine (Chong and Zak 1996). Further advantages of this software include the ability to estimate the variance-covariance matrix for all dependent and independent parameters of interest, likelihood profiling, and a Markov chain-Monte Carlo re-sampling algorithm for probability distribution determination. The ADMB model code and data files are listed in Appendix C and D, respectively.

This assessment of widow rockfish uses an explicit age-structured model with a Baranov catch equation as the underlying population model (Quinn and Deriso 1999). Equations and parameter definitions are given in Table 14. The population model begins in 1968 and tracks numbers and catches of male and female widow rockfish in age classes 3-20+ (as in past assessments). The starting year of 1968 was chosen based on the assumption that the 1965 year class was the earliest recruitment which could be reasonably estimated given a starting year of 1980 for the age composition information. Recruitment estimates prior to 1968 are assumed equal to the 1968 estimate in the model, so that the model is estimating recruitment at age 3 for the years 1968-1999.

The data used in this model include 4 fishery catch-at-age sample proportions (sum across sexes equal to one), landings in weight for each fishery, age composition and biomass index data from the AFSC triennial bottom trawl survey, fishery logbook CPUE from Oregon and California, and 3 whiting bycatch indices. Fishing mortality in each year is scaled to the fishery landings assuming a coefficient of variation of 5%. Applying the separability assumption, we estimate an age-specific selectivity function for each sex and fishery. The model includes the options for fitting a logistic, double logistic, and lognormal selectivity functions, with time varying options for the ascending portions of the logistic and double logistic functions. In the final stages of the model per-recruit analyses are performed using the proportional landings in each fishery in the last year to create catch weighted maturity, fecundity, and selectivity functions.

Natural Mortality

Natural mortality (*M*) has been fixed at 0.15 for both sexes and all ages, as in the previous widow rockfish assessment. A sensitivity analysis was performed in which a range of values for *M* were analyzed (see Sensitivity Analysis section).

Age Compositions

The age data are modeled as multinomial random variables, with the year-specific sample sizes set equal to the number of samples collected, rather than the number of fish, which often times overstates the confidence of the data (Table 8) (Quinn and Deriso 1999). The sample sizes in 1998 were used for the missing values in 1999. The actual sample size (n=123) for the 1980 triennial age composition data was used since it was relatively low in comparison to the fishery sample sizes.

Ageing Error

The only information available for determination of ageing error, was based on two point estimates of percent ageing agreement from the last two assessments (Rogers and Lenarz 1993; Ralston and Pearson 1997). From the previous assessments an estimate of 75% agreement for age 5 fish and 66% agreement for age 20 fish was modeled by assuming a linear relationship of percent agreement with age. These estimates of percent agreement at age were then fit to a set of age-specific normal distributions, which approximated the level of ageing agreement. The resulting matrix of true age versus reader age was then placed in the model.

Landings

In our model landings are treated as an estimated variable with an assumed constant coefficient of variation. For our model we have assumed the landings estimates have a cv=0.05. Year specific fishing mortalities are computed for each fishery for those years in which there are landings estimates available. Years with no landings estimates are assumed to have zero landings for those years, which only applies to 1968-1972 for widow rockfish.

Fraction of Landings in the North

Since there are area specific (north and south) estimates for weight-at-age and maturity, it is necessary to determine the fraction of the population to which each of these area specific estimates apply. We used the sum of the landings in the Vancouver-Columbia and both Oregon trawl fisheries relative to the total landings as an estimate of the proportion of the population to which the northern weight-at-age and maturity functions could be applied. The annual change in this fraction seemed highly variable and not likely to be indicative of true declines in area abundances. For this reason the time series of proportions of landings in the north were smoothed using a 7-year moving average (Figure 13). The results from the moving average were then put directly into the model, applying the 1973 value to the earlier years. A sensitivity analysis using a constant fraction for weighting the north and south data was analyzed (see Sensitivity Analysis section).

Discards

The level of discards of widow rockfish is virtually unknown. In past assessments a value of 6% of total weight was assumed for years 1979-1982 and 16% of total weight for the years 1983-1999 (Hightower and Lenarz 1990). The 16% estimate of discards is based on a dated study by Pikitch et al. (1988), which indicated most of the discards of widow rockfish were induced by regulations. The earlier 6% estimated is based on an ad hoc adjustment of the 16% by previous assessment authors (Hightower and Lenarz 1990). The 16% assumed value has likely become more uncertain in recent years due changes in regulations.

The typical method for accounting for discards in assessment models is to compute a catch which is the summation of reported landings and estimated discards (Williams et al. 1999). However, recent research has suggested that if discards are size selective towards more smaller fish, then the typical method of accounting for discards in population models is incorrect and may be worse than not accounting for discards at all (Williams *in review*). Whether size selective discarding occurs or not in the widow rockfish fisheries is unknown at this time.

Midwater Trawl Pelagic Juvenile Survey

The Tiburon Laboratory midwater trawl juvenile survey is scaled to represent an index of 100 day old larvae. For inclusion in the model the time series was lagged to correspond with the appropriate year class. Within the model a catchability coefficient and a power transformation parameter is estimated for the midwater trawl survey. The power transformation is included to account for possible density dependent mortality occurring between 100 days of age and age 3 (the age of recruitment in the model), which likely results in higher variance levels in the survey time series relative to age 3 recruitment time series.

Logbook and Bycatch Indices

The Oregon and California logbook indices and whiting bycatch indices are treated as biomass indices and are estimated in the model with a catchability parameter for each index. The model has been equipped for the possibility of a power transformation of the indices, but in this case all the time series will be treated with a power of 1.0. After various sensitivity analyses, the final preferred model did not include the California logbook index and the precision of the Oregon logbook index was decreased by increasing the CV multiplier to a value of 2.0.

Likelihood Component Weighting

Weighting in this assessment model has been set up as a multiplier on the coefficient of variation (CV) estimates for the landings and index likelihood components. For the age composition likelihood components a multiplier on the sample sizes was used for re-weighting. Using these multipliers allows for the variance assumptions of any re-weighting of likelihood components to be directly assessed. When components are “de-emphasized” a CV multiplier of 1000 was used and in the case of the triennial age composition information, the sample size was multiplied by 0.0001. The CV multiplier for the Oregon logbook data was increased to a value of 2.0 in the final model.

Model Selection

Initial model runs were performed with all auxiliary data included and all likelihood weights set to 1.0. The relative importance of each index was examined through an ordinary cross-validation analysis technique, whereby auxiliary components are de-emphasized one at a time and the results compared to each other. This technique allows determination of the contribution of each data source to the overall model fit, as well as to other components in the model. Table 15 shows the results of the cross-validation analysis, which resulted in some model runs converging on erroneous fits, as judged by residual analysis, or failure to produce a positive definite Hessian matrix, an indicator of inappropriate fit. The most gain in likelihood values was obtained when the midwater trawl survey was left out of the model.

De-emphasis of the midwater trawl survey may not be warranted given its utility in other assessments (Ralston et al. 1998; MacCall et al. 1999; Dorn et al. 1999). We determined the utility of the midwater trawl survey by examination of the recruitment estimates from the model run with the midwater trawl likelihood component de-emphasized. We used a power transformation to match the CV of the index to the CV of the recruitment estimates from the model for the time period of overlap. The results indicated a significant correlation ($P < 0.05$) between the recruitment estimates from the model with the midwater trawl component de-emphasized and the power transformed index values (Figure 13). For the reason mentioned above, the midwater trawl survey was left in with full emphasis and the triennial trawl survey and age compositions were de-emphasized in subsequent model runs.

The best set of selectivity functions was determined through a hierarchical analysis in which first a set of fishery specific, sex-specific, but year-constant logistic selectivity functions were fit within the model. Next, the two dome-shaped selectivity options were invoked and the model improvement was determined by analysis of the total likelihood and the use of the Akaike Information Criterion (AIC), which is essentially the total likelihood function with a penalty term to prevent over-parameterization (Burnham and Anderson 1998). The next step was to include a year-specific, time varying component for the case of the logistic and double logistic functions. The resulting likelihood values for this hierarchical analysis is shown in Table 16. Based on the highest AIC value the model with the set of year-specific double logistic selectivity functions appears to be the best model. Further testing with a combined selectivity function for both sexes revealed that sex-specific selectivity estimates were not warranted.

During the Stock Assessment Review (STAR) of this analysis several other features of the model were changed based on sensitivity analysis and closer examination of the data sources. The following is a synopsis of the changes made to the final base model (see Response to STAR Panel Recommendations section for a complete listing):

(1) Removal of the California logbook data and inclusion of the triennial trawl survey index and age composition data.
(2) Single-sex, double logistic selectivity functions for each fishery with time varying components for the north (Vancouver-Columbia and Oregon trawl fisheries) and south (Eureka-Conception fishery).
(3) Increase CV multiplier to a value of 2.0 for the Oregon logbook data.
(4) Use the widow/minute whiting bycatch index with constant CV's listed in Table 10.
(5) Use a single catchability coefficient for the foreign and joint-venture whiting bycatch indices.

(6) Do not include the 1999 whiting bycatch index value.

Model Results (Base Run)

The model selection process mentioned above determined the base model. Parameter estimates and quadratic-normal approximation standard deviations are shown in Table 17. The resulting time series of total biomass, spawning biomass, spawning output, recruitment, and fishing mortality are indicated in Table 18 and Figures 15-16. The year specific selectivity curves are shown in Figure 17. The spawning output-recruit relationship for widow rockfish is shown in Figure 18. The fits to the landings are shown in Figures 19-20, the fits to the various indices are shown in Figures 21-22 and the fits to the age composition data are represented by Pearson's standardized residuals (with n=1) in Figures 23-24. A historic comparison of the output from this analysis and the results from the last widow rockfish stock assessment are shown in Figures 25 (Ralston and Pearson 1997).

Sensitivity Analysis

A sensitivity analysis of various sex specific selectivity configurations was tested prior to the stock assessment review panel meeting. In that analysis the configuration with double logistic functions with time varying inflection points resulted in the lowest total likelihood fit (Table 16). Adjusting the likelihood for the number of parameters using the Akaike information criterion also indicated this model was the best, despite the large number of parameters (309 parameters). However, closer examination of the time varying components revealed similarity in the pattern for the northern fisheries (Vancouver-Columbia and Oregon trawl fisheries). During the stock assessment review panel meeting, several model configurations were explored. Results indicated that combining sexes and using only time varying inflection points for the north and south fisheries did not affect the outcome significantly. The final selectivity configuration consisted of combined sex, double logistic selectivity functions with time varying ascending inflection points for the north (Vancouver-Columbia and Oregon trawl fisheries) and south (Eureka-Conception fishery) fisheries.

The contribution of each data source was investigated through an ordinary cross-validation analysis where data sources were removed one at a time (Table 15). As mentioned earlier it was apparent that the most likelihood improvement could be achieved by leaving the midwater trawl survey out of the model. This analysis indicates that the midwater trawl survey and Oregon trawl logbook index are slightly contradictory since the lowest likelihood value for each component occurs when the other is removed from the model. Likewise the triennial biomass survey appears to be in conflict with both the midwater trawl survey and Oregon logbook index. Barring any evidence indicating which is the more correct source of information, all three sources of information were left in the model. It is also apparent that the whiting bycatch indices have very little influence on the overall model fit (Table 15).

A sensitivity analysis of the preferred widow rockfish model was run using different values for natural mortality, ranging from 0.25 to 0.05 (Table 19). The best model fit occurred with a natural mortality value of 0.13, not too different from the assumed value of 0.15. Based on the lowest likelihood value for each component, it is apparent that the age composition data and Oregon logbook data are more consistent with intermediate values of M. The landings, midwater trawl survey, joint-venture bycatch index, and modern bycatch index are more consistent with higher values of *M*, while the triennial biomass survey is more consistent with lower values of *M* (Table 19).

The convergence properties of the model were tested by running the model 46 times with starting values multiplied by random numbers between 0.5 and 1.5, representing a random perturbation of up to 50%. The results plotted against the 1999 status of the population relative to the unfished condition indicated that there was some variation in convergence, with various local minima (Figure 26). However, the lowest total log-likelihood value observed in the set of random perturbations was equal to the value obtained in the base model and no other values were lower, indicating the base model is apparently converging on the lowest log-likelihood value (Figure 26).

A retrospective analysis was performed through a jackknife type of exercise with repeated deletion of the last year of available data. The model results indicate that the model is very stable and/or the last few years of data have very little influence on previous years estimates (Figure 27).

Status of the Stock (Target Levels)

The level of unfished spawning output was determined using the average recruitment in the years 1968-1982, the years of recruitment prior to the fishery, multiplied by the spawning output-per-recruit (SPR) at fishing mortality (*F*) of zero. The ratio of last year's spawning output to the unfished level is the status of the population. Population status estimates of 25-40% indicate a precautionary zone where the 40-10 precautionary adjustment policy is implemented. Population status estimates below 25% are considered to indicate an overfished condition. The point estimate for the population status in 1999 is 23.6%.

In order to accurately reflect the variability in this estimate, the method described in Appendix A was used in conjunction with a profile likelihood method to obtain a description of the probability distribution for values of the population status. The resultant distribution is skewed towards higher percentages, with the population status at 50% probability equal to 23.6%. The probability that the population status is less than 25% (overfished) is 69.5%, which implies that there is a 30.5% probability that the population status is greater than 25% (not overfished) (Figure 28).

An alternate method of determining the population status may be to examine the stock-recruitment relationship. By fitting Beverton-Holt and Ricker type stock-recruitment models alternate estimates of the biomass at maximum sustainable yield (Bmsy) can be derived from the model fit. The overfishing threshold may then be defined as 50% of Bmsy. This alternate method for determining the population status is examined in Appendix B.

Management Recommendations

Harvest projections and target F's

The relationship between recruits per spawning output (R/S) and spawning output was examined for use in forecasting. The relationship indicates there is a slight tendency for R/S to increase with decreasing spawning output (Figure 29). However, the regression line describing this trend is not significant (P-value = 0.302) and therefore only the mean R/S was used for forecasting future recruitment. If there really is a trend of increasing R/S with spawning output, then using the mean R/S will slightly underestimate the rate of increase in the population forecasts. The mean R/S was computed within the model similar to the method used in Appendix A for the population status. This allows for a better treatment of the variability surrounding the forecast and avoids time consuming re-sampling schemes.

The widow rockfish spawning output and landings were forecast using the mean R/S for F levels corresponding to F=0, $F_{40\%}$, $F_{50\%}$, and $F_{65\%}$ (Table 20). The SPR rate harvest policy F levels were estimated in the model by using the last three years of landings to weight the area and fishery specific growth, maturity, and selectivity functions. The implementation of the 40-10 policy calls for an adjustment to landings or exploitation rate based on the status of the population relative to the unfished level. At low values of F (<0.2), the precautionary adjustment,

$$PA = \frac{0.4(S - 0.1)}{(0.3S)},$$

where S is the population status, may be applied directly to the values of F with little bias being incurred. For widow rockfish the estimates F corresponding to the SPR rate harvest policies $F_{40\%}$, $F_{50\%}$, and $F_{65\%}$ are 0.171, 0.122, and 0.07, respectively. The forecasts indicate that widow rockfish spawning output is likely to remain below 25% of the unfished level, the overfishing threshold, through 2000 under any of the exploitation levels examined here (Figure 30). At F=0 it appears that the widow rockfish spawning output will increase fairly rapidly, exceeding 40% of the unfished level by 2006 (Figure 31). The fishing rate corresponding to $F_{65\%}$ results in the population status reaching 40% of the unfished level by 2009. The corresponding harvest levels for the forecasts are listed in Table 18.

Response to STAR Panel Recommendations

The following is a list of analyses/corrections completed as requested by the Stock Assessment Review (STAR) Panel:

- Correct the 1981 and 1982 landings data. The 1981 and 1982 landings data initially did not include Oregon midwater trawl landings and therefore underestimated the catch. This led to underestimates of the unexploited stock size.
- Correct the way discards are estimated. The discards were calculated as a proportion of the landings rather than of the catch, so the discard rate estimate used was incorrect. The code was corrected to apply the proportion to the catch. This small error made little difference to the results.
- De-emphasize the California trawl logbook CPUE index. The California trawl index mixes midwater trawl data with bottom trawl data. Because the two gear types have differing catchability coefficients and the proportion of each in the index varies over time, the index is likely to be biased.
- Break the Oregon bottom trawl CPUE index into two separate time series. The Oregon bottom trawl CPUE index appears to have an abrupt change in 1990, when the Council imposed major trip limit reductions. After discussing the results, the Panel agreed that it would be more appropriate to maintain a single index series because significant information would be lost by trying to fit separate non-overlapping series. However, it was agreed the

CVs for the annual CPUE values should be estimated from the smoothed series, rather than use the original index values, which were felt to be unrealistically small.

- Sensitivity runs on fraction of the stock assumed north of 43° N. The model split the stock proportionally between the north and south on the 43° N parallel. The split did not affect the population dynamics, but did influence biological characteristics, namely the maturity and growth. Fish in the northern section are heavier and mature at an older age. The initial version of the model had the fraction in the north varying annually based on the percent of the landings in north. The Panel requested a run with a constant 60:40 north:south split. The analysis indicated little sensitivity of the assessment results to realistic fractions between the north and south.
- Increase emphasis on the triennial bottom trawl survey biomass index. The triennial bottom trawl survey biomass index was weighted to near-zero in the initial base run on the basis that the trends were inconsistent with other indices. However, there was no good scientific reason to exclude this index, which is based on a fisheries independent survey, so it was felt it should be given an equal weight unless evidence to the contrary was found. More information is required on the behavior of the index, but in the meantime it should be included in base-run models.
- Include separate triennial trawl survey indices for northern versus southern areas. The southern index has a temporary increasing trend, but there is little trend in the north. Given the split in the population between north and south, it was considered necessary to see whether splitting the index influenced the results.
- Simplify the time-varying fishery selectivity. The initial base-run model had time-varying asymptotic selectivity curves by sex for each of four fisheries. Examination of the estimated selectivity curves indicated that several simplifications might be appropriate. The Panel requested a series of hierarchical runs to explore some possible simplifications: time-variation in asymptotic selectivity by fishery, but not by sex; time-variation in asymptotic selectivity (sexes the same) for northern versus southern fisheries; and time-variation in domed selectivity (sexes the same) for northern versus southern fisheries.
- Use the whiting fishery widow per minute indices and de-emphasize the bycatch widow per whiting index. The initial model used three whiting fishery widow per minute indices: widow per minute indices for the foreign, joint venture, domestic fisheries from the central coast region. However, no significant difference was found between the foreign and joint venture series during a period of considerable overlap, so the same catchability coefficient was estimated for both series.
- Sensitivity analysis on selection curves for the trawl survey. Survey age composition data were limited to a small sample from 1980 only, so a number of different curves were applied to see whether the choice of model affected the results.
- Include an intercept term for the relationship between fishery CPUE and stock biomass. Because zero-catch hauls were censored from the index, a zero catch rate was impossible. To help adjust for the censored data, it was suggested that a constant intercept term be estimated in the CPUE sub-model to account for filtering of zero-catch hauls.
- Randomize the starting parameter values. A number of runs with random start values were requested and run to identify alternate minima and ensure that the model had converged to the global minimum.

- Carry out a retrospective analysis. A retrospective analysis was requested and completed. The retrospective analysis indicates whether the estimates of ending biomass are sensitive to recent data and structural assumptions.
- Sensitivity analysis that de-emphasized all tuning indices except the triennial bottom trawl survey. This was requested to test whether the population model and catches could be compatible with the triennial trawl survey, because the population model consistently favored the CPUE indices whether the survey was de-emphasized or not.
- Estimate recruitment variability within the model. Variability of historical recruitment was better estimated internally as part of the model. This allowed recruitment variability to be included in the estimate of the ratio of current biomass to unexploited biomass.
- Estimates of selectivity for forward projections and calculation of F50% should be based on the last three years. The average of the final three years of the data series was considered more reliable than using only the 1999 data, which were probably not typical and therefore not a good predictor for future years.

Research Needs

One of the weaknesses of the widow rockfish stock assessment is the need for a reliable abundance index, preferable fishery independent. Available widow rockfish data has seemingly reliable age data, but very poor information on abundance trends. The primary sources of information on trends in abundance of widow rockfish come from the Oregon logbook data and the triennial trawl survey. Both of these sources of information rely on bottom trawl gears, which may not be a good method of capturing a primarily pelagic rockfish species such as widow rockfish. Alternate sampling methods could include larval surveys, acoustic surveys, and/or midwater trawl surveys.

A continuously unknown value in West Coast groundfish fisheries is the amount and characteristics of at-sea discards. A comprehensive coast wide observer program is desperately needed for all West Coast groundfish fisheries including widow rockfish. Missing data or incorrect data on at-sea discards have the potential to severely bias results from stock assessments (Williams *in review*).

The difference in growth and patterns in the age composition data for widow rockfish in the north as compared to those in the south suggests there may be some differences in these portions of the stock. Research into tagging/movement studies and/or genetics may reveal whether these areas represent separate populations. If they are not separate these types of studies may at least reveal methods for describing exchanges of fish between the north and south areas. The other question which needs to be answered concerning the north and south portions of the population is the relative contribution to the coast wide biomass. In this analysis the fraction of biomass in the sub-areas was set based on fishery landings, which may not truly represent the relative abundances in these areas. The size of the population in these areas may be answered by a comprehensive survey as mentioned above.

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Table 1. U.S. commercial landings (mt) of widow rockfish by area and gear type.

Year	Vancouver, Columbia	Oregon Midwater Trawl	Oregon Bottom Trawl	Eureka, Monterey, and Conception	Total
1973	70			47	117
1974	26			17	43
1975	188			126	314
1976	376			252	628
1977	1318			883	2201
1978	605			502	1107
1979	966			2326	3292
1980	16190			5666	21856
1981	21779			6368	28146
1982	14803			11164	25967
1983	3221	1452	1488	6434	12594
1984	1450	3568	1334	3397	9748
1985	1537	3185	871	3554	9147
1986	2559	2977	1171	2773	9480
1987	3722	4985	1169	2878	12754
1988	3078	4102	1126	2213	10519
1989	3378	4871	1971	2295	12515
1990	2241	3235	2168	2418	10062
1991	1176	1846	1940	1388	6350
1992	947	1140	2624	1344	6054
1993	1732	1755	3385	1370	8242
1994	1073	1678	2382	1264	6397
1995	1087	1394	2278	1953	6712
1996	968	1464	2114	1533	6079
1997	1016	1516	2286	1683	6500
1998	557	759	1330	1295	3940
1999	493	1590	912	766	3761

Table 2. Management performance in obtaining the harvest guideline for widow rockfish.

Year	Harvest Guideline	Allowable Biological Catch	Landings	Catch
1980			21856	23167
1981			14571	15445
1982			17992	19072
1983		10500	10423	12091
1984		9300	9748	11308
1985		7400	9147	10610
1986		9300	9480	10996
1987		12500	12754	14795
1988		12100	10519	12202
1989	12100	12400	12515	14518
1990	12400	8900	10062	11671
1991	7000	7000	6350	7366
1992	7000	7000	6054	7023
1993	7000	7000	8242	9561
1994	6500	6500	6397	7420
1995	6500	7700	6712	7786
1996	6500	7700	6079	7052
1997	6500	7700	6500	7541
1998	5090	5750	3940	4571
1999	5090	5750	3761	4363
2000	5090	5750		

Table 3. Chronology of the regulatory history of widow rockfish by the Pacific Fishery Management Council.

Date	Regulation
10/13/82	75,000 lb trip limit
1/30/83	30,000 lb trip limit
9/10/83	1,000 lb trip limit
1/1/84	50,000 lb trip limit once per week
5/6/84	40,000 lb trip limit once per week
8/1/84	closed fishery with 1,000 trip limit for incidental catch
9/9/84	closed fishery
1/10/85	30,000 lb trip limit once a week or 60,000 lb trip limit once per two weeks, unlimited trips of less than 3,000 lbs
4/28/85	dropped 60,000 lb biweekly option
7/21/85	3,000 lb trip limit, unlimited number of trips
1/1/86	30,000 lb trip limit, only one weekly landing greater than 3,000 lbs
9/28/86	3,000 lb trip limit, unlimited number of trips
1/1/87	30,000 lb trip limit, only one weekly landing greater than 3000 lbs
11/25/87	closed fishery
1/1/88	30,000 lb trip limit, only one weekly landing greater than 3000 lbs, unlimited number of trips less than 3,000 lbs
9/21/88	3,000 lb trip limit, unlimited number of trips
1/1/89	30,000 lb trip limit, only one weekly landing greater than 3,000 lbs
4/26/89	10,000 lb trip limit once per week
10/11/89	3,000 lb trip limit with unlimited number of trips
1/1/90	15,000 lb trip limit once per week or 25,000 lb trip limit once per two weeks with only one landing greater than 3,000 lbs each week
12/12/90	closed fishery
1/1/91	10,000 lb trip limit per week or 20,000 lb trip limit every two weeks with only one landing greater than 3,000 lbs per week
9/25/91	3,000 lb trip limit with unlimited number of trips
1/1/92	30,000 lbs cumulative landings every 4 weeks
5/9/92	change from 3" mesh to 4.5" mesh in codend for roller gear north of Point Arena
8/12/92	3,000 lb trip limit with unlimited number of trips
12/2/92	30,000 lb cumulative trip limit per 4 weeks
12/1/93	3,000 lb trip limit with unlimited number of trips
1/1/94	30,000 lb cumulative limit per calender month
12/1/94	3,000 lb trip limit with unlimited number of trips
1/1/95	30,000 lb cumulative limit per calender month
4/14/95	45,000 lb cumulative limit per calender month
9/8/95	4.5" mesh applies to entire net and bottom trawl
1/1/96	70,000 lb cumulative limit per two months
9/1/96	50,000 lb cumulative limit per two months
11/1/96	25,000 lb cumulative limit per two months
1/1/97	70,000 lb cumulative limit per two months
5/1/97	60,000 lb cumulative limit per two months

Table 3. (cont.)

1/1/98	limited entry: 25,000 lb cumulative per two month period
	open access: 12,500 lb cumulative per two month period
5/1/98	limited entry: 30,000 lb cumulative per two month period
7/1/98	open access: 3,000 lb cumulative per month
10/1/98	limited entry: 19,000 cumulative per month
1/1/99	limited entry: cumulative limits: phase 1 - 70,000 lbs per period, phase 2 - 16,000 lbs per period, phase 3 - 30,000 lbs per period
	open access: 2,000 lbs per month
5/1/99	limited entry: decrease phase 2 and phase 3 limits to 11,000 lbs
7/2/99	open access: 8,000 lb cumulative limit per month
10/1/99	limited entry: vessels in Oregon and Washington using 30,000 lb cumulative monthly limit must have midwater trawl gear aboard or a state cumulative limit will be imposed

Table 4. Percent age composition data for the Vancouver-Columbia combined fishery, by sex and year with the sum across sexes equal to 1.

		Age															
Year	Sex	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1980	F	0.00	0.00	1.10	2.55	1.42	2.45	8.15	14.69	8.51	6.64	3.73	1.77	2.28	2.10	0.68	0.78	0.56	1.57
1981	F	0.00	0.99	2.06	5.15	4.69	2.22	2.08	5.92	7.62	6.72	3.60	2.61	1.72	0.96	0.48	0.52	0.46	2.28
1982	F	0.21	4.17	2.77	4.86	2.48	2.85	1.53	1.16	1.09	3.17	2.58	3.16	2.62	3.19	1.37	1.24	0.49	2.93
1983	F	0.00	0.62	16.20	12.12	4.28	2.15	0.86	1.26	1.20	1.45	2.74	1.92	1.79	1.10	0.85	0.61	0.36	2.38
1984	F	0.10	0.19	4.71	15.32	7.49	2.59	1.81	0.53	0.65	0.68	1.10	1.61	2.44	2.28	1.93	1.06	1.30	8.16
1985	F	0.00	0.99	8.09	9.55	11.41	6.04	2.77	0.74	0.66	0.44	0.57	0.43	0.93	0.73	0.84	0.46	0.59	6.46
1986	F	0.00	0.24	5.96	18.92	9.58	7.13	1.87	1.29	0.38	0.64	0.75	0.58	0.75	0.67	0.62	0.74	0.25	4.39
1987	F	0.01	0.36	1.06	9.73	26.39	5.92	3.67	3.62	1.06	0.99	0.63	0.13	0.80	0.77	0.42	0.60	0.45	3.61
1988	F	0.00	0.22	0.78	5.63	15.06	20.39	3.39	1.73	1.24	0.78	0.29	0.03	0.26	0.04	0.03	0.07	0.01	0.63
1989	F	0.00	0.40	0.65	7.68	8.89	18.12	9.95	1.02	0.87	0.49	0.05	0.08	0.11	0.18	0.00	0.07	0.41	1.98
1990	F	0.00	0.19	4.30	9.19	12.78	7.02	8.76	8.71	0.88	0.67	0.16	0.27	0.24	0.05	0.23	0.07	0.08	2.23
1991	F	0.00	0.00	0.42	5.23	9.23	10.53	6.88	6.69	5.40	1.41	1.01	0.60	0.32	0.20	0.05	0.24	0.27	3.46
1992	F	0.00	0.27	2.27	2.56	5.51	9.11	7.78	5.65	7.07	5.22	2.97	1.40	0.88	0.45	0.07	0.44	0.27	2.72
1993	F	0.00	0.08	0.73	5.56	3.96	5.94	6.74	4.93	5.03	8.19	4.77	3.14	1.48	0.90	0.43	0.40	0.15	3.28
1994	F	0.40	0.28	1.32	4.76	7.53	6.96	4.31	5.40	4.23	4.20	5.06	3.42	2.35	1.58	1.26	0.75	0.42	2.99
1995	F	0.08	1.08	3.28	5.33	7.79	7.99	5.42	3.50	2.45	2.76	1.76	1.76	1.08	0.70	1.10	0.48	0.13	1.24
1996	F	0.00	0.13	6.59	10.83	10.73	6.41	5.23	2.27	1.47	1.75	1.41	1.29	1.84	0.41	0.35	0.21	0.22	1.79
1997	F	0.00	0.13	2.97	17.20	13.57	5.16	3.36	2.28	2.09	1.68	1.91	0.80	0.54	0.94	0.50	0.25	0.35	2.42
1998	F	0.00	0.10	1.19	4.65	17.22	15.56	4.38	1.82	1.75	2.13	1.70	1.91	1.29	0.32	1.02	0.48	0.25	1.41
1999	F	0.00	0.22	0.70	3.78	5.09	12.61	12.27	6.98	4.82	2.36	1.36	0.87	0.92	0.37	0.33	0.65	0.46	1.32

Table 4 (cont.). Percent age composition data for the Vancouver-Columbia combined fishery, by sex and year with the sum across sexes equal to 1.

		Age																	
Year	Sex	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1980	M	0.00	0.00	0.87	2.02	2.15	4.97	8.07	11.88	4.44	2.74	0.66	1.00	0.74	0.39	0.13	0.37	0.19	0.40
1981	M	0.07	0.81	2.68	6.53	4.62	2.39	4.86	8.75	6.67	4.80	2.61	1.78	1.11	0.47	0.40	0.34	0.28	0.76
1982	M	0.11	4.80	3.56	7.33	2.65	3.57	2.09	1.70	2.72	6.26	5.89	5.24	4.31	2.35	1.71	1.12	1.13	1.62
1983	M	0.00	0.91	16.55	11.96	3.09	1.82	1.46	1.20	1.31	1.81	1.62	1.25	1.27	0.80	0.56	0.57	0.43	1.50
1984	M	0.00	0.33	5.70	16.18	8.39	3.32	1.37	0.43	0.54	0.65	0.72	1.23	1.23	1.00	0.66	0.73	0.75	2.83
1985	M	0.00	1.00	8.65	9.16	13.53	6.92	2.26	0.91	0.42	0.52	0.44	0.48	0.43	0.21	0.51	0.36	0.25	2.26
1986	M	0.00	1.02	6.52	18.33	7.37	4.84	1.42	0.56	0.56	0.48	0.30	0.29	0.41	0.56	0.26	0.19	0.10	2.01
1987	M	0.00	0.54	2.15	11.03	16.93	3.87	0.82	0.87	0.33	0.46	0.55	0.28	0.20	0.36	0.24	0.13	0.10	0.91
1988	M	0.00	0.00	1.49	5.95	13.80	20.42	3.66	1.32	0.50	0.22	0.07	0.24	0.30	0.07	0.02	0.04	0.06	1.26
1989	M	0.00	0.26	1.71	9.57	10.15	16.60	8.10	1.15	0.42	0.09	0.00	0.11	0.02	0.07	0.02	0.03	0.12	0.64
1990	M	0.00	0.03	4.85	8.94	12.71	7.53	5.61	2.63	0.75	0.23	0.05	0.02	0.00	0.02	0.03	0.26	0.05	0.46
1991	M	0.00	0.09	0.95	5.89	11.08	9.61	6.86	4.66	4.43	1.32	0.44	0.28	0.12	0.07	0.34	0.15	0.08	1.71
1992	M	0.00	0.23	1.94	3.06	7.42	7.79	8.14	4.66	4.91	2.69	1.81	0.75	0.46	0.26	0.18	0.00	0.07	1.00
1993	M	0.01	0.05	1.54	5.51	5.16	6.10	5.89	3.95	2.61	2.89	2.21	2.64	1.39	0.86	1.00	0.52	0.34	1.63
1994	M	0.00	0.12	1.02	4.18	8.88	6.00	4.70	3.73	2.73	2.20	2.53	1.59	1.29	1.06	0.49	0.33	0.24	1.70
1995	M	0.08	1.26	3.17	5.55	9.24	9.62	6.73	2.84	3.18	1.89	1.52	2.54	0.96	0.77	0.58	0.70	0.20	1.22
1996	M	0.06	1.09	5.43	10.93	10.64	6.41	3.55	2.06	1.40	1.18	0.74	0.63	0.86	0.32	0.40	0.36	0.24	0.78
1997	M	0.00	0.23	4.03	14.49	12.69	5.42	1.89	1.06	0.82	0.60	0.63	0.77	0.08	0.39	0.17	0.04	0.09	0.43
1998	M	0.00	0.20	1.43	4.56	15.47	11.47	4.39	1.40	0.65	0.66	0.64	0.30	0.26	0.21	0.58	0.11	0.00	0.49
1999	M	0.00	0.16	1.20	4.34	6.30	9.45	10.08	5.71	3.25	1.68	0.65	0.52	0.17	0.40	0.08	0.28	0.00	0.59

Table 5. Percent age composition data for the Oregon midwater trawl fishery, by sex and year with the sum across sexes equal to 1.

		Age															
Year	Sex	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1984	F	0.00	0.05	1.51	13.55	16.51	1.60	3.63	0.58	0.34	1.14	2.80	7.28	2.16	0.53	0.55	2.18	3.05	5.77
1985	F	0.00	0.00	5.97	6.50	25.00	8.64	1.10	1.26	0.94	0.00	0.12	0.70	1.80	0.27	0.15	0.12	0.19	0.68
1986	F	0.00	0.00	0.94	12.84	8.29	17.15	6.71	0.30	1.04	0.44	0.00	0.04	0.39	1.85	0.13	0.43	0.08	0.82
1987	F	0.00	0.09	1.24	10.93	22.29	8.62	3.17	2.79	0.11	0.28	0.13	0.01	0.00	0.12	0.63	0.04	0.03	0.65
1988	F	0.12	0.59	1.44	7.62	19.45	9.73	2.53	1.97	1.01	0.32	0.56	0.00	0.00	0.00	0.00	0.45	0.34	0.49
1989	F	0.00	0.34	2.37	3.35	7.75	19.59	8.79	3.12	1.59	1.53	0.90	0.18	0.00	0.07	0.00	0.16	0.64	1.19
1990	F	0.00	0.00	1.81	3.26	5.41	7.93	15.17	10.39	3.73	2.17	0.91	0.22	0.19	0.06	0.08	0.00	0.00	0.39
1991	F	0.00	0.00	1.06	6.16	9.17	6.51	6.93	9.58	4.69	1.33	0.97	0.46	0.34	0.09	0.05	0.05	0.23	1.91
1992	F	0.00	0.00	2.09	2.91	7.02	7.77	4.38	6.22	8.76	3.08	1.39	0.59	0.11	0.18	0.19	0.20	0.00	0.72
1993	F	0.00	0.07	1.08	6.71	3.96	8.08	6.79	3.90	4.47	6.34	3.45	2.39	2.14	0.82	0.45	0.41	0.19	0.81
1994	F	0.00	0.01	1.03	4.78	14.61	6.29	5.76	3.89	4.21	2.24	2.71	1.43	2.58	0.60	0.00	0.00	0.29	0.41
1995	F	0.00	0.64	0.22	1.91	4.28	10.66	10.78	6.74	5.72	5.42	1.55	3.52	0.88	0.29	0.09	0.00	0.00	0.20
1996	F	0.00	0.78	7.19	5.84	8.09	8.33	4.86	2.02	3.90	1.32	1.66	2.23	1.81	0.58	0.00	0.00	0.00	2.44
1997	F	0.00	0.21	1.99	18.52	8.52	3.58	2.81	1.51	1.00	0.91	1.01	1.08	0.50	1.38	0.00	0.18	0.00	0.36
1998	F	0.00	0.00	0.68	3.24	15.38	8.70	4.03	3.88	3.39	1.36	1.52	1.59	0.00	0.00	0.67	0.00	0.00	0.00
1999	F	0.00	0.00	1.26	1.89	6.35	23.97	10.26	4.75	2.25	1.16	1.66	1.11	0.00	1.12	0.60	0.00	0.00	0.00
1984	M	0.00	0.14	1.37	13.34	8.20	0.62	2.01	0.64	0.40	0.63	1.20	2.45	1.06	1.59	0.08	0.20	0.08	2.77
1985	M	0.00	0.17	6.39	6.46	22.44	6.12	0.74	0.57	0.29	0.00	0.16	0.50	1.31	0.22	0.22	0.00	0.00	0.96
1986	M	0.00	0.00	0.56	10.33	7.27	19.47	6.22	0.39	0.72	0.36	0.00	0.04	0.11	1.56	0.40	0.27	0.11	0.72
1987	M	0.00	0.00	1.42	11.82	21.54	6.98	3.50	1.62	0.18	0.25	0.22	0.03	0.02	0.13	0.26	0.00	0.65	0.24
1988	M	0.06	0.14	1.72	7.91	24.86	12.26	2.77	2.03	0.71	0.00	0.00	0.06	0.00	0.00	0.33	0.26	0.00	0.28
1989	M	0.00	0.41	1.56	4.69	11.48	18.82	7.03	1.30	1.41	0.23	0.02	0.01	0.05	0.07	0.21	0.21	0.35	0.58
1990	M	0.00	0.33	2.77	3.04	5.68	9.92	13.25	6.71	3.25	1.54	0.74	0.35	0.00	0.10	0.00	0.18	0.00	0.42
1991	M	0.00	0.00	0.74	6.85	9.77	10.19	6.69	8.60	4.07	0.95	0.77	0.33	0.26	0.09	0.06	0.00	0.06	1.04
1992	M	0.00	0.00	3.28	3.58	8.37	8.59	8.99	4.07	9.16	2.99	2.26	1.23	0.18	0.38	0.00	0.00	0.11	1.19
1993	M	0.00	0.00	1.72	6.99	5.62	8.53	5.10	3.58	3.37	6.15	2.50	1.51	1.19	0.55	0.00	0.32	0.12	0.72
1994	M	0.01	0.20	1.06	7.60	15.10	8.49	4.88	4.36	1.36	2.01	2.40	0.00	0.19	0.70	0.00	0.00	0.00	0.84
1995	M	0.00	0.51	2.05	2.25	12.77	9.93	6.78	4.47	2.89	0.93	2.81	0.88	0.00	0.00	0.00	0.73	0.00	0.11
1996	M	0.00	0.95	7.37	9.48	7.36	6.44	5.11	3.34	1.27	0.86	2.36	0.92	1.65	0.76	0.30	0.00	0.39	0.39
1997	M	0.00	0.24	3.24	26.83	12.44	4.16	2.24	2.43	1.14	0.96	0.56	0.00	0.95	1.09	0.00	0.00	0.00	0.18
1998	M	0.00	0.00	1.60	11.32	20.67	7.74	6.35	1.50	3.11	1.36	0.16	0.53	0.00	0.00	1.22	0.00	0.00	0.00
1999	M	0.00	0.00	0.01	1.87	10.22	20.16	8.55	2.26	0.01	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01

Table 6. Percent age composition data for the Oregon bottom trawl fishery, by sex and year with the sum across sexes equal to 1.

