Status and Future Prospects for the Pacific Ocean Perch Resource in Waters off Washington and Oregon as Assessed in 2003

by

Owen S. Hamel[1]
Ian J. Stewart[1,2]
and
Andre E. Punt[2]

July 15, 2003

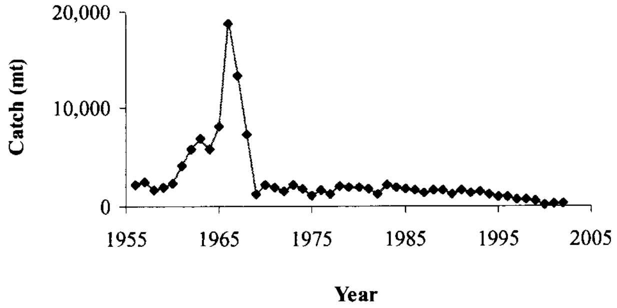
[1]Northwest Fisheries Science Center
U. S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
2725 Montlake Blvd East
Seattle, Washington 98112-2097

[2]School of Aquatic and Fishery Sciences
Box 355020
University of Washington
Seattle, Washington 98195-5020

Status and Future Prospects for the Pacific Ocean Perch Resource in Waters off Washington and Oregon as Assessed in 2003

This assessment applies to the Pacific ocean perch (*Sebastes alutus*) (POP) species of rockfish for the combined US Vancouver and Columbia INPFC areas. Catches are characterized by large removals of between 5,000 and 20,000 mt during the mid-1960's, primarily by foreign vessels. The fishery proceeded with more moderate removals of between 1,100 and 2,200 metric tons per year from 1969 through 1994, with the foreign fishery ending in 1977. Management measures further reduced landings to below 900 metric tons by 1995, with subsequent landings falling steadily until reaching between 100 and 300 metric tons per year from 2000 through 2002.

Catch history from 1956-2002



Catch estimates for past 10 years including discard

Year	*Catch*
1993	*1500*
1994	*1176*
1995	*965*
1996	*938*
1997	*751*
1998	*739*
1999	*593*
2000	*171*
2001	*307*
2002	*239*

The 2000 assessment used a forward projection age-structured model (Ianelli et al. 2000). The model used in the current assessment is based upon that model. However, there are a number of changes to the structure of the model. The multinomial likelihood assumed for the age- and size-composition data in the 2000 assessment was replaced by a robust normal likelihood. An ageing-error matrix was included to transform predicted age-compositions to age-compositions as they are observed by age-readers. The age 14 "plus" group for the "biased" fishery age-compositions (aged with the old surface ageing methods – 1966-80) was included in the likelihood function. The ability of the fishery selectivity curve to vary was limited by reducing the age at which selectivity is assumed to be flat to 14 (from 22), the maximum age for the "biased" age-composition data. The age at which survey selectivity is flat was increased from 10 to 12 to be more consistent with the way fishery selectivity is modeled. There were two survey selectivity functions in this assessment, one for the triennial shelf survey and another for the three slope (POP, AFSC and NWFSC) surveys. There are separate catchability coefficients for each survey.

A uniform prior was placed on the steepness of the stock-recruitment relationship and a uniform prior (in log space) was placed on the catchability coefficients for all four surveys. These priors reflect a lack of relevant auxiliary information. An informative prior, based on life history traits, was placed on natural mortality. The current model assumed no serial correlation in the recruitment anomalies unlike the 2000 assessment which attempted to estimate the extent of such serial correlation.

New data and changes to the data used in the previous assessment include updated (and reduced) estimates of historical foreign catch of Pacific ocean perch; biomass indices and age- or size-composition data (for some years) from the Alaska Fisheries Science Center (1992, 1996, 1997, 1999-2001), and Northwest Fisheries Science Center (1999-2002) slope surveys, and the most recent year of data from the triennial shelf survey (2001). Four years (1999-2002) of "unbiased" (break-and-burn) fishery age data were newly available and included when fitting the model. The inclusion of non-independent fishery age- and size-composition data for 13 years (1968-80) was removed, by omitting the size-composition data from the model fit. Two additional years of fishery catch data (2001-2), along with updated PacFin catch records for the years 1981-2000, were available and were included in the assessment.

The reduction of the historical catch estimates had the greatest effect of the changes and additions to the data, resulting in lower estimates of both equilibrium unfished biomass and maximum sustainable yield.

A number of sources of uncertainty are explicitly included in this assessment. For example, allowance is made for uncertainty in natural mortality, the parameters of the stock-recruitment relationship, and the survey catchability coefficients. However, sensitivity analyses based on alternative model structures / data set choices suggested that the overall uncertainty may be greater than that predicted by a single model specification. There are also other sources of uncertainty that are not included in the current model. These include the degree of connection between the stocks of Pacific ocean perch off British Columbia and those in PFMC waters; the effect of the PDO, ENSO and other climatic variables on recruitment, growth and survival of Pacific ocean perch; and gender differences in growth and survival.

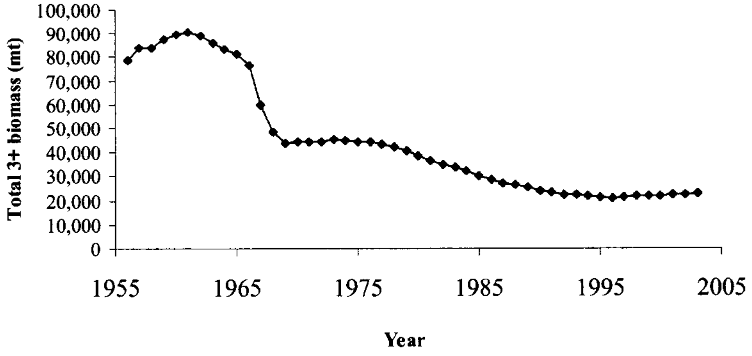
A reference case was selected which adequately captures the range for those sources of uncertainty considered in the model. Bayesian posterior distributions based on the reference case were estimated for key management and rebuilding variables. These distributions best reflect the uncertainty in this analysis, and are suitable for probabilistic decision making.

The point estimate (maximum of the posterior density function, MPD) for the depletion of the spawning biomass at the start of 2003 was 25.3%. The ABC for 2004 based on the MPD point estimate is 840 mt. The OY for 2004 from the rebuilding analysis based upon the MPD estimates and resampling from the historical recruitments between 1965 and 2001, and with a $P_{\max}$ of 0.7, is 375 mt.

The median value of the posterior distribution for the 2003 depletion was 28%. The median of the posterior distribution for ABC for 2004 is 931 mt. The OY for 2004 from the rebuilding analysis based upon the posterior distribution and resampling from the historical recruitments between 1965 and 2001, and with a $P_{\max}$ of 0.7, is 444 mt.

The point estimates of current biomass are relatively constant over the last several years, although there is some indication of an increasing trend in biomass in recent years.

3+ Biomass Levels from 1956 to 2003

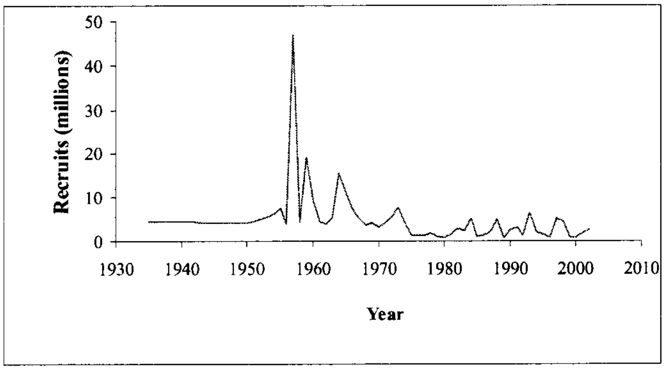


Biomass estimates for the past 10 years

Year	*Total 3+ biomass(mt)*
1994	*21,775*
1995	*21,359*
1996	*20,994*
1997	*21,193*
1998	*21,661*
1999	*21,631*
2000	*21,651*
2001	*22,171*
2002	*22,594*
2003	*23,073*

The first year for which there are age-composition data to support the estimate of recruitment is 1956, which also happens to be the first year for which catch data are available. The estimates of recruitment for the years prior to 1956 are close to the equilibrium estimate from the stock-recruitment relationship. The first few years with recruitment estimates that are informed by data are, however, still highly uncertain. The extremely large recruitment for 1957 may therefore partly reflect slightly higher average recruitment over the years 1935-56. Only by the early to mid-1960's are the estimates of recruitment reliable. Recent (1999-2000 in the table below) estimates of recruitment are highly variable by year, and lower on average than those for 1960-75, though similar to those for the 1980's. The estimates of recruitment for 2001 and 2002 are based on very limited information.