		Age															
Year	Sex	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1984	F	0.00	0.00	3.77	14.82	21.68	2.40	1.55	1.21	0.47	0.48	1.30	3.04	1.47	0.78	0.48	0.53	0.28	4.39
1985	F	0.11	0.00	2.48	6.18	19.53	12.13	1.79	0.57	0.61	0.01	0.11	2.66	3.68	0.50	0.92	0.35	0.39	3.21
1986	F	0.00	0.11	2.02	10.95	6.24	8.91	6.78	0.71	1.85	1.32	0.03	0.00	0.44	3.96	1.03	0.74	0.49	2.63
1987	F	0.00	0.16	1.06	11.66	16.68	5.85	5.13	2.98	0.37	0.38	0.16	0.32	0.03	0.49	1.72	1.41	0.35	2.36
1988	F	1.03	1.90	0.40	8.16	16.35	10.37	4.06	2.78	1.61	1.08	0.48	0.63	0.09	0.27	0.68	1.07	0.30	0.97
1989	F	0.00	0.13	2.76	2.93	6.92	14.45	8.88	3.83	4.02	1.55	0.56	0.40	0.40	0.41	0.56	0.39	1.00	1.75
1990	F	0.00	0.03	4.50	3.50	3.63	6.75	13.56	10.76	3.53	1.80	0.86	0.48	0.65	0.22	0.24	0.12	0.13	2.71
1991	F	0.00	0.03	0.87	6.13	5.84	6.62	7.78	11.06	5.66	3.36	3.38	0.66	0.47	0.34	0.20	0.04	0.30	3.43
1992	F	0.00	0.00	1.18	0.94	8.38	9.04	7.08	6.30	9.48	5.49	3.26	2.04	1.11	0.53	0.66	0.15	0.32	3.30
1993	F	0.00	0.00	0.28	2.70	2.98	7.30	7.54	4.14	3.99	5.45	3.60	2.92	1.99	1.78	0.75	1.06	0.78	3.97
1994	F	0.00	0.28	1.13	4.52	10.34	6.52	5.40	6.68	4.09	3.05	6.44	3.44	2.32	0.94	1.13	0.64	0.75	1.66
1995	F	0.00	0.33	1.50	3.03	11.65	9.32	4.32	3.92	6.00	2.97	2.05	1.84	0.35	0.29	0.45	0.24	0.00	1.44
1996	F	0.06	0.75	7.41	10.50	8.16	8.28	4.89	2.89	3.98	3.09	0.97	0.42	3.76	0.00	0.17	0.98	0.28	1.11
1997	F	0.00	0.79	3.09	10.41	9.46	3.04	4.58	3.08	1.87	1.45	0.80	1.27	0.95	1.58	0.46	0.06	0.49	1.42
1998	F	0.00	0.00	1.14	4.76	13.89	11.06	5.09	2.53	3.20	1.65	2.47	1.40	1.55	0.28	0.89	0.28	0.23	0.88
1999	F	0.00	0.00	3.31	7.17	6.49	12.30	6.30	4.67	4.46	0.86	1.25	0.54	0.58	0.25	0.00	0.16	0.13	0.16
1984	M	0.00	0.20	3.53	14.45	11.50	1.75	1.68	0.32	0.36	0.20	2.27	1.71	1.01	0.82	0.46	0.06	0.11	0.92
1985	M	0.00	0.31	4.52	9.19	18.94	4.75	0.30	0.41	0.47	0.00	0.13	1.13	2.33	0.00	0.68	0.52	0.02	1.09
1986	M	0.00	0.40	1.46	20.12	8.38	8.62	5.84	0.37	1.82	0.54	0.21	0.00	0.14	1.73	0.20	0.10	0.29	1.57
1987	M	0.00	0.00	1.15	11.17	20.35	7.21	3.97	1.64	0.30	0.25	0.71	0.00	0.00	0.61	0.55	0.21	0.00	0.80
1988	M	0.20	1.42	1.72	7.63	20.68	9.79	2.27	1.21	0.79	0.32	0.05	0.00	0.24	0.02	0.26	0.38	0.14	0.67
1989	M	0.00	0.92	2.56	5.32	9.39	17.53	6.40	2.66	1.42	0.83	0.00	0.51	0.02	0.00	0.13	0.07	0.63	0.64
1990	M	0.00	0.35	4.67	4.50	5.59	6.82	11.60	5.66	2.27	1.92	0.94	0.44	0.13	0.26	0.00	0.00	0.00	1.37
1991	M	0.00	0.02	0.53	5.58	9.95	7.79	4.59	7.65	3.66	0.91	1.14	0.28	0.13	0.35	0.02	0.00	0.09	1.13
1992	M	0.00	0.02	1.05	2.03	7.32	6.81	5.41	3.33	4.61	2.33	2.79	1.61	0.43	0.43	0.61	0.03	0.21	1.71
1993	M	0.00	0.00	0.64	3.32	3.23	7.91	9.23	4.83	3.12	5.58	3.36	2.68	1.38	0.56	0.12	0.58	0.08	2.15
1994	M	0.00	0.33	1.70	5.76	10.24	5.94	4.54	1.74	1.75	2.37	2.59	0.77	0.50	0.47	0.61	0.30	0.00	1.07
1995	M	0.00	0.28	1.79	10.51	8.56	11.70	5.45	4.60	1.90	2.19	0.66	1.33	0.21	0.73	0.00	0.05	0.00	0.33
1996	M	0.00	0.20	7.82	8.53	6.17	5.96	2.23	2.00	1.80	1.96	1.32	0.20	1.77	0.45	0.19	0.89	0.09	0.70
1997	M	0.00	0.61	4.33	23.15	11.99	4.70	3.15	2.01	0.91	1.72	0.72	0.62	0.07	0.56	0.25	0.02	0.00	0.36
1998	M	0.00	0.00	0.89	5.25	18.18	11.47	3.52	2.06	1.76	2.02	0.61	0.91	0.02	0.18	0.73	0.00	0.30	0.78
1999	M	0.00	0.71	3.42	7.33	11.71	16.21	6.46	2.84	0.78	0.03	0.00	0.82	0.16	0.03	0.02	0.03	0.66	0.16

Table 7. Percent age composition data for the Eureka-Conception combined fishery, by sex and year with the sum across sexes equal to 1.

		Age															
Year	Sex	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1980	F	0.00	0.00	0.40	0.73	0.87	0.43	6.99	17.06	8.10	7.38	6.19	3.62	2.77	1.19	1.37	1.38	0.76	2.02
1981	F	0.00	1.15	0.34	2.44	3.53	2.01	1.34	5.97	12.38	7.23	4.85	4.05	3.70	3.41	1.19	0.95	0.97	1.77
1982	F	0.00	0.03	2.93	0.94	3.44	2.98	2.56	0.62	3.73	11.36	5.64	3.62	3.78	3.61	2.24	2.28	1.83	6.09
1983	F	0.00	0.47	5.03	17.81	3.73	3.88	1.81	1.22	0.53	1.22	3.64	2.31	1.79	1.95	1.61	1.92	1.82	9.97
1984	F	0.00	0.00	2.41	11.05	10.03	2.59	3.15	1.97	0.76	0.72	3.03	5.48	1.77	1.23	1.04	0.89	0.95	6.16
1985	F	0.00	0.02	0.21	4.04	10.23	15.13	1.94	4.59	1.30	0.63	0.58	2.05	4.24	0.45	0.93	1.14	1.52	6.03
1986	F	0.00	0.15	1.85	1.85	6.04	8.42	11.94	0.89	2.78	1.59	0.51	0.24	0.36	2.84	0.35	0.77	0.27	4.23
1987	F	0.10	0.00	1.55	2.98	3.03	6.28	5.00	9.36	1.09	3.03	2.05	0.61	0.10	1.15	1.75	0.79	1.25	4.90
1988	F	0.10	10.42	3.30	6.41	6.24	5.42	3.05	4.38	4.52	0.96	1.71	1.31	0.62	0.37	1.33	1.53	0.98	5.06
1989	F	0.00	0.87	8.51	5.17	4.28	11.58	6.04	2.59	2.98	2.76	1.19	1.07	1.24	0.95	0.27	0.22	0.32	1.70
1990	F	0.00	0.08	3.17	9.75	6.01	4.71	7.20	4.81	3.52	2.56	2.69	2.64	2.32	0.35	0.73	0.42	0.40	4.00
1991	F	0.02	0.94	1.19	12.20	15.44	5.57	3.44	3.28	2.40	1.83	1.51	1.98	0.89	0.53	0.70	0.07	0.36	1.86
1992	F	0.00	0.03	1.14	3.49	10.59	10.13	4.80	3.64	4.52	1.75	3.04	2.81	2.06	0.82	0.15	0.62	0.23	6.01
1993	F	0.00	0.18	2.34	11.72	11.26	11.62	4.74	1.23	0.42	1.04	1.15	0.24	0.29	0.40	0.29	0.78	0.63	1.30
1994	F	0.35	0.25	1.25	6.40	12.18	8.11	8.28	1.59	2.36	1.14	0.80	0.87	0.82	0.89	0.72	0.03	0.22	2.35
1995	F	0.00	0.64	0.18	1.14	3.96	13.37	6.05	6.33	2.42	1.46	1.00	0.12	0.64	1.72	0.00	1.73	0.00	0.07
1996	F	0.19	0.29	4.13	4.36	4.79	6.83	5.88	4.08	3.79	3.05	0.87	1.12	1.28	0.43	0.15	0.91	0.57	0.40
1997	F	0.01	0.16	0.56	5.41	3.79	4.60	5.42	5.77	6.40	4.73	3.22	1.81	0.34	2.67	1.16	1.37	0.83	1.61
1998	F	0.00	0.12	4.11	2.99	8.05	2.86	4.73	5.61	5.65	6.77	3.67	1.16	1.25	0.57	1.46	0.29	0.58	1.50

Table 7 (cont.). Percent age composition data for the Eureka-Conception combined fishery, by sex and year with the sum across sexes equal to 1.

		Age															
Year	Sex	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1980	M	0.00	0.00	0.36	1.00	0.77	1.19	4.58	8.97	4.87	4.29	2.10	2.44	1.72	1.18	0.41	0.53	1.21	3.12
1981	M	0.00	1.36	0.34	3.55	3.10	2.10	2.29	6.25	8.43	6.10	3.80	1.52	0.87	1.68	0.39	0.27	0.08	0.56
1982	M	0.00	0.01	3.84	0.63	3.59	3.14	2.80	1.34	3.85	7.00	3.30	2.71	1.91	1.51	1.65	0.93	0.83	3.29
1983	M	0.00	0.03	3.32	14.32	2.27	2.45	1.12	1.62	0.35	0.96	2.47	1.69	1.13	0.76	0.59	1.48	1.30	3.45
1984	M	0.00	0.00	2.10	12.69	11.25	2.59	3.14	1.60	1.34	0.24	0.88	3.90	1.66	0.47	0.52	0.34	0.53	3.52
1985	M	0.00	0.10	0.53	4.13	11.94	13.20	1.77	2.19	1.36	0.35	0.26	0.92	2.94	0.42	0.47	0.43	0.26	3.70
1986	M	0.00	0.23	2.33	2.69	6.86	12.01	13.68	1.90	3.11	2.06	0.13	0.10	0.88	3.33	0.79	0.73	0.28	3.83
1987	M	0.03	0.00	2.77	3.82	3.18	5.71	6.82	14.21	0.52	3.64	1.68	0.50	0.04	1.58	2.52	1.35	0.69	5.90
1988	M	0.04	5.36	0.38	4.04	4.56	5.54	5.99	4.47	3.85	0.70	0.70	0.98	0.45	0.35	0.68	1.23	0.71	2.23
1989	M	0.00	1.27	10.27	5.79	4.05	10.38	5.64	3.76	2.08	1.02	1.63	0.50	0.32	0.09	0.08	0.15	0.51	0.72
1990	M	0.01	0.00	2.95	8.58	4.21	3.50	5.92	5.22	2.98	2.32	2.39	1.60	0.64	0.77	0.69	0.26	0.60	2.00
1991	M	0.00	0.73	1.94	12.03	10.78	4.26	3.00	3.39	2.00	1.71	1.61	1.34	0.24	0.48	0.32	0.27	0.20	1.53
1992	M	0.00	0.12	1.33	2.88	11.95	8.95	3.09	1.41	3.72	1.71	1.63	1.99	1.01	0.34	1.31	0.42	0.15	2.18
1993	M	0.00	0.00	6.68	14.01	8.97	9.02	1.85	0.75	1.04	0.74	1.01	0.24	1.87	0.65	0.31	0.36	0.05	2.82
1994	M	0.35	0.23	0.67	4.73	16.06	12.32	6.61	2.66	2.79	0.69	1.00	0.51	0.74	1.01	0.09	0.44	0.03	0.43
1995	M	0.00	2.92	2.99	1.63	7.33	14.70	8.96	8.87	2.87	1.11	1.20	1.19	1.60	0.07	1.57	1.39	0.00	0.76
1996	M	0.12	0.25	4.39	4.00	7.30	12.30	12.89	3.54	2.69	2.50	1.48	0.23	1.90	1.02	0.15	0.18	0.59	1.35
1997	M	0.00	0.17	0.93	8.33	3.30	6.44	6.47	5.78	4.63	3.50	2.68	1.47	1.18	2.13	0.18	0.62	1.12	1.22
1998	M	0.00	0.56	6.34	4.54	7.64	6.50	5.02	3.24	5.09	2.88	2.30	1.26	0.53	1.08	0.61	0.11	0.00	0.95

Table 8. Number of fish and samples collected for each year and fishery of age composition information used in the widow rockfish assessment.

	Eureka-Conception		Oregon Bottom Trawl		Oregon Midwater Trawl		Vancouver-Columbia	
Year	fish	samples	fish	samples	fish	samples	fish	samples
1980	693	101					1775	23
1981	1659	121					3050	44
1982	3247	164					3944	49
1983	2690	201					2480	26
1984	3031	178	753	26	959	23	2193	22
1985	3353	203	633	22	1530	49	1591	16
1986	8221	288	779	21	1892	54	2592	27
1987	7255	270	776	26	1807	61	1939	36
1988	4858	218	855	28	915	31	993	21
1989	7033	326	1051	47	1779	63	1494	30
1990	7791	332	1299	58	1434	61	2047	41
1991	6978	285	1592	77	1343	60	1739	35
1992	936	85	1735	88	649	29	1547	31
1993	597	40	1322	65	1192	51	1797	36
1994	3983	152	1356	63	576	22	1398	29
1995	235	11	897	40	251	11	1650	33
1996	1131	46	820	33	341	13	1347	30
1997	1157	62	1112	48	637	22	1497	35
1998	1327	37	1036	35	268	11	1099	34

Table 9. Oregon bottom trawl logbook catch-per-unit-effort index.

Year	CPUE (lbs./hr.)	CV
1984	1620	
1985	961	
1986	1921	
1987	1862	
1988	1098	0.208
1989	1646	0.143
1990	773	0.115
1991	835	0.114
1992	711	0.106
1993	600	0.126
1994	570	0.104
1995	666	0.119
1996	405	0.122
1997	644	0.122
1998	516	0.134

Table 10. Two indices of widow rockfish abundance derived from bycatch in the Pacific whiting fisheries.

		Widow/minute		Widow/Whiting	
Year	count	Mean	CV	Mean	CV
Foreign Fishery (FOR)					
1976	67	0.479	0.71	3.608	0.500
1977	272	0.165	0.71	5.901	0.599
1978	632	0.618	0.71	12.686	0.796
1979	408	0.215	0.71	9.901	0.443
1980	264	0.743	0.71	31.371	0.579
1981	289	0.731	0.71	32.971	0.620
1982	77	0.306	0.71	3.841	0.981
1983	0				
1984	329	1.304	0.71	39.646	0.323
1985	479	0.146	0.71	7.505	0.403
1986	416	0.297	0.71	7.969	0.922
1987	927	0.250	0.71	15.338	0.410
1988	329	1.041	0.71	38.303	0.649
Joint Venture Fishery (JV)					
1983	131	0.788	0.77	6.955	0.385
1985	216	0.394	0.77	12.896	0.581
1986	958	0.151	0.77	11.363	0.247
1987	1158	0.219	0.77	3.685	0.403
1988	1264	0.116	0.77	6.932	0.245
1989	2598	0.185	0.77	5.306	0.186
1990	1770	0.272	0.77	4.181	0.206
Domestic Offshore Fishery (DOM)					
1991	561	1.383	0.74	7.717	0.534
1992	521	0.794	0.74	8.241	0.195
1993	354	1.658	0.74	8.470	0.432
1994	692	0.814	0.74	5.873	0.223
1995	298	0.132	0.74	5.491	0.695
1996	478	3.821	0.74	5.463	0.304
1997	797	1.362	0.74	3.855	0.279
1998	806	2.379	0.74	4.537	0.302

Table 11. Yearly index estimates from the Tiburon Laboratory midwater trawl pelagic juvenile survey.

Year	Index Estimate	CV
1983	0.012	0.104
1984	0.671	0.663
1985	4.402	0.638
1986	0.049	0.172
1987	3.288	0.374
1988	1.620	0.294
1989	0.131	0.240
1990	0.104	0.193
1991	2.165	0.405
1992	0.000	0.000
1993	0.363	0.308
1994	0.065	0.157
1995	0.086	0.188
1996	0.000	0.000
1997	0.237	0.243
1998	0.007	0.107
1999	0.340	0.275

Table 12. California trawl logbook catch-per-unit-effort (CPUE) index for widow rockfish (Ralston 1999).

Year	CPUE (lbs./hr.)	CV
1982	2558	0.305
1983	476	0.191
1984	646	0.342
1985	355	0.169
1986	651	0.238
1987	1039	0.344
1988	1008	0.469
1989	332	0.211
1990	445	0.290
1991	140	0.293
1992	1101	1.164
1993	225	0.222
1994	597	0.593
1995	1049	0.330
1996	433	0.561

Table 13. Biomass estimates for widow rockfish from the Alaska Fisheries Science Center triennial bottom trawl survey.

Year	Biomass (mt)	CV
1977	3698	0.635
1980	1672	0.395
1983	3549	0.488
1986	4891	0.627
1989	9274	0.487
1992	12597	0.835
1995	3021	0.764
1998	4344	0.320

Table 14. Description of the catch-age model for widow rockfish.

General Definitions	**Symbol/Value**	**Use in Model or Equation**
Sex Index: $x = \{1,2\}$	1 = male 2 = female	
Year Index: $y = \{1968,\ldots,1999\}$		
Age Index: $a = \{3, 4, \ldots, 19, 20+\}$		
Fishery Index: $f = \{1, 2, 3, 4\}$		
Natural Mortality: Constant for all x, y, a	$M = 0.15$	
Discard: (see text)	D_y	Used for Landings
Fraction of Landings in North: (see text)	ϕ_y	Used for parsing area specific weight, maturity, and fecundity
Weight-at-age: (see text) for $f = \{1, 2, 3\}$ northern estimates for $f = \{4\}$ southern estimates	$W^f_{x,a}$	Used for Biomass and Landings
Maturity-at-age: (see text) for $f = \{1, 2, 3\}$ northern estimates for $f = \{4\}$ southern estimates	$P^f_{x=2,a}$	Used for Spawning Biomass
Fecundity-at-age: (see text) for $f = \{1, 2, 3\}$ northern estimates for $f = \{4\}$ southern estimates	$G^f_{x=2,a}$	Used for Spawning Output
Ageing error: $A_{a,a'}$, the probability of ageing a fish of true age a as age a'	$\sum_{a'=3}^{20+} A_{a,a'} = 1.0$	Model estimated age composition: $\tilde{\theta}_{x,y,a}$ Predicted (reader) age composition: $\hat{\theta}_{x,y,a} = \tilde{\theta}_{x,y,a} A_{a,a'}$
Selectivity:	$s^f_{x,y,a}$	Logistic: $s^f_{x,y,a} = \left[\frac{1}{1+e^{-\eta_{2,f,x}(a-\eta_{1,f,x})}}\right]$ Lognormal: $s^f_{x,y,a} = \frac{1}{h\eta_{\sigma,f,x}\sqrt{2\pi}} \exp\left[\frac{-(\log(h)-\eta_{m,f,x})^2}{2\eta^2_{\sigma,f,x}}\right]$ where, $h = \begin{cases} \eta_{h,f,x} + a & if \quad \eta_{h,f,x} + a > 1 \\ 100^{\eta_{h,f,x}+a-1} & if \quad \eta_{h,f,x} + a \le 1 \end{cases}$

		Double Logistic: $s^{f}_{x,y,a}=\left[\frac{1}{1+e^{-\eta_{2,f,x}\left(a-\eta_{1,f,x}\right)}}\right]\left[1-\frac{1}{1+e^{\eta_{4,f,x}\left(a-\eta_{3,f,x}\right)}}\right]\frac{1}{\max\left(s^{f}_{x,y}\right)}$
Fishing Mortality:	$F^{f}_{x,y,a}$	$F^{f}_{x,y,a}=e^{\mu^{f}+\delta^{f}_{y}}s^{f}_{x,y,a}$
Numbers in First Year: $y = 1968$	$N_{x,1968,a}$	$N_{x,1968,a}=e^{R^{\mu}+R^{\delta}_{1968}}0.5$ $N_{x,1968,a}=N_{x,1968,a-1}e^{-\sum_{f=1}^{4}\left(F^{f}_{x,1968,a-1}+M\right)}$ [for $3 < a < 20+$] $N_{x,1968,20+}=\frac{N_{x,1968,19}e^{-\sum_{f=1}^{4}\left(F^{f}_{x,1968,a-1}+M\right)}}{\left[1-e^{-\sum_{f=1}^{4}\left(F^{f}_{x,1968,20+}+M\right)}\right]}$
Numbers in Subsequent Years: $y > 1968$	$N_{x,y,a}$	$N_{x,y,a}=e^{R^{\mu}+R^{\delta}_{y}}0.5$ $N_{x,y,a}=N_{x,y-1,a-1}e^{-\sum_{f=1}^{4}\left(F^{f}_{x,y-1,a-1}+M\right)}$ $N_{x,y,20+}=N_{x,y-1,19}e^{-\sum_{f=1}^{4}\left(F^{f}_{x,y-1,19}+M\right)}+N_{x,y-1,20+}e^{-\sum_{f=1}^{4}\left(F^{f}_{x,y-1,20+}+M\right)}$
Catch	$C^{f}_{x,y,a}$	$C^{f}_{x,y,a}=N_{x,y,a}\frac{F^{f}_{x,y,a}}{\sum_{f=1}^{4}\left(F^{f}_{x,y,a}+M\right)}\left(1-e^{-\sum_{f=1}^{4}\left(F^{f}_{x,y,a}+M\right)}\right)$
Biomass	$B_{x,y,a}$	$B_{x,y,a}=N_{x,y,a}\phi_{y}W^{1}_{x,a}+N_{x,y,a}\left(1-\phi_{y}\right)W^{4}_{x,a}$
Spawning Biomass	SSB_{y}	$SSB_{y}=N_{2,y,a}\phi_{y}W^{1}_{2,a}P^{1}_{2,a}+N_{2,y,a}\left(1-\phi_{y}\right)W^{4}_{2,a}P^{4}_{2,a}$
Spawning Output	SO_{y}	$SO_{y}=N_{2,y,a}\phi_{y}P^{1}_{2,a}G^{1}_{2,a}+N_{2,y,a}\left(1-\phi_{y}\right)P^{4}_{2,a}G^{4}_{2,a}$

Data Description	**Symbol/Value**	**Expected Value**
AFSC Triennial Trawl Survey: y = {1977, 80, 83, 86, 89, 92, 95, 98}	I_y^T	$\hat{I}_y^T = e^{Q^T} \sum_{x=1}^{2} \sum_{a=3}^{20+} s_a^T B_{x,y,a}$
Oregon Bottom Trawl Logbook Index: y = {1984, …, 1998}	I_y^O	$\hat{I}_y^O = e^{Q^O} \sum_{x=1}^{2} \sum_{a=3}^{20+} s_{x,a}^3 B_{x,y,a}$
California Trawl Logbook Index: y = {1978, …, 1996}	I_y^C	$\hat{I}_y^C = e^{Q^C} \sum_{x=1}^{2} \sum_{a=3}^{20+} s_{x,a}^4 B_{x,y,a}$
Foreign Whiting Bycatch Index: y = {1976, …, 1982, 1984, …, 1988}	I_y^F	$\hat{I}_y^F = e^{Q^F} \sum_{x=1}^{2} \sum_{a=3}^{20+} s_{x,a}^2 B_{x,y,a}$
JV Whiting Bycatch Index: y = {1983, 1985, …, 1990}	I_y^J	$\hat{I}_y^J = e^{Q^J} \sum_{x=1}^{2} \sum_{a=3}^{20+} s_{x,a}^2 B_{x,y,a}$
Domestic Whiting Bycatch Index: y = {1991, …, 1999}	I_y^D	$\hat{I}_y^D = e^{Q^D} \sum_{x=1}^{2} \sum_{a=3}^{20+} s_{x,a}^2 B_{x,y,a}$
Midwater Trawl Pelagic Juvenile Survey: y = {1983, …, 1999}	I_y^M	$\hat{I}_y^M = e^{Q^M} \left(\sum_{x=1}^{2} N_{x,y+3,1} \right)^{\psi^M}$
AFSC Triennial Age Composition: y = 1980	$\theta_{1980,a}^T$	$\hat{\theta}_{1980,a}^T = \dfrac{\sum_{x=1}^{2} N_{x,1980,a} s_a^T}{\sum_{x=1}^{2} \sum_{a=3}^{20+} N_{x,1980,a} s_a^T}$
Fishery Age Compositions:	$\theta_{x,y,a}^f$	$\hat{\theta}_{x,y,a}^f = \dfrac{N_{x,y,a} s_a^f}{\sum_{x=1}^{2} \sum_{y} \sum_{a=3}^{20+} N_{x,y,a} s_a^f}$

Landings:	L_y^f	$\hat{L}_y^f = \dfrac{\sum_{x=1}^{2}\sum_{a=3}^{20+} C_{x,y,a}^{f} W_{x,a}^{f} 0.001}{\left(1+D_y\right)}$

Estimated Parameter Descriptions	**Symbol/Value**	
Log average recruitment	R^{μ}	
Log recruitment deviation	R_y^{δ}	$y = \{1968, \ldots, 1999\}$
Log average fishing mortality	μ^{f}	$f = \{1, 2, 3, 4\}$
Log fishing mortality deviation	δ_y^{f}	$f = \{1, 4\}, y = \{1973, \ldots, 1999\}$ $f = \{2, 3\}, y = \{1983, \ldots, 1999\}$
Log catchability for indices	Q^{i}	$i = \{T, O, C, F, J, D, M\}$
Power transform for juvenile survey	ψ^{M}	
Logistic fishery selectivity:		
age of 50% selection	$\eta_{1,x}^{f}$	$f = \{1, 2, 3, 4\}; x = \{1, 2\}$
slope parameters	$\eta_{2,x}^{f}$	$f = \{1, 2, 3, 4\}; x = \{1, 2\}$
Double logistic fishery selectivity:	$\eta_{3,x}^{f}$	$f = \{1, 2, 3, 4\}; x = \{1, 2\}$
(include logistic parameters)	$\eta_{4,x}^{f}$	$f = \{1, 2, 3, 4\}; x = \{1, 2\}$
Lognormal selectivity:		
mode	$\eta_{m,x}^{f}$	$f = \{1, 2, 3, 4\}; x = \{1, 2\}$
standard deviation	$\eta_{\sigma,x}^{f}$	$f = \{1, 2, 3, 4\}; x = \{1, 2\}$
horizontal shift	$\eta_{h,x}^{f}$	$f = \{1, 2, 3, 4\}; x = \{1, 2\}$
Logistic triennial survey selectivity:		
age of 50% selection	η_{1}^{T}	
slope parameters	η_{2}^{T}	

Likelihood Component	**Equation**	**Notes**
Fishery age compositions	$\mathsf{L}_1 = \sum_{f=1}^{4} \lambda_1 n_y^f \sum_{x=1}^{2} \sum_{a=3}^{20+} \theta_{x,y,a}^f \log\left(\hat{\theta}_{x,y,a}^f\right)$	Multinomial with sample size, *n*, set equal to sampled trips
Triennial age composition	$\mathsf{L}_2 = \lambda_2 n^T \sum_{a=3}^{20+} \theta_{1980,a}^T \log\left(\hat{\theta}_{1980,a}^T\right)$	Multinomial with true sample size
Fishery landings	$\mathsf{L}_3 = \sum_{f=1}^{4} \frac{\left[\log\left(L_y^f\right) - \log\left(\hat{L}_y^f\right)\right]^2}{2\left(\lambda_3 cv\right)^2} + \log\left(\lambda_3 cv\right)$	Coefficient of variation, *cv*, is assumed to be 0.05
AFSC triennial trawl survey	$\mathsf{L}_4 = \frac{\left[\log\left(I_y^T\right) - \log\left(\hat{I}_y^T\right)\right]^2}{2\left(\lambda_4 cv^T\right)^2} + \log\left(\lambda_4 cv^T\right)$	
Oregon bottom trawl logbook index	$\mathsf{L}_5 = \frac{\left[\log\left(I_y^O\right) - \log\left(\hat{I}_y^O\right)\right]^2}{2\left(\lambda_5 cv^O\right)^2} + \log\left(\lambda_5 cv^O\right)$	
California trawl logbook index	$\mathsf{L}_6 = \frac{\left[\log\left(I_y^C\right) - \log\left(\hat{I}_y^C\right)\right]^2}{2\left(\lambda_6 cv^C\right)^2} + \log\left(\lambda_6 cv^C\right)$	
Foreign whiting bycatch index	$\mathsf{L}_7 = \frac{\left[\log\left(I_y^F\right) - \log\left(\hat{I}_y^F\right)\right]^2}{2\left(\lambda_7 cv^F\right)^2} + \log\left(\lambda_7 cv^F\right)$	
JV whiting bycatch index	$\mathsf{L}_8 = \frac{\left[\log\left(I_y^J\right) - \log\left(\hat{I}_y^J\right)\right]^2}{2\left(\lambda_8 cv^J\right)^2} + \log\left(\lambda_8 cv^J\right)$	
Domestic whiting bycatch index	$\mathsf{L}_9 = \frac{\left[\log\left(I_y^D\right) - \log\left(\hat{I}_y^D\right)\right]^2}{2\left(\lambda_9 cv^D\right)^2} + \log\left(\lambda_9 cv^D\right)$	

Midwater trawl pelagic juvenile survey	$\mathsf{L}_{10} = \frac{\left[\log\left(I_y^M\right) - \log\left(\hat{I}_y^M\right)\right]^2}{2\left(\lambda_{10} cv^M\right)^2} + \log\left(\lambda_{10} cv^M\right)$	
Recruitment prior	$\mathsf{L}_{11} = \lambda_{11} \sum_{y=1968}^{1999} \left(R_y^{\delta}\right)^2$	
Fishing mortality priors	$\mathsf{L}_{12} = \lambda_{12} \sum_{f=1}^{4} \sum_{y} \left(\delta_y^f\right)^2$	$f = \{1, 4\}$, $y = \{1973, \ldots, 1999\}$ $f = \{2, 3\}$, $y = \{1983, \ldots, 1999\}$

Table 15. Widow rockfish model runs with various likelihood components de-emphasized (indicated by shading).

Likelihood Component	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
Triennial Biomass Survey	10.376	50.386	8.076	6.765	10.437	10.307	10.500	10.522	7.135
Triennial Age Comps	296.76	0.34	295.89	297.41	297.02	296.83	296.77	297.03	296.44
Fishery Age Comps	16030.1	16009.4	16005.8	16032.1	16029.5	16029.9	16029.9	16029.5	16005.2
Landings	-11.925	-11.913	-11.966	-11.946	-11.922	-11.926	-11.920	-11.918	-11.966
Midwater Trawl Index	-12.599	-12.203	96.725	-14.292	-12.590	-12.605	-12.491	-12.488	96.724
Oregon Logbook Index	-12.378	-13.609	-15.149	72.650	-12.373	-12.347	-12.582	-12.568	72.650
Foreign Bycatch Index	3.308	3.893	3.156	3.225	78.783	3.279	3.312	78.783	78.783
JV Bycatch Index	1.155	1.155	1.245	1.258	1.100	46.525	1.153	46.525	46.525
Modern Bycatch Index	4.046	4.147	4.083	3.886	4.047	4.043	52.853	52.853	52.853
Change in Comparable Components Relative to Case 1		-20.84	-30.31	-2.82	-0.32	-0.21	-0.16	-0.25	-28.50

Table 16. Widow rockfish model runs with various sets of selectivity functions.

Likelihood Component	Logistic Selectivity	Double Logistic Selectivity	Lognormal Selectivity	Year-Specific Logistic	Year-Specific Double Logistic
Triennial Biomass Survey	50.386	50.386	50.386	50.386	50.386
Triennial Age Comps	0.032	0.032	0.033	0.032	0.032
Fishery Age Comps	16241.6	16214.7	16210.4	16034.7	16006.9
Landings	-10.779	-10.846	-10.857	-10.781	-10.859
Midwater Trawl Index	-5.752	-5.399	-9.958	-12.584	-12.822
Oregon Logbook Index	1.041	0.255	4.405	-12.053	-12.568
California Logbook Index	17.070	17.168	17.139	19.711	20.030
Foreign Bycatch Index	15.268	15.054	15.880	14.562	14.074
JV Bycatch Index	-4.333	-4.292	-3.929	-4.328	-3.990
Modern Bycatch Index	-7.591	-7.744	-6.812	-7.905	-7.496
Total	16296.94	16269.31	16266.69	16071.74	16043.69
Number of Parameters	151	167	159	293	309
Akaike Information Criterion	-32291.9	-32204.6	-32215.4	-31557.5	-31469.4

Table 17. Model parameter estimates and associated standard deviations for the preferred model.

Parameter	Estimate	St.Dev.
R^{μ}	10.165	0.075103
R^{δ}_{1968}	0.13095	0.12607
R^{δ}_{1969}	0.39804	0.24098
R^{δ}_{1970}	0.37862	0.2247
R^{δ}_{1971}	0.57909	0.17917
R^{δ}_{1972}	0.43293	0.19084
R^{δ}_{1973}	1.4468	0.10564
R^{δ}_{1974}	0.49602	0.1383
R^{δ}_{1975}	-0.21371	0.16368
R^{δ}_{1976}	-0.71946	0.22584
R^{δ}_{1977}	-0.069642	0.17491
R^{δ}_{1978}	0.34119	0.13252
R^{δ}_{1979}	-1.202	0.32812
R^{δ}_{1980}	0.99896	0.089632
R^{δ}_{1981}	0.62855	0.09716
R^{δ}_{1982}	-0.033204	0.12945
R^{δ}_{1983}	0.60921	0.10523
R^{δ}_{1984}	0.87434	0.086909
R^{δ}_{1985}	-0.17959	0.13495
R^{δ}_{1986}	-0.69318	0.11281
R^{δ}_{1987}	0.228	0.10451
R^{δ}_{1988}	0.077844	0.088111
R^{δ}_{1989}	-0.48399	0.090252
R^{δ}_{1990}	0.13052	0.091166
R^{δ}_{1991}	-0.0086503	0.081072
R^{δ}_{1992}	-0.34708	0.083183
R^{δ}_{1993}	-0.35713	0.080871
R^{δ}_{1994}	0.19044	0.11579
R^{δ}_{1995}	-1.1487	0.29062
R^{δ}_{1996}	-0.17126	0.083294
R^{δ}_{1997}	-0.43562	0.086228
R^{δ}_{1998}	-0.3926	0.084014
R^{δ}_{1999}	-1.4857	1.6249
η^{1}_{2}	2.8848	0.59701
η^{1}_{1}	5.6224	0.13763
η^{2}_{2}	2.2135	0.21833
η^{2}_{1}	6.5455	0.11945
η^{3}_{2}	2.1552	0.261
η^{3}_{1}	6.2311	0.1462
η^{4}_{2}	2.3687	0.19898
η^{4}_{1}	5.9647	0.092603
$\eta^{\{1,2,3\}}_{1,1980}$	-0.31356	0.14107
$\eta^{\{1,2,3\}}_{1,1981}$	-0.55233	0.17567
$\eta^{\{1,2,3\}}_{1,1982}$	-0.23999	0.1343
$\eta^{\{1,2,3\}}_{1,1983}$	-0.5107	0.18668
$\eta^{\{1,2,3\}}_{1,1984}$	-0.55868	0.24316
$\eta^{\{1,2,3\}}_{1,1985}$	-0.27356	0.17267
$\eta^{\{1,2,3\}}_{1,1986}$	0.079748	0.14523
$\eta^{\{1,2,3\}}_{1,1987}$	0.32649	0.15454
$\eta^{\{1,2,3\}}_{1,1988}$	0.7899	0.19666
$\eta^{\{1,2,3\}}_{1,1989}$	0.63723	0.18737
$\eta^{\{1,2,3\}}_{1,1990}$	0.12853	0.17715
$\eta^{\{1,2,3\}}_{1,1991}$	0.3994	0.22608
$\eta^{\{1,2,3\}}_{1,1992}$	-0.22699	0.2055
$\eta^{\{1,2,3\}}_{1,1993}$	-0.49715	0.21106
$\eta^{\{1,2,3\}}_{1,1994}$	0.27532	0.26692
$\eta^{\{1,2,3\}}_{1,1995}$	-0.053127	0.23138
$\eta^{\{1,2,3\}}_{1,1996}$	-0.25423	0.28604
$\eta^{\{1,2,3\}}_{1,1997}$	-0.32263	0.39041
$\eta^{\{1,2,3\}}_{1,1998}$	0.34249	0.36268
$\eta^{\{1,2,3\}}_{1,1999}$	0.82382	0.29192
$\eta^{4}_{1,1980}$	1.1449	0.58222
$\eta^{4}_{1,1981}$	0.10575	0.33558
$\eta^{4}_{1,1982}$	0.056266	0.19432
$\eta^{4}_{1,1983}$	-0.38397	0.14787
$\eta^{4}_{1,1984}$	-0.16634	0.17792
$\eta^{4}_{1,1985}$	0.53234	0.16767
$\eta^{4}_{1,1986}$	0.71639	0.13512
$\eta^{4}_{1,1987}$	1.2491	0.14949
$\eta^{4}_{1,1988}$	-1.9042	0.15982
$\eta^{4}_{1,1989}$	-1.1171	0.1328
$\eta^{4}_{1,1990}$	-0.22626	0.13378
$\eta^{4}_{1,1991}$	-0.4699	0.14873
$\eta^{4}_{1,1992}$	0.38592	0.24533
$\eta^{4}_{1,1993}$	-0.59895	0.32073
$\eta^{4}_{1,1994}$	0.21378	0.18221
$\eta^{4}_{1,1995}$	0.30359	0.78214
$\eta^{4}_{1,1996}$	0.014928	0.30986
$\eta^{4}_{1,1997}$	0.64097	0.27316
$\eta^{4}_{1,1998}$	-0.49725	0.34811

Table 17 (cont.) Model parameter estimates and associated standard deviations for the preferred model.

Parameter	**Estimate**	**St.Dev.**	**Parameter**	**Estimate**	**St.Dev.**
η^{1}_{4}	0.25383	0.11055	δ^{1}_{1993}	0.73013	0.080392
η^{1}_{3}	16.895	2.0993	δ^{1}_{1994}	0.42675	0.10377
η^{2}_{4}	0.18499	0.023483	δ^{1}_{1995}	0.43968	0.093759
η^{2}_{3}	0.00003749	0.020909	δ^{1}_{1996}	0.33427	0.11506
η^{3}_{4}	0.093879	0.020887	δ^{1}_{1997}	0.38242	0.11757
η^{3}_{3}	0.00031411	0.16463	δ^{1}_{1998}	-0.05624	0.13486
η^{4}_{4}	0.43607	0.23021	δ^{1}_{1999}	-0.05606	0.14528
η^{4}_{3}	22.237	1.8896	μ^{2}	-2.6496	0.095565
η^{T}_{2}	3.0648	1.0908	δ^{2}_{1983}	-0.4445	0.088323
η^{T}_{1}	6.0697	0.25266	δ^{2}_{1984}	0.18735	0.084028
Q^{T}	-2.9795	0.19882	δ^{2}_{1985}	0.033187	0.080262
Q^{M}	-69.219	11.948	δ^{2}_{1986}	-0.00784	0.086088
ψ^{M}	6.5311	1.1299	δ^{2}_{1987}	0.39013	0.077304
Q^{O}	-4.0848	0.11312	δ^{2}_{1988}	0.2446	0.070029
$Q^{\{F,J\}}$	-12.169	0.17756	δ^{2}_{1989}	0.60615	0.069022
Q^{D}	-10.28	0.28701	δ^{2}_{1990}	0.46666	0.062888
log_rmean	10.404	0.16135	δ^{2}_{1991}	0.023149	0.063328
rmean_cv	0.60435	0.12235	δ^{2}_{1992}	-0.39021	0.087216
log_rpsmean	0.41679	1.2248	δ^{2}_{1993}	0.06476	0.061779
rpsmean_cv	0.65884	0.85149	δ^{2}_{1994}	-0.03489	0.077026
μ^{1}	-3.8816	0.079695	δ^{2}_{1995}	-0.14744	0.078842
δ^{1}_{1973}	-3.4877	0.091863	δ^{2}_{1996}	-0.17216	0.095997
δ^{1}_{1974}	-4.5269	0.084931	δ^{2}_{1997}	-0.15924	0.086171
δ^{1}_{1975}	-2.6147	0.079866	δ^{2}_{1998}	-0.68941	0.11204
δ^{1}_{1976}	-2.0745	0.072771	δ^{2}_{1999}	0.029698	0.11891
δ^{1}_{1977}	-0.8716	0.072842	μ^{3}	-3.1185	0.098922
δ^{1}_{1978}	-1.6134	0.075894	δ^{3}_{1983}	-0.34182	0.085324
δ^{1}_{1979}	-1.0077	0.078681	δ^{3}_{1984}	-0.58556	0.087253
δ^{1}_{1980}	1.9315	0.078197	δ^{3}_{1985}	-1.0402	0.082762
δ^{1}_{1981}	2.4413	0.075169	δ^{3}_{1986}	-0.70102	0.08105
δ^{1}_{1982}	2.3463	0.077737	δ^{3}_{1987}	-0.80458	0.075492
δ^{1}_{1983}	0.90219	0.080078	δ^{3}_{1988}	-0.76552	0.072018
δ^{1}_{1984}	0.11981	0.072856	δ^{3}_{1989}	-0.01443	0.066114
δ^{1}_{1985}	0.25386	0.069777	δ^{3}_{1990}	0.29483	0.061686
δ^{1}_{1986}	0.79646	0.07433	δ^{3}_{1991}	0.28395	0.060294
δ^{1}_{1987}	1.1821	0.077307	δ^{3}_{1992}	0.68684	0.07188
δ^{1}_{1988}	1.1048	0.070534	δ^{3}_{1993}	0.97288	0.072851
δ^{1}_{1989}	1.327	0.06286	δ^{3}_{1994}	0.5624	0.069854
δ^{1}_{1990}	0.98495	0.071072	δ^{3}_{1995}	0.59898	0.075336
δ^{1}_{1991}	0.44227	0.079609	δ^{3}_{1996}	0.47109	0.089517
δ^{1}_{1992}	0.16298	0.071608	δ^{3}_{1997}	0.50806	0.086043

Table 17 (cont.) Model parameter estimates and associated standard deviations for the preferred model.

Parameter	**Estimate**	**St.Dev.**
δ^3_{1998}	0.13633	0.10696
δ^3_{1999}	-0.26222	0.11646
μ^4	-3.823	0.07456
δ^4_{1973}	-3.9904	0.088255
δ^4_{1974}	-5.0432	0.082543
δ^4_{1975}	-3.089	0.078129
δ^4_{1976}	-2.4962	0.073726
δ^4_{1977}	-1.3265	0.072463
δ^4_{1978}	-1.8927	0.073151
δ^4_{1979}	-0.25075	0.073737
δ^4_{1980}	0.81924	0.077157
δ^4_{1981}	1.1066	0.076016
δ^4_{1982}	1.9495	0.068548
δ^4_{1983}	1.5832	0.069468
δ^4_{1984}	0.99647	0.069734
δ^4_{1985}	1.183	0.067812
δ^4_{1986}	1.0055	0.06495
δ^4_{1987}	1.1838	0.068441
δ^4_{1988}	0.4846	0.058733
δ^4_{1989}	0.70165	0.057608
δ^4_{1990}	0.98762	0.060356
δ^4_{1991}	0.45422	0.061685
δ^4_{1992}	0.59146	0.075529
δ^4_{1993}	0.49598	0.084629
δ^4_{1994}	0.59405	0.087246
δ^4_{1995}	1.0878	0.15739
δ^4_{1996}	0.85698	0.11872
δ^4_{1997}	1.1042	0.1416
δ^4_{1998}	0.67349	0.13048
δ^4_{1999}	0.22928	0.12783
F40	0.16934	0.042019
F45	0.14265	0.034766
F50	0.1203	0.029443
F55	0.10118	0.025393
F65	0.06993	0.019677
F70	0.056884	0.017598

Table 18. Estimated population trends of widow rockfish from the preferred model.