Recruitment estimates (1935-2002)

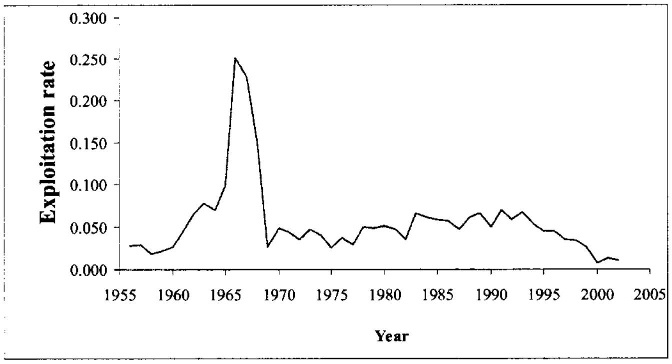


Recruitment estimates for the past 10 years (millions of recruits)

Year	*Recruitment*
1993	6.3035
1994	2.1485
1995	1.6477
1996	0.6562
1997	5.0646
1998	4.2753
1999	0.6699
2000	0.7996
2001	1.8888
2002	2.4637

The exploitation rate (percent of biomass taken) on fully-selected animals peaked near 25% in the mid-1960's when foreign fishing was intensive. The exploitation rate dropped by the late 1960's, but increased slowly and steadily from 1975 to the early 1990's, due to decreasing exploitable biomass. Over the past 10 years the exploitation rate has fallen from over 6% to near 1%.

Exploitation rate estimates (1956-2002)



Exploitation estimates for the past 10 years

Year	*Exploitation rate*
1993	0.0670
1994	0.0541
1995	0.0454
1996	0.0451
1997	0.0353
1998	0.0342
1999	0.0275
2000	0.0079
2001	0.0138
2002	0.0106

Near term projections show a slow and non-monotonic increase in exploitable biomass. These were calculated using the rebuilding model, resampling recruitments to get an estimate of OY with 70% chance of rebuilding by Tmax. A similar projection is made using the Bayesian posterior median OY catch values from the rebuilding analysis in the table below.

Six- year point-estimate projections of catch, spawning biomass, and ABC based on recruitment-resampling MPD and Bayesian posterior median OY projections.

Year	*MPD OY*	*ABC point estimate*	*Spawning biomass point estimate*	*Bayesian posterior median OY*	*ABC point estimate*	*Spawning biomass point estimate*
2003	377 mt	939 mt	9,946 mt	377 mt	939 mt	9,946 mt
2004	376 mt	840 mt	10,206 mt	444 mt	840 mt	10,206 mt
2005	376 mt	841 mt	10,169 mt	447 mt	838 mt	10,134 mt
2006	373 mt	836 mt	10,126 mt	447 mt	830 mt	10,056 mt
2007	373 mt	834 mt	10,192 mt	449 mt	826 mt	10,093 mt
2008	373 mt	835 mt	10,328 mt	450 mt	824 mt	10,200 mt
2009	382 mt	855 mt	10,493 mt	460 mt	841 mt	10,333 mt

It is likely that the current management plan (i.e., bycatch only) is not conducive to accurate estimation of the removals from the fishery. This assessment relies heavily on the accuracy of these estimates.

The recruitment pattern for POP is similar to many rockfish species. Recent decades have provided rather poor year-classes compared to the 1950s and 1960s. The exploitation status of POP continues to be set to bycatch only. Since POP are at the southern limit of their geographical range, while the overall species condition has improved in other areas more central to their range (e.g., in the Canadian EEZ and in the Gulf of Alaska). Management actions of setting harvest guidelines to bycatch only (ABC=0) implemented over the past several years have not yet resulted in substantial stock increases based on available data.

Contents

List of Tables

List of Figures

1.1 Introduction

In 1981 the Pacific Fishery Management Council (PFMC) adopted a 20-year plan to rebuild the depleted Pacific ocean perch (*Sebastes alutus*) resource in waters off the Washington and Oregon coast. This plan was based on the results of two studies. The first study employed a cohort analysis of 1966-76 catch and age-composition data as a basis for examining various schedules of rebuilding (Gunderson 1978). This report was later updated with four additional years of catch and age information (Gunderson 1981). The second study provided an evaluation of alternative trip limits as a management tool for the Pacific ocean perch fishery (Tagart et al. 1980). Controls on catch of Pacific ocean perch, and assessments of this species off Washington and Oregon have continued to the present day.

In this assessment, we have combined the data from the International North Pacific Fisheries Commission (INPFC) Columbia and US-Vancouver areas, and modeled the Pacific ocean perch stocks in these areas as a single stock. Examination of size-composition data for these areas indicates, however, that years of good recruitment coincide. Genetic studies of stock structure suggest mixing of the breeding animals between the two INPFC areas (Wishard et al. 1980, Seeb and Gunderson 1988). Examination of the along-shore catch-rate distribution of Pacific ocean perch during the surveys does not reveal substantial gaps which might indicate the need for separate management stocks. Common recruitment patterns, genetic similarities, and similar catch-rate distributions therefore suggest that the Pacific ocean perch along the west coast of the US are likely to be from a single stock. If separate stocks do exist, a biological basis for splitting them has not been established. Nevertheless, we recommend that management actions on a coast-wide stock should account for problems of effort concentration and distribute the catch relatively evenly because local "pockets" of relatively isolated Pacific ocean perch probably do exist (D. Gunderson, pers. comm.).

Prior to 1965, the Pacific ocean perch resource in the US Vancouver and Columbia areas of the INPFC were harvested almost entirely by Canadian and United States vessels. Most of the vessels were of multi-purpose design and used in other fisheries, such as salmon and herring, when not engaged in the groundfish fishery (Forrester et al. 1978). Generally under 200 gross tons and less than 33 meters (m) in length, these vessels had very little at-sea processing capabilities. These characteristics, for the most part, restricted the distance these vessels could fish from home ports, and limited the size of their landings. Landings from 1956-65 averaged slightly over 2,000 metric tons (mt) in each of the two INPFC areas included in this assessment, with an overall increasing trend of catch over this period.

Catches increased dramatically after 1965 with the introduction of large distant-water fishing fleets from the Soviet Union and Japan. Both nations employed large factory stern trawlers as their primary method for harvesting Pacific ocean perch. These vessels generally operated independently by processing and freezing their own catches. Support vessels, such as refrigerated transports, oil tankers, and supply ships permitted the large stern trawlers to operate at sea for extended periods of time. Peak removals by all nations combined are estimated at over 15,000 mt in 1966 and over 12,000 mt in 1967. These numbers are smaller than those used in the 2000 assessment because of a recent re-analysis of the foreign catch data (Rogers, 2003).

Catches declined rapidly following these peak years, and Pacific ocean perch stocks were considered to be severely depleted throughout the Oregon-Vancouver Island region by 1969 (Gunderson 1977, Gunderson et al. 1977). Landed catches over the period 1978-94 averaged 474 mt and 833 mt in the US-Vancouver and Columbia areas respectively. Landings for the combined region have continued to decline.

Pacific ocean perch stocks in the northeast Pacific were managed by the Canadian

Government in its waters, and by the individual states in waters off of the United States, prior to 1977. With implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1977, primary responsibility for management of the groundfish stocks off Washington, Oregon and California shifted from the states to the Pacific Fishery Management Council (PFMC). At that time, however, a Fishery Management Plan (FMP) for the west coast groundfish stocks had not yet been approved. In the interim, the state agencies worked with the PFMC to address conservation issues. In 1981, the PFMC adopted a management strategy to rebuild the depleted Pacific ocean perch stocks to levels that would produce Maximum Sustainable Yield (MSY) within 20 years. On the basis of cohort analysis (Gunderson 1978), the PFMC set Acceptable Biological Catch (ABC) levels to 600mt for the US portion of the INPFC Vancouver area and 950 mt for the Columbia area. To implement this strategy, the states of Oregon and Washington established landing limits for Pacific ocean perch caught in their waters. Trip limits have remained in effect to this day (Table 1). Recent catches have reflected bycatch only.

Research surveys have been used to provide fishery-independent information about the abundance, distribution, and biological characteristics of Pacific ocean perch. A coast–wide survey of the rockfish resource was conducted in 1977 (Gunderson and Sample 1980) with the objective of defining the distribution and measuring the abundance of the major species taken in bottom trawls. The 1977 coast wide shelf survey has since been repeated every three years, yielding fishery-independent indices of the resource size every three years from 1977-2001. The inter-annual variability of these nine survey indices is substantial and, given the large amount of sampling error each year, identifying trends from the indices alone is inappropriate unless a formal time-series approach is used (e.g., Pennington 1985).

The relative imprecision of the biomass index derived for Pacific ocean perch from the 1977 rockfish survey prompted requests from the fishing industry and resource managers for closer attention to the status of the resource. In response, the National Marine Fisheries Service (NMFS) coordinated a cooperative research survey of the Pacific ocean perch stocks off Washington and Oregon with the Washington Department of Fisheries (WDF) and the Oregon Department of Fish and Wildlife (ODFW) in March-May 1979. (Wilkins and Golden 1983). This survey provided a more precise biomass index, indicating stock sizes similar to those calculated from the 1977 triennial survey. Another Pacific ocean perch survey was conducted in 1985 to determine what impact six years of restrictive catch regulations had on the status of these stocks.

The values of the survey indices and the associated errors are modeled with several other data types as presented below. This improves the ability to assess population trends by taking into account the biology of the species and the fisheries involved in their harvest.

1.2. Data

1.2.1. Removals and regulations

Catch history

Landings data from the Pacific ocean perch fishery off the west coast of the continental United States are available from 1956 to the present (Figure 1; Table 2). This fishery took large catches during the mid-1960's. Canadian and United States vessels in the Vancouver and Columbia areas harvested this resource prior to 1965 when foreign vessels (mainly trawlers from the ex-Soviet Union and Japan) began intensive harvesting operations for Pacific ocean perch in the Vancouver area and, one year later, in the Columbia area. During the periods 1966-68 and 1972-74, the foreign fleets accounted for the bulk of the Pacific ocean perch removals. The foreign fishery for Pacific ocean perch ended in 1977 following the passage of the MSCFA. Foreign catch estimates for the years 1966-76 are taken from Rogers (2003). Figure 2 compares the catch series on which the analyses of this paper are based with that using during the 2000 assessment. Removals since

1979 have been restricted by the PFMC to promote the rebuilding of the resource. Estimated harvests by area show that a large proportion of the catches during the 1980s were from the Columbia area, but that catches are now split more evenly between the US-Vancouver and Columbia areas. Historical estimated total catches by domestic and foreign vessels are given in Table 2. These are adjusted for a 5% discard rate from 1956-80 (domestic catches), reflecting the relatively unregulated nature of the fishery over this time period, and a 16% discard rate thereafter, based on the work of Pikitch et al. (1988). A more recent report by Sampson (2002) reports a discard rate of about 10%, while the raw, unweighted, 2002 West coast fishery observer data gives a discard rate of 13%.

Fishery Size and age composition

Gunderson (1981) compiled fishery age-composition data for the Vancouver and Columbia INPFC areas. While the patterns of recruitment appear similar, the magnitudes of year-class strength varied between areas. The age-composition data for the two areas are combined (Table 3) to simplify the analysis, and because the fisheries operating in the two areas share many similarities.

The fishery age-composition data for 1966-80 were determined using the otolith surface ageing technique which involved counting the number of annual bands apparent on the surface of the otolith. This ageing technique is biased for Pacific ocean perch; the ages of animals older than 15 tend to be under-estimated. Therefore, when fitting the historic age-composition data, the information for animals aged 14 years and older are pooled into a "plus-group" at age 14 to reduce the impact of this bias. Fishery age-composition data based on the break-and-burn technique are available for 1999-2002 from the PACFIN database (Table 4). The break-and-burn technique is considered to provide unbiased estimates of age (Chilton and Beamish 1982). Therefore, for these more recent fishery age compositions data, ages 3-24 are fitted as individual age classes, with age 25 being the plus-group.

It is necessary to account for ageing error when fitting the model to the age-composition data. This involves converting from the model estimate of the age of a fish to its age given ageing error using an ageing-error matrix (which specifies the probability that a fish of given age will be aged to be any other age). The ageing-error matrix is based the assumption that ageing error is normally distributed with a mean of 0 (i.e. no bias) and a CV of 0.064. This CV is based on the results of a double-read analysis of 1,161 Pacific ocean perch otoliths at the Newport Laboratory of the Northwest Fisheries Science Center, NMFS (unpublished data). The distribution for the observed age of an animal in the plus-group is determined by first assuming that the age distribution of animals in the plus-group follows an exponential decline model with age (10% total annual mortality) and then applying the ageing-error matrix to this age distribution. Finally the observed age of an animal in the plus-group is calculated by summing this age distribution for each possible observed age and reforming the plus-group at age 25.

Fishery size-composition data were obtained from ODFW (1983-89, 1994-99) and from WDF (1968-88, 1994-99) The model is fitted to the size-composition data (17-40cm, where 40cm is a plus-group) from the commercial fishery for the years for which fishery size-composition data are available but fishery age-composition data are not (see Table 5). While the size-composition data from these years are not used when fitting the model, the fit to these data is nevertheless examined as part of the model diagnostics. An age to length conversion matrix is used to convert model-predicted age-compositions to model-predicted size-compositions when fitting to the size-composition data.

CPUE data

Catch-per-unit-of-effort (CPUE) data from the domestic fishery were combined for the INPFC Vancouver and Columbia areas (Figure 3; from Gunderson (1977)). Although these data reflect catch rates for the US fleet, the highest catch rates coincided with the beginning of removals by the foreign fleet. This suggests that, barring unaccounted changes in fishing efficiency during this period, the level of abundance was high at that time.

Recent logbook information is available for the several regions along the Pacific coast. A description of these data and a preliminary analysis of them was provided in Ianelli and Zimmerman (1998). However, it is unclear what, if any, relationship recent CPUE has with population abundance due to the largely bycatch nature of the present fisheries. For this reason the more recent CPUE data were not considered in the present assessment.

1.2.2. Surveys

NMFS Cruises

The results from four fishery-independent surveys are used in this assessment (Figure 4; Tables 6-9).

1. The triennial shelf survey that was conducted every third year from 1977-2001.
2. The POP surveys for 1979 and 1985.
3. The AFSC slope survey for "super-year" 1992 (including 1992-93 data), and for the years 1996, 1997 and 1999-2001.
4. The NWFSC slope survey for the years 1999-2002.

Size- rather than age-composition data are used when fitting the model for the years prior to 1989 (ages were determined using the biased surface ageing technique prior to 1989) and for those years for which there are no age-composition data. Survey age-composition data are not available for the 1995 triennial survey, the AFSC slope survey or the NWFSC slope survey, except for 2002.

The model-predicted age- and size-compositions are computed as described above for the commercial fishery. Size- and age-composition data from all the surveys are considered when evaluating the model fits.

A list of data used in this assessment is given in Table 10.