Year	Age 3 Recruits (1,000's)	Age 3+ Biomass (mt)	Spawning Biomass (mt)	Spawning Output (10^6 eggs)	Fishing Mortality
1968	29603	170050	79164	30662	0.000
1969	39748	172610	79216	30664	0.000
1970	37990	175380	79340	30667	0.000
1971	47532	180930	79935	30716	0.000
1972	39929	185370	81064	30910	0.000
1973	112580	208160	83346	31371	0.001
1974	42955	217800	86295	32096	0.000
1975	20667	220530	91792	33298	0.002
1976	11070	217560	97919	35254	0.004
1977	23596	214820	102340	37731	0.014
1978	39407	212070	103510	39189	0.007
1979	2219	200700	101550	39316	0.024
1980	73666	203480	97283	38031	0.190
1981	48325	184710	81962	32253	0.300
1982	24940	156440	65700	25329	0.366
1983	47876	138690	52717	19457	0.234
1984	62307	138070	49035	17592	0.192
1985	21666	133480	48076	17055	0.186
1986	13094	126830	47341	16665	0.197
1987	32540	122460	46872	16480	0.262
1988	28129	113140	44019	15782	0.208
1989	16110	103210	40928	14978	0.294
1990	29622	94565	35356	13019	0.285
1991	25813	88361	31578	11552	0.197
1992	18452	84924	30582	11078	0.199
1993	18265	81692	29749	10632	0.270
1994	31413	79630	27791	9860	0.216
1995	8327	73766	26908	9533	0.237
1996	21956	71003	25516	8985	0.209
1997	16901	67795	24530	8664	0.228
1998	17637	64256	23269	8262	0.148
1999	5917	60551	23077	8223	0.153

Table 19. Sensitivity analysis showing changes in the widow rockfish model likelihood components in response to various levels of natural mortality (M).

	Natural Mortality					Base					
Likelihood Component	**0.25**	**0.23**	**0.21**	**0.19**	**0.17**	**0.15**	**0.13**	**0.11**	**0.09**	**0.07**	**0.05**
Triennial Biomass Survey	10.90	10.79	10.67	10.50	10.52	10.36	10.20	9.97	9.73	9.73	2.69
Triennial Age Comps	296.50	295.92	295.32	294.91	296.59	297.15	297.47	297.55	297.37	298.30	305.61
Fishery Age Comps	16035.8	16034.3	16033.2	16032.5	16029.4	16027.9	16027.0	16027.3	16028.8	16034.7	16077.9
Landings	-11.97	-11.97	-11.96	-11.95	-11.94	-11.93	-11.91	-11.89	-11.87	-11.84	-11.88
Midwater Trawl Index	-14.44	-14.10	-13.67	-13.36	-13.02	-12.71	-12.25	-11.83	-11.37	-10.37	-15.14
Oregon Logbook Index	-12.10	-12.20	-12.30	-12.32	-12.38	-12.33	-12.30	-12.20	-12.10	-11.43	5.89
Foreign Bycatch Index	4.58	4.28	4.00	3.73	3.56	3.35	3.15	2.96	2.79	2.88	2.55
JV Bycatch Index	0.89	0.95	1.01	1.06	1.12	1.18	1.24	1.29	1.35	1.32	1.63
Modern Bycatch Index	3.97	3.99	4.00	4.01	4.03	4.04	4.06	4.07	4.08	4.29	4.00
Sum	16314.1	16312.0	16310.3	16309.1	16307.9	16307.0	16306.6	16307.2	16308.8	16317.6	16373.3

Table 20. Forecasts for widow rockfish using the mean recruits per spawning output and applying the 40-10 policy precautionary adjustment.

Fishing Rate	Year	Age 3+ Biomass (mt)	Spawning Output	Population Status	Age 3 Recruits (1,000's)	Fishing Mortality	Total Yield (mt)
F40%	2000	61620	8226	23.6%	26132	0.129	4420
	2001	64216	8268	23.7%	24906	0.130	3927
	2002	67176	8226	23.6%	24782	0.130	3903
	2003	70602	8203	23.5%	24958	0.130	3815
	2004	74306	8445	24.2%	25087	0.130	3914
	2005	77654	8919	25.6%	24959	0.132	4290
	2006	80385	9416	27.0%	24889	0.137	4765
	2007	82695	9845	28.2%	25623	0.142	5213
	2008	84894	10195	29.2%	27062	0.146	5576
	2009	87188	10467	30.0%	28570	0.148	5847
F50%	2000	61620	8226	23.6%	26132	0.092	3537
	2001	65320	8494	24.4%	24906	0.092	2864
	2002	69241	8668	24.9%	24782	0.094	2943
	2003	73392	8823	25.3%	24958	0.096	2987
	2004	77831	9200	26.4%	25773	0.097	3145
	2005	82093	9793	28.1%	26299	0.099	3494
	2006	85970	10416	29.9%	26769	0.103	3906
	2007	89642	10990	31.5%	27915	0.106	4298
	2008	93360	11516	33.0%	29714	0.109	4643
	2009	97266	11992	34.4%	31603	0.112	4946
F65%	2000	61620	8226	23.6%	26132	0.053	1661
	2001	66491	8734	25.0%	24906	0.054	1775
	2002	71493	9150	26.2%	24782	0.056	1883
	2003	76568	9528	27.3%	24958	0.058	1969
	2004	81996	10099	29.0%	26500	0.059	2207
	2005	87483	10876	31.2%	27761	0.061	2514
	2006	92889	11696	33.5%	28910	0.063	2818
	2007	98380	12493	35.8%	30641	0.065	3099
	2008	104161	13278	38.1%	32999	0.067	3370
	2009	110336	14057	40.3%	35488	0.069	3635
F100% (F=0)	2000	61620	8226	23.6%	26132	0	0
	2001	68173	9078	26.0%	24906	0	0
	2002	74849	9869	28.3%	24782	0	0
	2003	81560	10639	30.5%	24958	0	0
	2004	88852	11591	33.2%	27545	0	0
	2005	96679	12765	36.6%	29945	0	0
	2006	105020	14027	40.2%	32280	0	0
	2007	114048	15324	43.9%	35168	0	0
	2008	123948	16687	47.8%	38731	0	0
	2009	134829	18137	52.0%	42560	0	0

Figure 1. U.S. commercial landings (mt) of widow rockfish by area and gear type.

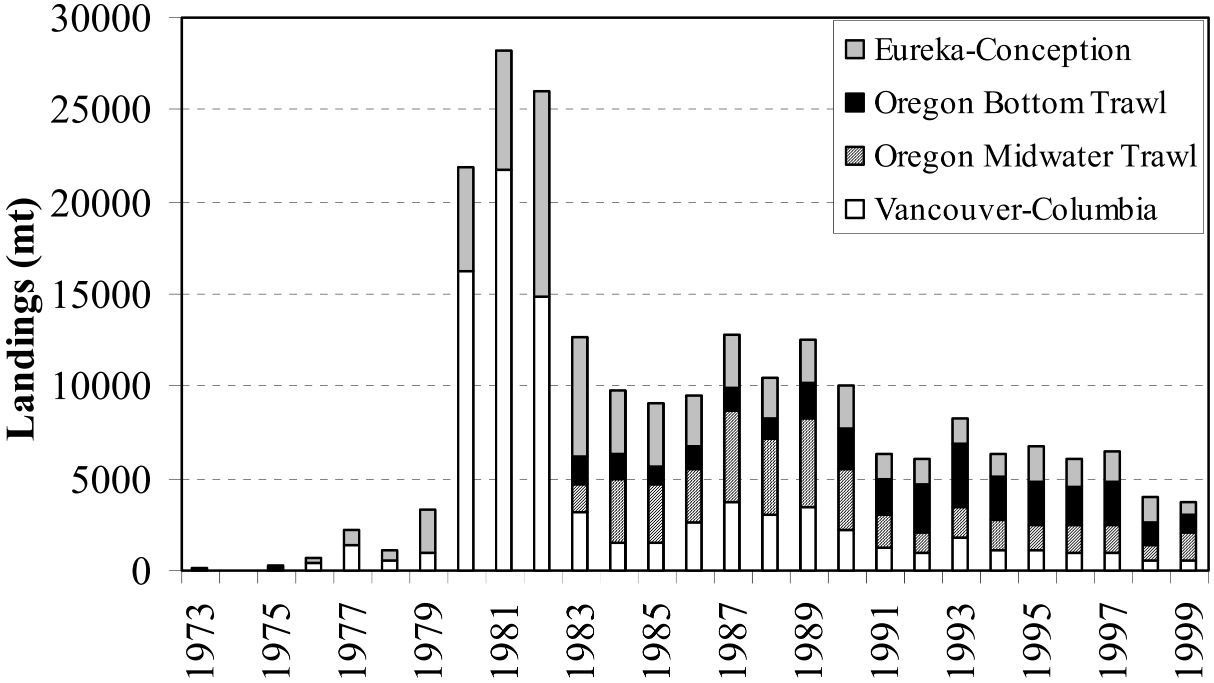
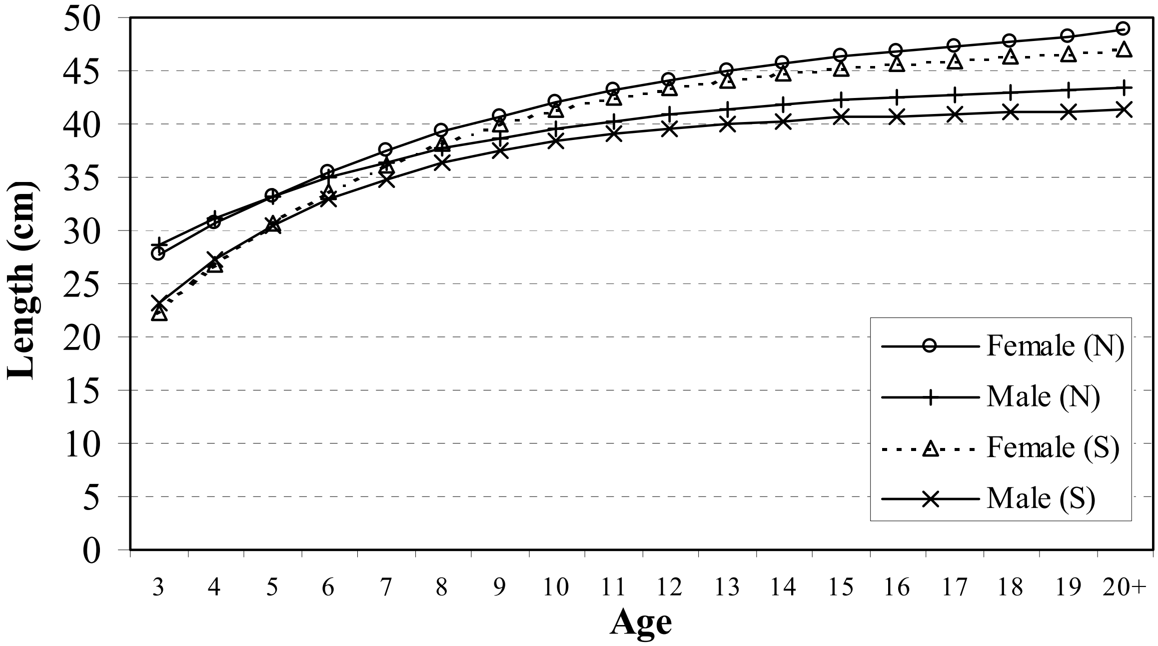


Figure 2. Growth functions for widow rockfish from north (N) and south (S) of 43° latitude used in this assessment.



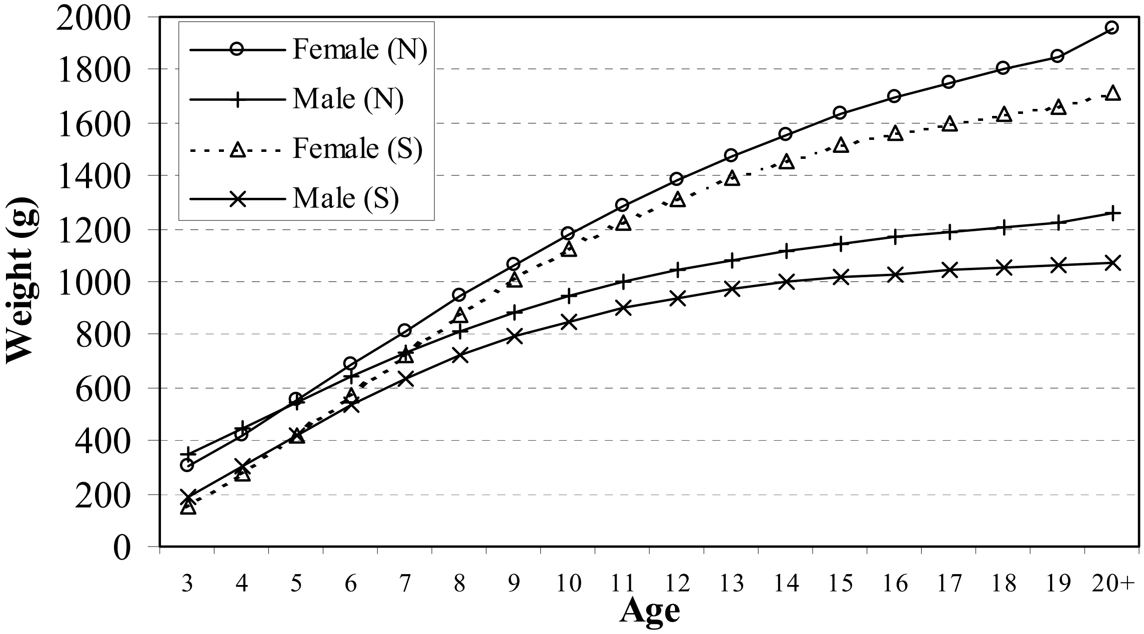
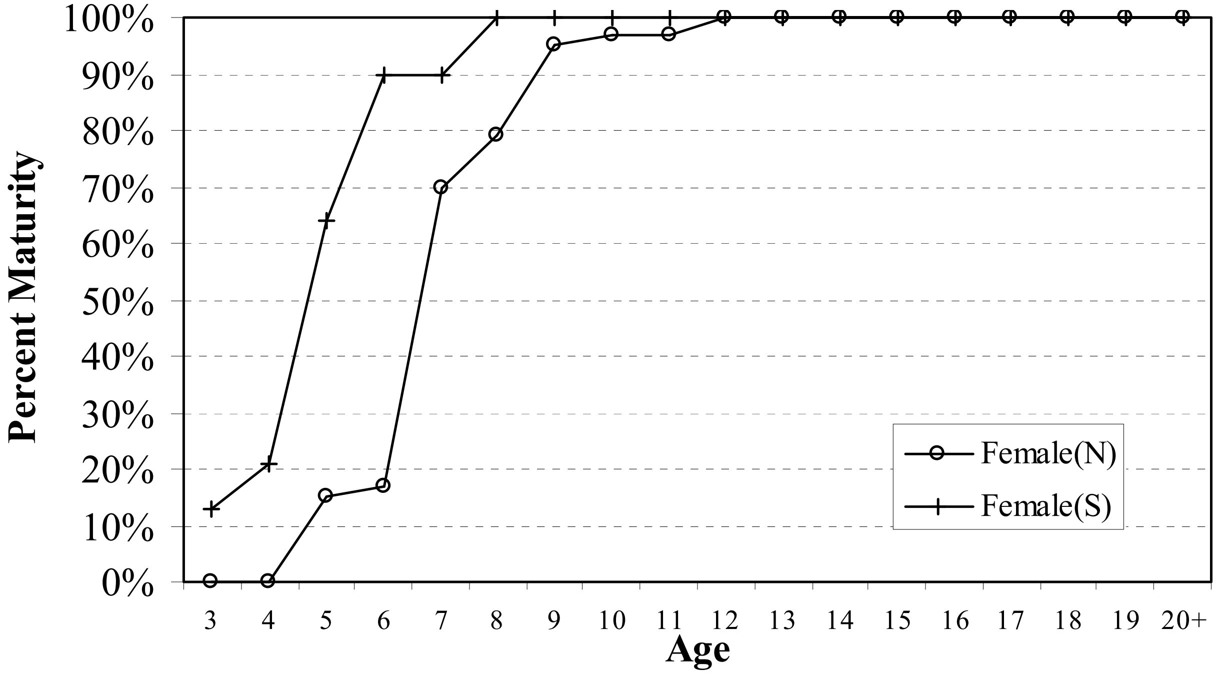


Figure 3. Maturity and fecundity functions for widow rockfish from north (N) and south (S) of 43° latitude used in this assessment.



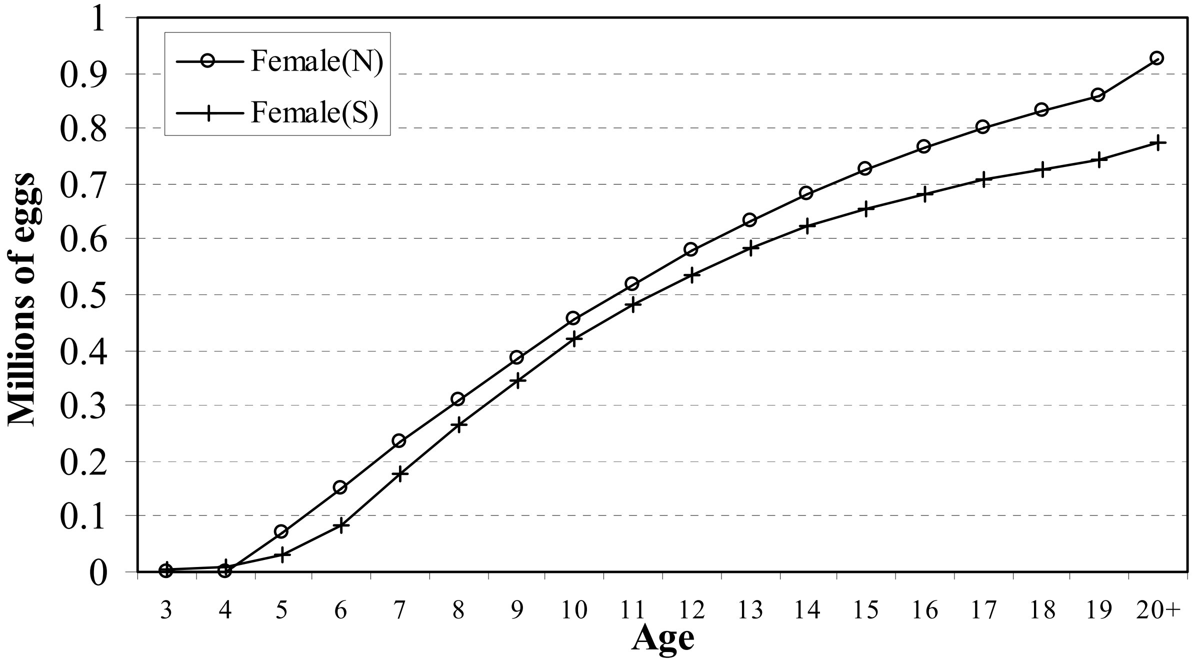


Figure 4. Percent age composition data for the Vancouver-Columbia combined fishery, by sex and year with the sum across sexes equal to 1.

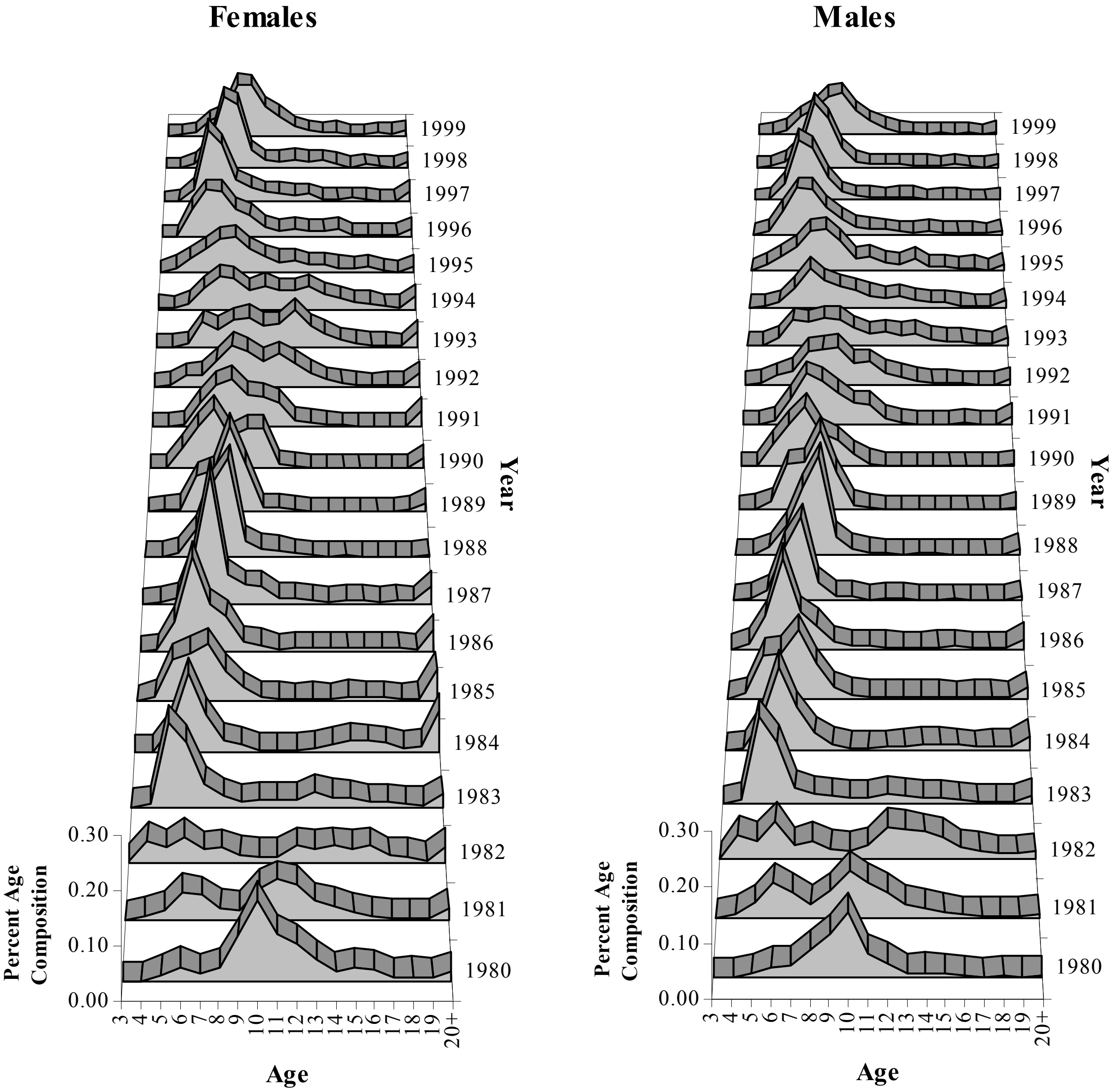


Figure 5. Percent age composition data for the Oregon midwater trawl fishery, by sex and year with the sum across sexes equal to 1.

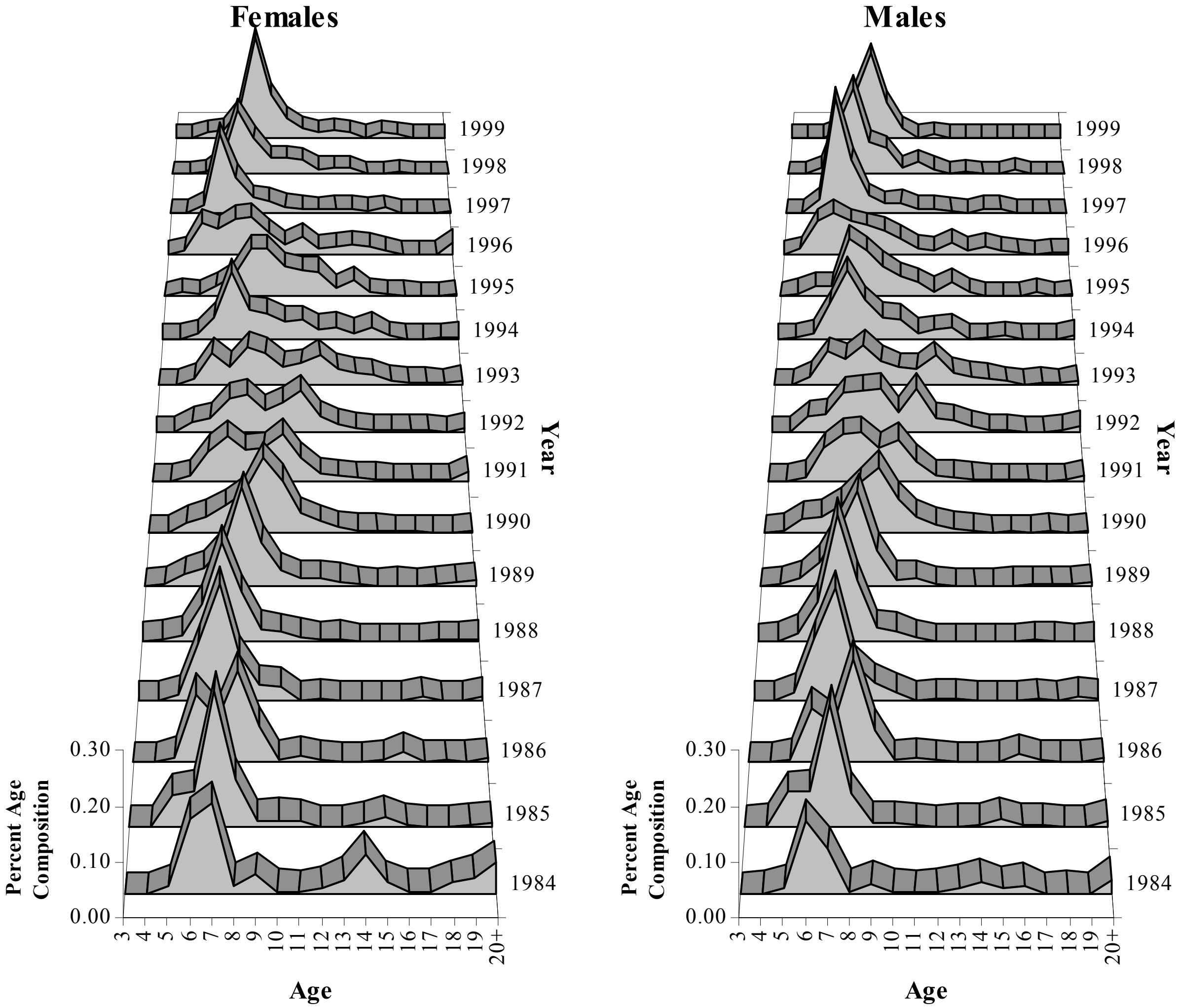


Figure 6. Percent age composition data for the Oregon bottom trawl fishery, by sex and year with the sum across sexes equal to 1.

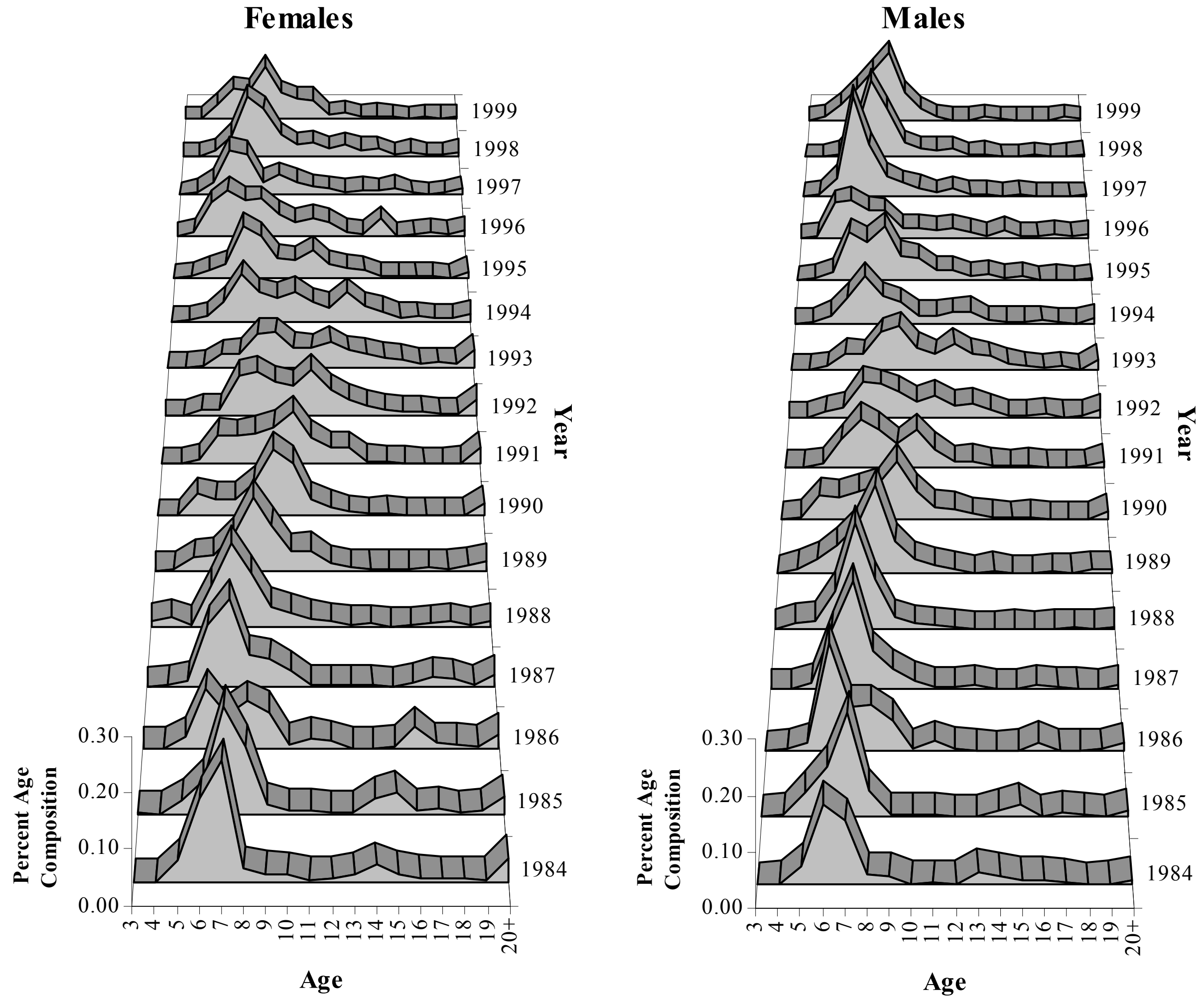


Figure 7. Percent age composition data for the Eureka-Conception combined fishery, by sex and year with the sum across sexes equal to 1.

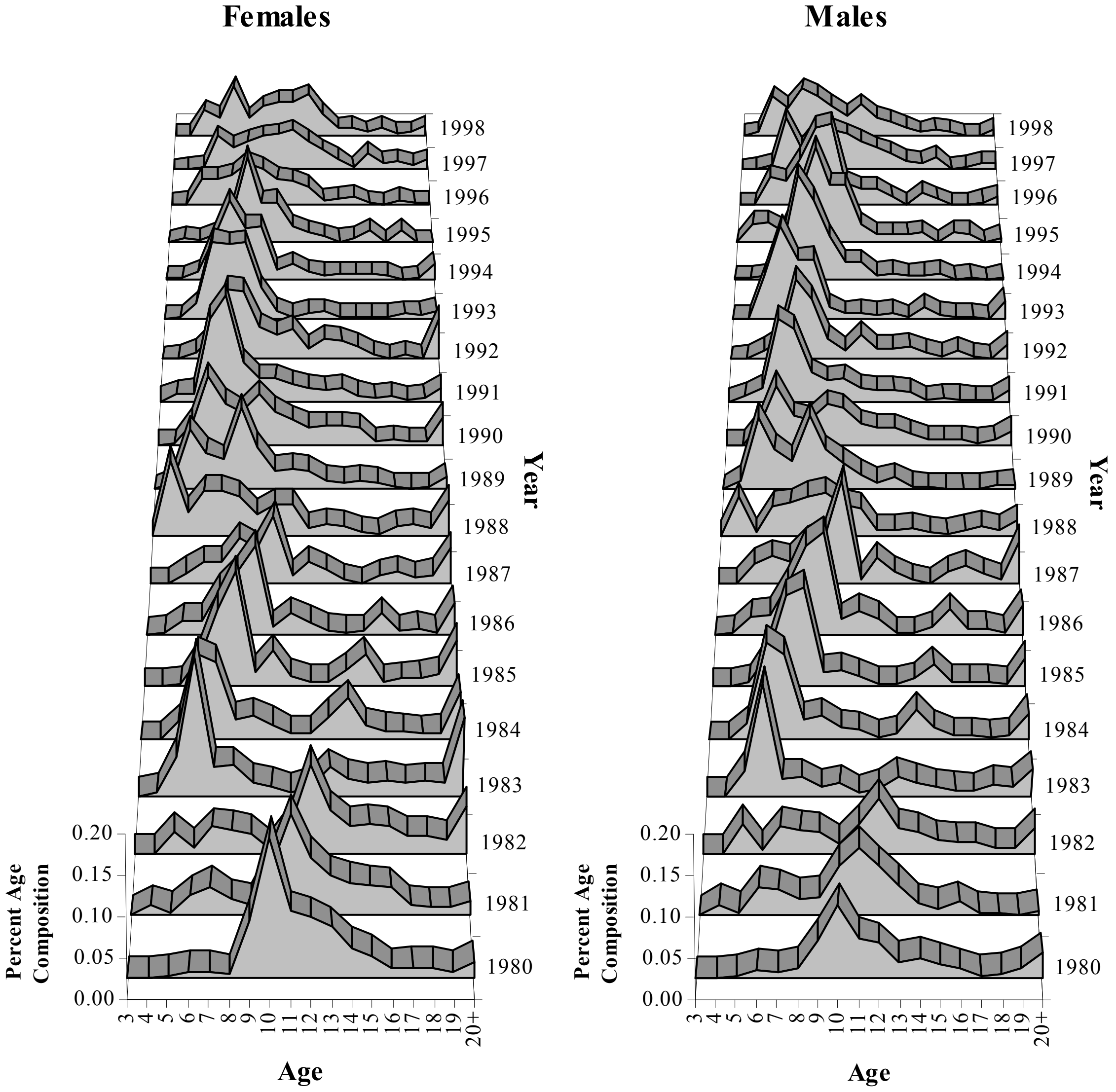


Figure 8. Oregon bottom trawl logbook catch-per-unit-effort index.

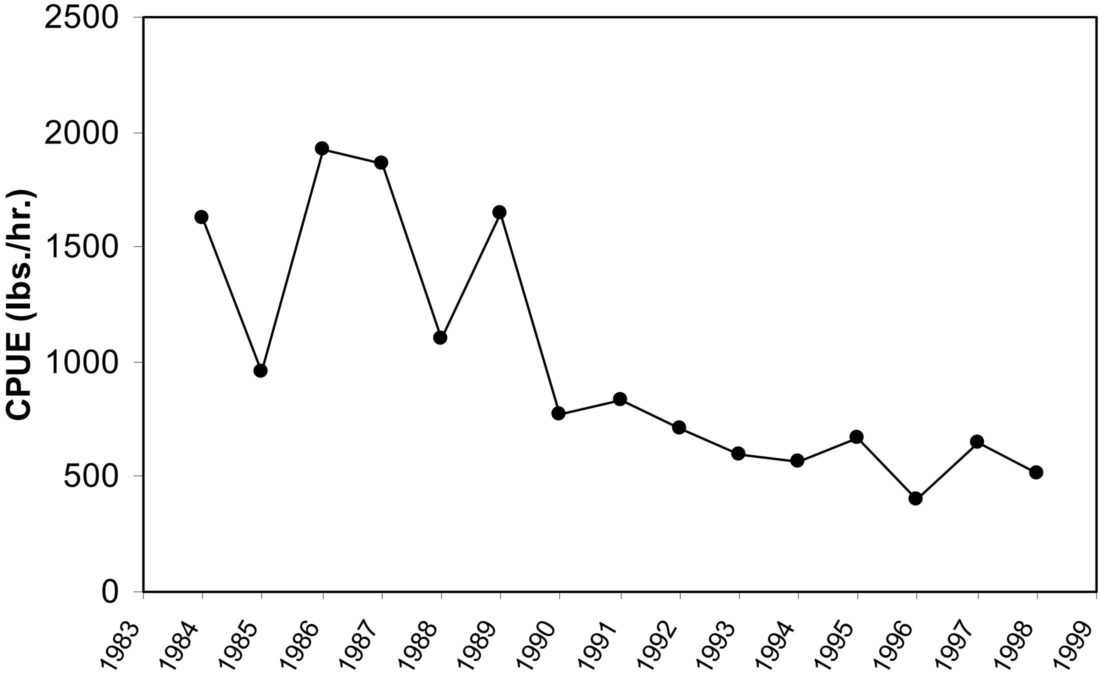
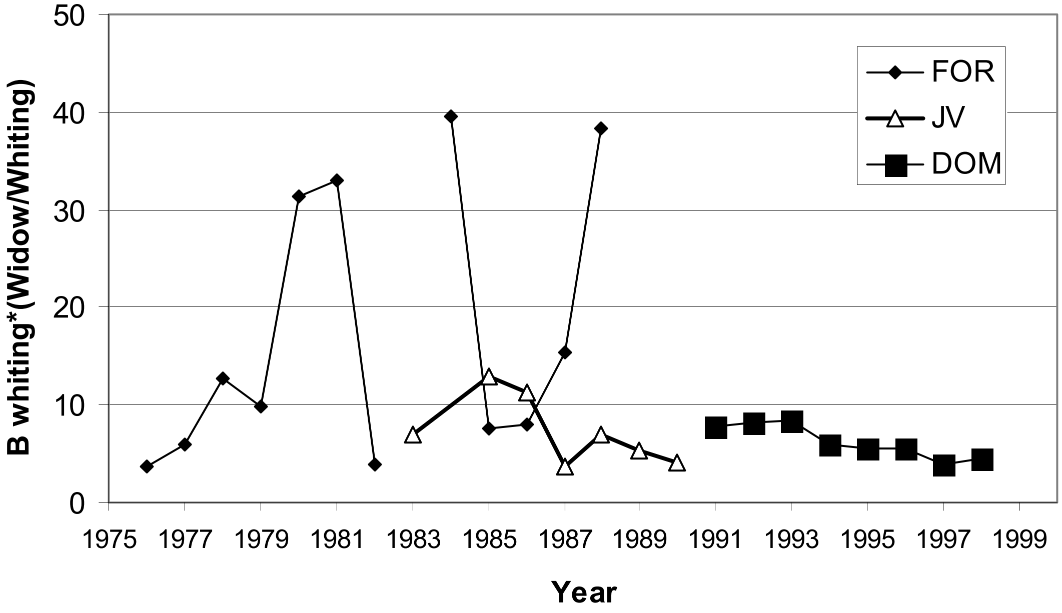


Figure 9. Two indices of widow rockfish abundance derived from bycatch in the Pacific whiting fisheries.



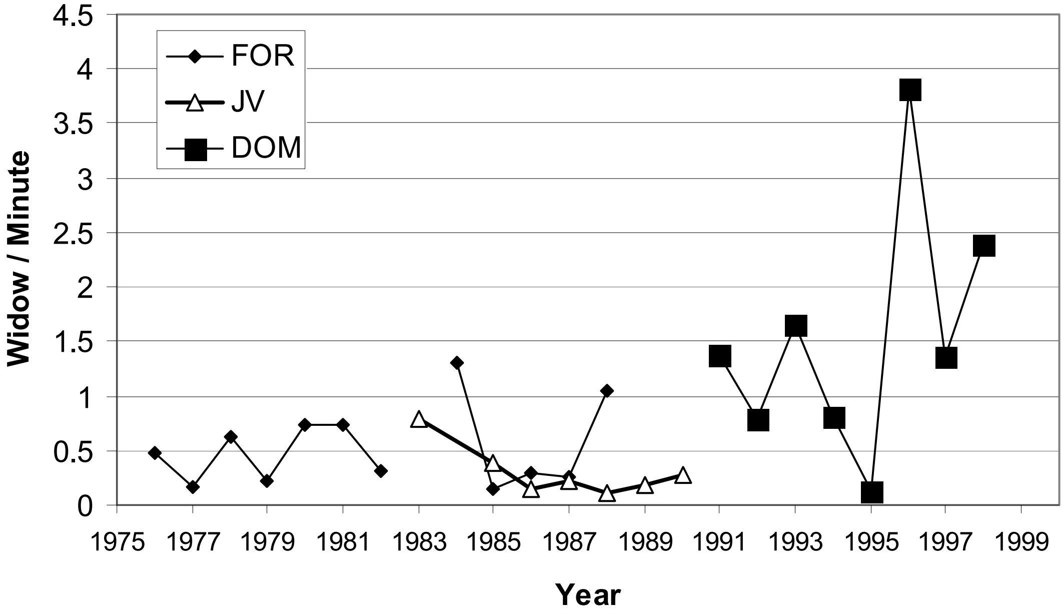


Figure 10. Yearly index estimates from the Tiburon Laboratory midwater trawl pelagic juvenile survey.

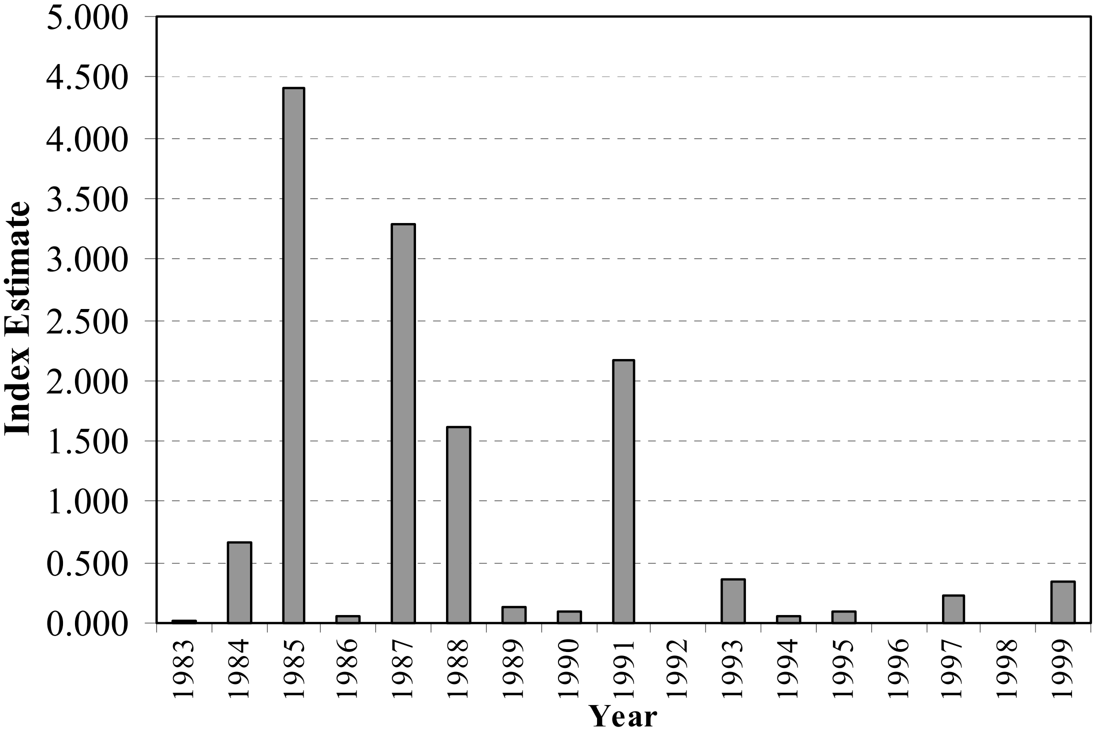


Figure 11. California trawl logbook catch-per-unit-effort (CPUE) index for widow rockfish (Ralston 1999).

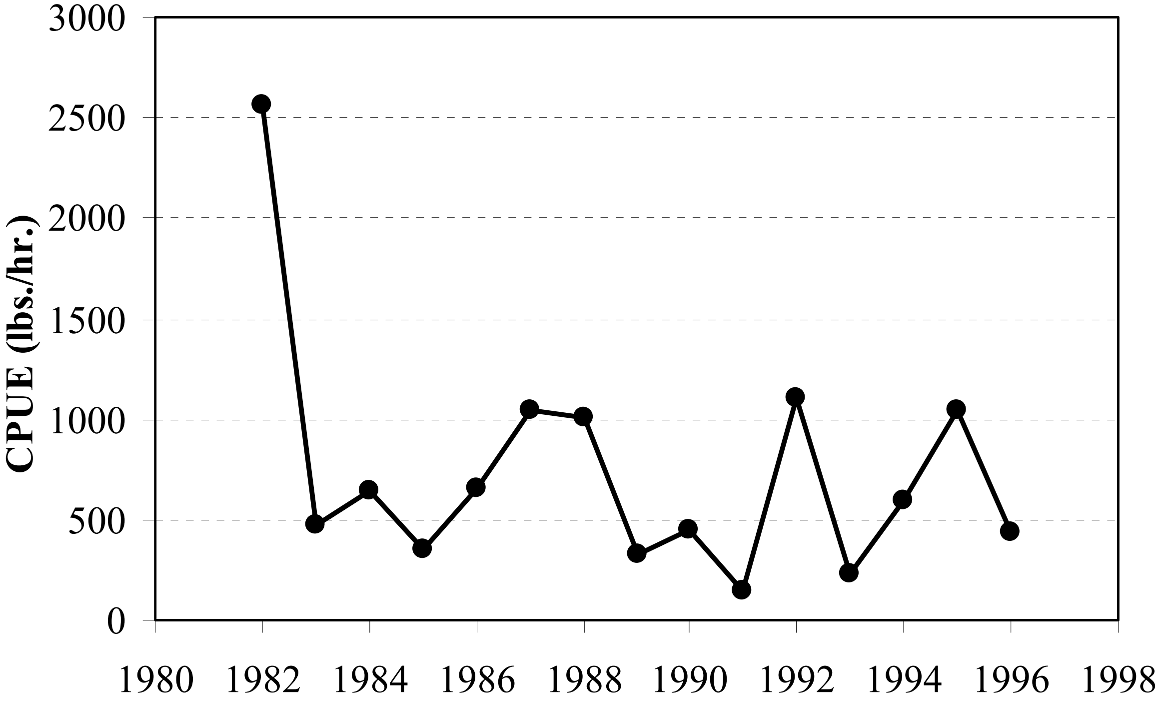


Figure 12. Biomass estimates for widow rockfish from the Alaska Fisheries Science Center triennial bottom trawl survey.

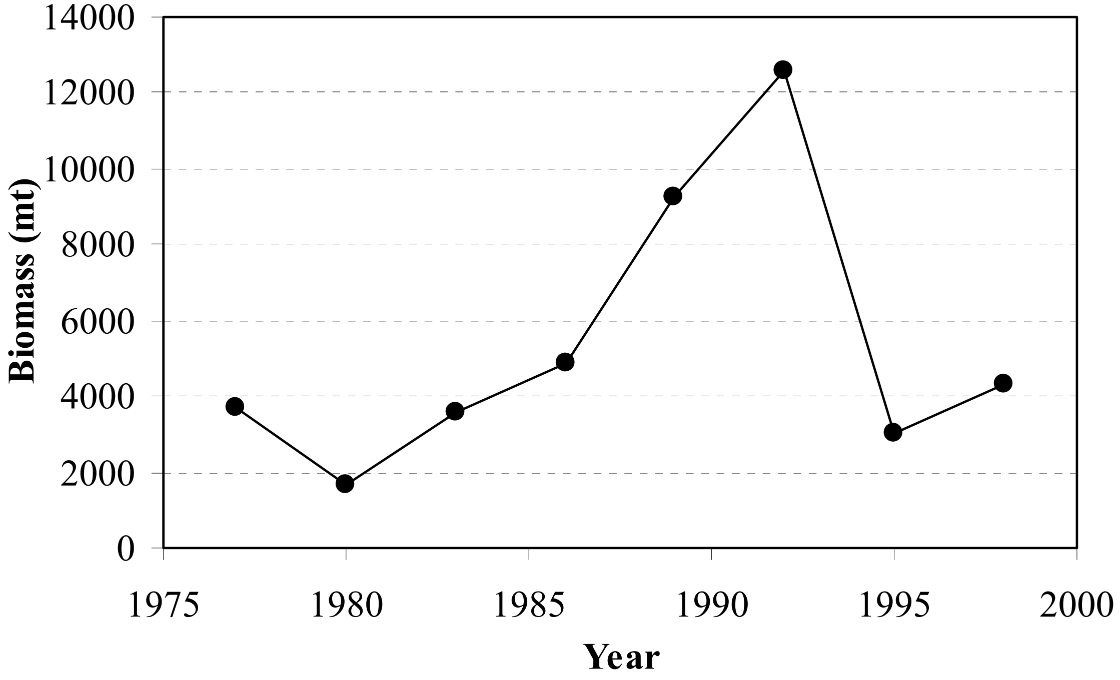


Figure 13. Fraction of landings in the north area, defined as the Vancouver-Columbia and Oregon trawl fisheries, with a 7-year moving average.

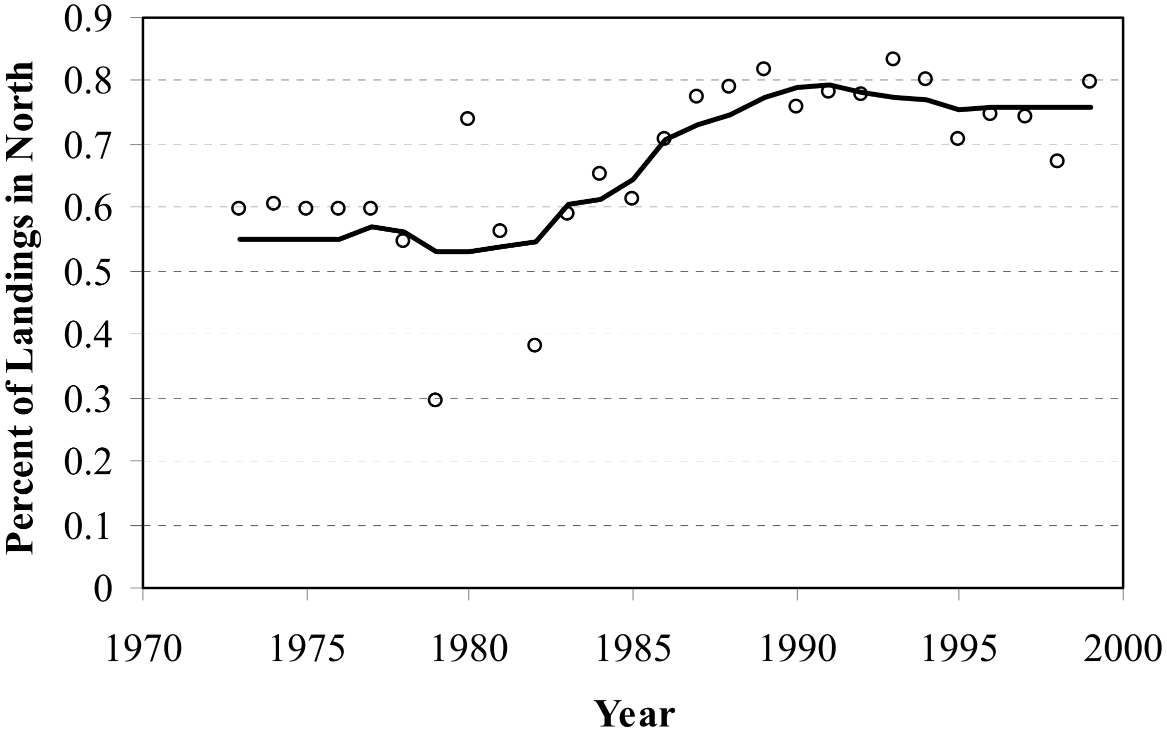


Figure 14. Relationship of age 3 recruitment estimates for widow rockfish from a model run with the midwater trawl index component de-emphasized and the power transformed index values.

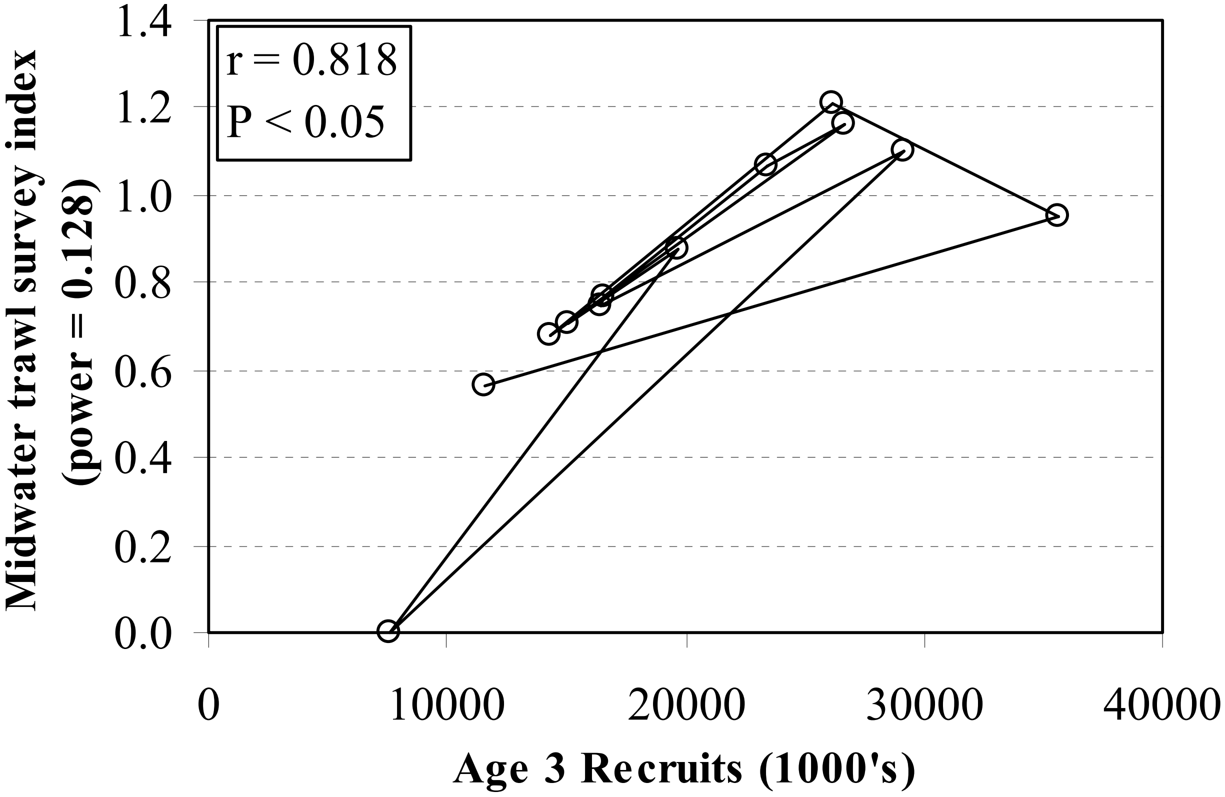
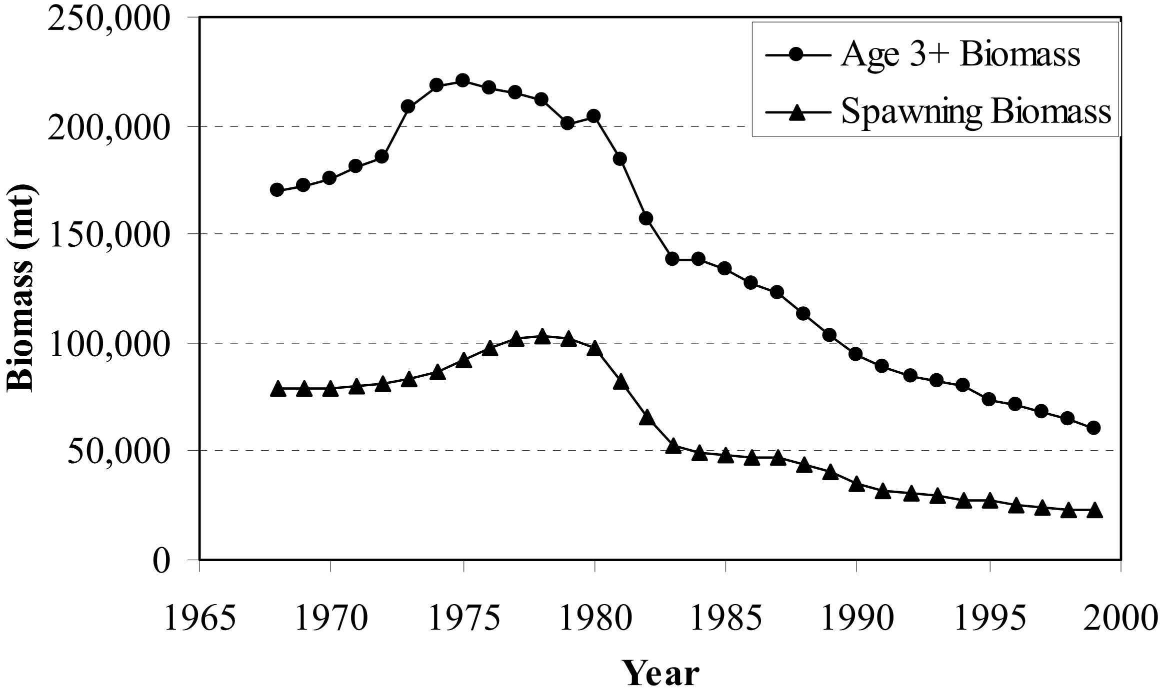


Figure 15. Age 3+ biomass (mt), spawning biomass (mt), and spawning output (10^6 eggs) estimates from the preferred widow rockfish model. Dotted lines indicate 95% confidence interval estimates.



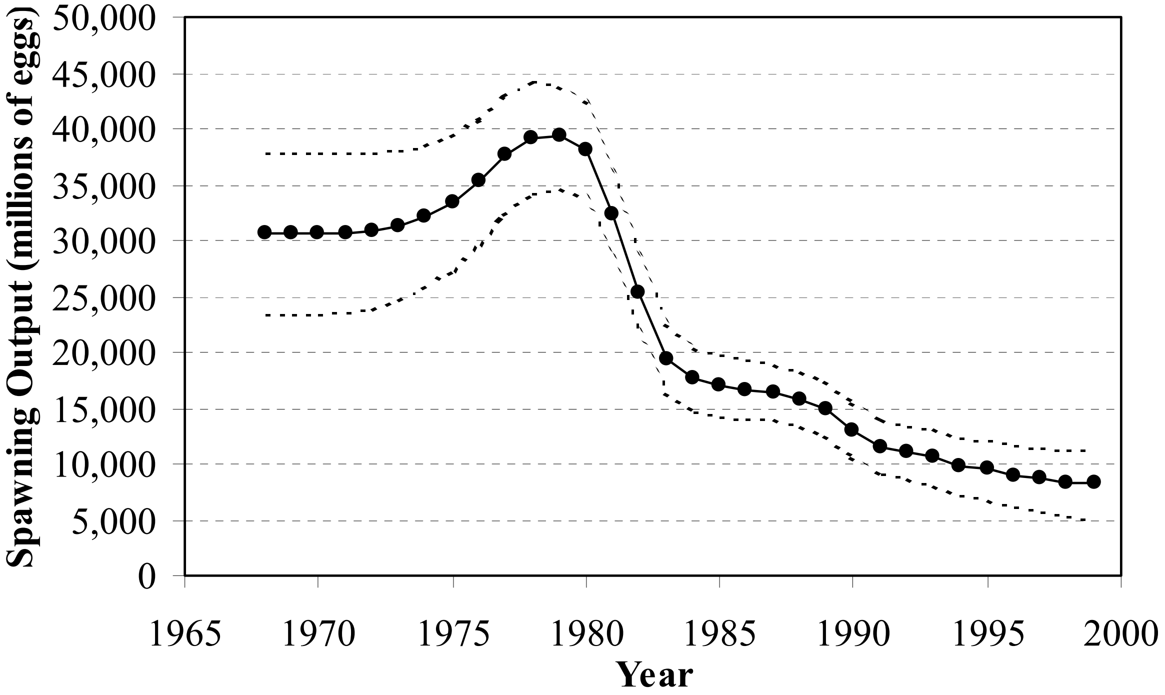
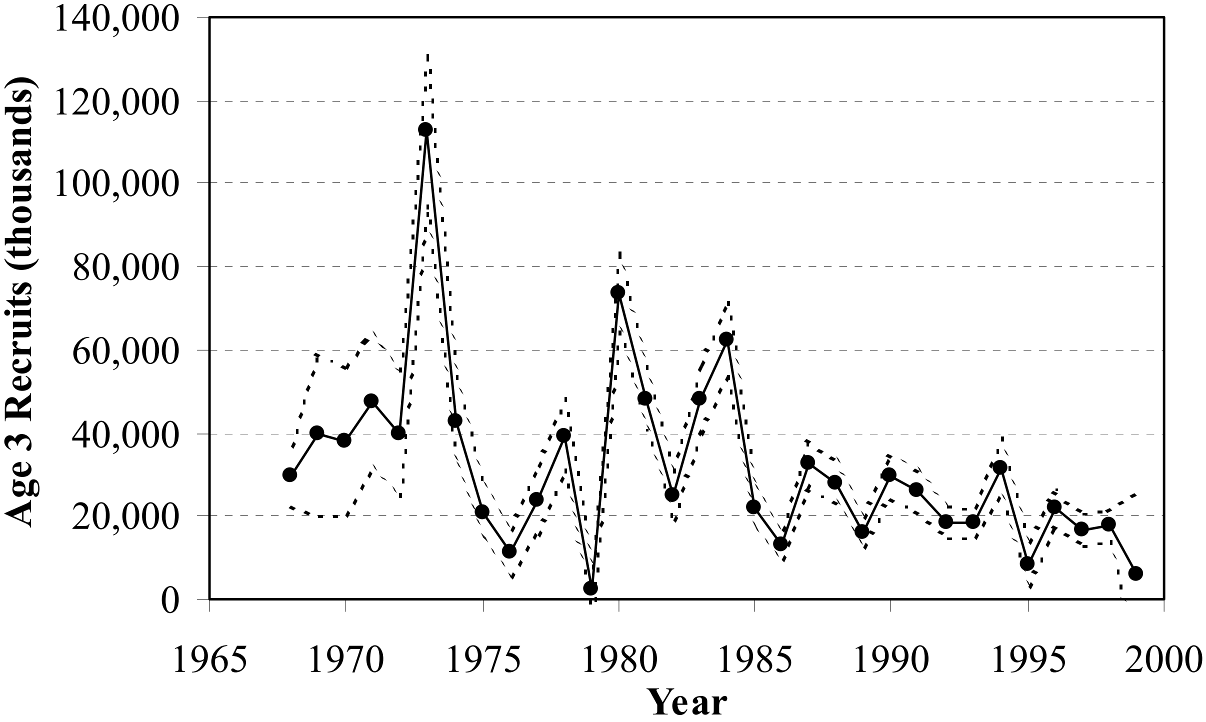


Figure 16. Recruitment and fishery specific fishing mortality estimates from the preferred widow rockfish model. Dotted lines indicate 95% confidence interval estimates.



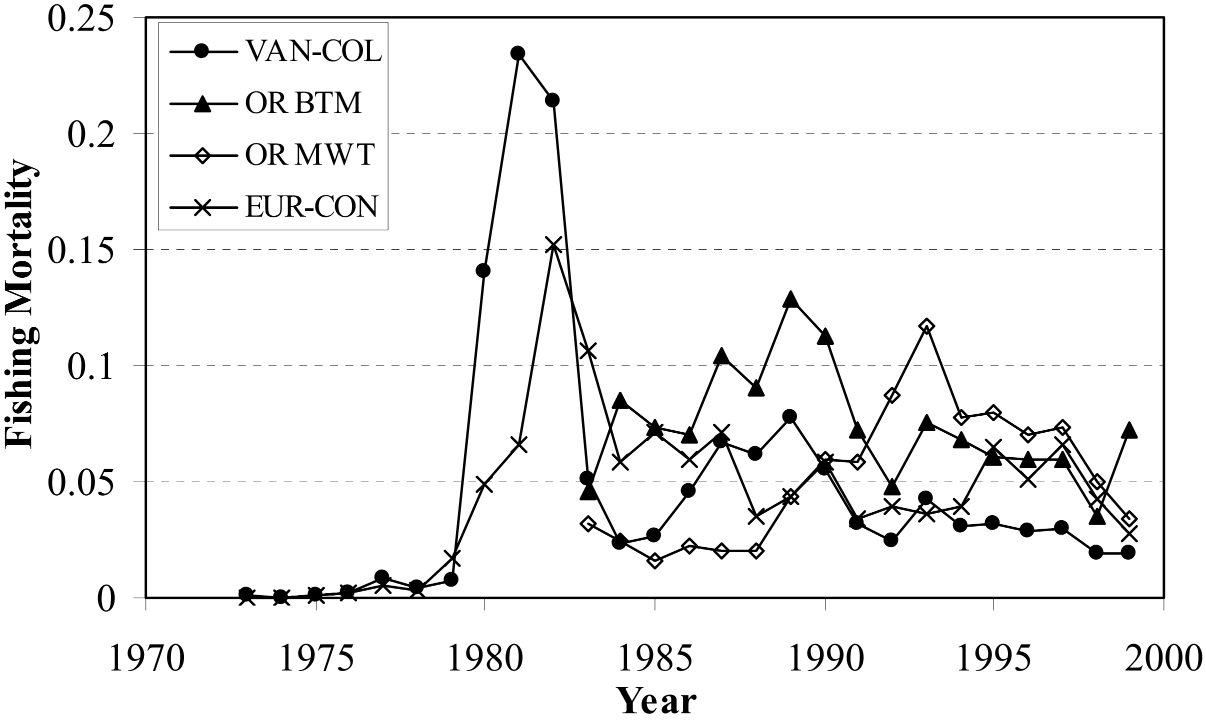


Figure 17. Range of year-specific selectivity estimates from the preferred widow rockfish model.

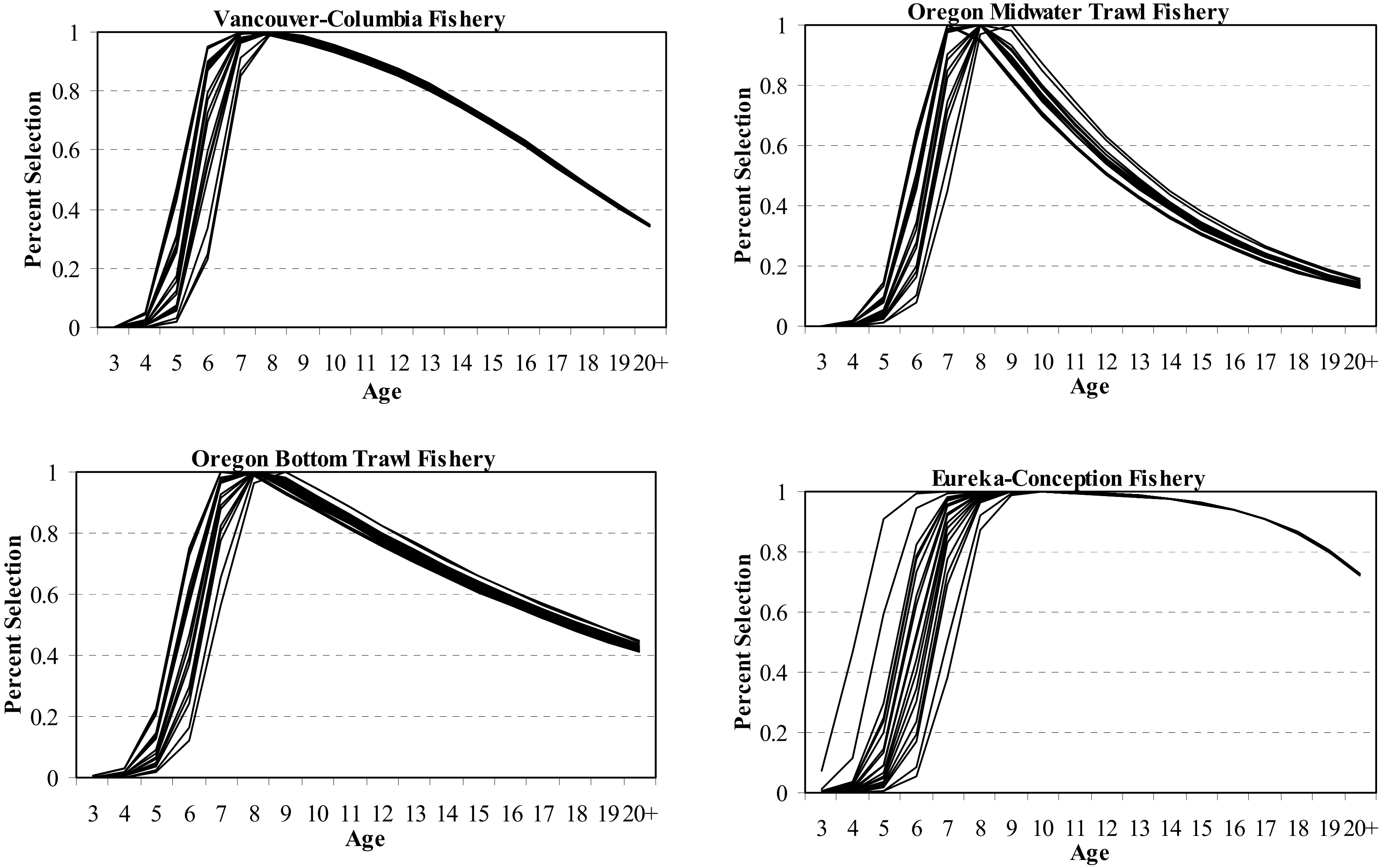


Figure 18. Spawning output and recruitment relationship from the preferred widow rockfish model.

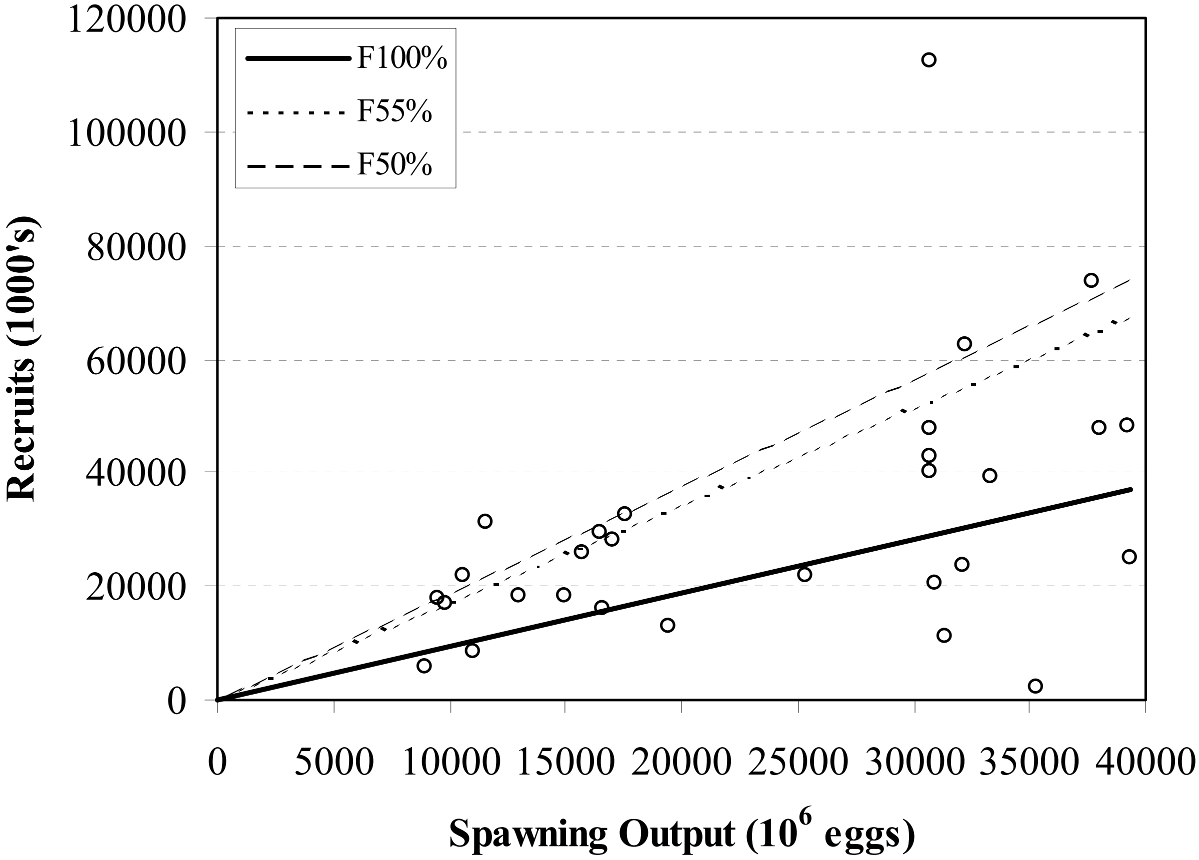
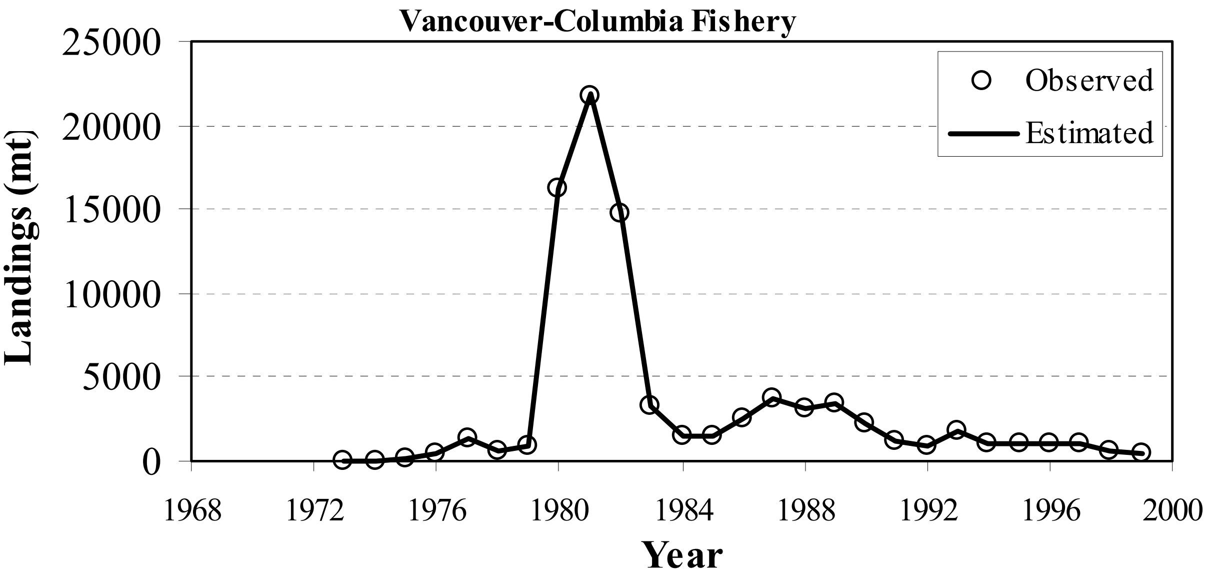


Figure 19. Model fits to the Vancouver-Columbia and Oregon midwater trawl fisheries landings data.



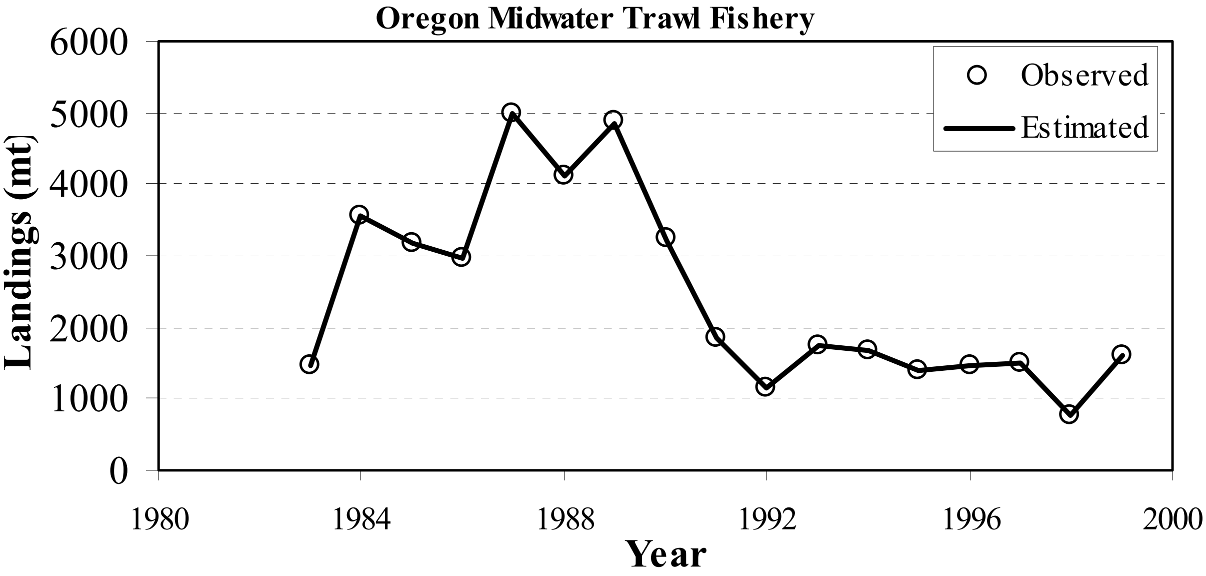
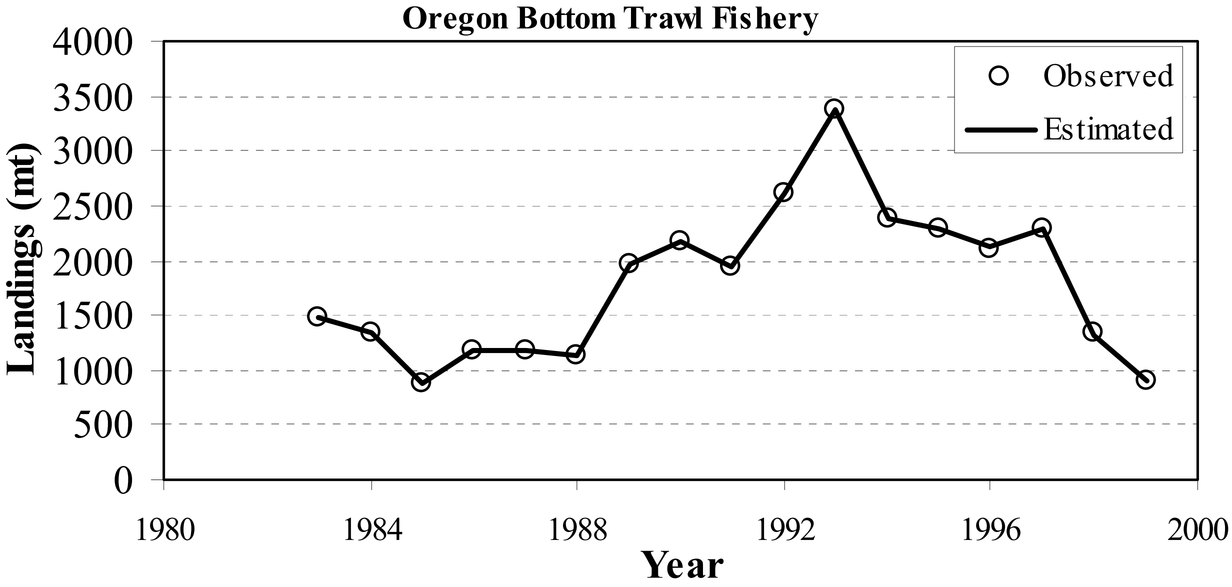


Figure 20. Model fits to the Oregon bottom trawl and Eureka-Conception fisheries landings data.



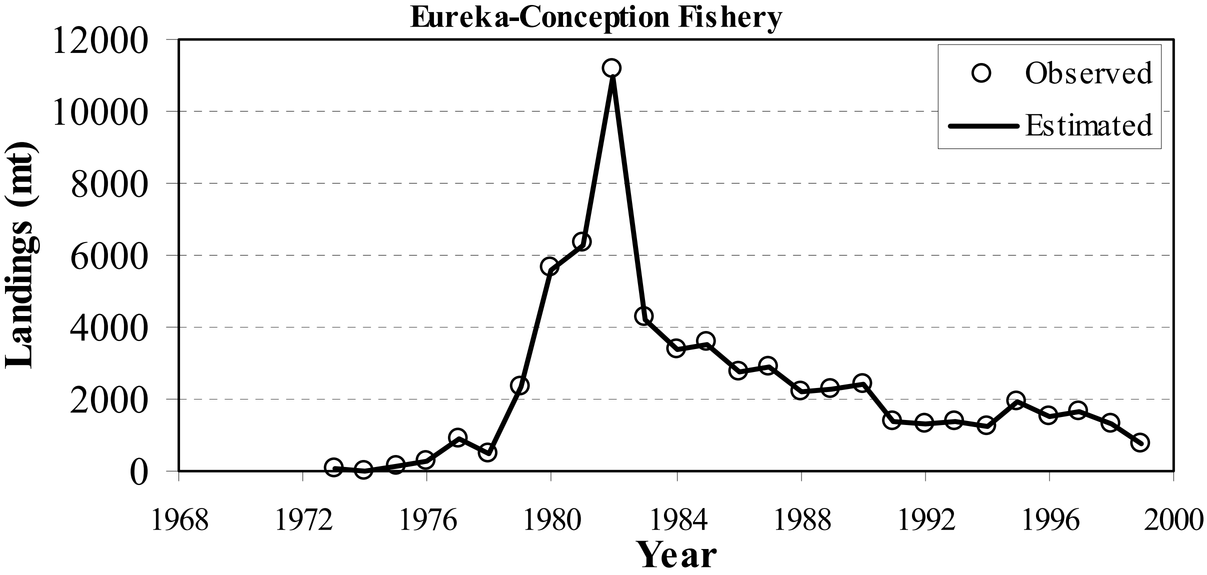


Figure 21. Widow rockfish model fits to the midwater trawl juvenile survey, fishery logbook index, and biomass survey.