1.2.3. Biology and life history

Natural mortality, longevity, and age at recruitment

Assessments of Pacific ocean perch have changed substantially over the past two decades because of the impact of improved methods of age determination. Previously, Pacific ocean perch age determinations were done using scales and surface readings from otoliths. These gave estimates of natural mortality of about $0.15 yr^{-1}$ and longevity of about 30 years (Gunderson 1977). Based on the now-accepted break-and-burn method of age determination using otoliths, Chilton and Beamish (1982) determined the maximum age of *S. alutus* to be 90 years. Using similar information, Archibald et al. (1981) concluded that natural mortality for Pacific ocean perch should be on the order of $0.05 yr^{-1}$. Hoenig's (1983) relationship estimates that if Pacific ocean perch longevity is between 70 and 90 years (Beamish 1979, Chilton and Beamish 1982), M would be between 0.046 and $0.059 yr^{-1}$. In this assessment we follow the 2000 assessment by placing a fairly tight base-case prior distribution on natural mortality (lognormal with median $0.05 yr^{-1}$ and σ 0.1). Essentially, this acknowledges that there is some uncertainty regarding the value for M, while nevertheless constraining the estimate of M not to differ very substantially from past estimates. An alternative, more diffuse (median 0.055 and σ 0.25), prior is used in one of the tests of sensitivity (Figure 5). The age at recruitment is set at 3yr and ages 25 and older are grouped into a plus-group.

Sex ratio, maturation and fecundity

Survey data indicate that sex ratios are different among INPFC areas (e.g. Ito et al. 1987). The differences are, however, minor (within 5% of 1:1) so, for the purposes, of this assessment, a sex ratio of 1:1 is assumed. For the 1995 assessment, maturity-at-size was based on a total of 400 female Pacific ocean perch examined visually during the 1986-92 triennial surveys. However, the reliability of maturation studies using visual inspection has been questioned and histological examinations have found that visual examinations can be biased. We selected age 8 as an estimate of the age-at-50% female sexual maturity based upon the recommendation of the 2000 POP STAR panel. The maturity ogive is given in Figure 6. As part of the sensitivity analysis, a model run was conducted with a higher age-at-50%-maturity (10 years).

Length-weight relationship

The length-weight relationship for Pacific ocean perch was estimated using survey data collected from the west coast surveys (1977-89) Estimates from the 593 samples lead to the following relationship:

$$W(L) = 9.82 \cdot 10^{-3} L^{3.1265}$$

where L is length in cm and W is weight in grams. The mean weights-at-age were computed from the means lengths-at-age and this relationship (Figure 7).

Length at age

The length-age matrix used for this assessment is the same as that used for the 2000 assessment, which was based on 2,855 samples collected during the 1989-98 triennial surveys and aged using the break-and-burn method (Figure 8).

1.2.4 Changes in data from the 2000 assessment

The estimates of the historical foreign catch of Pacific ocean perch (1965-77) decreased from a total of 97,107 mt (used in the 2000 assessment) to 40,664 mt based upon the work of Rogers (2003) (Figure 2). The 2001 and 2002 catch data are included in this assessment, while the domestic catch data from 1981-2002 were updated to include not only the POP PACFIN catch category, as in previous assessments, but also the Nominal and Unspecified POP categories, which generally represented less than 10% (and often closer to 1%) of the total POP landings estimate. Finally, the present assessment assumed discard rates to be 5% before 1981 and 16% thereafter (Table 2). The 2000 assessment ignored discards.

In addition to making use of the biomass and age-composition data for the latest (2001) triennial survey, this assessment also includes data from surveys not considered in previous assessments: (1) the AFSC slope survey (survey biomass estimates for 'super year' 1992 and the years 1996, 1997, 1999, 2000, 2001, and size-composition data for 1996, 1997, 1999 and 2000) and (2) the NWFSC slope survey (survey biomass estimates for 1999-2002 and age-composition data for 2002).

Survey size-composition data were used only when survey age-composition data were not available during the 2000 assessment. However, the fishery age- and size-composition data (1968-80) were both included in the likelihood function in the 2000 assessment In this assessment, this use of both size- and age-composition data for any single year has been eliminated, and fishery size-composition data are ignored if the corresponding age-composition data are available. In addition, "unbiased" fishery age-composition data for 1999-2002 based on ageing 300-900 otoliths for each year using the break-and-burn method have been included in the likelihood function.

1.3. Assessment model

1.3.1. Past assessment methods

The condition of Pacific ocean perch stocks off British Columbia, Washington and Oregon have been assessed periodically since the intense pulse of exploitation in 1966-68. The mean exploitable biomass in the Vancouver area during 1966-68 was estimated at about 34,000 mt (Westrheim et al. 1972). Following the years of heavy fishing, catch-per-unit-of-effort (CPUE) for the Washington-based fleet in the Vancouver area dropped to 55% of the 1966-68 levels, indicating a decrease in biomass to 18,700 mt during 1969-71 (Technical Subcommittee 1972). Catch rates declined further during 1972-74 which indicated a further reduction in biomass by about 11% (Gunderson et al. 1977). The mean weighted CPUE rose slightly over the period 1975-77 (Fraidenburg et al. 1978a). However, this may have been completely or partially due to improvements in gear efficiency with the use of "high rise" trawl nets.

Columbia area biomass estimates since 1966 have been calculated by dividing landings by estimated exploitation rates. The mean biomass estimates declined from 23,000 mt during 1966-68 to 7,300 mt during 1969-72 and 4,300 mt during 1973-74 (Gunderson et al. 1977). An area-swept extrapolation from commercial CPUE data in the Columbia area resulted in a biomass estimate of 8,000 - 9,600 mt in 1977 (Fraidenburg et al. 1978b). Since the commercial fishery operates mainly in areas of high abundance, these estimates area likely to be positively biased.

A coast–wide survey of the rockfish resource was conducted in 1977 (Gunderson and Sample 1980) with the objective of defining the distribution and measuring the abundance of the major species taken in bottom trawls. The 1977 coast-wide shelf survey has since been repeated every three years, yielding fishery-independent indices of biomass every three years from 1977-2001. The relative imprecision of biomass indices derived for Pacific ocean perch from the 1977 rockfish survey prompted requests from the fishing industry and resource managers for closer attention to the status of the resource. In response, the National Marine Fisheries Service (NMFS) coordinated a cooperative research survey of the Pacific ocean perch stocks off Washington and Oregon with the Washington Department of Fisheries and the Oregon Department of Fish and Wildlife in March-May 1979. (Wilkins and Golden 1983). This survey provided more a precise biomass index, indicating stock sizes similar to those calculated from the 1977 triennial survey. Another Pacific ocean perch survey was conducted in 1985 to determine what impact six years of restrictive catch regulations had on the status of these stocks.

The survey design used for the 1985 POP survey was similar to that used in 1979 (Wilkins and Golden 1983), but was standardized to correct for inconsistencies that arose during the 1979 fieldwork. The two most serious inconsistencies involved the use of three different trawls by four different vessels and variable depth coverage (165 - 475 m off Washington and 165-420 m off Oregon). The 1985 survey was designed to correct these inconsistencies and to compensate for the differences between the two surveys. Sampling was done with the same style trawl net (Noreastern) in all areas. In the southern part of the Columbia area, which had been sampled exclusively with the Mystic trawl in 1979, half of the stations were sampled with the Noreastern and half with the Mystic. The relative fishing power of the two nets was used to adjust Noreastern trawl catch rates in that area to the fishing efficiency of the Mystic trawl. In this way the abundance in the southernmost subarea was calculated based on Mystic catch rates for comparison with 1979 results. No attempt was made to adjust fishing power in the Columbia Middle area although a modified 400 eastern trawl was used there in 1979. In calculating the 1985 Columbia South area abundance and size-composition data for comparison with the 1979 results, hauls deeper than 420 m in the Columbia Middle and South subareas were excluded from the data to conform with the 1979 depth coverage. Standardization of the survey design had no effect on the survey pattern in the Vancouver or the Columbia North areas.

Due to the directed effort of the 1979 and 1985 surveys to focus on Pacific ocean perch, these were at one time considered as estimates of absolute abundance whereas the triennial surveys have been always taken to be relative abundance indices.

In the 1992 and 1995 assessment documents, the population dynamics of Pacific ocean perch in the US-Vancouver and Columbia areas combined were examined using a statistical age-structured model (1990). The 2000 model was a forward projection age-structured model based upon the work of Fournier and Archibald (1982), Methot (2000) and Tagart et al. (1997).

1.3.2. Changes between the 2000 assessment model and the current model

A number of important changes have been made since the last assessment. Some of these are due to the inclusion of new data sources, while others have to do with other factors, including grouping data, modeling selectivities, the inclusion of ageing error, choice of prior distributions for the model parameters, and choice of the likelihood functions.

1. Fishery selectivity was estimated with separate parameters for ages 3-22 (subject to penalties) and allowed to change every 5th year in the 2000 assessment. The range of ages has been reduced to 3-14 to better reflect the number of age-classes for which historical (1966-80) fishery age-composition data are available, while the entire selectivity curve is allowed to change every 6th year to better accommodate the 47 years for which fishery catch data are available. The impacts of allowing the fishery selectivity to change every 5th year and time-invariant fishery selectivity are both examined in the tests of sensitivity.

2. The same time-invariant selectivity curve was assumed for the triennial and POP surveys during the 2000 assessment. Data from the AFSC and NWFSC slope surveys are included for the first time in the present assessment. Two time-invariant selectivity curves are estimated: one for the triennial survey and another for the POP and the two slope surveys combined.

3. For the base-case analysis, and in common with the 2000 assessment, survey selectivities are estimated with separate parameters for each age. The maximum age for which a survey selectivity parameter is estimated has been increased from age 10 to age 12. The survey selectivity for age 10 is set to 1.0 rather than having survey selectivity average 1.0 over all ages to better allow selectivity to be compared among surveys and so that survey catchability is defined consistently across surveys. The sensitivity of the results to time-varying survey selectivity is considered in one of the sensitivity analyses.

4. The present assessment includes ageing error in contrast to the 2000 assessment. The age-reading error model is based on the results of a double-read analysis of 1,161 Pacific ocean perch otoliths conducted at the Newport field station of the NWFSC (Figure 9).

5. The likelihood function for the historical (1966-80) age-composition data now includes all ages 3-14$^+$; the 2000 assessment ignored the age 14 plus-group.

6. The likelihood function for the age- and size-composition data has been taken to be the robust formulation of Fournier et al. (1990, 1998); the 2000 assessment assumed that the age- and size-composition data were multinomially distributed.

7. The base-case lognormal prior distribution for survey catchability (*q*) for the triennial survey in the 2000 assessment had a mean of 1.13 and a mode of 0.78 (i.e. a median of 1.0 and σ 0.5) while the less informative prior considered in the tests of sensitivity had a mean of 1.38 and a mode of 0.53 (i.e. a median of 1.0 and σ 0.8). This prior was expert opinion based on a meta-analysis of trawl survey catchability estimates for a variety of species (Harley et al. 2000). The catchability coefficient for the POP survey was assigned a non-informative prior (i.e. $U[-\infty,\infty]$ on log(q)). There are four surveys in the present assessment, and priors need to be assigned to the catchability coefficients for each. It was decided that there was not enough information to support an informative prior, and so uniform priors (i.e. $U[-\infty,\infty]$ on log(q)) were placed on the catchability coefficient for all four surveys for the base-case analysis. Sensitivity is explored to a more informative prior distribution (median 0.98, σ 0.45, mean 1.08, mode 0.8) which was stated in the 2000 assessment document as a more informative prior(Figure 10). Note that for this sensitivity analysis, we use the prior distribution reported in the 2000 assessment document which did not coincide with the prior distribution actually used in the analysis in 2000.

8. The survey biomass indices are assumed to be log-normally distributed in the current assessment; these indices were assumed to be normally distributed in the 2000 assessment.

9. The prior distribution placed on the steepness of the stock-recruitment relationship during the 2000 assessment was based upon Dorn's (2000) hierarchical meta-analysis of rockfish steepness. However, this prior distribution was a combination of the priors for the Beverton-Holt and Ricker stock-recruitment models, and was therefore inappropriate for either model. Furthermore, the Dorn's (2000) meta-analysis included results from the 1998 Pacific ocean perch assessment, the data for which is included in both the 2000 and 2003 assessments, resulting in the double use of data. Minte-Vera et al. (2003) present the correct prior distributions, i.e. excluding the data for West Coast Pacific ocean perch when conducting the meta-analysis. However, two of the most informative stocks in this corrected meta-analysis are Alaskan Pacific ocean perch stocks that have much higher steepness values than have been calculated for the West Coast Pacific ocean perch in previous assessments. It is not clear that the Alaskan stocks of Pacific ocean perch should have similar dynamics to the West Coast stock which suggests that even the revised prior of Minte-Vera et al. (2003) may be questionable for West Coast Pacific ocean perch. Therefore, the prior for steepness in the base-case analysis has been taken to be uniform over the interval [0.21-0.99]. Sensitivity is explored to the prior for Beverton-Holt steepness for Pacific ocean perch derived by Minte-Vera et al. (2003).

10. The extent of temporal autocorrelation in recruitment, ρ, was treated as an estimable parameter in the 2000 assessment. However, the point estimate of ρ fell into the extreme of the tail of its marginal posterior. Owing to this and to difficulties associated with estimating ρ, this parameter has been removed (set to 0.0) from the assessment model for the base-case analysis. The sensitivity of the results to fixing ρ to 0.5 is examined in one of the tests of sensitivity.

11. The standard deviation of the recruitment residuals σ_r is set at 1.0 in the base-case analysis. The value used in the 2000 assessment, 0.76, is used in one of the tests of sensitivity.

12. In the 2000 assessment, the recruitment likelihood function involved two parts, the first involving the deviations from the stock-recruitment relationship and the second

the deviation from the mean recruitment. This second part has been removed from the model as it is inconsistent with the assumption of a stock-recruitment relationship.

13. The bias-correction for recruitment (needed due to the assumption that recruitment is log-normally-distributed about its expected value) has been removed from the recruitment likelihood prior to 1956 when running the model to obtain MPD estimates, as no data exists to support estimation of recruitments for these years. For the MCMC runs, where more realistic year-to-year variation in recruitment estimates exist even for years prior to 1956, the bias correction is included in the recruitment likelihood prior in all years.

1.3.3. Model features unchanged from the 2000 assessment model

The population dynamics model used in the present assessment is the same as that on which the 2000 assessment was based, i.e. a forward projection age-structured model similar to those developed by Methot (1990) and Tagart et al. (1997). As in past years, the concept of the estimation is to simulate the population dynamics using a process model, and to evaluate alternative simulated population trajectories in terms of how well they are able to mimic the available data. The observation model allows for both sampling error and ageing error. The model equations, the descriptions of the parameters of the model and the formulation of the likelihood function are given in Table 11.

Following the 2000 assessment, a prior probability distribution was placed on natural mortality instead of assuming a constant fixed value. The sensitivity of the results to a more diffuse prior for natural mortality is examined in one of the tests of sensitivity. Fishery selectivity is allowed to be a smooth function of age, and to vary over time. The prior distributions for natural mortality (Figure 5), R_0 and the recruitment residuals remain unchanged although the prior distribution for survey catchability has been modified (see Section 1.3.2, point 7).

The same parameterization of the Beverton-Holt stock-recruitment relationship was used in this assessment as was the case for the 2000 assessment:

$$\hat{R}_i = \frac{S_{i-3}e^{\xi_i}}{\alpha + \beta S_{i-3}}, \qquad \xi_i = \rho\xi_{i+1} + \sqrt{1-\rho^2}\,\omega_i \qquad \omega_i \sim N(0,\sigma_R^2)$$

where $\hat{R}_i$ is the expected recruitment at age 3 in year *i*,
S_i is the female spawning biomass in year *i*,
ξ_i is the correlated recruitment anomaly for year *i*, and
α, β are parameters of the stock-recruitment relationship.

The values for the stock-recruitment relationship parameters α and β are calculated from the values of R_0 (the number of 0-year-olds in the absence of exploitation and recruitment variability) and the "steepness" of the stock-recruit relationship (*h*). Steepness is the fraction of R_0 to be expected (in the absence of recruitment variability) when the mature biomass is reduced to 20% of its level (Francis 1992)[1], so that:

---

[1] For steepness = 0.2, recruitment is a linear function of spawning biomass (implying no surplus production if the Beverton-Holt stock-recruitment model is correct and there is no depensatory mortality) while for steepness = 1.0, recruitment is constant for all levels of spawning stock size.

$$\alpha = \tilde{B}_0 \frac{1-h}{4h}; \quad \beta = \frac{5h-1}{4hR_0}$$

where $\tilde{B}_0$ is the total egg production (or an appropriate proxy such as female spawning biomass) in the absence of exploitation (and recruitment variability), expressed as a fraction of R_0.