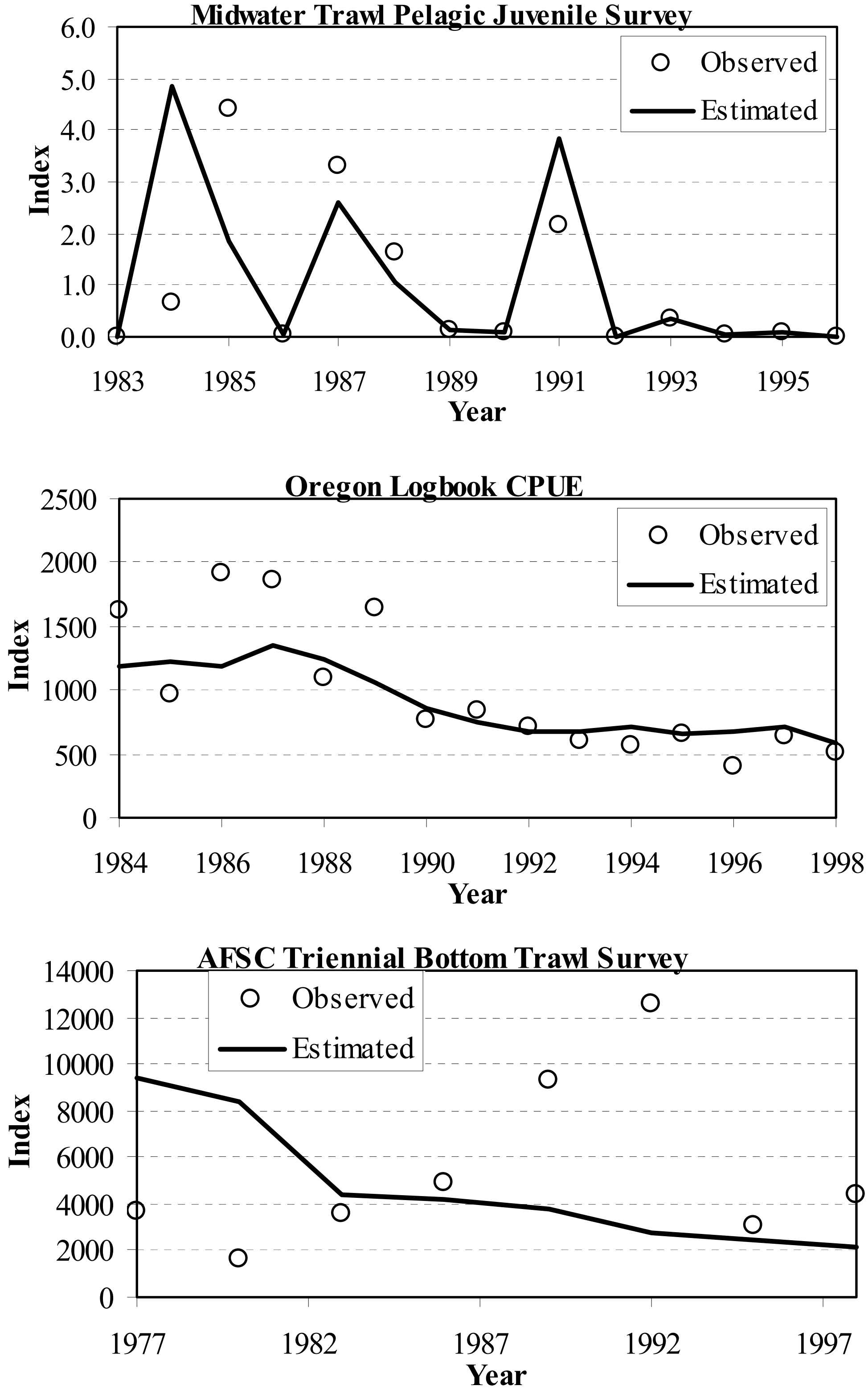
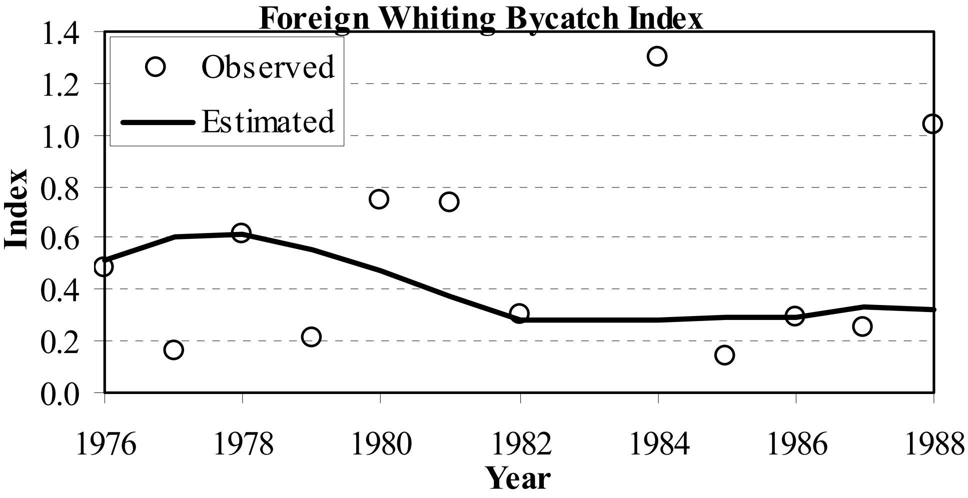
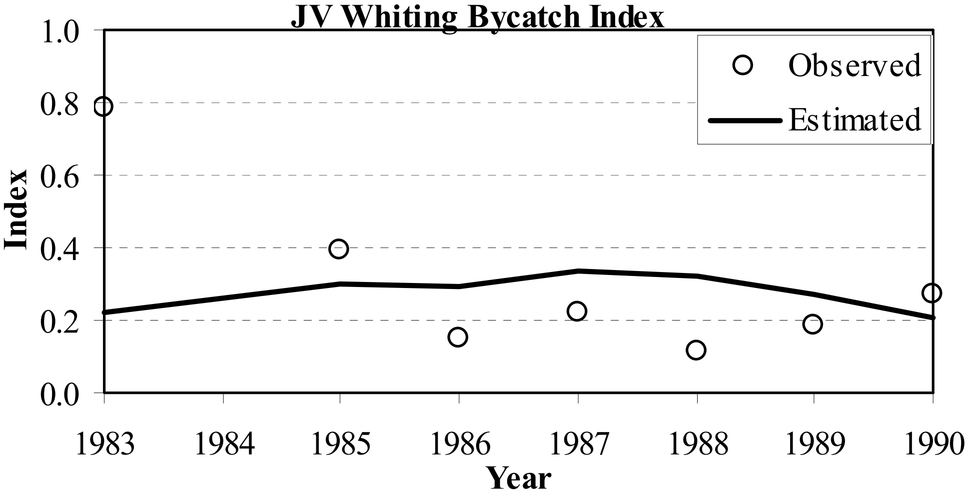


Figure 22. Widow rockfish model fits to the various whiting bycatch indices.


Foreign Whiting Bycatch Index


JV Whiting Bycatch Index

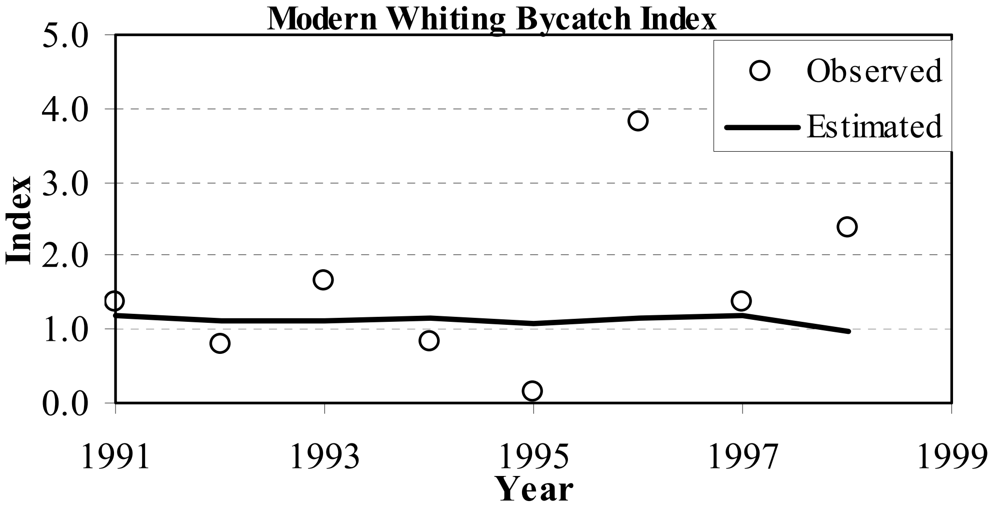
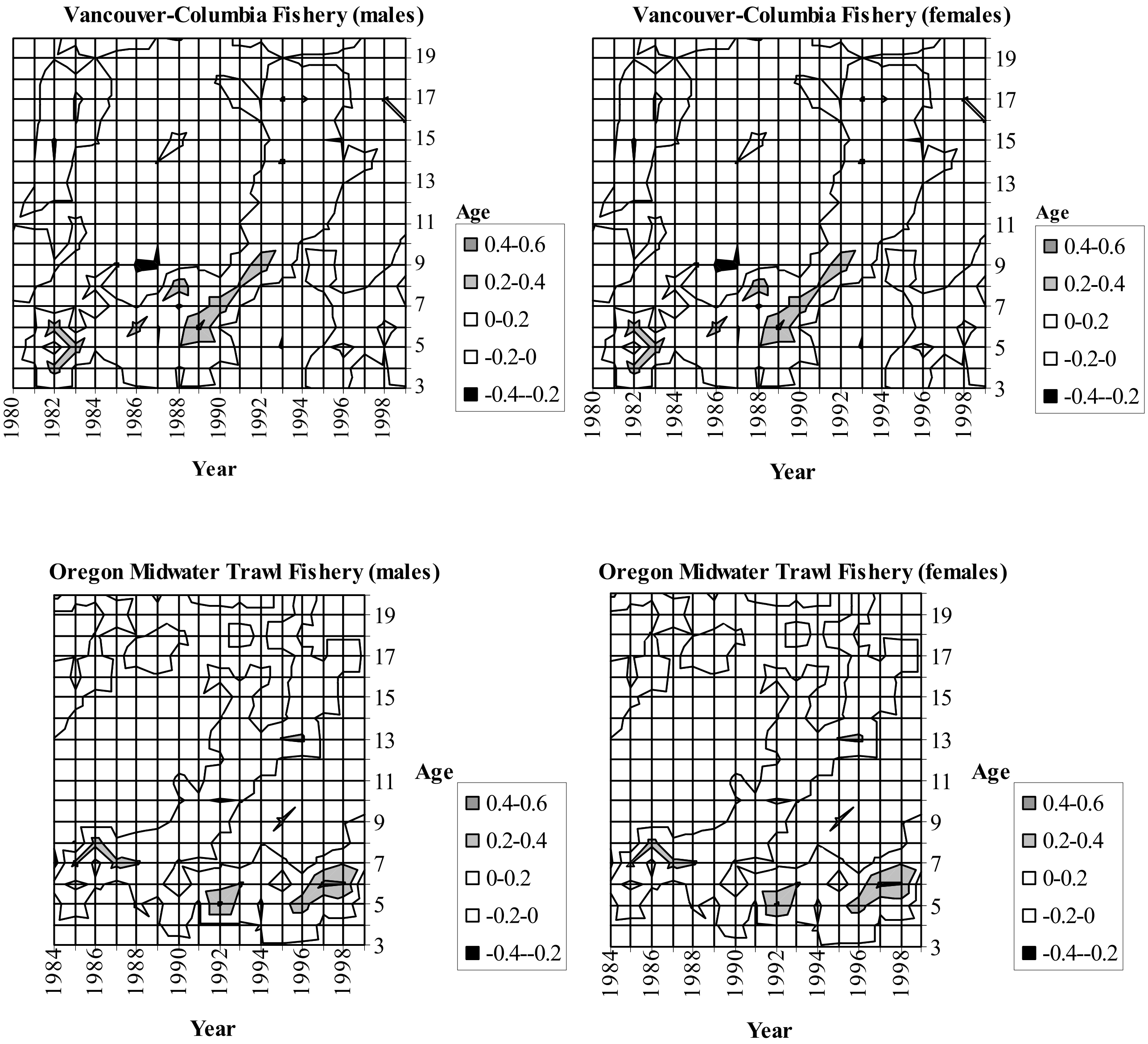

Modern Whiting Bycatch Index

Figure 23. Age composition residuals from the widow rockfish model. Residuals were computed using Pearson's standardization with the sample size set to 1 for all ages and years.



Vancouver-Columbia Fishery (males)

Vancouver-Columbia Fishery (females)

Oregon Midwater Trawl Fishery (males)

Oregon Midwater Trawl Fishery (females)

Figure 24. Age composition residuals from the widow rockfish model. Residuals were computed using Pearson's standardization with the sample size set to 1 for all ages and years.

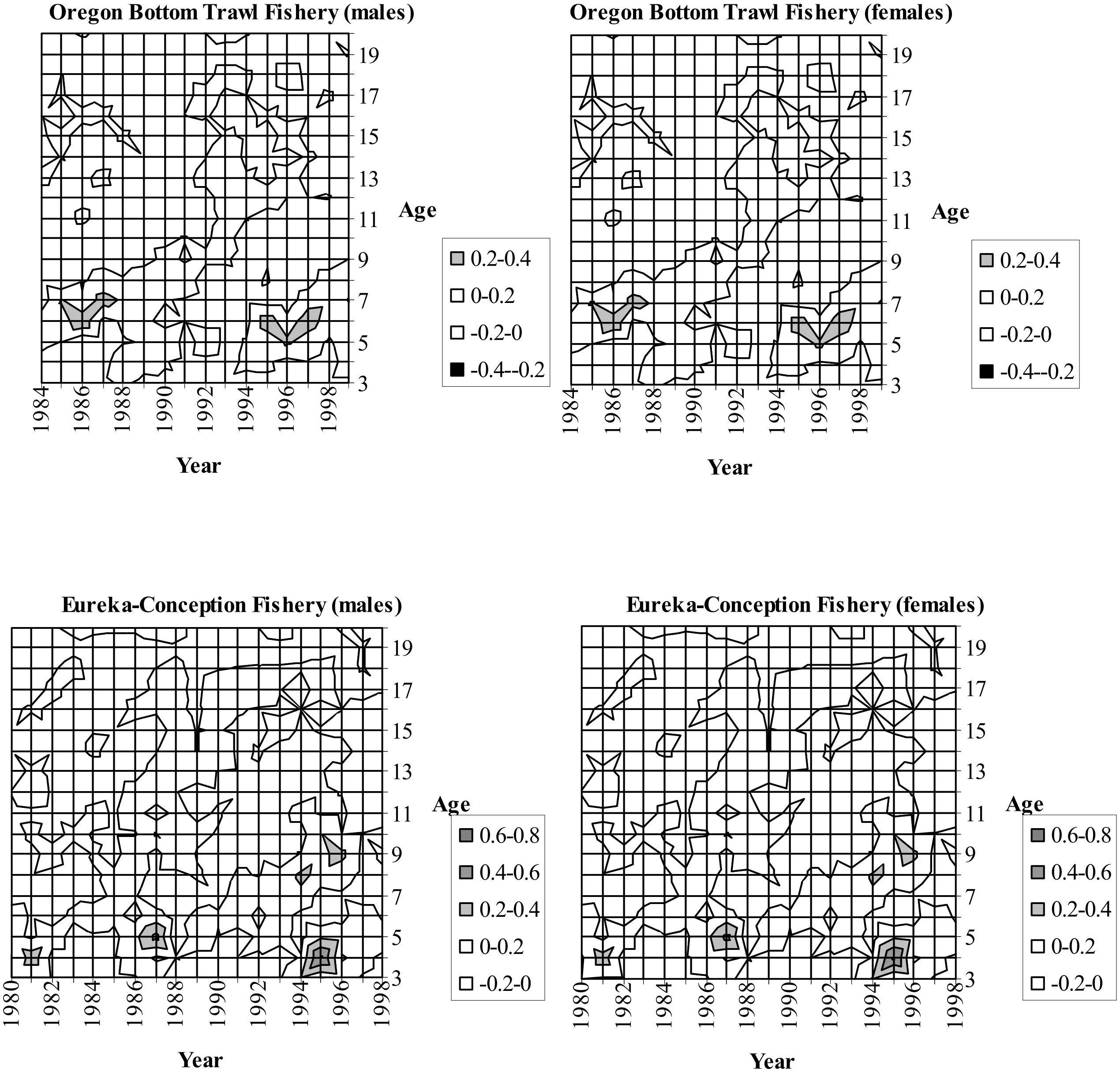


Figure 25. Historic comparison of widow rockfish stock assessment results from 1997 and 2000.

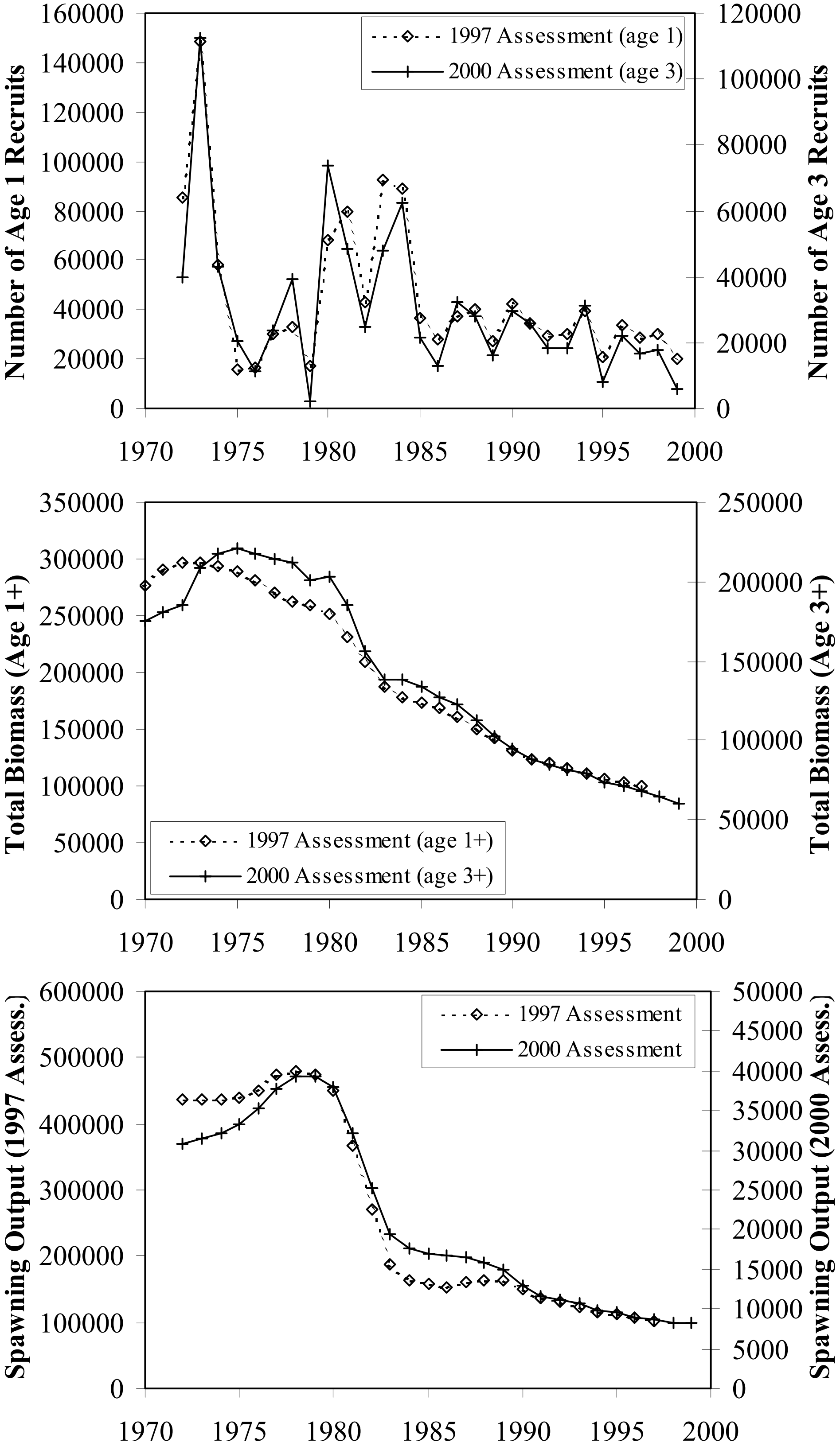


Figure 26. Model results from 46 runs using 50% random perturbations in the base model starting values.

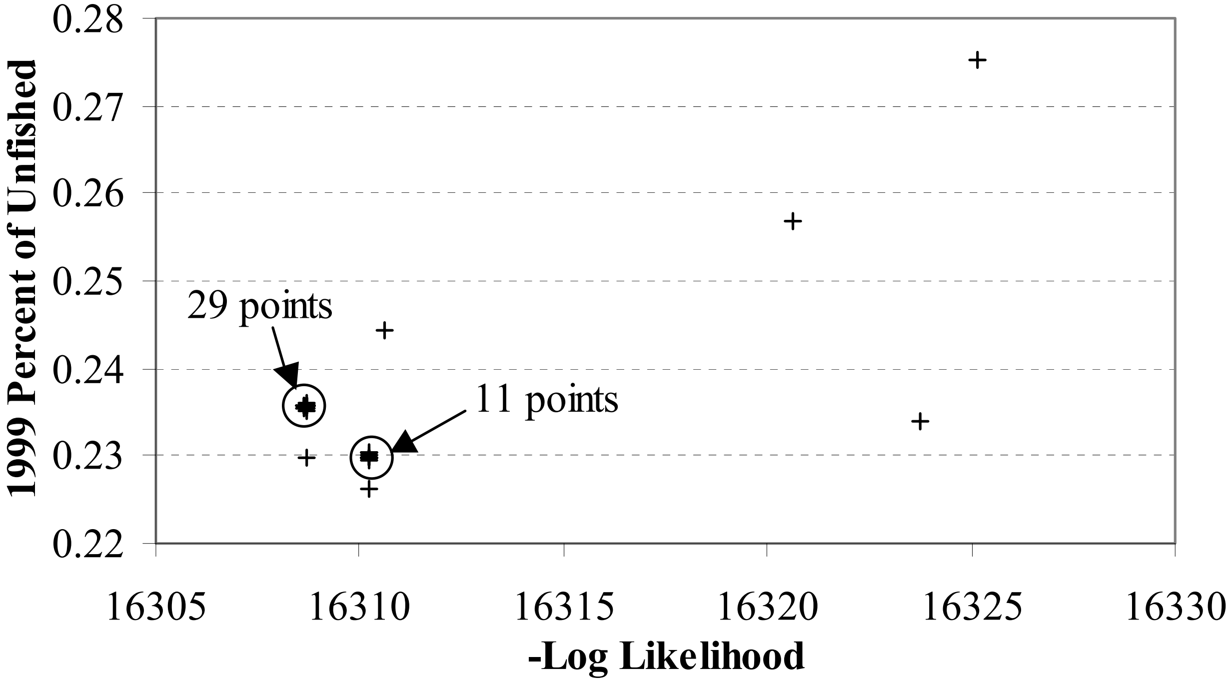


Figure 27. Retrospective analysis results showing biomass, recruitment, and spawning output estimates from model output with repeated deletion of the last year of available data (indicated by circled data point).

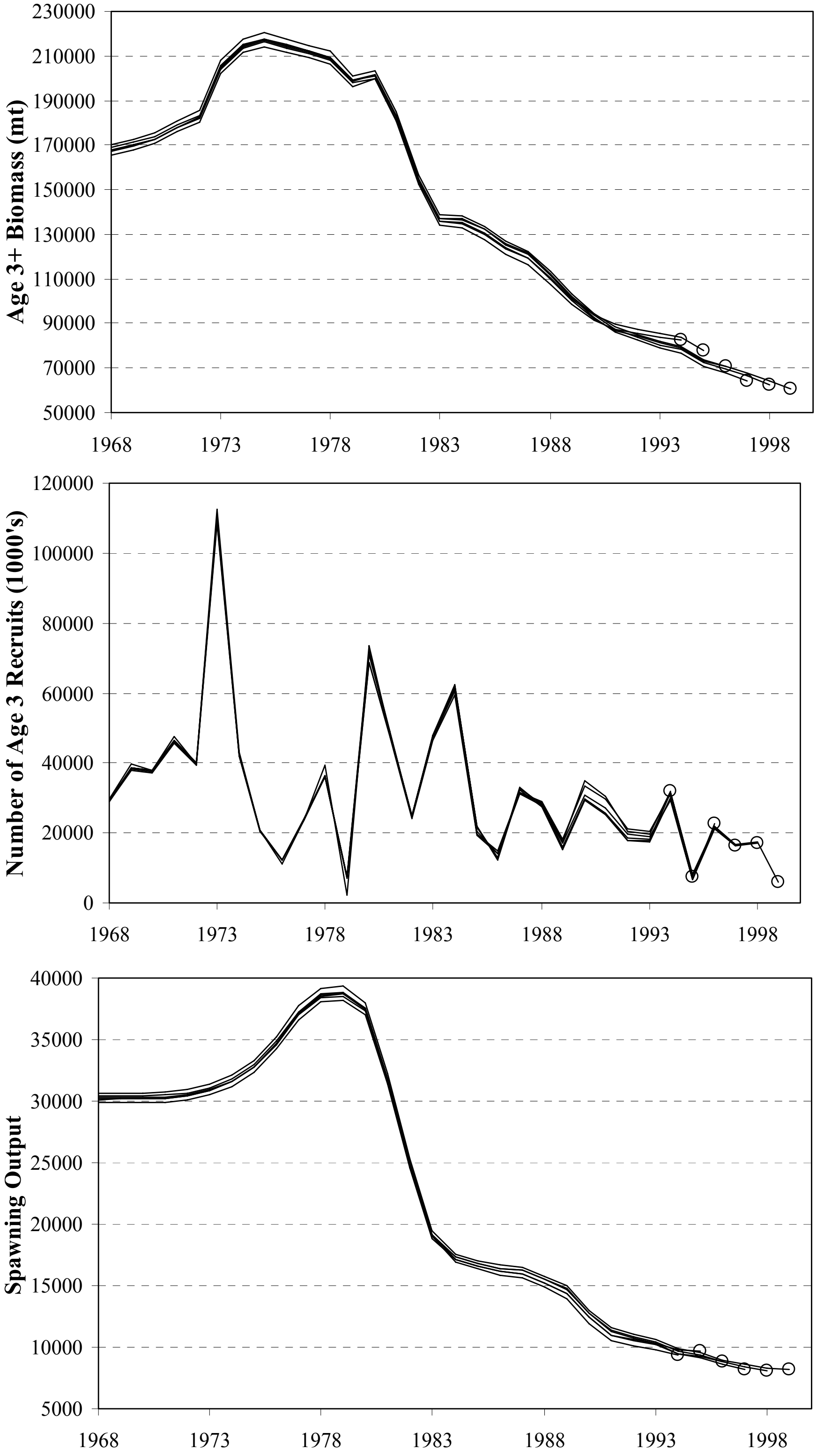


Figure 28. Profile likelihood for the ratio of 1999 spawning output (SO) to an estimate of the unfished level (SO_0). The unfished level was computed as the average recruitment from 1968-1976 times the spawning output-per-recruit with $F = 0$.

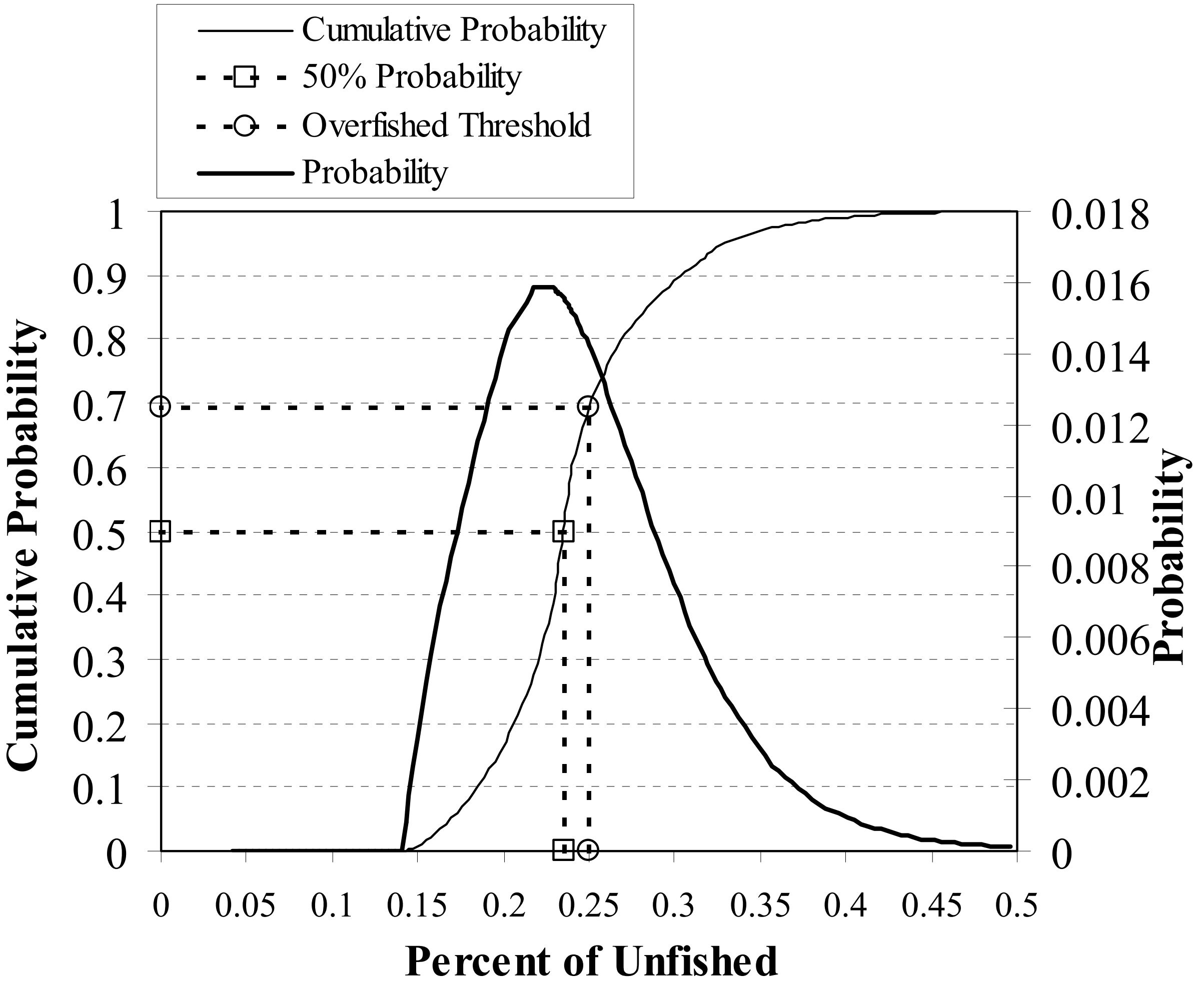


Figure 29. Relationship of recruits per spawning output (R/S) to spawning output. Bold line indicates non-significant regression line (P-value = 0.302).

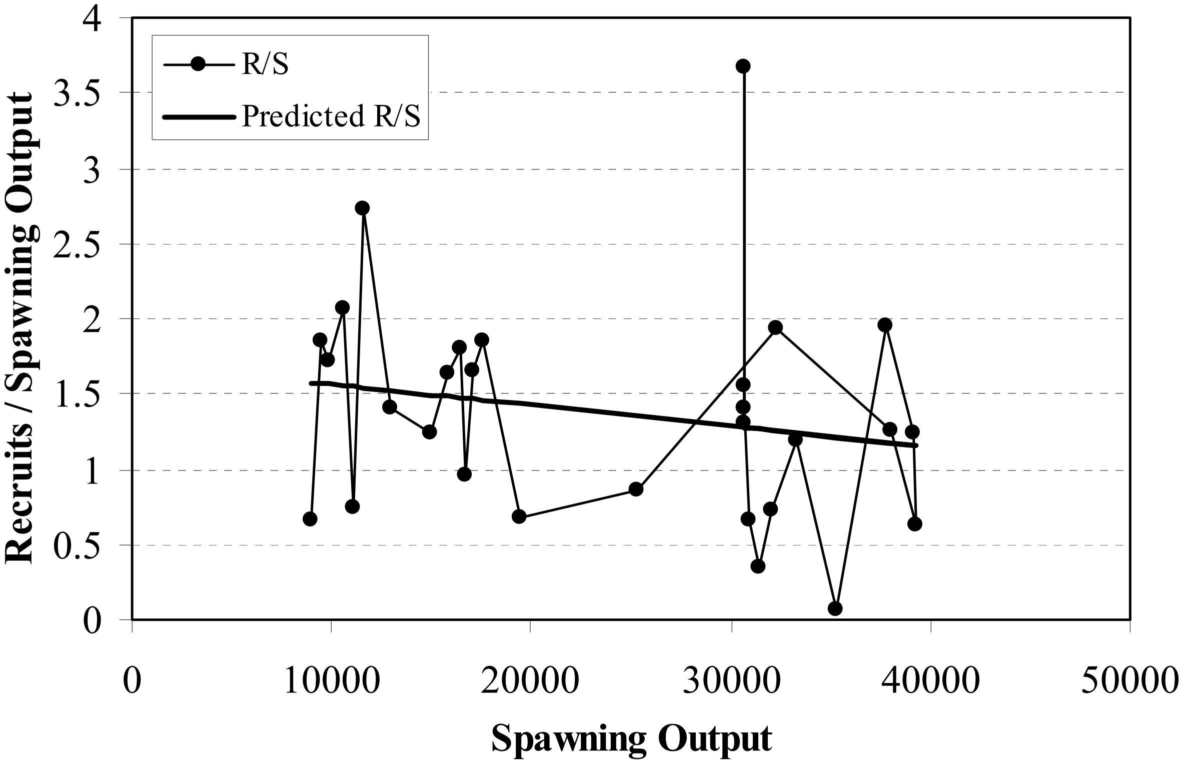


Figure 30. Forecasts of widow rockfish spawning output using the mean recruits per spawning output for various levels of fishing mortality (*F*) with the 40-10 policy precautionary adjustment applied to the fishing mortality levels.

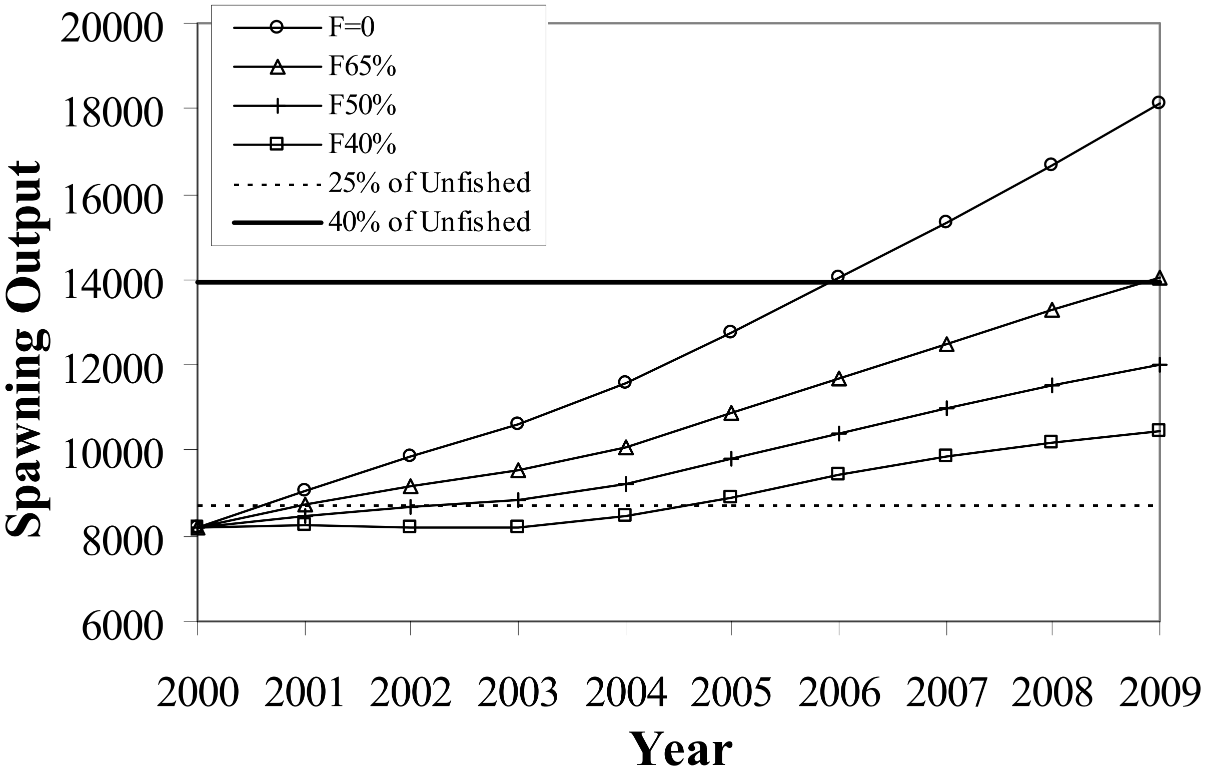
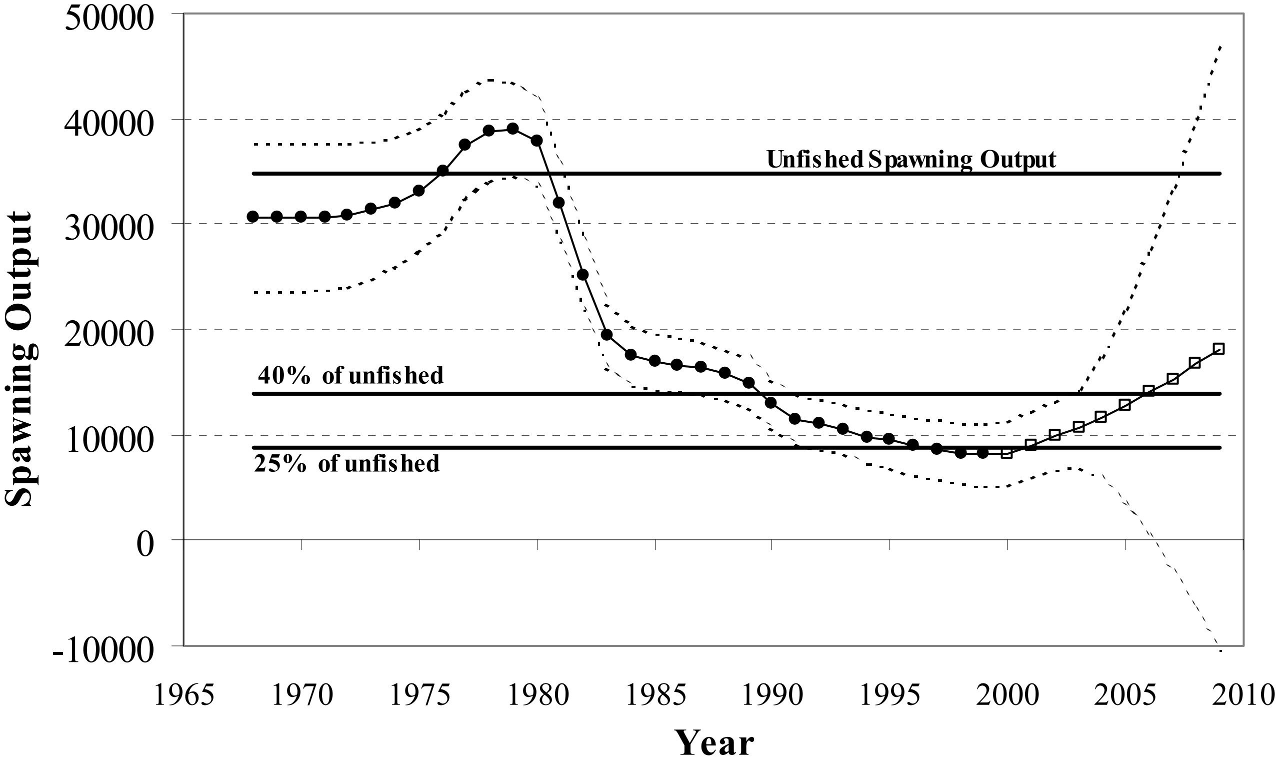


Figure 31. Forecast of widow rockfish spawning output using the mean recruits per spawning output at zero fishing mortality. Dotted lines indicate 95% confidence intervals.



Appendix A.

Quantifying the true uncertainty in estimation of mean historical recruitment

It is necessary to quantify both estimation variability and annual variability in determining historical mean recruitment. ADMB can only quantify the former, but it is likely that annual variability will be the greater because only a small number of years are used for averaging recruitment.

We assume that log recruitment is independent and normally distributed from year to year according to

$$\log(R_i) \sim N(\eta, \sigma^2)$$

The objective is to quantify our knowledge about the mean log-recruitment, η.

The standard non-informative prior for η is the uniform and for σ is uniform on the log scale. The contribution to the negative log-likelihood from this non-informative hyperprior and from the above prior for $\log(R_i)$ is then

$$\log(\sigma) + \sum_{i=1968}^{1982} \left(\frac{[\log(R_i) - \eta]^2}{2\sigma^2} + \log(\sigma) \right)$$

where the summation is over the years used to represent historical recruitment.

Within ADMB this requires defining the parameters η and σ and adding the above term to the objective function. The unknown quantity η can then be used within ADMB as the estimate of mean historical recruitment (e.g. for purposes of SSB ratio calculations).

This approach is heuristic for two reasons

- The assumption of independence between years
- The above modification is based on Bayesian ideology, whereas the ADMB run may simply be minimizing the objective function – in which case the profile calculated by ADMB is an approximation to the posterior density of that parameter.

However this method does seem to give plausible profiles on the SSB ratio in practice and is certainly a great improvement on just using the profile obtained by considering only estimation error.

Russell Millar
14 June 2000

Appendix B.

Consideration of Minimum Stock Size/Overfishing Thresholds for Widow Rockfish

Alec D. MacCall -- 7/14/2000
NMFS Santa Cruz/Tiburon Laboratory

Summary

Three methods are used to evaluate whether widow rockfish abundance is below the minimum stock size threshold (MSST) and warrants determination of an overfished condition.

Default definition: The estimated spawning output in 1999 is 8223 units, which is 23.6% of the estimated unfished level (34900 units), and is below the default MSST value of 25% established by FMP Amendment 11.

National Standard Guideline approach: The MSST is 50% of the abundance producing maximum sustainable yield (Bmsy). A first approximation uses the biomass producing maximum surplus recruitment (Bmsr) as a proxy for Bmsy. The Beverton-Holt SRR indicates that the stock is healthy (near Bmsr), while the Ricker SRR indicates that the stock is near the MSST of 0.5Bmsr. A second approximation uses an equilibrium relationship between yield per recruit and spawning output per recruit to convert stock-recruitment relationships to equilibrium yield curves. Results are similar to those from the first approximation.

On the basis of the National Standard Guidelines approach, the 1999 abundance does not qualify for an "overfished" status determination. However the fishery warrants careful monitoring and management.

Introduction

The Groundfish FMP Amendment 11 established a default Minimum Stock Size Threshold (MSST) or Overfishing Threshold of 25% of the estimated unfished abundance. Stocks falling below this level of abundance qualify as "overfished." Amendment 11 allowed for cases where more complete information is available, particularly those in which Bmsy can be determined from the stock assessment information, and in such cases an alternative threshold is one-half Bmsy, in accordance with the National Standard Guidelines.

The recent stock assessment estimates the spawning output of widow rockfish in 1999 to be 8223 units, and the unfished abundance was estimated to be 34900 units. The point estimate of the relative 1999 spawning output is 23.6% of the unfished level, which falls below the default threshold of 25% established by Amendment 11. However, this determination of relative abundance is imprecise: An approximate 95% equal-tailed confidence interval is 16% to 38.6%.

Given the imprecision of the current status relative to the default overfishing threshold, it is useful to consider the status of the 1999 abundance with regard to possible stock-recruitment relationships for widow rockfish. In particular, the question is, "How does the current (1999) abundance compare with estimates of Bmsy from stock-recruitment models?"

Stock-Recruitment Analysis

Stock and recruitment estimates from the 2000 widow rockfish assessment are shown in Figure B1. The estimation errors are shown as bars of ±2SE. Use of these errors to weight the nonlinear stock-recruitment resulted in poor fits to the data points, and was rejected in favor of equal weighting. The rationale for this decision is that the scatter of observations about the regression line is primarily the result of process error rather than measurement error. Regression methods using a mix of process and measurement error exist, but are beyond the scope of this analysis.

Stock-recruitment regressions followed conventional approaches described in the books by Hilborn and Walters, and Quinn and Deriso. Recruitments were fit by non-linear regression under log transform, and were back-transformed by $\exp(\ln R_{pred}+s^2/2)$ where s^2 is the error variance under log transformation. The Ricker model used a conventional parametrization. The Beverton-Holt model was parametrized according to the steepness parameter of Mace and Doonan (i.e., relative recruitment at 20% of unfished abundance), the ratio of spawning outpu to recruitment in an unfished condition, and unfished recruitment. This is the same function used in Dorn's meta-analysis, except that the bias correction is applied in the back-transformation after fitting the regression, rather than being placed inside the likelihood function. Parameter estimates and goodness-of-fit statistics were obtained for each steepness reported in Dorn's meta-analysis. Dorn's values were used as the prior probability distribution, and were combined with the goodness-of-fit probabilities from the regressions to produce Bayes posterior distributions shown in Figure B2. Additional fits were examined, including the unconstrained least-squares fit, and a fit constrained to an Fmsy SPR of 50% (the default value preferred by the recent review panel).

For both SRRs, the goodness-of-fit is relatively uninformative over a wide range of steepnesses (Figure B2). Consequently, the posterior distributions tend to be little changed from the prior probability distributions obtained from Martin Dorn. The best fitting Ricker and Beverton-Holt curves (Figure B3) are nearly indistinguishable, but the fits constrained to FmsySPR=0.5 differ considerably. The constrained Beverton-Holt curve appears to be a reasonable fit. The constrained Ricker SRR is too highly curved and passes above the recent cloud of observations, suggesting that 0.5 is too low an SPR for the Ricker model (this is consistent with the review panel findings).

Important note: Although the Ricker and Beverton-Holt SRRs may lead to very different conclusions regarding the status of the stock, there is no basis for knowing which curve is closer to the true relationship. For the present purposes, the two models represent the range of our uncertainty, and should be regarded as equally likely.

Maximum Surplus Recruitment

A first approximation of Bmsy is given by Bmsr, the abundance that produces the maximum surplus recruitment, i.e., the maximum excess of recruits over the number necessary to replace the parental stock.

The Beverton-Holt SRR tends to give low estimates of Bmsr relative to those from the Ricker SRR. Consequently, the Beverton-Holt SRR indicates that the present abundance is healthy, and may not even be as low as Bmsr. In contrast, the Ricker model indicates that the present abundance may be very near 50% of Bmsr.

Maximum Sustainable Yield

A second approximation of Bmsy is given by an equilibrium yield curve, calculated by multiplying the recruitment from the fitted SRR by an appropriate value of yield per recruit. This approach produces an estimate of Bmsy under an equilibrium age distribution.

Values of yield per recruit (Y/R) and spawning output per recruit (S/R) were calculated over a range of fishing mortality rates, using an EXCEL spreadsheet. Selectivities, weights at age and fecundities at age were obtained from the stock assessment model. The relationship between equilibrium Y/R and S/R is shown in Figure B4, and is fit very closely by a quadratic approximation,

$$P(S/R) = 427.5375 - 273.8863*(S/R) -117.3698*(S/R)^2,$$

where P is yield per recruit. The stock-recruitment curve consisting of points (Ri, Si) is converted to a yield curve (Yi, Si) by

$$Yi = Ri*P(Si/Ri).$$

Bmsy was obtained by determining the value of S that produces the maximum value of Y, using the SOLVER tool in EXCEL.

Results

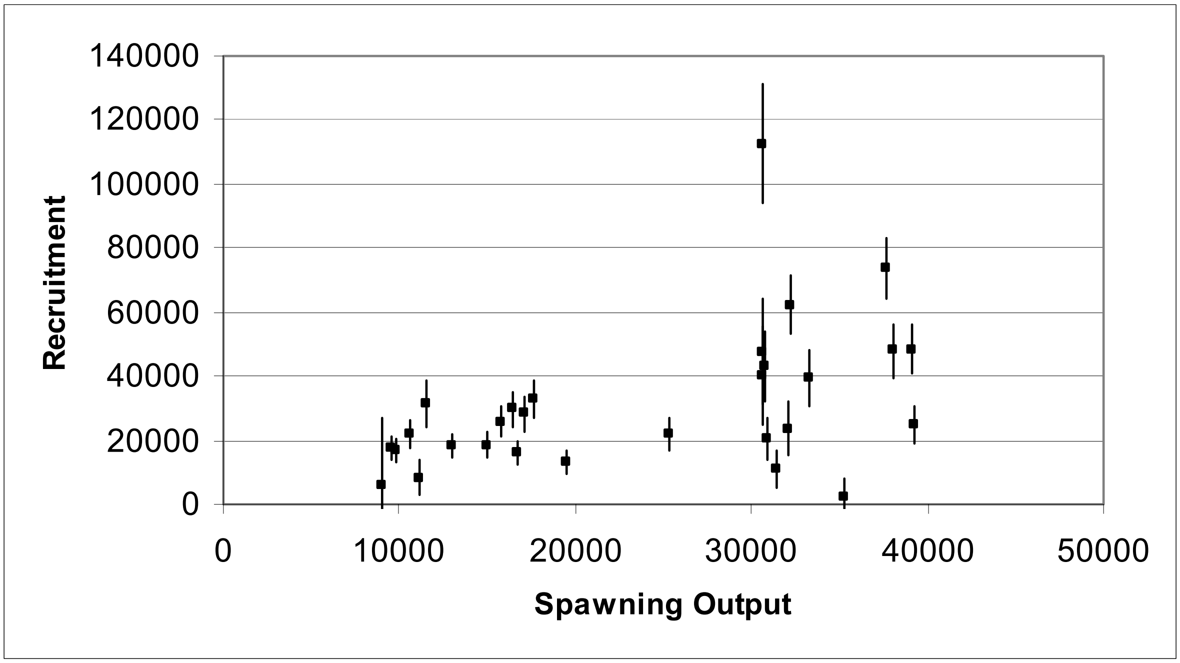
Posterior probability distributions for the two approaches to estimating Bmsy are shown in Figure B5. The difference between the Ricker and Beverton-Holt SRRs is large, but the two approaches are in close agreement with each other. The Beverton-Holt SRR indicates a healthy abundance, whereas the Ricker SRR indicates a stock that is very nearly overfished.

The following table summarizes estimates of stock status (values of B1999/Bmsy) for alternative stock-recruitment models and alternative methods of estimation. A value below 0.5 qualifies as overfished.

	Beverton-Holt		Ricker	
Approach:	MSR	MSY	MSR	MSY
MinSSQ (Best fit)	0.63	0.63	0.53	0.54
Maximum Posterior Likelihood	1.19	1.11	0.51	0.53
SPR=50% at Fmsy	0.84	0.82	0.62	0.61

These results suggest that the widow rockfish stock is not overfished under the criteria suggested by the National Standard Guidelines. If the Ricker and Beverton-Holt SRRs are assumed to be equally likely, there is a roughly 25% chance that the 1999 spawning output is below one-half Bmsy.

Figure B1.



140000
120000
100000
80000
60000
40000
20000
0
Recruitment
0
10000
20000
30000
40000
50000
Spawning Output

Figure B2.


Beverton-Holt SRR
Probability
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.2
0.4
0.6
0.8
1
Steepness

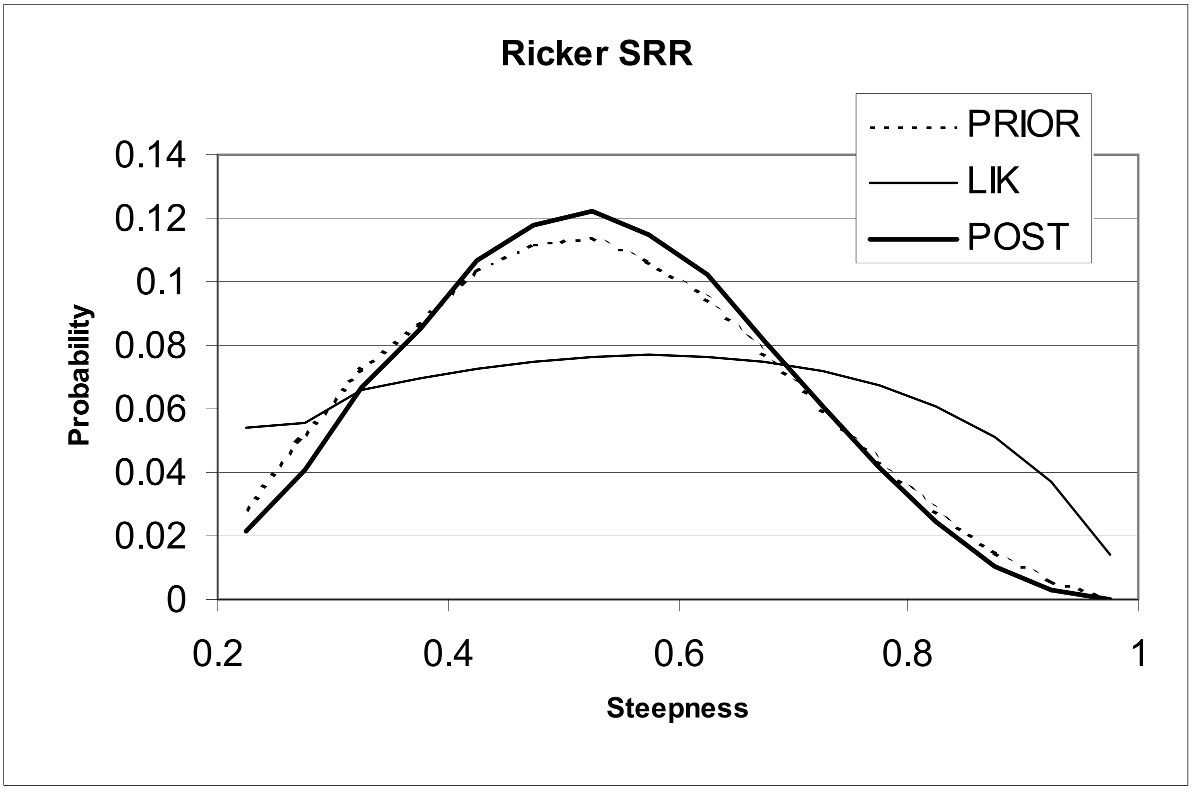
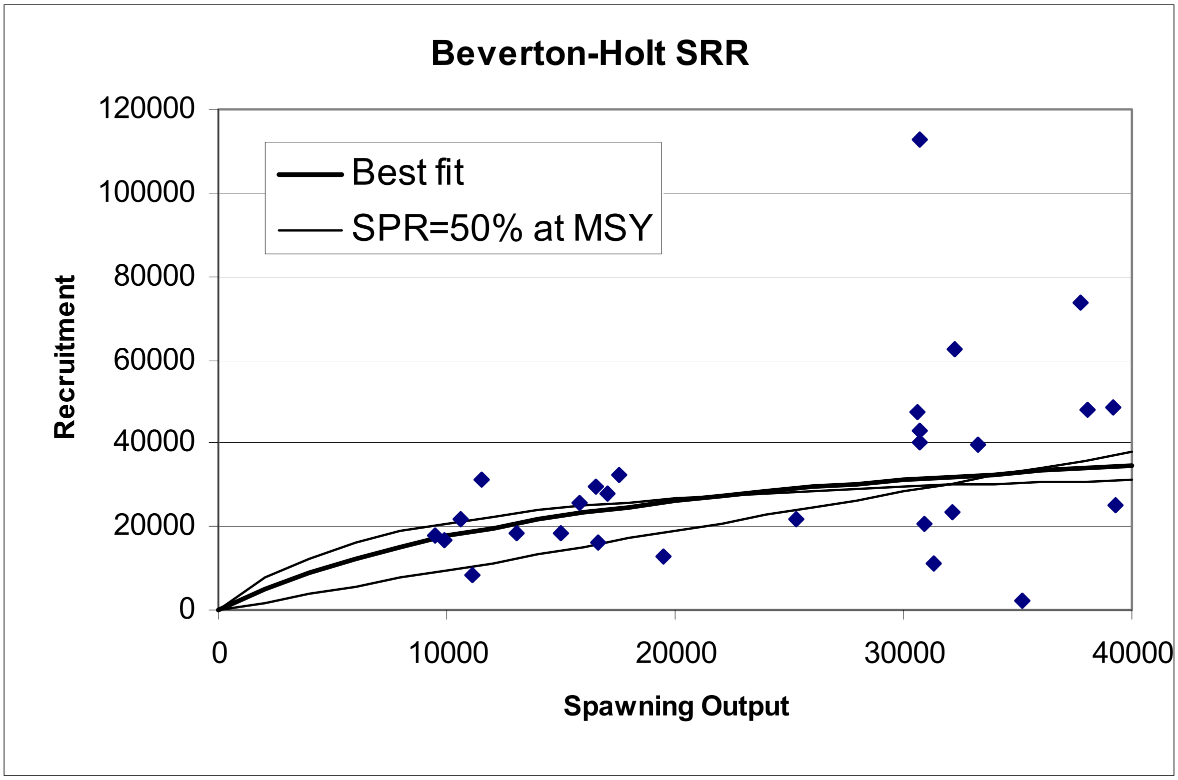

Ricker SRR
PRIOR
LIK
POST
Probability
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.2
0.4
0.6
0.8
1
Steepness

Figure B3.


Beverton-Holt SRR
Best fit
SPR=50% at MSY
Recruitment
0
20000
40000
60000
80000
100000
120000
0
10000
20000
30000
40000
Spawning Output

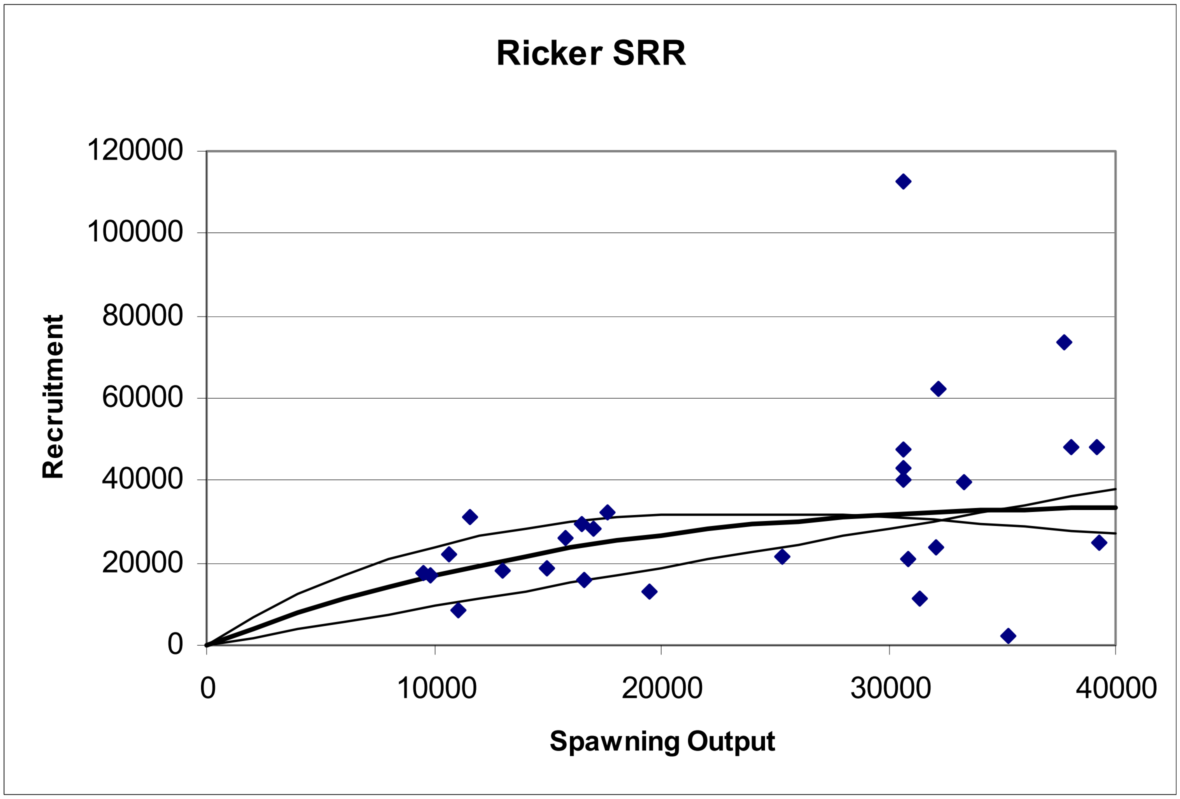

Ricker SRR
Recruitment
0
20000
40000
60000
80000
100000
120000
0
10000
20000
30000
40000
Spawning Output

Figure B4.

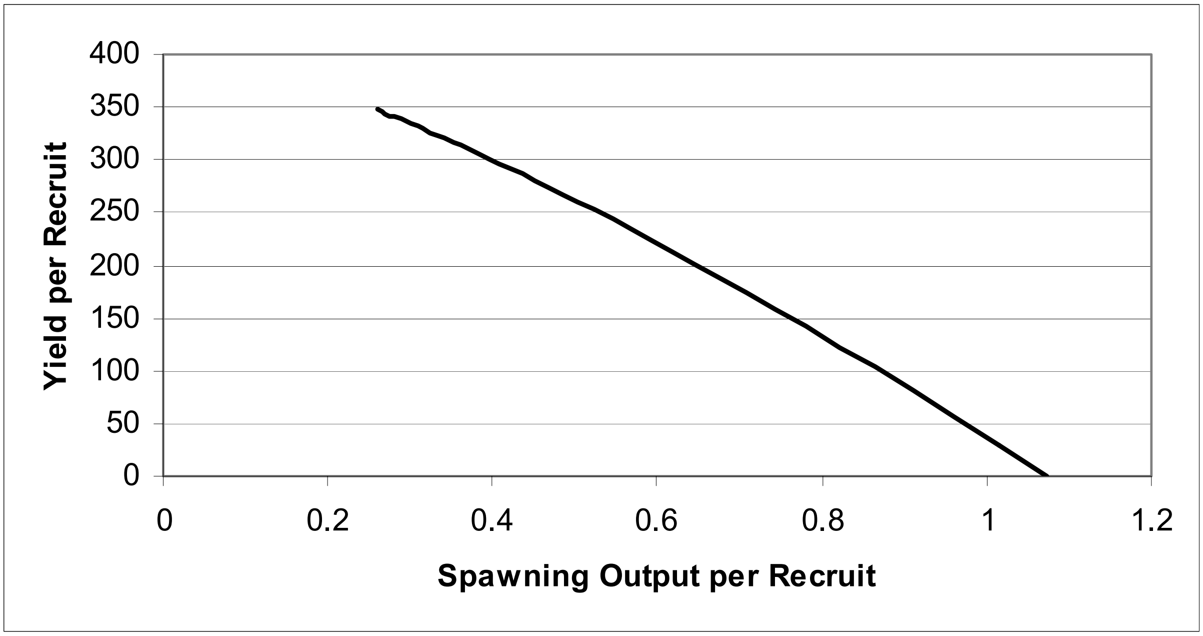
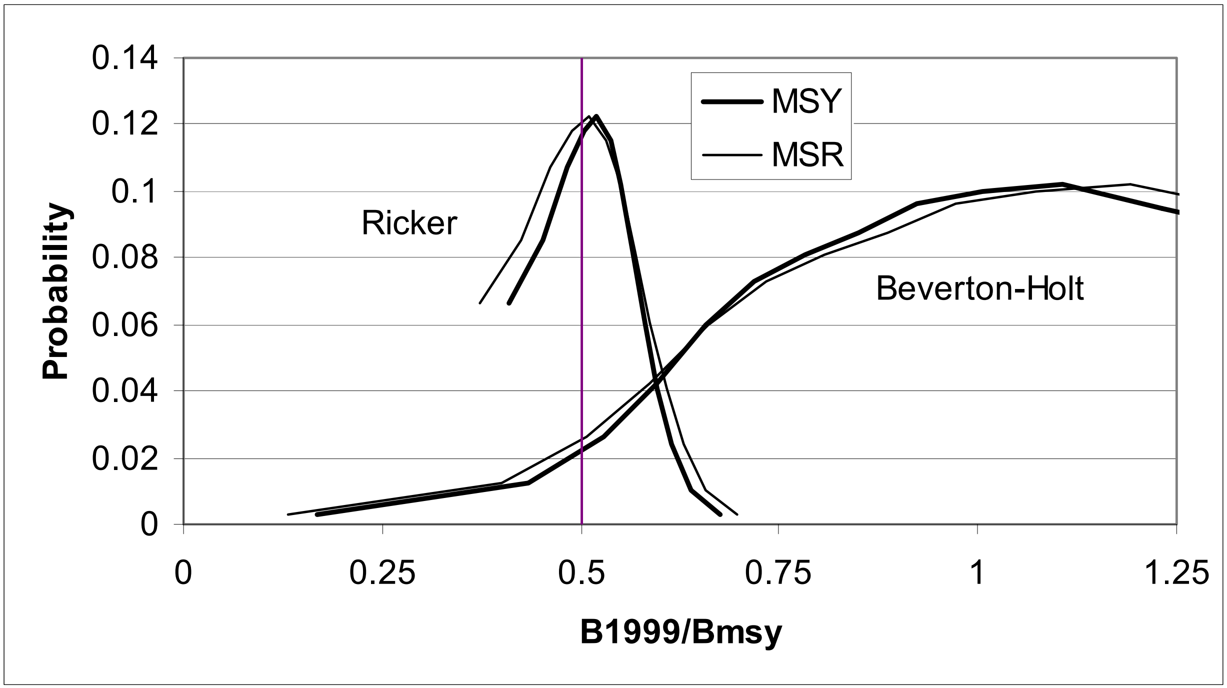

400
350
300
250
200
150
100
50
0
Yield per Recruit
0
0.2
0.4
0.6
0.8
1
1.2
Spawning Output per Recruit

Figure B5.



0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Probability
MSY
MSR
Ricker
Beverton-Holt
0
0.25
0.5
0.75
1
1.25
B1999/Bmsy