Estimation of the stock-recruitment relationship is integrated into the assessment. Therefore, assumptions about the priors for the parameters of this relationship (i.e. R_0 and h) are critical, particularly if the data are non-informative. F_{MSY} and related quantities such as MSY and B_{MSY} can be computed using the fitted stock-recruitment relationship as in Ianelli and Zimmerman (1998). The stock-recruitment relationship can also be seen as a surrogate for other factors affecting recruitment numbers, including climatic effects such as the Pacific Decadal Oscillation (PDO). In this assessment, a uniform prior distribution is assumed for steepness. An alternative prior, based on Dorn's meta analysis (Minte-Vera et al. 2003, and see Figure 11) is included as a test of sensitivity.

1.3.4. Likelihood contributions

The objective function minimized to obtain the point estimates of the model parameters includes contributions by the data (survey biomass estimates, CPUE data, fishery and survey age- and size- composition data; Table 10) and well as penalties (on the differences between estimates of recruitment and the values predicted from the deterministic component of the stock-recruitment relationship; on the differences between model-predicted and estimated total catches; on the variation in fishing mortality; on the extent of smoothness and dome-shapedness of fishery and survey selectivity; and on the extent to which fishery selectivity changes over time). The functional forms for each of these likelihood contributions are reported in Table 11.

The model was assumed to have converged when the largest gradient component of the objective function in the final phase was less than 10^{-7}. Issues of model convergence were assessed in several ways.

1. The Hessian matrix was inverted to ensure that it was positive definite; a non-positive definite Hessian matrix is an indication of a poorly converged or over-parameterized model.
2. The estimation was always initiated with starting values that were far from the final solution.
3. The estimation was conducted in several phases to avoid problems when highly non-linear models (such as that used here) enter biologically unreasonable regions (e.g., stock sizes smaller than the total catch or stock sizes several orders of magnitude too high).

1.3.5. Bayesian analysis

The joint posterior density function is proportional to the product of the likelihood function (see Table 11) and the prior probability distribution. A list of the estimable parameters and the priors assumed for them in the baseline analysis are given in Table 11. The Metropolis-Hastings variant of the Markov-Chain Monte Carlo (MCMC) algorithm (Hastings 1970; Gilks et al. 1996; Gelman et al. 1995) with a multivariate normal jump function was used to sample 3,000 equally likely parameter vectors from the joint posterior density function. This sample implicitly accounts for correlation among the model parameters and considers uncertainty in all parameter dimensions simultaneously. The samples on which inference is based were generated by running 12,000,000 cycles of the MCMC algorithm, discarding the first 3,000,000 as a burn-in period and selecting every 3,000th parameter vector thereafter. The initial parameter vector was taken to be the vector of maximum posterior density (MPD) estimates. A potential problem with the MCMC algorithm is how to determine whether convergence to the actual posterior distribution has occurred, and the selection of 12,000,000, 3,000,000 and 3,000 was based on generating a sample which showed no noteworthy signs of lack of convergence to the posterior distribution. We evaluated whether convergence had occurred in two ways.

1) Applying the MCMC algorithm from two alternative initial parameter vectors in addition to the application from the MPD estimates. The alternative initial parameter vectors were constructed by adding uniformly distributed noise to the MPD estimates, where the range of the normal distributions were ±2 standard deviations about the MPD estimates. The results of the three MCMC samples were compared using a variety of statistics including the statistic developed by Brooks and Gelman (1998).

2) Applying the diagnostic statistics developed by Geweke (1992), Heidelberger and Welch (1983), and Raftery and Lewis (1992) and by examining the extent of auto-correlation among the samples in the chain.

1.4. Results

1.4.1. Model selection and evaluation

The initial *a priori* model (Model 1) was based on the modifications to the 2000 assessment model (Ianelli et al. 2000) described above. These modifications include all of the following.

1. No serial correlation in the recruitment residuals (i.e. ρ=0).
2. The standard deviation of the fluctuations about the stock-recruitment relationship, σ_R, was set at 1.0.
3. A uniform prior was assumed for steepness.
4. Uniform priors (on a log-scale) were assumed for survey catchability.
5. The oldest age for which fishery selectivity was estimated was decreased from 22 to 14 years while the oldest age for which survey selectivity was estimated was increased from 10 to 12 years.
6. Fishery selectivity was allowed to change every 6th rather than every 5th year.
7. Survey selectivity for age 10 was set to 1.0 rather than imposing a constraint that average selectivity across ages equals 1.0.

1.4.2. Base-run results

Figure 12 shows the time-trajectories of the point estimates (i.e. those that correspond to the maximum of the objective function, which are also those corresponding to the maximum of posterior density function) for spawning biomass, fishery exploitation rate and recruitment. The fit to the stock-recruitment relationship (Figure 13) indicates a substantial amount of variability, especially during the early part of the time-series when several strong year-classes occurred. Recruitment was substantially larger than the predictions based on the stock-recruitment relationship for the majority of years from the mid-1950's through the early 1970's although recruitment also declined over this period. Fishing mortality peaked at around 28% in 1966-67 and has, until recently, stabilized between 3 and 7%. Over the past three years, fishing mortality has been approximately 0.7-1.3%.

The fits of the model 1 to the various indices are summarized in Figure 14 (survey biomass indices and fishery CPUE data), Figures 15 and 16 (fishery age-composition data), Figures 17 and 18 (survey age-composition data), Figure 19 (fishery size-composition data) and Figure 20 (survey size-composition). There is no evidence for model mis-specification in any of these fits.

The fishery selectivity pattern changes moderately over time (Figure 21). This may be partly due to the switch to fitting age- rather than size-composition data in 1980 and the differences in quality between or intrinsic information in these two sources of data. The selectivity patterns for both the triennial and slope surveys exhibit domes (Figure 22), although that for the triennial survey occurs at a lower age. As expected, selectivity for younger ages is notably lower for the slope surveys than for the triennial survey.

Table 12 lists the numbers-at-age matrix for Model 1 while Table 13 lists the point estimates of catch-at-age for this Model. Model 1 estimates that the spawning stock biomass was depleted to 25.3% of its unfished equilibrium level of 39,291 mt in 2003 (Table 14). In terms of exploitable (age 3+) biomass, the depletion is to 26.5% of unfished equilibrium level of 87,177 mt. The estimate of M is 0.053 yr^{-1} while steepness is estimated at 0.532. The estimate of MSY is 1,172 mt, which is smaller than all of the annual catches (including discard) from 1956-94; therefore overfishing ($F > F_{\text{MSY}}$) occurred throughout this period although the fishing mortality in 2002 was less than F_{MSY}.

The sensitivity analysis (Table 14) considered the following changes to the assumptions underlying Model 1:

1) Model 1b: replace the uninformative priors assumed for the catchability coefficients for all four surveys by (informative) prior distributions (mean = 1.08; mode = 0.8).
2) Model 1c: replace the uniform prior for steepness by the "correct" (i.e. Minte-Vera et al., submitted) prior from Dorn's meta-analysis.
3) Model 1d: increase the value of the parameter that determines the extent of serial correlation in the recruitment anomalies (ρ) from 0 to 0.5.
4) Model 1e: reduce the assumed standard deviation for the recruitment anomalies from 1.0 to 0.76 (the value used in the 2000 assessment).
5) Model 1f: increase the age at which fishery selectivity is assumed to be flat from 14 to 22 (the value used in the 2000 assessment).
6) Model 1g: Replace reference model prior for natural mortality with a more informative prior.
7) Model 1h: Do not allow the fishery selectivity to change over time.
8) Model 1i: Allow the survey selectivity to change every 5th year.
9) Model 1j: Increase the age at which the maturity curve has an inflection point (i.e. the age-at-50%-maturity) from age 8 to age 10.
10) Model 1k: Ignore the aging-error model and hence assume that there is no ageing error (an assumption on which the 2000 assessment was based).
11) Model 1l: Retrospective analysis – ignore the assessment data for 2002 (as if assessment were conducted in 2002)
12) Model 1m: Retrospective analysis – ignore the assessment data for 2001 and 2002 (as if assessment were conducted in 2001)
13) Model 1n: Omit the triennial survey indices from the likelihood function.
14) Model 1o: Omit the POP survey indices from the likelihood function.
15) Model 1p: Omit the AFSC slope survey indices from the likelihood function.
16) Model 1q: Omit the NWFSC slope survey indices from the likelihood function.
17) Model 1r: Omit the CPUE data from the likelihood function.