Appendix C. AD Model Builder code for the widow rockfish assessment model.

```
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//
//  Widow Rockfish Model
//
//  Erik H. Williams, NMFS, Santa Cruz/Tiburon Lab
//  (erik.williams@noaa.gov), June 2000
//
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
DATA_SECTION
// Starting and ending year of the model
init_int styr;
init_int endyr;
// Recruitment age and total number of age bins
init_int recage;
init_int nages;
// Vector of ages for age bins
init_ivector agebins(1,nages);

// Natural mortality
init_number M;

//Discard percentage by year (prior to 1979 assumed 0)
init_vector D_values(1979,endyr);

//Smoothed Fraction of Landings in the North
init_vector frac_Lnorth(styr,endyr);

//--><>--Biologicals--><>--><>--><>--><>--><>--><>--><>--><>--><>--
//weight-at-age for females(f) and males(m) in the north(n) and south(s)
init_vector wgt_fn(1,nages);
init_vector wgt_mn(1,nages);
init_vector wgt_fs(1,nages);
init_vector wgt_ms(1,nages);
//maturity of females in the north(n) and south(s)
init_vector mat_fn(1,nages);
init_vector mat_fs(1,nages);
//fecundity of females in the north(n) and south(s)
init_vector fecund_fn(1,nages);
init_vector fecund_fs(1,nages);

//--><>--Triennial Survey--><>--><>--><>--><>--><>--><>--><>--><>--
init_int nyrs_trisurv;
init_ivector yrs_trisurv(1,nyrs_trisurv);
init_vector obs_trisurv_B(1,nyrs_trisurv);
init_vector obs_trisurv_cv(1,nyrs_trisurv);
init_vector obs_trisurv_agec(1,nages);  //from 1980 only

//--><>--Midwater Trawl Index--><>--><>--><>--><>--><>--><>--><>-->
init_int nyrs_mwtsurv;
init_ivector yrs_mwtsurv(1,nyrs_mwtsurv);
init_vector obs_mwtsurv(1,nyrs_mwtsurv);
init_vector obs_mwtsurv_cv(1,nyrs_mwtsurv);

//--><>--Oregon Bottom Trawl Logbook Index--><>--><>--><>--><>--><>
init_int nyrs_orlog;
init_ivector yrs_orlog(1,nyrs_orlog);
init_vector obs_orlog(1,nyrs_orlog);
init_vector obs_orlog_cv(1,nyrs_orlog);

//--><>--nonJV Whiting Bycatch Index--><>--><>--><>--><>--><>-->
init_int nyrs_njvbci;
init_ivector yrs_njvbci(1,nyrs_njvbci);
init_vector obs_njvbci(1,nyrs_njvbci);
init_vector obs_njvbci_cv(1,nyrs_njvbci);

//--><>--JV Whiting Bycatch Index--><>--><>--><>--><>--><>-->
init_int nyrs_jvbci;
init_ivector yrs_jvbci(1,nyrs_jvbci);
```

```
init_vector obs_jvbci(1,nyrs_jvbci);
init_vector obs_jvbci_cv(1,nyrs_jvbci);

//--><>--Modern Whiting Bycatch Index--><>--><>--><>--><>--><>-->
init_int nyrs_modbci;
init_ivector yrs_modbci(1,nyrs_modbci);
init_vector obs_modbci(1,nyrs_modbci);
init_vector obs_modbci_cv(1,nyrs_modbci);

//--><>--US-VAN, COL Fishery--><>--><>--><>--><>--><>--><>--><>--><
// Landings (mt)
init_int nyrs_fish1_L;
init_ivector yrs_fish1_L(1,nyrs_fish1_L);
init_vector obs_L_fish1(1,nyrs_fish1_L);
// Age Compositions [females(f), males(m)]
init_int nyrs_fish1_agec;
init_ivector yrs_fish1_agec(1,nyrs_fish1_agec);
init_vector nsamp_fish1_agec(1,nyrs_fish1_agec);
init_matrix obs_fish1_agec_f(1,nyrs_fish1_agec,1,nages);
init_matrix obs_fish1_agec_m(1,nyrs_fish1_agec,1,nages);

//--><>--OR Midwater Trawl Fishery--><>--><>--><>--><>--><>--><>-->
// Landings (mt)
init_int nyrs_fish2_L;
init_ivector yrs_fish2_L(1,nyrs_fish2_L);
init_vector obs_L_fish2(1,nyrs_fish2_L);
// Age Compositions [females(f), males(m)]
init_int nyrs_fish2_agec;
init_ivector yrs_fish2_agec(1,nyrs_fish2_agec);
init_vector nsamp_fish2_agec(1,nyrs_fish2_agec);
init_matrix obs_fish2_agec_f(1,nyrs_fish2_agec,1,nages);
init_matrix obs_fish2_agec_m(1,nyrs_fish2_agec,1,nages);

//--><>--OR Bottom Trawl Fishery--><>--><>--><>--><>--><>--><>-->
// Landings (mt)
init_int nyrs_fish3_L;
init_ivector yrs_fish3_L(1,nyrs_fish3_L);
init_vector obs_L_fish3(1,nyrs_fish3_L);
// Age Compositions [females(f), males(m)]
init_int nyrs_fish3_agec;
init_ivector yrs_fish3_agec(1,nyrs_fish3_agec);
init_vector nsamp_fish3_agec(1,nyrs_fish3_agec);
init_matrix obs_fish3_agec_f(1,nyrs_fish3_agec,1,nages);
init_matrix obs_fish3_agec_m(1,nyrs_fish3_agec,1,nages);

//--><>--EUR-CON Fishery--><>--><>--><>--><>--><>--><>-->
// Landings (mt)
init_int nyrs_fish4_L;
init_ivector yrs_fish4_L(1,nyrs_fish4_L);
init_vector obs_L_fish4(1,nyrs_fish4_L);
// Age Compositions [females(f), males(m)]
init_int nyrs_fish4_agec;
init_ivector yrs_fish4_agec(1,nyrs_fish4_agec);
init_vector nsamp_fish4_agec(1,nyrs_fish4_agec);
init_matrix obs_fish4_agec_f(1,nyrs_fish4_agec,1,nages);
init_matrix obs_fish4_agec_m(1,nyrs_fish4_agec,1,nages);

//--><>--Ageing Error Matrix--><>--><>--><>--><>--><>--><>--><>--><
//row is true age, column is observed age (column sums to 1)
init_matrix age_error(1,nages,1,nages);

// Indices for year(y), age(a), and sex(s)
int y;
int a;
int s;

PARAMETER_SECTION
//Natural Mortality
//init_bounded_number M(0.05,0.25,5)

//Population (males = 1, females = 2)
```

```
init_number log_avg_N_rec(1);
init_bounded_dev_vector log_dev_N_rec(styr,endyr,-10,10,3);
3darray N(1,2,styr,endyr,1,nages);
3darray B(1,2,styr,endyr,1,nages);
sdreport_vector rec(styr,endyr);
sdreport_vector totB(styr,endyr);
sdreport_vector SSB(styr,endyr);
sdreport_vector SO(styr,endyr);
sdreport_number SO_1;
sdreport_number SO_2;
sdreport_number SO_3;
sdreport_number curr_stat_1;
sdreport_number curr_stat_2;
sdreport_number curr_stat_3;
likeprof_number curr_stat_4;

//Survey and Index Predictions
vector pred_trisurv_agec(1,nages);
vector pred_trisurv_B(1,nyrs_trisurv);
vector pred_mwtsurv(1,nyrs_mwtsurv);
vector pred_orlog(1,nyrs_orlog);
vector pred_njvbci(1,nyrs_njvbci);
vector pred_jvbci(1,nyrs_jvbci);
vector pred_modbci(1,nyrs_modbci);

//Catch (numbers), Landings (mt) (males = 1, females = 2)
3darray C_fish1(1,2,styr,endyr,1,nages);
3darray C_fish2(1,2,styr,endyr,1,nages);
3darray C_fish3(1,2,styr,endyr,1,nages);
3darray C_fish4(1,2,styr,endyr,1,nages);
3darray C_total(1,2,styr,endyr,1,nages);
3darray L_fish1(1,2,styr,endyr,1,nages);
3darray L_fish2(1,2,styr,endyr,1,nages);
3darray L_fish3(1,2,styr,endyr,1,nages);
3darray L_fish4(1,2,styr,endyr,1,nages);
3darray L_total(1,2,styr,endyr,1,nages);
3darray pred_fish1_agec(1,2,1,nyrs_fish1_agec,1,nages);
3darray pred_fish2_agec(1,2,1,nyrs_fish2_agec,1,nages);
3darray pred_fish3_agec(1,2,1,nyrs_fish3_agec,1,nages);
3darray pred_fish4_agec(1,2,1,nyrs_fish4_agec,1,nages);
vector pred_L_fish1(1,nyrs_fish1_L);
vector pred_L_fish2(1,nyrs_fish2_L);
vector pred_L_fish3(1,nyrs_fish3_L);
vector pred_L_fish4(1,nyrs_fish4_L);
number L_fish1_cv;
number L_fish2_cv;
number L_fish3_cv;
number L_fish4_cv;

//Discards
vector D(styr,endyr);

//Selectivity constant for sex
//---logistic and double logistic--------------------------------------------
init_bounded_number selpar_slope_fish1(0.1,20.0,1);
init_bounded_number selpar_L50_fish1(3,12,1);
init_bounded_number selpar_slope_fish2(0.1,20.0,1);
init_bounded_number selpar_L50_fish2(3,12,1);
init_bounded_number selpar_slope_fish3(0.1,20.0,1);
init_bounded_number selpar_L50_fish3(3,12,1);
init_bounded_number selpar_slope_fish4(0.1,20.0,1);
init_bounded_number selpar_L50_fish4(3,12,1);
//---logistic and double logistic (time varying)----------------------------------
init_bounded_dev_vector selpar_L50_dev_fish1(1,nyrs_fish1_agec,-5.0,5.0,3);
init_bounded_dev_vector selpar_L50_dev_fish2(1,nyrs_fish4_agec,-5.0,5.0,3);
//---double logistic selectivity--------------------------------------------
init_bounded_number selpar_slope2_fish1(0,5,2);
init_bounded_number selpar_L502_fish1(0,30,2);
init_bounded_number selpar_slope2_fish2(0,5,2);
init_bounded_number selpar_L502_fish2(0,30,2);
init_bounded_number selpar_slope2_fish3(0,5,2);
```

```
init_bounded_number selpar_L502_fish3(0,30,2);
init_bounded_number selpar_slope2_fish4(0,5,2);
init_bounded_number selpar_L502_fish4(0,30,2);
//---lognormal selectivity function--------------------------
//---1=mean, 2=std, 3=horizontal adjustment------------------
//init_bounded_vector selpar_logn1_fish1(1,2,1,10,1);
//init_bounded_vector selpar_logn2_fish1(1,2,0.1,2.5,1);
//init_bounded_vector selpar_logn3_fish1(1,2,-10,10,1);
//init_bounded_vector selpar_logn1_fish2(1,2,1,10,1);
//init_bounded_vector selpar_logn2_fish2(1,2,0.1,2.5,1);
//init_bounded_vector selpar_logn3_fish2(1,2,-10,10,1);
//init_bounded_vector selpar_logn1_fish3(1,2,1,10,1);
//init_bounded_vector selpar_logn2_fish3(1,2,0.1,2.5,1);
//init_bounded_vector selpar_logn3_fish3(1,2,-10,10,1);
//init_bounded_vector selpar_logn1_fish4(1,2,1,10,1);
//init_bounded_vector selpar_logn2_fish4(1,2,0.1,2.5,1);
//init_bounded_vector selpar_logn3_fish4(1,2,-10,10,1);
//number temp_selpar1;
//number temp_selpar2;
//number temp_selpar3;
//number temp_selpar4;
matrix sel_fish1(styr,endyr,1,nages);
matrix sel_fish2(styr,endyr,1,nages);
matrix sel_fish3(styr,endyr,1,nages);
matrix sel_fish4(styr,endyr,1,nages);
//---Triennial survey (logistic)------------------------------
init_bounded_number selpar_slope_trisurv(0.1,20.0,1);
init_bounded_number selpar_L50_trisurv(3,12,1);
vector sel_trisurv(1,nages);

//Catchability
init_bounded_number log_q_trisurv(-20,0,1);
init_bounded_number log_q_mwtsurv(-120,0,1);
init_bounded_number pow_mwtsurv(1.0,20.0,1);
init_bounded_number log_q_orlog(-20,0,1);
number pow_orlog;
//init_bounded_number log_q_njvbci(-20,0,1);
init_bounded_number log_q_jvbci(-20,0,1);
init_bounded_number log_q_modbci(-20,0,1);

//Index cv's
vector trisurv_cv(1,nyrs_trisurv);
vector mwtsurv_cv(1,nyrs_mwtsurv);
vector orlog_cv(1,nyrs_orlog);
vector njvbci_cv(1,nyrs_njvbci);
vector jvbci_cv(1,nyrs_jvbci);
vector modbci_cv(1,nyrs_modbci);

//Mortality
init_number log_avg_F_fish1(1);
init_bounded_dev_vector log_F_dev_fish1(1973,1999,-8,8,2);
3darray F_fish1(1,2,styr,endyr,1,nages);
init_number log_avg_F_fish2(1);
init_bounded_dev_vector log_F_dev_fish2(1983,1999,-8,8,2);
3darray F_fish2(1,2,styr,endyr,1,nages);
init_number log_avg_F_fish3(1);
init_bounded_dev_vector log_F_dev_fish3(1983,1999,-8,8,2);
3darray F_fish3(1,2,styr,endyr,1,nages);
init_number log_avg_F_fish4(1);
init_bounded_dev_vector log_F_dev_fish4(1973,1999,-8,8,2);
3darray F_fish4(1,2,styr,endyr,1,nages);
3darray F_total(1,2,styr,endyr,1,nages);
3darray Z(1,2,styr,endyr,1,nages);

//Per-recruit stuff
matrix N_spr(1,5,1,nages);
init_bounded_number F40(0.01,1.0,5);
init_bounded_number F45(0.01,1.0,5);
init_bounded_number F50(0.01,1.0,5);
init_bounded_number F55(0.01,1.0,5);
number SPR_F100;
```

```
number SPR_F40;
number SPR_F45;
number SPR_F50;
number SPR_F55;
//landings weighted selectivity, maturity, and weight-at-age
3darray frac_lastL(1,2,1,4,1,3); //fraction of landings of each fishery in the last 3 years
matrix sel_fish1_last(1,2,1,nages);
matrix sel_fish2_last(1,2,1,nages);
matrix sel_fish3_last(1,2,1,nages);
matrix sel_fish4_last(1,2,1,nages);
matrix sel_wgtfish(1,2,1,nages);
vector mat_wgt(1,nages);
vector wgt_wgtf(1,nages);
vector fecund_wgt(1,nages);

//mean var calc
init_bounded_number rmean(1,100000,5);
init_bounded_number rmean_cv(0,10,5);
number f_rmeanvar;

//Likelihood weights and components
vector lambda(1,11);
number f_trisurv_B;
number f_trisurv_agec;
number f_fish1_agec;
number f_L_fish1;
number f_mwtsurv;
number f_orlog;
number f_njvbci;
number f_jvbci;
number f_modbci;
number f_N_dev;
number f_F_dev;
number f_SPR;
objective_function_value f;

INITIALIZATION_SECTION
log_avg_N_rec 10.0;
selpar_slope_fish1 2.0;
selpar_L50_fish1 6.0;
selpar_slope_fish2 2.0;
selpar_L50_fish2 6.0;
selpar_slope_fish3 2.0;
selpar_L50_fish3 6.0;
selpar_slope_fish4 2.0;
selpar_L50_fish4 6.0;
selpar_slope2_fish1 0.3;
selpar_L502_fish1 15.0;
selpar_slope2_fish2 0.3;
selpar_L502_fish2 15.0;
selpar_slope2_fish3 0.3;
selpar_L502_fish3 15.0;
selpar_slope2_fish4 0.3;
selpar_L502_fish4 15.0;
selpar_slope_trisurv 2.0;
selpar_L50_trisurv 6.0;
log_q_trisurv -3.0;
log_q_mwtsurv -10.0;
pow_mwtsurv 6.0;
log_q_orlog -9.0;
//log_q_njvbci -9.0;
log_q_jvbci -9.0;
log_q_modbci -9.0;
log_avg_F_fish1 -3.0;
log_avg_F_fish2 -3.0;
log_avg_F_fish3 -3.0;
log_avg_F_fish4 -3.0;

//rmean stuff
rmean 15000;
rmean_cv 0.5;
```

```
RUNTIME_SECTION
maximum_function_evaluations 1000 2000 3000 4000 5000;
convergence_criteria 1e-3 1e-4 1e-6 1e-8 1e-9;

PRELIMINARY_CALCS_SECTION
  curr_stat_4.set_stepnumber(12);
  curr_stat_4.set_stepsize(0.2);

  pow_orlog=1.0;

  F_fish1.initialize();
  F_fish2.initialize();
  F_fish3.initialize();
  F_fish4.initialize();
  C_fish1.initialize();
  C_fish2.initialize();
  C_fish3.initialize();
  C_fish4.initialize();

  //setup for discard vector
  D.initialize();
  D(1979,endyr)=D(1979,endyr)+D_values;

  //assumed value for landings cv
  L_fish1_cv=0.05;
  L_fish2_cv=0.05;
  L_fish3_cv=0.05;
  L_fish4_cv=0.05;

  //Weights for likelihood components
  lambda(1)=1.0;   //Triennial survey biomass cv
  lambda(2)=1.0;   //Triennial age comps sample size
  lambda(3)=1.0;   //Fishery age comps sample size
  lambda(4)=1.0;   //Landings cv
  lambda(5)=1.0;   //Midwater trawl index cv
  lambda(6)=2.0;   //Oregon logbook index cv
  lambda(7)=1.0;   //NonJV whiting bycatch index cv
  lambda(8)=1.0;   //JV whiting bycatch index cv
  lambda(9)=1.0;   //Modern whiting bycatch index cv
  lambda(10)=0.01;   //Recruitment deviations
  lambda(11)=0.01;   //F deviations

  //re-weight cv's
  trisurv_cv=obs_trisurv_cv*lambda(1);
  L_fish1_cv=L_fish1_cv*lambda(4);
  L_fish2_cv=L_fish2_cv*lambda(4);
  L_fish3_cv=L_fish3_cv*lambda(4);
  L_fish4_cv=L_fish4_cv*lambda(4);
  mwtsurv_cv=obs_mwtsurv_cv*lambda(5);
  orlog_cv=obs_orlog_cv*lambda(6);
  njvbci_cv=obs_njvbci_cv*lambda(7);
  jvbci_cv=obs_jvbci_cv*lambda(8);
  modbci_cv=obs_modbci_cv*lambda(9);

  pred_mwtsurv=obs_mwtsurv;

TOP_OF_MAIN_SECTION
  arrmblsize=1000000;
  gradient_structure::set_MAX_NVAR_OFFSET(1600);
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(1000000);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(1000000);

PROCEDURE_SECTION
  get_selectivity();
  get_mortality();
  get_numbers_at_age();
  get_catch_at_age();
  get_biomasses();
  get_pred_agecomps();
  evaluate_the_objective_function();
```

```
FUNCTION get_selectivity
  //--below needed for time varying logistic----------------------------------------
  for (y=styr; y<=endyr; y++)
  {
    for (a=1; a<=nages; a++)
    {
      //---logistic--------------------------------------------------------------
      //sel_fish1(y,a)=1./(1.+mfexp(-1.*selpar_slope_fish1*(double(agebins(a))-
selpar_L50_fish1)));
      //sel_fish2(y,a)=1./(1.+mfexp(-1.*selpar_slope_fish2*(double(agebins(a))-
selpar_L50_fish2)));
      //sel_fish3(y,a)=1./(1.+mfexp(-1.*selpar_slope_fish3*(double(agebins(a))-
selpar_L50_fish3)));
      //sel_fish4(y,a)=1./(1.+mfexp(-1.*selpar_slope_fish4*(double(agebins(a))-
selpar_L50_fish4)));
      //---double logistic-------------------------------------------------------
      sel_fish1(y,a)=(1./(1.+mfexp(-1.*selpar_slope_fish1*(double(agebins(a))-
selpar_L50_fish1))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_fish1*(double(agebins(a))-
selpar_L502_fish1)))));
      sel_fish2(y,a)=(1./(1.+mfexp(-1.*selpar_slope_fish2*(double(agebins(a))-
selpar_L50_fish2))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_fish2*(double(agebins(a))-
selpar_L502_fish2)))));
      sel_fish3(y,a)=(1./(1.+mfexp(-1.*selpar_slope_fish3*(double(agebins(a))-
selpar_L50_fish3))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_fish3*(double(agebins(a))-
selpar_L502_fish3)))));
      sel_fish4(y,a)=(1./(1.+mfexp(-1.*selpar_slope_fish4*(double(agebins(a))-
selpar_L50_fish4))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_fish4*(double(agebins(a))-
selpar_L502_fish4)))));
      //---lognormal selectivity function----------------------------------------------
      //temp_selpar1=a+selpar_logn3_fish1;
      //if(temp_selpar1<=1)
      //{
      //  temp_selpar1=pow(100,(temp_selpar1-1));
      //}
      //temp_selpar2=a+selpar_logn3_fish2;
      //if(temp_selpar2<=1)
      //{
      //  temp_selpar2=pow(100,(temp_selpar2-1));
      //}
      //temp_selpar3=a+selpar_logn3_fish3;
      //if(temp_selpar3<=1)
      //{
      //temp_selpar3=pow(100,(temp_selpar3-1));
      //}
      //temp_selpar4=a+selpar_logn3_fish4;
      //if(temp_selpar4<=1)
      //{
      //  temp_selpar4=pow(100,(temp_selpar4-1));
      //}
      //sel_fish1(y,a)=((1/(temp_selpar1*pow(2*3.1415926,0.5)*selpar_logn2_fish1))*exp(-
0.5*square(log(temp_selpar1)-
selpar_logn1_fish1)/square(selpar_logn2_fish1)))/((1/(exp(selpar_logn1_fish1-
square(selpar_logn2_fish1))*pow(2*3.1415926,0.5)*selpar_logn2_fish1))*exp(-
0.5*square(log(exp(selpar_logn1_fish1-square(selpar_logn2_fish1)))-
selpar_logn1_fish1)/square(selpar_logn2_fish1)));
      //sel_fish2(y,a)=((1/(temp_selpar2*pow(2*3.1415926,0.5)*selpar_logn2_fish2))*exp(-
0.5*square(log(temp_selpar2)-
selpar_logn1_fish2)/square(selpar_logn2_fish2)))/((1/(exp(selpar_logn1_fish2-
square(selpar_logn2_fish2))*pow(2*3.1415926,0.5)*selpar_logn2_fish2))*exp(-
0.5*square(log(exp(selpar_logn1_fish2-square(selpar_logn2_fish2)))-
selpar_logn1_fish2)/square(selpar_logn2_fish2)));
      //sel_fish3(y,a)=((1/(temp_selpar3*pow(2*3.1415926,0.5)*selpar_logn2_fish3))*exp(-
0.5*square(log(temp_selpar3)-
selpar_logn1_fish3)/square(selpar_logn2_fish3)))/((1/(exp(selpar_logn1_fish3-
square(selpar_logn2_fish3))*pow(2*3.1415926,0.5)*selpar_logn2_fish3))*exp(-
0.5*square(log(exp(selpar_logn1_fish3-square(selpar_logn2_fish3)))-
selpar_logn1_fish3)/square(selpar_logn2_fish3)));
      //sel_fish4(y,a)=((1/(temp_selpar4*pow(2*3.1415926,0.5)*selpar_logn2_fish4))*exp(-
0.5*square(log(temp_selpar4)-
selpar_logn1_fish4)/square(selpar_logn2_fish4)))/((1/(exp(selpar_logn1_fish4-
```

```
square(selpar_logn2_fish4))*pow(2*3.1415926,0.5)*selpar_logn2_fish4))*exp(-
0.5*square(log(exp(selpar_logn1_fish4-square(selpar_logn2_fish4)))-
selpar_logn1_fish4)/square(selpar_logn2_fish4)));
      sel_trisurv(a)=1./(1.+mfexp(-1.*selpar_slope_trisurv*(double(agebins(a))-
selpar_L50_trisurv)));
      //---logistic (time varying)-----------------------------------------------------
      if (y>=yrs_fish1_agec(1))
      {
      //  sel_fish1(y,a)=1./(1.+mfexp(-1.*selpar_slope_fish1*(double(agebins(a))-
(selpar_L50_fish1+selpar_L50_dev_fish1(y-yrs_fish1_agec(1)+1)))));
        //---double logistic---------------------------------------------------------------
        sel_fish1(y,a)=(1./(1.+mfexp(-1.*selpar_slope_fish1*(double(agebins(a))-
(selpar_L50_fish1+selpar_L50_dev_fish1(y-yrs_fish1_agec(1)+1))))))*(1-(1./(1.+mfexp(-
1*selpar_slope2_fish1*(double(agebins(a))-selpar_L502_fish1)))));
      }
      if (y>=yrs_fish2_agec(1))
      {
      //  sel_fish2(y,a)=1./(1.+mfexp(-1.*selpar_slope_fish2*(double(agebins(a))-
(selpar_L50_fish2+selpar_L50_dev_fish1(y-yrs_fish2_agec(1)+1)))));
        //---double logistic---------------------------------------------------------------
        sel_fish2(y,a)=(1./(1.+mfexp(-1.*selpar_slope_fish2*(double(agebins(a))-
(selpar_L50_fish2+selpar_L50_dev_fish1(y-yrs_fish2_agec(1)+1))))))*(1-(1./(1.+mfexp(-
1*selpar_slope2_fish2*(double(agebins(a))-selpar_L502_fish2)))));
      }
      if (y>=yrs_fish3_agec(1))
      {
      //  sel_fish3(y,a)=1./(1.+mfexp(-1.*selpar_slope_fish3*(double(agebins(a))-
(selpar_L50_fish3+selpar_L50_dev_fish1(y-yrs_fish3_agec(1)+1)))));
        //---double logistic---------------------------------------------------------------
        sel_fish3(y,a)=(1./(1.+mfexp(-1.*selpar_slope_fish3*(double(agebins(a))-
(selpar_L50_fish3+selpar_L50_dev_fish1(y-yrs_fish3_agec(1)+1))))))*(1-(1./(1.+mfexp(-
1*selpar_slope2_fish3*(double(agebins(a))-selpar_L502_fish3)))));
      }
      //!!!fish4 age comps only run 1984-1998!!!
      if (y>=yrs_fish4_agec(1) && y<endyr)
      {
      //  sel_fish4(y,a)=1./(1.+mfexp(-1.*selpar_slope_fish4*(double(agebins(a))-
(selpar_L50_fish4+selpar_L50_dev_fish2(y-yrs_fish4_agec(1)+1)))));
        //---double logistic---------------------------------------------------------------
        sel_fish4(y,a)=(1./(1.+mfexp(-1.*selpar_slope_fish4*(double(agebins(a))-
(selpar_L50_fish4+selpar_L50_dev_fish2(y-yrs_fish4_agec(1)+1))))))*(1-(1./(1.+mfexp(-
1*selpar_slope2_fish4*(double(agebins(a))-selpar_L502_fish4)))));
      }
    }
    //---double logistic stuff----------------------------------------------------------
    sel_fish1(y)=sel_fish1(y)/max(sel_fish1(y));
    sel_fish2(y)=sel_fish2(y)/max(sel_fish2(y));
    sel_fish3(y)=sel_fish3(y)/max(sel_fish3(y));
    sel_fish4(y)=sel_fish4(y)/max(sel_fish4(y));
  }

FUNCTION get_mortality
  for (s=1; s<=2; s++)
  {
    for (y=styr; y<=endyr; y++)
    {
      if(y>=yrs_fish1_L(1))
      {
        F_fish1(s,y)=sel_fish1(y)*mfexp(log_avg_F_fish1+log_F_dev_fish1(y));
      }
      if(y>=yrs_fish2_L(1))
      {
        F_fish2(s,y)=sel_fish2(y)*mfexp(log_avg_F_fish2+log_F_dev_fish2(y));
        F_fish3(s,y)=sel_fish3(y)*mfexp(log_avg_F_fish3+log_F_dev_fish3(y));
      }
      if(y>=yrs_fish4_L(1))
      {
        F_fish4(s,y)=sel_fish4(y)*mfexp(log_avg_F_fish4+log_F_dev_fish4(y));
      }
      F_total(s,y)=F_fish1(s,y)+F_fish2(s,y)+F_fish3(s,y)+F_fish4(s,y);
      Z(s,y)=F_total(s,y)+M;
```

```
    }
  }

FUNCTION get_numbers_at_age
//Initial age
  for (s=1; s<=2; s++)
  {
    N(s,styr,1)=mfexp(log_avg_N_rec+log_dev_N_rec(styr))*0.5; //assumed 50% sex ratio
    for (a=2; a<=nages; a++)
    {
      N(s,styr,a)=N(s,styr,a-1)*mfexp(-1.*Z(s,styr,a-1));
    }
    N(s,styr,nages)=N(s,styr,nages-1)*mfexp(-1.*Z(s,styr,nages-1))/(1.-mfexp(-
1.*Z(s,styr,nages)));
  }

//Rest of years ages
  for (s=1; s<=2; s++)
  {
    for (y=styr+1; y<=endyr; y++)
    {
      N(s,y,1)=mfexp(log_avg_N_rec+log_dev_N_rec(y))*0.5;
    }
    for (y=styr; y<endyr; y++)
    {
      N(s,y+1)(2,nages)=++elem_prod(N(s,y)(1,nages-1),(mfexp(-1.*Z(s,y)(1,nages-1))));
      N(s,y+1,nages)+=N(s,y,nages)*mfexp(-1.*Z(s,y,nages));
    }
  }

//Recruitment time series
  for (y=styr; y<=endyr; y++)
  {
    rec(y)=N(1,y,1)+N(2,y,1);
  }

//Predicted midwater trawl survey index
  for (y=1; y<=nyrs_mwtsurv-3; y++)
  {

pred_mwtsurv(y)=mfexp(log_q_mwtsurv)*pow((N(1,yrs_mwtsurv(y)+3,1)+N(2,yrs_mwtsurv(y)+3,1))*exp(M*
3),pow_mwtsurv);
  }

FUNCTION get_catch_at_age
  for (s=1; s<=2; s++)
  {
    for (y=styr; y<=endyr; y++)
    {
      for(a=1; a<=nages; a++)
      {
        C_fish1(s,y,a)=N(s,y,a)*F_fish1(s,y,a)*(1.-mfexp(-1.*Z(s,y,a)))/Z(s,y,a);
        C_fish2(s,y,a)=N(s,y,a)*F_fish2(s,y,a)*(1.-mfexp(-1.*Z(s,y,a)))/Z(s,y,a);
        C_fish3(s,y,a)=N(s,y,a)*F_fish3(s,y,a)*(1.-mfexp(-1.*Z(s,y,a)))/Z(s,y,a);
        C_fish4(s,y,a)=N(s,y,a)*F_fish4(s,y,a)*(1.-mfexp(-1.*Z(s,y,a)))/Z(s,y,a);
        C_total(s,y,a)=N(s,y,a)*F_total(s,y,a)*(1.-mfexp(-1.*Z(s,y,a)))/Z(s,y,a);
      }
    }
  }

FUNCTION get_biomasses
  for (y=styr; y<=endyr; y++)
  {
    L_fish1(1,y)=elem_prod(C_fish1(1,y),(wgt_mn*.001))*(1.0-D(y));
    L_fish1(2,y)=elem_prod(C_fish1(2,y),(wgt_fn*.001))*(1.0-D(y));
    L_fish2(1,y)=elem_prod(C_fish2(1,y),(wgt_mn*.001))*(1.0-D(y));
    L_fish2(2,y)=elem_prod(C_fish2(2,y),(wgt_fn*.001))*(1.0-D(y));
    L_fish3(1,y)=elem_prod(C_fish3(1,y),(wgt_mn*.001))*(1.0-D(y));
    L_fish3(2,y)=elem_prod(C_fish3(2,y),(wgt_fn*.001))*(1.0-D(y));
    L_fish4(1,y)=elem_prod(C_fish4(1,y),(wgt_ms*.001))*(1.0-D(y));
    L_fish4(2,y)=elem_prod(C_fish4(2,y),(wgt_fs*.001))*(1.0-D(y));
```

```
    L_total(1,y)=L_fish1(1,y)+L_fish2(1,y)+L_fish3(1,y)+L_fish4(1,y);
    L_total(2,y)=L_fish1(2,y)+L_fish2(2,y)+L_fish3(2,y)+L_fish4(2,y);
    B(1,y)=elem_prod((N(1,y)*frac_Lnorth(y)),(wgt_mn*.001))+elem_prod((N(1,y)*(1-
frac_Lnorth(y))),(wgt_ms*.001));
    B(2,y)=elem_prod((N(2,y)*frac_Lnorth(y)),(wgt_fn*.001))+elem_prod((N(2,y)*(1-
frac_Lnorth(y))),(wgt_fs*.001));
    totB(y)=sum(B(1,y)+B(2,y));

SSB(y)=sum(elem_prod(elem_prod((N(2,y)*frac_Lnorth(y)),(wgt_fn*.001)),mat_fn)+elem_prod(elem_prod
((N(2,y)*(1-frac_Lnorth(y))),(wgt_fs*.001)),mat_fs));
  }

  //Compute spawning potential
  for (y=styr; y<=endyr; y++)
  {

SO(y)=sum(elem_prod(elem_prod((N(2,y)*frac_Lnorth(y)),mat_fn),fecund_fn)+elem_prod(elem_prod((N(2
,y)*(1-frac_Lnorth(y))),mat_fs),fecund_fs));
  }

  //Predicted Oregon bottom trawl logbook index
  for (y=1; y<=nyrs_orlog; y++)
  {

pred_orlog(y)=mfexp(log_q_orlog)*pow((B(1,yrs_orlog(y))*sel_fish3(yrs_orlog(y))+B(2,yrs_orlog(y))
*sel_fish3(yrs_orlog(y))),pow_orlog);
  }

  //Predicted nonJV whiting bycatch index
  //same q as jv
  for (y=1; y<=nyrs_njvbci; y++)
  {

pred_njvbci(y)=mfexp(log_q_jvbci)*(B(1,yrs_njvbci(y))*sel_fish2(yrs_njvbci(y))+B(2,yrs_njvbci(y))
*sel_fish2(yrs_njvbci(y)));
  }

  //Predicted JV whiting bycatch index
  for (y=1; y<=nyrs_jvbci; y++)
  {

pred_jvbci(y)=mfexp(log_q_jvbci)*(B(1,yrs_jvbci(y))*sel_fish2(yrs_jvbci(y))+B(2,yrs_jvbci(y))*sel
_fish2(yrs_jvbci(y)));
  }

  //Predicted modern whiting bycatch index
  for (y=1; y<=nyrs_modbci; y++)
  {

pred_modbci(y)=mfexp(log_q_modbci)*(B(1,yrs_modbci(y))*sel_fish2(yrs_modbci(y))+B(2,yrs_modbci(y)
)*sel_fish2(yrs_modbci(y)));
  }

//predicted landings
  for (y=1; y<=nyrs_fish1_L; y++)
  {
    pred_L_fish1(y)=sum(L_fish1(1,yrs_fish1_L(y))+L_fish1(2,yrs_fish1_L(y)));
  }
  for (y=1; y<=nyrs_fish2_L; y++)
  {
    pred_L_fish2(y)=sum(L_fish2(1,yrs_fish2_L(y))+L_fish2(2,yrs_fish2_L(y)));
    pred_L_fish3(y)=sum(L_fish3(1,yrs_fish3_L(y))+L_fish3(2,yrs_fish3_L(y)));
  }
  for (y=1; y<=nyrs_fish4_L; y++)
  {
    pred_L_fish4(y)=sum(L_fish4(1,yrs_fish4_L(y))+L_fish4(2,yrs_fish4_L(y)));
  }

//predicted triennial survey B
  for (y=1; y<=nyrs_trisurv; y++)
  {
```

```
pred_trisurv_B(y)=mfexp(log_q_trisurv)*(B(1,yrs_trisurv(y))*sel_trisurv+B(2,yrs_trisurv(y))*sel_t
risurv);
  }

FUNCTION get_pred_agecomps
//fishery age comps
  for (s=1; s<=2; s++)
  {
    for (y=1; y<=nyrs_fish1_agec; y++)
    {
      for (a=1; a<=nages; a++)
      {

pred_fish1_agec(s,y,a)=C_fish1(s,yrs_fish1_agec(y),a)/(sum(C_fish1(1,yrs_fish1_agec(y)))+sum(C_fi
sh1(2,yrs_fish1_agec(y))));
      }
      pred_fish1_agec(s,y)=age_error*pred_fish1_agec(s,y);
    }
    for (y=1; y<=nyrs_fish2_agec; y++)
    {
      for (a=1; a<=nages; a++)
      {

pred_fish2_agec(s,y,a)=C_fish2(s,yrs_fish2_agec(y),a)/(sum(C_fish2(1,yrs_fish2_agec(y)))+sum(C_fi
sh2(2,yrs_fish2_agec(y))));

pred_fish3_agec(s,y,a)=C_fish3(s,yrs_fish3_agec(y),a)/(sum(C_fish3(1,yrs_fish3_agec(y)))+sum(C_fi
sh3(2,yrs_fish3_agec(y))));
      }
      pred_fish2_agec(s,y)=age_error*pred_fish2_agec(s,y);
      pred_fish3_agec(s,y)=age_error*pred_fish3_agec(s,y);
    }
    for (y=1; y<=nyrs_fish4_agec; y++)
    {
      for (a=1; a<=nages; a++)
      {

pred_fish4_agec(s,y,a)=C_fish4(s,yrs_fish4_agec(y),a)/(sum(C_fish4(1,yrs_fish4_agec(y)))+sum(C_fi
sh4(2,yrs_fish4_agec(y))));
      }
      pred_fish4_agec(s,y)=age_error*pred_fish4_agec(s,y);
    }
  }

//triennial survey age comps (1980 only)
  for(a=1; a<=nages; a++)
  {

pred_trisurv_agec=elem_prod((N(1,1980)+N(2,1980)),sel_trisurv)/sum(elem_prod((N(1,1980)+N(2,1980)
),sel_trisurv));
  }

FUNCTION evaluate_the_objective_function
  f=0.;
  f_trisurv_B=0.;
  for (y=1; y<=nyrs_trisurv; y++)
  {
    f_trisurv_B+=square(log(obs_trisurv_B(y)+.001)-
log(pred_trisurv_B(y)+.001))/(2.0*square(trisurv_cv(y)))+log(trisurv_cv(y));
  }
  f+=f_trisurv_B;
  //cout << "trisurv B " << f_trisurv_B << endl;

  f_trisurv_agec=0.;
  f_trisurv_agec-
=lambda(2)*123*sum(elem_prod((obs_trisurv_agec+.001),log(pred_trisurv_agec+.001)));
  f+=f_trisurv_agec;
  //cout << "trisurv agec " << f_trisurv_agec << endl;

  f_fish1_agec=0.;
```

```
  for (y=1; y<=nyrs_fish1_agec; y++)
  {
    f_fish1_agec-
=lambda(3)*nsamp_fish1_agec(y)*sum(elem_prod((obs_fish1_agec_f(y)+.001),log(pred_fish1_agec(2,y)+
.001)));
    f_fish1_agec-
=lambda(3)*nsamp_fish1_agec(y)*sum(elem_prod((obs_fish1_agec_m(y)+.001),log(pred_fish1_agec(1,y)+
.001)));
  }
  for (y=1; y<=nyrs_fish2_agec; y++)
  {
    f_fish1_agec-
=lambda(3)*nsamp_fish2_agec(y)*sum(elem_prod((obs_fish2_agec_f(y)+.001),log(pred_fish2_agec(2,y)+
.001)));
    f_fish1_agec-
=lambda(3)*nsamp_fish2_agec(y)*sum(elem_prod((obs_fish2_agec_m(y)+.001),log(pred_fish2_agec(1,y)+
.001)));
    f_fish1_agec-
=lambda(3)*nsamp_fish3_agec(y)*sum(elem_prod((obs_fish3_agec_f(y)+.001),log(pred_fish3_agec(2,y)+
.001)));
    f_fish1_agec-
=lambda(3)*nsamp_fish3_agec(y)*sum(elem_prod((obs_fish3_agec_m(y)+.001),log(pred_fish3_agec(1,y)+
.001)));
  }
  for (y=1; y<=nyrs_fish4_agec; y++)
  {
    f_fish1_agec-
=lambda(3)*nsamp_fish4_agec(y)*sum(elem_prod((obs_fish4_agec_f(y)+.001),log(pred_fish4_agec(2,y)+
.001)));
    f_fish1_agec-
=lambda(3)*nsamp_fish4_agec(y)*sum(elem_prod((obs_fish4_agec_m(y)+.001),log(pred_fish4_agec(1,y)+
.001)));
  }
  f+=f_fish1_agec;
  //cout << "fish1 agec " << f_fish1_agec << endl;

  f_L_fish1=norm2(log(obs_L_fish1+.001)-
log(pred_L_fish1+.001))/(2.0*square(L_fish1_cv))+log(L_fish1_cv);
  f_L_fish1+=norm2(log(obs_L_fish2+.001)-
log(pred_L_fish2+.001))/(2.0*square(L_fish2_cv))+log(L_fish2_cv);
  f_L_fish1+=norm2(log(obs_L_fish3+.001)-
log(pred_L_fish3+.001))/(2.0*square(L_fish3_cv))+log(L_fish3_cv);
  f_L_fish1+=norm2(log(obs_L_fish4+.001)-
log(pred_L_fish4+.001))/(2.0*square(L_fish4_cv))+log(L_fish4_cv);
  f+=f_L_fish1;
  //cout << "fish1 land " << f_L_fish1 << endl;

  f_mwtsurv=0.0;
  for (y=1; y<=nyrs_mwtsurv; y++)
  {
    f_mwtsurv+=square(log(obs_mwtsurv(y)+.001)-
log(pred_mwtsurv(y)+.001))/(2.0*square(mwtsurv_cv(y)))+log(mwtsurv_cv(y));
  }
  f+=f_mwtsurv;
  //cout << "mwt surv " << f_mwtsurv << endl;

  f_orlog=0.0;
  for (y=1; y<=nyrs_orlog; y++)
  {
    f_orlog+=square(log(obs_orlog(y)+.001)-
log(pred_orlog(y)+.001))/(2.0*square(orlog_cv(y)))+log(orlog_cv(y));
  }
  f+=f_orlog;
  //cout << "OR logbook " << f_orlog << endl;

  f_njvbci=0.0;
  for (y=1; y<=nyrs_njvbci; y++)
  {
    f_njvbci+=square(log(obs_njvbci(y)+.001)-
log(pred_njvbci(y)+.001))/(2.0*square(njvbci_cv(y)))+log(njvbci_cv(y));
  }
```

```
  f+=f_njvbci;
  //cout << "nonJV bycatch " << f_njvbci << endl;

  f_jvbci=0.0;
  for (y=1; y<=nyrs_jvbci; y++)
  {
    f_jvbci+=square(log(obs_jvbci(y)+.001)-
log(pred_jvbci(y)+.001))/(2.0*square(jvbci_cv(y)))+log(jvbci_cv(y));
  }
  f+=f_jvbci;
  //cout << "nonJV bycatch " << f_jvbci << endl;

  f_modbci=0.0;
  for (y=1; y<=nyrs_modbci; y++)
  {
    f_modbci+=square(log(obs_modbci(y)+.001)-
log(pred_modbci(y)+.001))/(2.0*square(modbci_cv(y)))+log(modbci_cv(y));
  }
  f+=f_modbci;
  //cout << "nonJV bycatch " << f_modbci << endl;

  f_N_dev=norm2(log_dev_N_rec);
  f+=lambda(10)*f_N_dev;
  //cout << "N dev " << lambda(7)*f_N_dev << endl;

  f_F_dev=norm2(log_F_dev_fish1);
  f_F_dev+=norm2(log_F_dev_fish2);
  f_F_dev+=norm2(log_F_dev_fish3);
  f_F_dev+=norm2(log_F_dev_fish4);
  f+=lambda(11)*f_F_dev;
  //cout << "F dev " << lambda(8)*f_F_dev << endl;

  //--><>--Per-recruit Stuff--><>--><>--><>--><>--><>--><>--><>--><>--><>--
  f_SPR=0.0;
  if(active(F40))
  {
    //Compute weighted selectivity, maturity, weight-at-age
    for (s=1; s<=2; s++)
    {
      for (y=1997; y<=endyr; y++)
      {
        frac_lastL(s,1,y-1996)=sum(L_fish1(s,y))/sum(L_total(s,y));
        frac_lastL(s,2,y-1996)=sum(L_fish2(s,y))/sum(L_total(s,y));
        frac_lastL(s,3,y-1996)=sum(L_fish3(s,y))/sum(L_total(s,y));
        frac_lastL(s,4,y-1996)=sum(L_fish4(s,y))/sum(L_total(s,y));
      }
      for (a=1; a<=nages; a++)
      {
        sel_fish1_last(s,a)=(1./(1.+mfexp(-1.*selpar_slope_fish1*(double(agebins(a))-
(selpar_L50_fish1+mean(selpar_L50_dev_fish1(18,20)))))))*(1-(1./(1.+mfexp(-
1*selpar_slope2_fish1*(double(agebins(a))-selpar_L502_fish1)))));
        sel_fish2_last(s,a)=(1./(1.+mfexp(-1.*selpar_slope_fish2*(double(agebins(a))-
(selpar_L50_fish2+mean(selpar_L50_dev_fish1(18,20)))))))*(1-(1./(1.+mfexp(-
1*selpar_slope2_fish2*(double(agebins(a))-selpar_L502_fish2)))));
        sel_fish3_last(s,a)=(1./(1.+mfexp(-1.*selpar_slope_fish3*(double(agebins(a))-
(selpar_L50_fish3+mean(selpar_L50_dev_fish1(18,20)))))))*(1-(1./(1.+mfexp(-
1*selpar_slope2_fish3*(double(agebins(a))-selpar_L502_fish3)))));
        sel_fish4_last(s,a)=(1./(1.+mfexp(-1.*selpar_slope_fish4*(double(agebins(a))-
(selpar_L50_fish4+mean(selpar_L50_dev_fish2(17,19)))))))*(1-(1./(1.+mfexp(-
1*selpar_slope2_fish4*(double(agebins(a))-selpar_L502_fish4)))));
      }
      sel_fish1_last(s)=sel_fish1_last(s)/max(sel_fish1_last(s));
      sel_fish2_last(s)=sel_fish2_last(s)/max(sel_fish2_last(s));
      sel_fish3_last(s)=sel_fish3_last(s)/max(sel_fish3_last(s));
      sel_fish4_last(s)=sel_fish4_last(s)/max(sel_fish4_last(s));

sel_wgtfish(s)=sel_fish1_last(s)*mean(frac_lastL(s,1))+sel_fish2_last(s)*mean(frac_lastL(s,2))+se
l_fish3_last(s)*mean(frac_lastL(s,3))+sel_fish4_last(s)*mean(frac_lastL(s,4));
    }
    mat_wgt=mean(frac_lastL(2,4))*mat_fs+(1-mean(frac_lastL(2,4)))*mat_fn;
    wgt_wgtf=mean(frac_lastL(2,4))*wgt_fs+(1-mean(frac_lastL(2,4)))*wgt_fn;
```

```
    fecund_wgt=mean(frac_lastL(2,4))*fecund_fs+(1-mean(frac_lastL(2,4)))*fecund_fn;
    //Compute SPR rates
    SPR_F100=0.;
    SPR_F40=0.;
    SPR_F45=0.;
    SPR_F50=0.;
    SPR_F55=0.;
    for(int i=1; i<=5; i++)
    {
      N_spr(i,1)=1.0;
    }
    for(a=2; a<nages; a++)
    {
      N_spr(1,a)=N_spr(1,a-1)*exp(-1.0*M);
      N_spr(2,a)=N_spr(2,a-1)*exp(-1.0*(M+F40*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-1)*0.5)));
      N_spr(3,a)=N_spr(3,a-1)*exp(-1.0*(M+F45*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-1)*0.5)));
      N_spr(4,a)=N_spr(4,a-1)*exp(-1.0*(M+F50*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-1)*0.5)));
      N_spr(5,a)=N_spr(5,a-1)*exp(-1.0*(M+F55*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-1)*0.5)));
    }
    N_spr(1,nages)=N_spr(1,nages-1)*exp(-1.0*M)/(1.0-exp(-1.0*M));
    N_spr(2,nages)=N_spr(2,nages-1)*exp(-1.0*(M+F40*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-
1)*0.5)))/(1.0-exp(-1.0*(M+F40*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-1)*0.5))));
    N_spr(3,nages)=N_spr(3,nages-1)*exp(-1.0*(M+F45*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-
1)*0.5)))/(1.0-exp(-1.0*(M+F45*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-1)*0.5))));
    N_spr(4,nages)=N_spr(4,nages-1)*exp(-1.0*(M+F50*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-
1)*0.5)))/(1.0-exp(-1.0*(M+F50*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-1)*0.5))));
    N_spr(5,nages)=N_spr(5,nages-1)*exp(-1.0*(M+F55*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-
1)*0.5)))/(1.0-exp(-1.0*(M+F55*(sel_wgtfish(2,a-1)*0.5+sel_wgtfish(1,a-1)*0.5))));
    for(a=1; a<=nages; a++)
    {
      SPR_F100+=N_spr(1,a)*0.5*mat_wgt(a)*fecund_wgt(a);
      SPR_F40+=N_spr(2,a)*0.5*mat_wgt(a)*fecund_wgt(a);
      SPR_F45+=N_spr(3,a)*0.5*mat_wgt(a)*fecund_wgt(a);
      SPR_F50+=N_spr(4,a)*0.5*mat_wgt(a)*fecund_wgt(a);
      SPR_F55+=N_spr(5,a)*0.5*mat_wgt(a)*fecund_wgt(a);
    }
    f_SPR=100.0*square(SPR_F40/SPR_F100-0.4);
    f_SPR+=100.0*square(SPR_F45/SPR_F100-0.45);
    f_SPR+=100.0*square(SPR_F50/SPR_F100-0.50);
    f_SPR+=100.0*square(SPR_F55/SPR_F100-0.55);
    //Compute Bzero and current status of stock
    SO_1=mfexp(log_avg_N_rec)*SPR_F100;
    SO_2=(sum(rec(styr,1980))/size_count(rec(styr,1980)))*SPR_F100;
    SO_3=(sum(rec(styr,1976))/size_count(rec(styr,1976)))*SPR_F100;
    curr_stat_1=SO(endyr)/SO_1;
    curr_stat_2=SO(endyr)/SO_2;
    curr_stat_3=SO(endyr)/SO_3;
  }
  f+=f_SPR;
  if(active(rmean))
  {
    f_rmeanvar=0;
    for (y=styr; y<=1982; y++)
    {
      f_rmeanvar+=square(log(rec(y))-log(rmean))/(2*square(rmean_cv))+log(rmean_cv);
    }
    f_rmeanvar+=log(rmean_cv);
    curr_stat_4=SO(endyr)/(rmean*SPR_F100);
  }
  f+=f_rmeanvar;

REPORT_SECTION
  report << "trisurv B " << f_trisurv_B << " wgt. " << lambda(1) << " cv " << mean(trisurv_cv) <<
endl;
  report << "trisurv agec " << f_trisurv_agec << " wgt. " << lambda(2) << endl;
  report << "fish1 agec " << f_fish1_agec << " wgt. " << lambda(3) << endl;
  report << "fish1 land " << f_L_fish1 << " wgt. " << lambda(4) << " cv " << L_fish1_cv << endl;
  report << "mwt index " << f_mwtsurv << " wgt. " << lambda(5) << " cv " << mean(mwtsurv_cv) <<
endl;
  report << "OR logbook " << f_orlog << " wgt. " << lambda(6) << " cv " << mean(orlog_cv) <<
endl;
```

```
  report << "nonJV bycatch " << f_njvbci << " wgt. " << lambda(7) << " cv " << mean(njvbci_cv) <<
endl;
  report << "JV bycatch " << f_jvbci << " wgt. " << lambda(8) << " cv " << mean(jvbci_cv) <<
endl;
  report << "modern bycatch " << f_modbci << " wgt. " << lambda(9) << " cv " << mean(modbci_cv)
<< endl;
  report << "N dev " << f_N_dev << " wgt. " << lambda(10) << endl;
  report << "F dev " << f_F_dev << " wgt. " << lambda(11) << endl;

  report << "Recruitment time series" << endl;
  report << "Year 1968 1969 1970       1971    1972    1973    1974    1975    1976    1977    1978
        1979    1980    1981    1982    1983    1984    1985    1986    1987    1988    1989    1990
        1991    1992    1993    1994    1995    1996    1997    1998    1999" << endl;
  report << "NA  NA NA NA     NA      85308   148485  57806   16064   16300   29951   32876   17258
        68414   79663   43165   92742   89193   36808   27904   37447   39894   26951   42171   34763
        29611   29839   39280   20462   33532   29056   29957   20422" << endl;
  report << rec << endl;

  report << "Total biomass time series" << endl;
  report << totB << endl;

  report << "Spawning biomass time series" << endl;
  report << SSB << endl;

  report << "Spawning potential time series" << endl;
  report << SO << endl;

  report << "SO (1968-1999) " << SO_1 << " Status " << curr_stat_1 << endl;
  report << "SO (1968-1980) " << SO_2 << " Status " << curr_stat_2 << endl;
  report << "SO (1968-1976) " << SO_3 << " Status " << curr_stat_3 << endl;

  report << "Natural mortality " << M << endl;

  report << "Discard Percentage " << endl;
  report << D << endl;

  report << "Observed and Predicted landings fish1 " << endl;
  report << obs_L_fish1 << endl;
  report << pred_L_fish1 << endl;
  report << "Observed and Predicted landings fish2 " << endl;
  report << obs_L_fish2 << endl;
  report << pred_L_fish2 << endl;
  report << "Observed and Predicted landings fish3 " << endl;
  report << obs_L_fish3 << endl;
  report << pred_L_fish3 << endl;
  report << "Observed and Predicted landings fish4 " << endl;
  report << obs_L_fish4 << endl;
  report << pred_L_fish4 << endl;

  report << "Observed and Predicted triennial biomass " << endl;
  report << "Triennial q " << mfexp(log_q_trisurv) << endl;
  report << obs_trisurv_B << endl;
  report << pred_trisurv_B << endl;

  report << "Observed and Predicted midwater survey " << endl;
  report << "MWT q " << mfexp(log_q_mwtsurv) << " Power " << pow_mwtsurv << endl;
  report << obs_mwtsurv << endl;
  report << pred_mwtsurv << endl;

  report << "Observed and Predicted OR logbook index " << endl;
  report << "OR logbook q " << mfexp(log_q_orlog) << endl;
  report << obs_orlog << endl;
  report << pred_orlog << endl;

  report << "Observed and Predicted nonJV whiting bycatch index " << endl;
  report << "nonJV bycatch q " << mfexp(log_q_jvbci) << endl;
  report << obs_njvbci << endl;
  report << pred_njvbci << endl;

  report << "Observed and Predicted JV whiting bycatch index " << endl;
  report << "JV bycatch q " << mfexp(log_q_jvbci) << endl;
```

```
  report << obs_jvbci << endl;
  report << pred_jvbci << endl;

  report << "Observed and Predicted modern whiting bycatch index " << endl;
  report << "modern bycatch q " << mfexp(log_q_modbci) << endl;
  report << obs_modbci << endl;
  report << pred_modbci << endl;

  report << "Observed and Predicted Triennial age comps " << endl;
  report << obs_trisurv_agec << endl;
  report << pred_trisurv_agec << endl;

  report << "F time series" << endl;
  report << mfexp(log_avg_F_fish1+log_F_dev_fish1) << endl;
  report << mfexp(log_avg_F_fish2+log_F_dev_fish2) << endl;
  report << mfexp(log_avg_F_fish3+log_F_dev_fish3) << endl;
  report << mfexp(log_avg_F_fish4+log_F_dev_fish4) << endl;

  report << "Fishery Selectivity" << endl;
  report << "Fishery 1" << endl;
  report << sel_fish1 << endl;
  report << "Fishery 2" << endl;
  report << sel_fish2 << endl;
  report << "Fishery 3" << endl;
  report << sel_fish3 << endl;
  report << "Fishery 4" << endl;
  report << sel_fish4 << endl;

  report << "Triennial Survey" << endl;
  report << sel_trisurv << endl;

  report << "Observed and Predicted fishery 1 age comps (males)" << endl;
  report << elem_div((obs_fish1_agec_m-pred_fish1_agec(1)),pow(elem_prod(pred_fish1_agec(1),(1-
pred_fish1_agec(1))),0.5)) << endl;

  report << "Observed and Predicted fishery 1 age comps (females)" << endl;
  report << elem_div((obs_fish1_agec_m-pred_fish1_agec(2)),pow(elem_prod(pred_fish1_agec(2),(1-
pred_fish1_agec(2))),0.5)) << endl;

  report << "Observed and Predicted fishery 2 age comps (males)" << endl;
  report << elem_div((obs_fish2_agec_m-pred_fish2_agec(1)),pow(elem_prod(pred_fish2_agec(1),(1-
pred_fish2_agec(1))),0.5)) << endl;

  report << "Observed and Predicted fishery 2 age comps (females)" << endl;
  report << elem_div((obs_fish2_agec_m-pred_fish2_agec(2)),pow(elem_prod(pred_fish2_agec(2),(1-
pred_fish2_agec(2))),0.5)) << endl;

  report << "Observed and Predicted fishery 3 age comps (males)" << endl;
  report << elem_div((obs_fish3_agec_m-pred_fish3_agec(1)),pow(elem_prod(pred_fish3_agec(1),(1-
pred_fish3_agec(1))),0.5)) << endl;

  report << "Observed and Predicted fishery 3 age comps (females)" << endl;
  report << elem_div((obs_fish3_agec_m-pred_fish3_agec(2)),pow(elem_prod(pred_fish3_agec(2),(1-
pred_fish3_agec(2))),0.5)) << endl;

  report << "Observed and Predicted fishery 4 age comps (males)" << endl;
  report << elem_div((obs_fish4_agec_m-pred_fish4_agec(1)),pow(elem_prod(pred_fish4_agec(1),(1-
pred_fish4_agec(1))),0.5)) << endl;

  report << "Observed and Predicted fishery 4 age comps (females)" << endl;
  report << elem_div((obs_fish4_agec_m-pred_fish4_agec(2)),pow(elem_prod(pred_fish4_agec(2),(1-
pred_fish4_agec(2))),0.5)) << endl;

  report << "N males " << endl;
  report << N(1) << endl;
  report << "N females " << endl;
  report << N(2) << endl;

  report << "F total males " << endl;
  report << F_total(1) << endl;
  report << "F total females " << endl;
```

```
report << F_total(2) << endl;

report << "C total males " << endl;
report << C_total(1) << endl;
report << "C total females " << endl;
report << C_total(2) << endl;

report << "L total males " << endl;
report << L_total(1) << endl;
report << "L total females " << endl;
report << L_total(2) << endl;

report << "B males " << endl;
report << B(1) << endl;
report << "B females " << endl;
report << B(2) << endl;

report << "SPR F=0 " << SPR_F100 << endl;
report << "SPR F40% " << SPR_F40 << endl;
report << "SPR F45% " << SPR_F45 << endl;
report << "SPR F50% " << SPR_F50 << endl;
report << "SPR F55% " << SPR_F55 << endl;

report << "N_spr " << endl;
report << "F=0 " << N_spr(1) << endl;
report << "F40% " << N_spr(2) << endl;
report << "F45% " << N_spr(3) << endl;
report << "F50% " << N_spr(4) << endl;
report << "F55% " << N_spr(5) << endl;

report << "Fraction of fishery landings in last 3 years" << endl;
report << frac_lastL << endl;
report << "weighted selectivity" << endl;
report << sel_wgtfish << endl;
report << "weighted maturity" << endl;
report << mat_wgt << endl;
report << "weighted female weights" << endl;
report << wgt_wgtf << endl;
report << "weighted male weights" << endl;
report << mean(frac_lastL(1,4))*wgt_ms+(1-mean(frac_lastL(1,4)))*wgt_mn << endl;
report << "weighted fecundity" << endl;
report << fecund_wgt << endl;
```