The results of the sensitivity analyses do not indicate great variation in results from the reference model (Model 1). Depletion levels for all but one of the sensitivity tests lie between 0.20 and 0.30. The exception is Model 1n, when the triennial survey indices are excluded from the assessment and depletion and MSY drop to 0.084 and 598t respectively. High sensitivity in this case is, however, perhaps not surprising because the triennial survey represents the longest time-series of biomass indices included in the assessment, and hence should be a key factor determining the final model outcomes.

Ignoring the data for 2001 and 2002 (Model 1m) has a much larger impact on current spawning biomass and hence depletion than omitting the data for 2002 only (Model 1l). This is because the 2001 triennial survey index is fairly low and influential. Note that the depletion level of 0.288 for Model 1m is for the year 2001 and should be compared to the estimated depletion level of 0.230 for 2001 in Model 1. Ignoring the 2001 data also leads to a markedly higher estimate of steepness and hence *MSY*.

Models 1b and 1c change the priors for survey catchability and steepness. Only the latter sensitivity test has a notable impact of the estimates of steepness (0.714 compared to 0.532 for Model 1) and depletion (0.272 compared to 0.253 for Model 1). The increased steepness (comparable with that when the data for 2001 and 2002 are ignored) imply a more optimistic picture of recovery and sustainable catch.

1.4.4. Markov-Chain Monte Carlo results

Evaluation of convergence

Figure 23 summarizes the convergence statistics for nine of the key model outputs (the ratio of the spawning biomass in 2003 to B_0, steepness, B_0, M, the spawning biomass in 2003, and the four survey catchability coefficients) based on the three MCMC chains. The panels for each chain show the trace, the posterior density function (estimated using a normal kernel density), the correlation at different lags, the 50-point moving average against cycle number (dotted line in the rightmost panels), and the running mean and running 95% probability intervals (solid lines in the rightmost panels). The results in Figure 23 and the values for the other diagnostic statistics do not indicate any serious convergence problems. One exception to this is that B_0 fails the Geweke test. However, this is a consequence of the fairly large number of samples from the posterior distribution; further thinning of the chain does not change the marginal posterior distributions notably but leads to B_0 passing the Geweke test.

It is not feasible to produce figures summarizing the convergence statistics for all of the very many parameters of the model. Figures 24a – e summarize the values of six statistics (the ratio of the batch standard deviation to the naive standard deviation, the extent of lag-1 auto-correlation, the value of the value of Raftery-Lewis statistic, the *p*-value computed from the Geweke statistic, whether the Heidelberger and Welch test is passed or not, and the value of the single-chain Gelman statistic) for a variety of model parameters and outputs. Ideally, the value of the first statistic should be close to 1, the value of the second statistic should be close to zero, the value of the third statistic should be less than 5, the value of the fourth statistic should be greater than 0.05, and the value of the last statistic should be less than 1.05. The results in Figure 24 suggest that the sample from the posterior is close to ideal. The *p*-value for the Geweke statistic is less than 0.05 reasonably often. However, this is not a major concern because this statistic can be triggered at random and the other statistics suggest that convergence has been achieved very successfully.

The posteriors

Figures 25-26 display posterior distributions for the time-trajectories of spawning biomass and recruitment. The median values of these time-trajectories are given in Table 15. The posterior distributions for nine key output quantities are displayed in Figure 27. These distributions summarize the uncertainty of the estimates of these quantities. The posterior medians for the nine output quantities are close to maximum posterior density estimates (see Table 14). Figure 28 shows the correlation among the nine key output quantities along with the ABC for 2004.

The posterior probability that the 2003 spawning biomass is less than $0.25B_0$ is 0.4 (i.e. there is a 40% probability that Pacific ocean perch is currently overfished). The posterior probability that the 2003 spawning biomass is less than half of B_{MSY} is ~0.1.

The posterior distribution for steepness is relatively wide (Figure 27). This confirms the expectation that the data are relatively uninformative about the shape of stock-recruitment relationship. A major cause of this uncertainty is the extremely high early recruitment estimates (see Figures 12 and 13) which do not fall on the stock-recruitment relationship irrespective of the value for steepness. In reality, the stock-recruitment relationship may have changed since the 1940s and 1950s, possibly due to climate change.

1.4.5. Future research

There are a number of areas of future research, e.g.:

> Inclusion of age 1 and 2 Pacific ocean perch catches and discards. This would involve a further examination of the size or age data for the discards, which are likely different from those for the retained catches.
>
> Estimation of effective sample sizes for fishery and survey size- and age-composition data.
>
> Use of simulation models to evaluate how well it is possible to estimate recruitment using size-composition data or biased or unbiased age-composition data, or a mix of the three, as is the case in actuality for Pacific ocean perch. Such an analysis could inform whether recruitment from individual good recruitment years is spread out over several years when assessed using the model, and if smaller recruitments can lead to the same patterns if the recruitment anomalies are autocorrelated. The effects of assuming one pattern of recruitment, when another is accurate, on the estimates of the model parameters, especially those of the stock-recruitment relationship, could have a large impact on the assessment and the predictions of rebuilding OYs.
>
> Estimation of climatic effects on recruitment, growth and survival. A first step might be to include PDO (Pacific decadal oscillation) or other climatic variables in the assessment as a predictor of recruitment success.
>
> Selection of an appropriate prior distribution for the survey catchability coefficients, or at least for the current NWFSC survey which will be continuing.
>
> Inclusion of males and females separately in the model. While the sex-ratio is believed to be approximately 1:1, the growth rates and mean maximum sizes of males and females are slightly different, which may have some effect on selectivity and the estimates of total biomass.

Acknowledgements

The authors would like to thank Jim Ianelli for providing the code from the 2000 assessment and responding to our questions regarding that code and assessment, B. Chasco for the use of S-plus code to create the time series of posterior distributions of biomass and recruitment estimates, and Mark Wilkins and Bob Lauth for providing biomass estimates and age and length comps from the Triennial and AFSC slope surveys.

1.5. References

Archibald, C.P., W. Shaw, and B.M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-79. Can. Tech. Rep. Fish. Aquat. Sci. 1048, 57 p.

Beamish, R.J. 1979. New information on the longevity of Pacific ocean perch *(Sebastes alutus*). J. Fish. Res. Board Can. 36:1395-1400.

Brooks, S. and A. Gelman. 1998. General methods for monitoring convergence of iterative simulations. *Journal of Computational and Graphical Statistics* 7: 434-55.

Chilton, D.E., and R.J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60, 102 p.

Dorn, M. 2000. Advice on West Coast rockfish harvest rates from Bayesian meta-analysis of stock-recruit relationships. Draft paper submitted to West Coast Groundfish Productivity Workshop, March 20-24th.

Forrester, C. R., A. J. Beardsley, and Y. Takahashi. 1978. Groundfish, shrimp, and herring fisheries in the Bering Sea and northeast Pacific-historical catch statistics through 1970. Int. North Pac. Fish. Comm., Bull. 37, 147 p.

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

Fournier, D.A., J. R. Sigert, J. Markowski and J. Hampton. 1990. MULTIFAN: a likelihood-based method for estimating growth parameters and age composition from multiple length frequncy data sets illustrated using data for southern bluefin tuna (thunnus maccoyii). Can. J. Fish. Aquat. Sci. 47: 301-317.

Fournier, D.A., J. Hampton, and J. R. Sigert. 1998. MULTIFAN-CL: a length-based, age-structured model for fisheries stock assessment, with application to South Pacific albacore, *Thunnus alalunga*. Can. J. Fish. Aquat. Sci. 55: 2105-2116.