Appendix D. AD Model Builder data file for the widow rockfish assessment model.

```
#--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
#
#  Widow Rockfish Model
#
#  Erik H. Williams, NMFS, Santa Cruz/Tiburon Lab
#  (erik.williams@noaa.gov), May 2000
#
#--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
# Starting and ending year of the model
# 1962 = age 19 in 1980
1968
1999
# Recruitment age and total number of age bins
3
18
# Vector of ages for age bins
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

# Natural mortality
0.15

# Discard Percent by year (1979-endyr)
0.06 0.06 0.06 0.06 0.16 0.16 0.16 0.16 0.16 0.16 0.16 0.16 0.16 0.16 0.16 0.16 0.16 0.16 0.16
0.16 0.16

# Smoothed fraction of total landings in the north
0.55 0.55 0.55 0.55 0.55 0.55 0.55 0.55 0.55 0.57 0.56 0.53 0.53 0.54 0.55 0.61 0.61 0.64 0.71
0.73 0.75 0.77 0.79 0.79 0.78 0.77 0.77 0.75 0.76 0.76 0.76 0.76

#--><>--Biologicals--><>--><>--><>--><>--><>--><>--><>--><>--><>--
# weight (g) of females (north) [age 22 used for wgt of 20+]
302.1   422.6   551.6   684.2   816.1   944.4   1066.7 1181.7 1288.5 1386.6 1476.0 1556.9 1629.7
        1694.9 1753.1 1804.7 1850.5 1958.0
# weight (g) of males (north) [age 22 used for wgt of 20+]
344.8   448.2   549.0   644.2   731.7   810.7   880.9   942.6   996.3   1042.7 1082.6 1116.7 1145.7
        1170.3 1191.1 1208.7 1223.5 1255.3
# weight (g) of females (south) [age 22 used for wgt of 20+]
148.3   273.6   419.9   574.4   727.4   872.1   1004.6 1123.0 1226.9 1316.8 1393.7 1459.0 1514.0
        1560.1 1598.6 1630.5 1657.0 1712.0
# weight (g) of males (south) [age 22 used for wgt of 20+]
183.3   299.8   419.2   531.7   632.2   718.8   791.6   851.6   900.4   939.6   971.0   995.9   1015.6
        1031.1 1043.3 1052.9 1060.4 1074.4
# percent maturity of females (north)
0.01    0.02    0.10    0.32    0.68    0.90    0.98    0.99    1.00    1.00    1.00    1.00    1.00
        1.00    1.00    1.00    1.00    1.00
# percent maturity of females (south)
0.13    0.21    0.64    0.9     0.9     1       1       1       1       1       1       1       1
        1       1       1       1       1
# fecundity of females (north) (millions of eggs)
0.0000  0.0000  0.0723  0.1526  0.2325  0.3102  0.3843  0.4540  0.5186  0.5780  0.6322  0.6812  0.7253
        0.7648  0.8000  0.8313  0.8590  0.9241
# fecundity of females (south) (millions of eggs)
0.0050  0.0100  0.0300  0.0861  0.1788  0.2664  0.3466  0.4184  0.4813  0.5358  0.5824  0.6219  0.6552
        0.6831  0.7064  0.7258  0.7419  0.7751

#--><>--Triennial Survey--><>--><>--><>--><>--><>--><>--><>--><>--
# number of survey estimates
8
#years of survey
1977 1980 1983 1986 1989 1992 1995 1998
#survey biomass
3697.7  1671.8  3549.3  4890.8  9273.7  12597.4 3020.8  4343.8
#coefficient of variation of survey estimates
0.635   0.395   0.488   0.627   0.487   0.835   0.764   0.320
#age compositions from 1980 only
0.000   0.000   0.008   0.041   0.041   0.228   0.260   0.220   0.073   0.065   0.033   0.008   0.008
        0.008   0.000   0.000   0.008   0.000
```

```
#--><>--Midwater Trawl Index--><>--><>--><>--><>--><>--><>--><>--><>--><>--
# number of index estimates
17
#years of index
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
#index values
0.01152 0.67107 4.40170 0.04924 3.28840 1.61956 0.13121 0.10398 2.16503 0.00000 0.36321 0.06459 0.08556
        0.00000 0.23740 0.00719 0.34040
#cv of index values
0.104   0.663   0.638   0.172   0.374   0.294   0.240   0.193   0.405   1.000   0.308   0.157   0.188
        1.000   0.243   0.107   0.275

#--><>--Oregon Bottom Trawl Logbook Index--><>--><>--><>--><>--><>--><>--><>--><>--
# number of index estimates
15
#years of index
1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998
#index values
1620.5  961.0   1921.0  1862.5  1098.3  1645.9  772.7   835.3   711.2   599.8   569.7   665.6   405.0
        643.8   515.7
#index cv
0.129   0.129   0.129   0.129   0.208   0.143   0.115   0.114   0.106   0.126   0.104   0.119   0.122
        0.122   0.134

#--><>--nonJV Whiting Bycatch Index--><>--><>--><>--><>--><>--><>--><>--><>--
# number of index estimates
12
#years of index
#note no 1983 value
1976 1977 1978 1979 1980 1981 1982 1984 1985 1986 1987 1988
#index values
#3.61   5.90    12.69   9.90    31.37   32.97   3.84    39.65   7.50    7.97    15.34   38.30
0.479 0.165 0.618 0.215 0.743 0.731 0.306 1.304 0.146 0.297 0.250 1.041
#coefficient of variation of index values
#0.50   0.60    0.80    0.44    0.58    0.62    0.98    0.32    0.40    0.92    0.41    0.65
0.71 0.71 0.71 0.71 0.71 0.71 0.71 0.71 0.71 0.71 0.71 0.71

#--><>--JV Whiting Bycatch Index--><>--><>--><>--><>--><>--><>--><>--><>--
# number of index estimates
7
#years of index
#note no 1984 value
1983 1985 1986 1987 1988 1989 1990
#index values
#6.96   12.90   11.36   3.68    6.93    5.31    4.18
0.788 0.394 0.151 0.219 0.116 0.185 0.272
#coefficient of variation of index values
#0.38   0.58    0.25    0.40    0.25    0.19    0.21
0.77 0.77 0.77 0.77 0.77 0.77 0.77

#--><>--Modern Whiting Bycatch Index--><>--><>--><>--><>--><>--><>--><>--><>--
# number of index estimates
8
#years of index
1991 1992 1993 1994 1995 1996 1997 1998
#index values
#7.72   8.24    8.47    5.87    5.49    5.46    3.85    4.54    3.58
1.383 0.794 1.658 0.814 0.132 3.821 1.362 2.379
#coefficient of variation of index values
#0.53   0.19    0.43    0.22    0.70    0.30    0.28    0.30    0.20
0.74 0.74 0.74 0.74 0.74 0.74 0.74 0.74


#--><>--US-VAN, COL Fishery--><>--><>--><>--><>--><>--><>--><>--><
# Landings
#number of landings records
27
#years of landings
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
#landings estimates
```

```
70      26      188     376     1318    605     966     16190   21779   14803
3221    1450    1537    2559    3722    3078    3378    2241    1176    947
1732    1073    1087    968     1016    557     493
# Age Compositions [females(f), males(m)]
#number of years of age comps
20
#years of age comps
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998
1999
#sample sizes
#number of fish
#1775   3050    3944    2480    2193    1591    2592    1939    993     1494    2047    1739    1547
        1797    1398    1650    1347    1497    1099 1099
#number of sampled trips
23      44      49      26      22      16      27      36      21      30      41      35      31
        36      29      33      30      35      34  34
# female age comps
0       0       0.011008698     0.025495935     0.014175586     0.024475716     0.081518498
        0.146945663     0.08510358      0.066405612     0.037299719     0.01766977      0.022801374
        0.021027685     0.006764486     0.007798943     0.005561376     0.015735562
0       0.009914704     0.020554919     0.051479602     0.046936524     0.022204764     0.020791261
        0.059150693     0.076205251     0.067217724     0.035978818     0.026141426     0.017209751
        0.00958428      0.004843658     0.00516797      0.00457605      0.02282255
0.002120579     0.041692139     0.027654216     0.048578368     0.024813003     0.028479659
        0.015257297     0.011624179     0.010879888     0.031654014     0.025785028     0.031602059
        0.026247234     0.031851354     0.013673638     0.012380599     0.004939183     0.029319027
0       0.006203883     0.162001695     0.121199492     0.04276442      0.021472936     0.00864567
        0.012624466     0.011967663     0.014529592     0.027376964     0.019169162     0.0179263
        0.011018203     0.008484821     0.006131153     0.003634011     0.023815186
0.000993689     0.001933983     0.047083691     0.153215067     0.074869879     0.02586002
        0.0181306       0.005284266     0.006472656     0.006773498     0.01100026      0.016138012
        0.024375998     0.02276174      0.019314432     0.010576346     0.012991546     0.081628401
0       0.009896828     0.08094866      0.095452577     0.114069908     0.060403878     0.027703579
        0.007365291     0.006623188     0.004408027     0.005742007     0.00433318      0.009320344
        0.007254878     0.008416869     0.004612397     0.005925675     0.064638323
0       0.002382369     0.059609342     0.189195411     0.09582393      0.071326185     0.018738688
        0.012904134     0.003787348     0.006368446     0.007537455     0.005839293     0.007510033
        0.006677202     0.006249953     0.00736378      0.002489351     0.043880016
0.000127576     0.003591859     0.010615863     0.097307895     0.263901928     0.059165485
        0.036690621     0.036241425     0.010621949     0.009897394     0.006345463     0.001255312
        0.007965975     0.007682093     0.004237532     0.005968821     0.004494632     0.036120909
0       0.00224043      0.007848104     0.056337889     0.150618221     0.20385332      0.033860187
        0.01732911      0.012440024     0.007752989     0.002862803     0.000281222     0.002620066
        0.000407401     0.000278473     0.000690822     0.000131402     0.006344679
0       0.003995684     0.006510181     0.076797798     0.088861355     0.181229732     0.099485777
        0.01019149      0.008684717     0.004879026     0.000532741     0.000795692     0.001100187
        0.001785176     0       0.000715135     0.004113733     0.019770443
0       0.001875853     0.04302239      0.091885812     0.127846192     0.070197685     0.087601865
        0.087106372     0.008763201     0.006675525     0.001611177     0.002713235     0.002387862
        0.000548345     0.002268118     0.000691212     0.000805176     0.022255466
0       0       0.004191913     0.052252787     0.092259396     0.105329921     0.068821459
        0.0668814       0.054041834     0.014068092     0.010133788     0.00602271      0.00318191
        0.001969373     0.000492121     0.002435733     0.002685347     0.034569292
0       0.002699656     0.022704859     0.025632105     0.055102903     0.091090375     0.077760076
        0.056457609     0.070688515     0.052188662     0.029698388     0.014014154     0.008776322
        0.004470527     0.000695777     0.004426093     0.002726751     0.027186223
0       0.00084988      0.007321312     0.055649987     0.039576052     0.059352946     0.067361287
        0.049272067     0.050338871     0.081901493     0.047749153     0.031366692     0.014790208
        0.008966365     0.004344822     0.003970137     0.001529276     0.032782735
0.003985519     0.002795591     0.013233386     0.047648484     0.075260747     0.069567854
        0.043055657     0.054030648     0.042318        0.04199509      0.050555662     0.034167238
        0.023496395     0.015796916     0.012597441     0.007547405     0.004163268     0.029868683
0.00079008      0.010767047     0.032812973     0.053347603     0.077909871     0.079865994
        0.054240979     0.034987786     0.024541796     0.027630459     0.017637671     0.017617197
        0.010840565     0.006950655     0.010991322     0.004765605     0.001300049     0.012358374
0       0.001314092     0.065899889     0.108301002     0.10726589      0.064100948     0.052275082
        0.022724365     0.014682045     0.017455491     0.014069251     0.012902344     0.018435769
        0.004100044     0.00347282      0.00210197      0.002190474     0.017885505
0       0.001310572     0.029723003     0.1719647       0.135707066     0.051589866     0.033631022
        0.022770957     0.020903529     0.016771309     0.019137265     0.007997404     0.005371704
        0.009428279     0.005049074     0.002499929     0.003521592     0.024184515
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0       0.001033914    0.011866178    0.046500458    0.172153987    0.155644363    0.043813016
        0.018199817    0.017517874    0.021299725    0.016989918    0.01911824     0.012942255
        0.003230064    0.010214482    0.004845096    0.002450962    0.014104491
0       0.002243514    0.007023173    0.037806934    0.050931775    0.126104973    0.122669127
        0.069811717    0.048197099    0.023560909    0.013638956    0.008700931    0.009239145
        0.003669952    0.003322236    0.006541191    0.004575391    0.013160416
# male age comps
0       0       0.00872576     0.02021539     0.021482802    0.049680495    0.080699006
        0.11877926     0.044398698    0.027428109    0.00660913     0.010013668    0.00741329
        0.003929901    0.001335312    0.003656893    0.001877729    0.003966354
0.000690834    0.008082664    0.026769302    0.065337363    0.046240573    0.023899092
        0.048613371    0.08750944     0.066650532    0.048012497    0.026101491    0.017765005
        0.011101813    0.004685196    0.003985266    0.003390077    0.0028172      0.007568339
0.001064407    0.047951612    0.035635096    0.073266199    0.026483054    0.035682709
        0.020873694    0.01699188     0.027225099    0.062581854    0.058856954    0.052426193
        0.043069475    0.023492563    0.017115405    0.011226805    0.011291038    0.0162145
0       0.009071873    0.165509608    0.11959174     0.030889345    0.018152433    0.014568563
        0.012039897    0.013078718    0.018140022    0.016221492    0.01246312     0.01273865
        0.007970499    0.005637682    0.005698497    0.004301984    0.014960262
0       0.003261073    0.056979562    0.161769523    0.083936156    0.033201992    0.013739743
        0.004271042    0.005410594    0.00650261     0.007216295    0.012290233    0.01234428
        0.009954477    0.006615263    0.007336762    0.00746309     0.02830322
0       0.009970082    0.086529825    0.09156158     0.135270799    0.069193921    0.022632543
        0.009079877    0.004168622    0.005224977    0.004356536    0.004779078    0.004253555
        0.002088823    0.00506095     0.003640975    0.002472614    0.022599632
0       0.010181185    0.065213343    0.183297887    0.07370957     0.048418604    0.01418148
        0.005598924    0.005611789    0.004777942    0.003036446    0.002908475    0.004147225
        0.005635487    0.002617661    0.00190163     0.000986532    0.020092884
0       0.005431734    0.021479087    0.110263713    0.169290666    0.038686558    0.008239875
        0.008687609    0.003318933    0.004594697    0.005514756    0.002836383    0.002017362
        0.003637874    0.002396439    0.001343447    0.000967535    0.0090606
0       0       0.014939684    0.059454424    0.138010509    0.204226084    0.036637771
        0.013189125    0.004958911    0.002191773    0.000707041    0.002355613    0.003029667
        0.000684225    0.000164115    0.000422795    0.000556671    0.01257445
0       0.002598601    0.017119657    0.095689459    0.101514398    0.165988982    0.080995382
        0.011467232    0.004242422    0.000880555    0       0.001062695    0.000163648
        0.000696135    0.000163648    0.000348574    0.001247622    0.00637212
0       0.00025683     0.048527313    0.089429407    0.127091805    0.07533966     0.056098854
        0.026295796    0.007486894    0.00232097     0.000508706    0.000154016    0
        0.000187461    0.000311335    0.002582343    0.000526461    0.004626663
0       0.000882976    0.009461341    0.058914189    0.110781451    0.096096875    0.06855319
        0.046588063    0.044312225    0.013173569    0.004395335    0.002838136    0.001180558
        0.000709756    0.003380002    0.001485247    0.000835895    0.017074118
0       0.002337679    0.019363614    0.030647766    0.074182571    0.07785328     0.081412361
        0.046583434    0.049094515    0.026902277    0.018132458    0.007513737    0.004581071
        0.002632463    0.001760033    0       0.000697944    0.009985803
8.52425E-05    0.000451658    0.015369094    0.055074918    0.051619416    0.061013266
        0.058905105    0.039476179    0.026100741    0.028894659    0.022099433    0.026390184
        0.013935875    0.008573232    0.009998181    0.005153354    0.003417969    0.016318211
0       0.001230416    0.010170184    0.041760067    0.088832843    0.05998424     0.047039201
        0.037322276    0.027315028    0.021953932    0.025339056    0.015885791    0.012869989
        0.010623443    0.00485155     0.003322912    0.002428244    0.016986845
0.000817067    0.012608706    0.031667403    0.055464719    0.092403974    0.096177559
        0.067267524    0.028446595    0.031836773    0.018917246    0.015208803    0.025408185
        0.009560059    0.007714678    0.005849755    0.007009283    0.002049182    0.012236466
0.000632996    0.010934092    0.054329914    0.109301482    0.106359686    0.064072088
        0.035504535    0.020580067    0.014039429    0.011809512    0.007432412    0.006323226
        0.008580078    0.003248674    0.003978832    0.003553628    0.002363634    0.007778732
0       0.002322209    0.040251324    0.144865575    0.126926782    0.054207364    0.018880254
        0.010646801    0.008162365    0.00604704     0.006299494    0.00770485     0.00080293
        0.003943563    0.001746214    0.000401921    0.000946929    0.004282599
0       0.00196517     0.014254812    0.045567369    0.154747938    0.11467461     0.043871677
        0.014036664    0.006493126    0.006623281    0.006386801    0.002995417    0.002595784
        0.002137489    0.005789184    0.001052246    0       0.004883593
0       0.001645626    0.012017429    0.043420882    0.062962976    0.094501842    0.10080778
        0.057074757    0.032547587    0.01681086     0.006452827    0.005201968    0.00174317
        0.004025701    0.00081478     0.002825335    0       0.005949041

#--><>--OR Midwater Trawl Fishery--><>--><>--><>--><>--><>--><>--><>--><
# Landings
#number of landings records
```

```
17
#years of landings
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
#landings estimates
1451.9  3567.6  3185.0  2976.9  4984.8  4101.7  4870.9  3234.8  1846.2  1139.7  1754.8  1678.4  1394.3
        1463.6  1515.6  758.5   1590.1
# Age Compositions [females(f), males(m)]
#number of years of age comps
16
#years of age comps
1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
#sample sizes
#number of fish
#959    1530    1892    1807    915     1779    1434    1343    649     1192    576     251     341
        637     268 268
#sampled trips
23      49      54      61      31      63      61      60      29      51      22      11      13
        22      11 11
# female age comps
0.0000  0.0005  0.0151  0.1355  0.1651  0.0160  0.0363  0.0058  0.0034  0.0114  0.0280  0.0728  0.0216
        0.0053  0.0055  0.0218  0.0305  0.0577
0.0000  0.0000  0.0597  0.0650  0.2500  0.0864  0.0110  0.0126  0.0094  0.0000  0.0012  0.0070  0.0180
        0.0027  0.0015  0.0012  0.0019  0.0068
0.0000  0.0000  0.0094  0.1284  0.0829  0.1715  0.0671  0.0030  0.0104  0.0044  0.0000  0.0004  0.0039
        0.0185  0.0013  0.0043  0.0008  0.0082
0.0000  0.0009  0.0124  0.1093  0.2229  0.0862  0.0317  0.0279  0.0011  0.0028  0.0013  0.0001  0.0000
        0.0012  0.0063  0.0004  0.0003  0.0065
0.0012  0.0059  0.0144  0.0762  0.1945  0.0973  0.0253  0.0197  0.0101  0.0032  0.0056  0.0000  0.0000
        0.0000  0.0000  0.0045  0.0034  0.0049
0.0000  0.0034  0.0237  0.0335  0.0775  0.1959  0.0879  0.0312  0.0159  0.0153  0.0090  0.0018  0.0000
        0.0007  0.0000  0.0016  0.0064  0.0119
0.0000  0.0000  0.0181  0.0326  0.0541  0.0793  0.1517  0.1039  0.0373  0.0217  0.0091  0.0022  0.0019
        0.0006  0.0008  0.0000  0.0000  0.0039
0.0000  0.0000  0.0106  0.0616  0.0917  0.0651  0.0693  0.0958  0.0469  0.0133  0.0097  0.0046  0.0034
        0.0009  0.0005  0.0005  0.0023  0.0191
0.0000  0.0000  0.0209  0.0291  0.0702  0.0777  0.0438  0.0622  0.0876  0.0308  0.0139  0.0059  0.0011
        0.0018  0.0019  0.0020  0.0000  0.0072
0.0000  0.0007  0.0108  0.0671  0.0396  0.0808  0.0679  0.0390  0.0447  0.0634  0.0345  0.0239  0.0214
        0.0082  0.0045  0.0041  0.0019  0.0081
0.0000  0.0001  0.0103  0.0478  0.1461  0.0629  0.0576  0.0389  0.0421  0.0224  0.0271  0.0143  0.0258
        0.0060  0.0000  0.0000  0.0029  0.0041
0.0000  0.0064  0.0022  0.0191  0.0428  0.1066  0.1078  0.0674  0.0572  0.0542  0.0155  0.0352  0.0088
        0.0029  0.0009  0.0000  0.0000  0.0020
0.0000  0.0078  0.0719  0.0584  0.0809  0.0833  0.0486  0.0202  0.0390  0.0132  0.0166  0.0223  0.0181
        0.0058  0.0000  0.0000  0.0000  0.0244
0.0000  0.0021  0.0199  0.1852  0.0852  0.0358  0.0281  0.0151  0.0100  0.0091  0.0101  0.0108  0.0050
        0.0138  0.0000  0.0018  0.0000  0.0036
0.0000  0.0000  0.0068  0.0324  0.1538  0.0870  0.0403  0.0388  0.0339  0.0136  0.0152  0.0159  0.0000
        0.0000  0.0067  0.0000  0.0000  0.0000
0.0000  0.0000  0.0126  0.0189  0.0635  0.2397  0.1026  0.0475  0.0225  0.0116  0.0166  0.0111  0.0000
        0.0112  0.0060  0.0000  0.0000  0.0000
# male age comps
0.0000  0.0014  0.0137  0.1334  0.0820  0.0062  0.0201  0.0064  0.0040  0.0063  0.0120  0.0245  0.0106
        0.0159  0.0008  0.0020  0.0008  0.0277
0.0000  0.0017  0.0639  0.0646  0.2244  0.0612  0.0074  0.0057  0.0029  0.0000  0.0016  0.0050  0.0131
        0.0022  0.0022  0.0000  0.0000  0.0096
0.0000  0.0000  0.0056  0.1033  0.0727  0.1947  0.0622  0.0039  0.0072  0.0036  0.0000  0.0004  0.0011
        0.0156  0.0040  0.0027  0.0011  0.0072
0.0000  0.0000  0.0142  0.1182  0.2154  0.0698  0.0350  0.0162  0.0018  0.0025  0.0022  0.0003  0.0002
        0.0013  0.0026  0.0000  0.0065  0.0024
0.0006  0.0014  0.0172  0.0791  0.2486  0.1226  0.0277  0.0203  0.0071  0.0000  0.0000  0.0006  0.0000
        0.0000  0.0033  0.0026  0.0000  0.0028
0.0000  0.0041  0.0156  0.0469  0.1148  0.1882  0.0703  0.0130  0.0141  0.0023  0.0002  0.0001  0.0005
        0.0007  0.0021  0.0021  0.0035  0.0058
0.0000  0.0033  0.0277  0.0304  0.0568  0.0992  0.1325  0.0671  0.0325  0.0154  0.0074  0.0035  0.0000
        0.0010  0.0000  0.0018  0.0000  0.0042
0.0000  0.0000  0.0074  0.0685  0.0977  0.1019  0.0669  0.0860  0.0407  0.0095  0.0077  0.0033  0.0026
        0.0009  0.0006  0.0000  0.0006  0.0104
0.0000  0.0000  0.0328  0.0358  0.0837  0.0859  0.0899  0.0407  0.0916  0.0299  0.0226  0.0123  0.0018
        0.0038  0.0000  0.0000  0.0011  0.0119
```

```
0.0000  0.0000  0.0172  0.0699  0.0562  0.0853  0.0510  0.0358  0.0337  0.0615  0.0250  0.0151  0.0119
        0.0055  0.0000  0.0032  0.0012  0.0072
0.0001  0.0020  0.0106  0.0760  0.1510  0.0849  0.0488  0.0436  0.0136  0.0201  0.0240  0.0000  0.0019
        0.0070  0.0000  0.0000  0.0000  0.0084
0.0000  0.0051  0.0205  0.0225  0.1277  0.0993  0.0678  0.0447  0.0289  0.0093  0.0281  0.0088  0.0000
        0.0000  0.0000  0.0073  0.0000  0.0011
0.0000  0.0095  0.0737  0.0948  0.0736  0.0644  0.0511  0.0334  0.0127  0.0086  0.0236  0.0092  0.0165
        0.0076  0.0030  0.0000  0.0039  0.0039
0.0000  0.0024  0.0324  0.2683  0.1244  0.0416  0.0224  0.0243  0.0114  0.0096  0.0056  0.0000  0.0095
        0.0109  0.0000  0.0000  0.0000  0.0018
0.0000  0.0000  0.0160  0.1132  0.2067  0.0774  0.0635  0.0150  0.0311  0.0136  0.0016  0.0053  0.0000
        0.0000  0.0122  0.0000  0.0000  0.0000
0.0000  0.0000  0.0001  0.0187  0.1022  0.2016  0.0855  0.0226  0.0001  0.0055  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0000  0.0001

#--><>--OR Bottom Trawl Fishery--><>--><>--><>--><>--><>--><>--><>--><>--><
# Landings
#number of landings records
17
#years of landings
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
#landings estimates
1487.6  1334.2  870.8   1170.6  1169.4  1126.1  1970.9  2168.1  1940.1  2623.9  3385.4  2382.3  2278.3
        2114.5  2285.6  1329.9  911.7
# Age Compositions [females(f), males(m)]
#number of years of age comps
16
#years of age comps
1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
#sample sizes
#number of fish
#753    633     779     776     855     1051    1299    1592    1735    1322    1356    897     820
        1112    1036 1036
#number of trips sampled
26      22      21      26      28      47      58      77      88      65      63      40      33
        48      35 35
# female age comps
0.0000  0.0000  0.0377  0.1482  0.2168  0.0240  0.0155  0.0121  0.0047  0.0048  0.0130  0.0304  0.0147
        0.0078  0.0048  0.0053  0.0028  0.0439
0.0011  0.0000  0.0248  0.0618  0.1953  0.1213  0.0179  0.0057  0.0061  0.0001  0.0011  0.0266  0.0368
        0.0050  0.0092  0.0035  0.0039  0.0321
0.0000  0.0011  0.0202  0.1095  0.0624  0.0891  0.0678  0.0071  0.0185  0.0132  0.0003  0.0000  0.0044
        0.0396  0.0103  0.0074  0.0049  0.0263
0.0000  0.0016  0.0106  0.1166  0.1668  0.0585  0.0513  0.0298  0.0037  0.0038  0.0016  0.0032  0.0003
        0.0049  0.0172  0.0141  0.0035  0.0236
0.0103  0.0190  0.0040  0.0816  0.1635  0.1037  0.0406  0.0278  0.0161  0.0108  0.0048  0.0063  0.0009
        0.0027  0.0068  0.0107  0.0030  0.0097
0.0000  0.0013  0.0276  0.0293  0.0692  0.1445  0.0888  0.0383  0.0402  0.0155  0.0056  0.0040  0.0040
        0.0041  0.0056  0.0039  0.0100  0.0175
0.0000  0.0003  0.0450  0.0350  0.0363  0.0675  0.1356  0.1076  0.0353  0.0180  0.0086  0.0048  0.0065
        0.0022  0.0024  0.0012  0.0013  0.0271
0.0000  0.0003  0.0087  0.0613  0.0584  0.0662  0.0778  0.1106  0.0566  0.0336  0.0338  0.0066  0.0047
        0.0034  0.0020  0.0004  0.0030  0.0343
0.0000  0.0000  0.0118  0.0094  0.0838  0.0904  0.0708  0.0630  0.0948  0.0549  0.0326  0.0204  0.0111
        0.0053  0.0066  0.0015  0.0032  0.0330
0.0000  0.0000  0.0028  0.0270  0.0298  0.0730  0.0754  0.0414  0.0399  0.0545  0.0360  0.0292  0.0199
        0.0178  0.0075  0.0106  0.0078  0.0397
0.0000  0.0028  0.0113  0.0452  0.1034  0.0652  0.0540  0.0668  0.0409  0.0305  0.0644  0.0344  0.0232
        0.0094  0.0113  0.0064  0.0075  0.0166
0.0000  0.0033  0.0150  0.0303  0.1165  0.0932  0.0432  0.0392  0.0600  0.0297  0.0205  0.0184  0.0035
        0.0029  0.0045  0.0024  0.0000  0.0144
0.0006  0.0075  0.0741  0.1050  0.0816  0.0828  0.0489  0.0289  0.0398  0.0309  0.0097  0.0042  0.0376
        0.0000  0.0017  0.0098  0.0028  0.0111
0.0000  0.0079  0.0309  0.1041  0.0946  0.0304  0.0458  0.0308  0.0187  0.0145  0.0080  0.0127  0.0095
        0.0158  0.0046  0.0006  0.0049  0.0142
0.0000  0.0000  0.0114  0.0476  0.1389  0.1106  0.0509  0.0253  0.0320  0.0165  0.0247  0.0140  0.0155
        0.0028  0.0089  0.0028  0.0023  0.0088
0.0000  0.0000  0.0331  0.0717  0.0649  0.1230  0.0630  0.0467  0.0446  0.0086  0.0125  0.0054  0.0058
        0.0025  0.0000  0.0016  0.0013  0.0016
# male age comps
```

```
0.0000  0.0020  0.0353  0.1445  0.1150  0.0175  0.0168  0.0032  0.0036  0.0020  0.0227  0.0171  0.0101
        0.0082  0.0046  0.0006  0.0011  0.0092
0.0000  0.0031  0.0452  0.0919  0.1894  0.0475  0.0030  0.0041  0.0047  0.0000  0.0013  0.0113  0.0233
        0.0000  0.0068  0.0052  0.0002  0.0109
0.0000  0.0040  0.0146  0.2012  0.0838  0.0862  0.0584  0.0037  0.0182  0.0054  0.0021  0.0000  0.0014
        0.0173  0.0020  0.0010  0.0029  0.0157
0.0000  0.0000  0.0115  0.1117  0.2035  0.0721  0.0397  0.0164  0.0030  0.0025  0.0071  0.0000  0.0000
        0.0061  0.0055  0.0021  0.0000  0.0080
0.0020  0.0142  0.0172  0.0763  0.2068  0.0979  0.0227  0.0121  0.0079  0.0032  0.0005  0.0000  0.0024
        0.0002  0.0026  0.0038  0.0014  0.0067
0.0000  0.0092  0.0256  0.0532  0.0939  0.1753  0.0640  0.0266  0.0142  0.0083  0.0000  0.0051  0.0002
        0.0000  0.0013  0.0007  0.0063  0.0064
0.0000  0.0035  0.0467  0.0450  0.0559  0.0682  0.1160  0.0566  0.0227  0.0192  0.0094  0.0044  0.0013
        0.0026  0.0000  0.0000  0.0000  0.0137
0.0000  0.0002  0.0053  0.0558  0.0995  0.0779  0.0459  0.0765  0.0366  0.0091  0.0114  0.0028  0.0013
        0.0035  0.0002  0.0000  0.0009  0.0113
0.0000  0.0002  0.0105  0.0203  0.0732  0.0681  0.0541  0.0333  0.0461  0.0233  0.0279  0.0161  0.0043
        0.0043  0.0061  0.0003  0.0021  0.0171
0.0000  0.0000  0.0064  0.0332  0.0323  0.0791  0.0923  0.0483  0.0312  0.0558  0.0336  0.0268  0.0138
        0.0056  0.0012  0.0058  0.0008  0.0215
0.0000  0.0033  0.0170  0.0576  0.1024  0.0594  0.0454  0.0174  0.0175  0.0237  0.0259  0.0077  0.0050
        0.0047  0.0061  0.0030  0.0000  0.0107
0.0000  0.0028  0.0179  0.1051  0.0856  0.1170  0.0545  0.0460  0.0190  0.0219  0.0066  0.0133  0.0021
        0.0073  0.0000  0.0005  0.0000  0.0033
0.0000  0.0020  0.0782  0.0853  0.0617  0.0596  0.0223  0.0200  0.0180  0.0196  0.0132  0.0020  0.0177
        0.0045  0.0019  0.0089  0.0009  0.0070
0.0000  0.0061  0.0433  0.2315  0.1199  0.0470  0.0315  0.0201  0.0091  0.0172  0.0072  0.0062  0.0007
        0.0056  0.0025  0.0002  0.0000  0.0036
0.0000  0.0000  0.0089  0.0525  0.1818  0.1147  0.0352  0.0206  0.0176  0.0202  0.0061  0.0091  0.0002
        0.0018  0.0073  0.0000  0.0030  0.0078
0.0000  0.0071  0.0342  0.0733  0.1171  0.1621  0.0646  0.0284  0.0078  0.0003  0.0000  0.0082  0.0016
        0.0003  0.0002  0.0003  0.0066  0.0016

#-->&lt;>--EUR-CON Fishery-->&lt;>-->&lt;>-->&lt;>-->&lt;>-->&lt;>-->&lt;>-->&lt;>--><
# Landings
#number of landings records
27
#years of landings
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
#landings estimates
47.0    17.0    126.0   252.0   883.0   502.0   2326.0  5666.0  6367.6  11164.4 6434.1  3396.7  3554.1
        2773.2  2877.7  2212.5  2295.2  2418.2  1388.0  1344.1  1369.9  1263.5  1952.8  1533.5  1683.2
        1295.2  766.0
# Age Compositions [females(f), males(m)]
#number of years of age comps
19
#years of age comps
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998
#sample sizes
#693    1659    3247    2690    3031    3353    8221    7255    4858    7033    7791    6978    936
        597     3983    235     1131    1157    1327
#number of trips sampled
101     121     164     201     178     203     288     270     218     326     332     285     85
        40      152     11      46      62      37
# female age comps
0.0000  0.0000  0.0040  0.0073  0.0087  0.0043  0.0699  0.1706  0.0810  0.0738  0.0619  0.0362  0.0277
        0.0119  0.0137  0.0138  0.0076  0.0202
0.0000  0.0115  0.0034  0.0244  0.0353  0.0201  0.0134  0.0597  0.1238  0.0723  0.0485  0.0405  0.0370
        0.0341  0.0119  0.0095  0.0097  0.0177
0.0000  0.0003  0.0293  0.0094  0.0344  0.0298  0.0256  0.0062  0.0373  0.1136  0.0564  0.0362  0.0378
        0.0361  0.0224  0.0228  0.0183  0.0609
0.0000  0.0047  0.0503  0.1781  0.0373  0.0388  0.0181  0.0122  0.0053  0.0122  0.0364  0.0231  0.0179
        0.0195  0.0161  0.0192  0.0182  0.0997
0.0000  0.0000  0.0241  0.1105  0.1003  0.0259  0.0315  0.0197  0.0076  0.0072  0.0303  0.0548  0.0177
        0.0123  0.0104  0.0089  0.0095  0.0616
0.0000  0.0002  0.0021  0.0404  0.1023  0.1513  0.0194  0.0459  0.0130  0.0063  0.0058  0.0205  0.0424
        0.0045  0.0093  0.0114  0.0152  0.0603
0.0000  0.0015  0.0185  0.0185  0.0604  0.0842  0.1194  0.0089  0.0278  0.0159  0.0051  0.0024  0.0036
        0.0284  0.0035  0.0077  0.0027  0.0423
```

```
0.0010  0.0000  0.0155  0.0298  0.0303  0.0628  0.0500  0.0936  0.0109  0.0303  0.0205  0.0061  0.0010
        0.0115  0.0175  0.0079  0.0125  0.0490
0.0010  0.1042  0.0330  0.0641  0.0624  0.0542  0.0305  0.0438  0.0452  0.0096  0.0171  0.0131  0.0062
        0.0037  0.0133  0.0153  0.0098  0.0506
0.0000  0.0087  0.0851  0.0517  0.0428  0.1158  0.0604  0.0259  0.0298  0.0276  0.0119  0.0107  0.0124
        0.0095  0.0027  0.0022  0.0032  0.0170
0.0000  0.0008  0.0317  0.0975  0.0601  0.0471  0.0720  0.0481  0.0352  0.0256  0.0269  0.0264  0.0232
        0.0035  0.0073  0.0042  0.0040  0.0400
0.0002  0.0094  0.0119  0.1220  0.1544  0.0557  0.0344  0.0328  0.0240  0.0183  0.0151  0.0198  0.0089
        0.0053  0.0070  0.0007  0.0036  0.0186
0.0000  0.0003  0.0114  0.0349  0.1059  0.1013  0.0480  0.0364  0.0452  0.0175  0.0304  0.0281  0.0206
        0.0082  0.0015  0.0062  0.0023  0.0601
0.0000  0.0018  0.0234  0.1172  0.1126  0.1162  0.0474  0.0123  0.0042  0.0104  0.0115  0.0024  0.0029
        0.0040  0.0029  0.0078  0.0063  0.0130
0.0035  0.0025  0.0125  0.0640  0.1218  0.0811  0.0828  0.0159  0.0236  0.0114  0.0080  0.0087  0.0082
        0.0089  0.0072  0.0003  0.0022  0.0235
0.0000  0.0064  0.0018  0.0114  0.0396  0.1337  0.0605  0.0633  0.0242  0.0146  0.0100  0.0012  0.0064
        0.0172  0.0000  0.0173  0.0000  0.0007
0.0019  0.0029  0.0413  0.0436  0.0479  0.0683  0.0588  0.0408  0.0379  0.0305  0.0087  0.0112  0.0128
        0.0043  0.0015  0.0091  0.0057  0.0040
0.0001  0.0016  0.0056  0.0541  0.0379  0.0460  0.0542  0.0577  0.0640  0.0473  0.0322  0.0181  0.0034
        0.0267  0.0116  0.0137  0.0083  0.0161
0.0000  0.0012  0.0411  0.0299  0.0805  0.0286  0.0473  0.0561  0.0565  0.0677  0.0367  0.0116  0.0125
        0.0057  0.0146  0.0029  0.0058  0.0150
# male age comps
0.0000  0.0000  0.0036  0.0100  0.0077  0.0119  0.0458  0.0897  0.0487  0.0429  0.0210  0.0244  0.0172
        0.0118  0.0041  0.0053  0.0121  0.0312
0.0000  0.0136  0.0034  0.0355  0.0310  0.0210  0.0229  0.0625  0.0843  0.0610  0.0380  0.0152  0.0087
        0.0168  0.0039  0.0027  0.0008  0.0056
0.0000  0.0001  0.0384  0.0063  0.0359  0.0314  0.0280  0.0134  0.0385  0.0700  0.0330  0.0271  0.0191
        0.0151  0.0165  0.0093  0.0083  0.0329
0.0000  0.0003  0.0332  0.1432  0.0227  0.0245  0.0112  0.0162  0.0035  0.0096  0.0247  0.0169  0.0113
        0.0076  0.0059  0.0148  0.0130  0.0345
0.0000  0.0000  0.0210  0.1269  0.1125  0.0259  0.0314  0.0160  0.0134  0.0024  0.0088  0.0390  0.0166
        0.0047  0.0052  0.0034  0.0053  0.0352
0.0000  0.0010  0.0053  0.0413  0.1194  0.1320  0.0177  0.0219  0.0136  0.0035  0.0026  0.0092  0.0294
        0.0042  0.0047  0.0043  0.0026  0.0370
0.0000  0.0023  0.0233  0.0269  0.0686  0.1201  0.1368  0.0190  0.0311  0.0206  0.0013  0.0010  0.0088
        0.0333  0.0079  0.0073  0.0028  0.0383
0.0003  0.0000  0.0277  0.0382  0.0318  0.0571  0.0682  0.1421  0.0052  0.0364  0.0168  0.0050  0.0004
        0.0158  0.0252  0.0135  0.0069  0.0590
0.0004  0.0536  0.0038  0.0404  0.0456  0.0554  0.0599  0.0447  0.0385  0.0070  0.0070  0.0098  0.0045
        0.0035  0.0068  0.0123  0.0071  0.0223
0.0000  0.0127  0.1027  0.0579  0.0405  0.1038  0.0564  0.0376  0.0208  0.0102  0.0163  0.0050  0.0032
        0.0009  0.0008  0.0015  0.0051  0.0072
0.0001  0.0000  0.0295  0.0858  0.0421  0.0350  0.0592  0.0522  0.0298  0.0232  0.0239  0.0160  0.0064
        0.0077  0.0069  0.0026  0.0060  0.0200
0.0000  0.0073  0.0194  0.1203  0.1078  0.0426  0.0300  0.0339  0.0200  0.0171  0.0161  0.0134  0.0024
        0.0048  0.0032  0.0027  0.0020  0.0153
0.0000  0.0012  0.0133  0.0288  0.1195  0.0895  0.0309  0.0141  0.0372  0.0171  0.0163  0.0199  0.0101
        0.0034  0.0131  0.0042  0.0015  0.0218
0.0000  0.0000  0.0668  0.1401  0.0897  0.0902  0.0185  0.0075  0.0104  0.0074  0.0101  0.0024  0.0187
        0.0065  0.0031  0.0036  0.0005  0.0282
0.0035  0.0023  0.0067  0.0473  0.1606  0.1232  0.0661  0.0266  0.0279  0.0069  0.0100  0.0051  0.0074
        0.0101  0.0009  0.0044  0.0003  0.0043
0.0000  0.0292  0.0299  0.0163  0.0733  0.1470  0.0896  0.0887  0.0287  0.0111  0.0120  0.0119  0.0160
        0.0007  0.0157  0.0139  0.0000  0.0076
0.0012  0.0025  0.0439  0.0400  0.0730  0.1230  0.1289  0.0354  0.0269  0.0250  0.0148  0.0023  0.0190
        0.0102  0.0015  0.0018  0.0059  0.0135
0.0000  0.0017  0.0093  0.0833  0.0330  0.0644  0.0647  0.0578  0.0463  0.0350  0.0268  0.0147  0.0118
        0.0213  0.0018  0.0062  0.0112  0.0122
0.0000  0.0056  0.0634  0.0454  0.0764  0.0650  0.0502  0.0324  0.0509  0.0288  0.0230  0.0126  0.0053
        0.0108  0.0061  0.0011  0.0000  0.0095

#--><>--Ageing Error Matrix--><>--><>--><>--><>--><>--><>--><>--><
#row is true age, column is observed age (column sums to 1)
0.762   0.1217  0.0006  0       0       0       0       0       0       0       0       0       0
        0       0       0       0       0
0.2315  0.756   0.1244  0.0006  0       0       0       0       0       0       0       0       0
        0       0       0       0       0
```

```
0.0065  0.1217  0.75    0.1274  0.0007  0       0       0       0       0       0       0       0
        0       0       0       0       0
0       0.0005  0.1244  0.744   0.1303  0.0008  0       0       0       0       0       0       0
        0       0       0       0       0
0       0       0.0006  0.1274  0.738   0.1332  0.0009  0       0       0       0       0       0
        0       0       0       0       0
0       0       0       0.0006  0.1303  0.732   0.1361  0.001   0       0       0       0       0
        0       0       0       0       0
0       0       0       0       0.0007  0.1332  0.726   0.139   0.0011  0       0       0       0
        0       0       0       0       0
0       0       0       0       0       0.0008  0.1361  0.72    0.1419  0.0012  0       0       0
        0       0       0       0       0
0       0       0       0       0       0       0.0009  0.139   0.714   0.1448  0.0014  0       0
        0       0       0       0       0
0       0       0       0       0       0       0       0.001   0.1419  0.708   0.1476  0.0015  0
        0       0       0       0       0
0       0       0       0       0       0       0       0       0.0011  0.1448  0.702   0.1505  0.0017
        0       0       0       0       0
0       0       0       0       0       0       0       0       0       0.0012  0.1476  0.696   0.1533
        0.0019  0       0       0       0
0       0       0       0       0       0       0       0       0       0       0.0014  0.1505  0.69
        0.1561  0.002   0       0       0
0       0       0       0       0       0       0       0       0       0       0       0.0015  0.1533
        0.684   0.159   0.0023  0       0
0       0       0       0       0       0       0       0       0       0       0       0       0.0017
        0.1561  0.678   0.1617  0.0026  0.0007
0       0       0       0       0       0       0       0       0       0       0       0       0
        0.0019  0.159   0.672   0.1657  0.0313
0       0       0       0       0       0       0       0       0       0       0       0       0
        0       0.002   0.1617  0.666   0.308
0       0       0       0       0       0       0       0       0       0       0       0       0
        0       0       0.0023  0.1657  0.66
```