Fraidenburg, M. E., J. E. Smith, W. H. Barss, and T. Jow. 1978. Minimum estimates of all nations removals, North American trawl species composition, and CPUE for "other rockfish" in the northeastern Pacific ocean. Wash. Dep. Fish., Tech. Rep. 34, 31 p.

Fraidenburg, M.E., S.J. Westrheim, and R.L. Demory. 1978. The status of Pacific ocean perch *(Sebastes alutus*) stocks off British Columbia, Washington and Oregon in 1977.

Francis, R.I.C.C. 1992. Use of risk analysis to assess fishery management strategies: a case study using orange roughy *(Hoplostethus atlanticus*) on the Chatham Rise, New Zealand. Can. J. Fish. Aquat. Sci. 49: 922-930.

Gilks, W.R., S. Richardson, and D.J. Spiegelhalter. 1996. Markov Chain Monte Carlo in Practice. Chapman and Hall, London. 486 p.

Gelman, A, J.B. Carlin, H.S. Stern, and D.B. Rubin. 1995. Bayesian data analysis. Chapman and Hall. London. 526 p.

Geweke, J. 1992. Evaluating the accuracy of sampling-based approaches to the calculation of posterior moments. pp. 169-93. In: Bayesian Statistics 4 (eds J.M. Bernardo, J. Berger, A.P. Dawid and A.F.M. Smith.) Oxford University Press, Oxford

Gunderson, D.R. 1977. Population biology of Pacific ocean perch, *Sebastes alutus*, stocks in the Washington-Queen Charlotte Sound region and their response to fishing. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 75:369-403.

Gunderson, D.R. 1978. Results of cohort analysis for Pacific ocean perch stocks off British Columbia, Washington, and Oregon and an evaluation of alternative rebuilding strategies for these stocks. Unpubl. rep., 20 p. Available Pacific Fishery Management Council, Suite 420, 2000 S.W. First Avenue, Portland, OR 97201.

Gunderson, D.R. 1981. An updated cohort analysis for Pacific ocean perch stocks off Washington and Oregon. Unpubl. rep., 29 p. Available Pacific Fishery Management Council, Suite 420, 2000 S.W. First Avenue, Portland, OR 97201.

Gunderson, D.R., and T.M. Sample. 1980. Distribution and abundance of rockfish off Washington, Oregon, and California during 1977. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 42(3-4):2-16.

Gunderson, D.R., S. J. Westrheim, R.L. Demory, and M.E. Fraidenburg. 1977. The status of Pacific ocean perch *(Sebastes alutus*) stocks off British Columbia, Washington, and Oregon in 1974. Can. Fish. Mar. Serv. Resour. Dev. Tech. Rep. 690, 63 p.

Harley, S.J., Myers, R.A., Barrowman, N.J., Bowen, K.G., and Amiro, E. 2000. Ecosystem models of the Scotian Shelf: Estimation of catchabilities. Unpublished manuscript.

Hastings, W.K. 1970. Monte Carlo sampling methods using Markov chains and their applications. *Biometrika* 57: 97-109.

Heidelberger, P. and P.D. Welch. 1983. Simulation run length control in the presence of an initial transient. *Operations Research* 31: 1109-44.

Hoenig, J.H. 1983. Empirical use of longevity data to estimate mortality rates. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 82:898-903.

Ianelli, J.N. and M. Zimmerman. 1998. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 1998. In Status of the Pacific coast groundfish fishery through 1998 and recommended acceptable biological catches for 1999. Pacific Fishery Management Council, Portland, OR.

Ianelli, J.N., M. Wilkins and S. Harley. 2000. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 2000. In Status of the Pacific coast groundfish fishery through 2000 and recommended acceptable biological catches for 2001. Pacific Fishery Management Council, Portland, OR.

Ito, D.H., D.K. Kimura, and M.E. Wilkins. 1987. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 1986. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-113, 50 p.

Methot, R.D. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. INPFC Bull. 50: 259-77. Pacific Fishery Management Council. 1980.

Methot, R.D. 2000.Technical description of the Stock Synthesis Assessment Program. NOAA Technical Memorandum NMFS-NWFSC-43.

Minte-Vera, C. V., T. A. Branch, I. J. Stewart, and M. W. Dorn. Unpublished document (2003). Practical application of meta-analysis results: avoiding the double use of data.

Pennington, M., 1985. Estimating the relative abundance of fish from a series of trawl surveys. Biometrics, 41:197-202.

Pikitch, E.K., D.L. Erickson, and J.R. Wallace. 1988. An evaluation of the effectiveness of trip limits as a management tool. Northwest and Alaska Fisheries Center, National Marine Fisheries Service NWAFC Processed Report No. 88-27.

Raftery, A.E. and S. Lewis. 1992. How many iterations in the Gibbs sampler? pp. 763-73. In: Bayesian Statistics 4 (eds J.M. Bernardo, J. Berger, A.P. Dawid and A.F.M. Smith.) Oxford University Press, Oxford.

Rogers, J.B. Unpublished document (2003). Species allocation of *Sebastes* and *Sebastolobus* species caught by foreign countries off Washington, Oregon and California, U.S.A. in 1965-1976.

Sampson, D.B. 2002. Unpublished Document. Analysis of data form the at-sea data collection project. Final report to the Oregon Trawl Commission.

Seeb, L. W., and D. R. Gunderson. 1988. Genetic variation and population structure of Pacific ocean perch *(Sebastes alutus*). Can. J. Fish. Aquat. Sci. 45:78-88.

Tagart, J.V., J.N. Ianelli, A. Hoffmann, and F.R. Wallace. 1997. Status of the yellowtail rockfish resource in 1997. Pacific Fishery Management Council, Portland, OR.

Tagart, J.V., J.T. Golden, D.K. Kimura, and R.L. Demory. 1980. Evaluation of alternative trip limits for Pacific ocean perch. Unpubl. rep., 22 p. Available Pacific Fishery management Council, Metro Center, Suite 420, 2000 S.W. First Avenue, Portland, OR 97201.

Technical Subcommittee. 1972. Unpublished report of the Technical Subcommittee, International Trawl Fishery Committee, 13th annual meeting, June 28-30, 1972, 45 p. Available Pacific Marine Fisheries Commission, 528 S.W. Mill Street, Portland, OR 97201.

Westrheim, S. J., D. R. Gunderson, and J. M. Meehan. 1972. On the status of Pacific ocean perch *(Sebastes alutus*) stocks off British Columbia, Washington, and Oregon in 1970. Fish. Res. Board Can. Tech. Rep. 326, 48 p.

Wilkins, M. E. and J. T. Golden. 1983. Condition of the Pacific ocean perch resource off Washington and Oregon during 1979: Results of a cooperative trawl survey. N. Am. J. Fish. Manage. 3:103-122.

Wishard, L. N., F. M. Utter, and D. R. Gunderson. 1980. Stock separation of five rockfish species using naturally occurring biochemical genetic markers. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 42(3-4): 64-73.

1.6. Tables

Table 1. Pacific Fishery Management Council groundfish management/regulatory actions regarding Pacific ocean perch (POP) since Fishery Management Plan implementation in 1982.

Date	Regulatory Action
November 10, 1983	Recommended closure of Columbia area to POP fishing until the end of the year as 950 t OY for this species has been reached; retain 5,000 pound trip limit or 10 percent of total trip weight on landings of POP in the Vancouver area.
January 1, 1984	Continuation of 5,000 pound trip limit or 10 percent of total trip weight on POP as specified in FMP. Fishery closes when area OY's are reached (see action effective November 10, 1983 above).
August 1, 1984	Recommended immediate reduction in trip limit for POP in the Vancouver and Columbia areas to 20 percent by weight of all fish on board, not to exceed 5,000 pounds per vessel per trip. When OY is reached in either area, landings of POP will be prohibited in that area (Oregon and Washington implemented POP recommendation in mid-July).
August 16, 1984 (Automatic closure)	Commercial fishing for POP in the Columbia area closed for remainder of the year. (See items regarding this species effective January 1 and August 1, 1984 above.)
January 10, 1985	Recommended Vancouver and Columbia areas POP trip limit of 20 percent by weight of all fish on board (no 5,000 pound limit as specified in last half of 1984).
April 28, 1985	Recommended the Vancouver and Columbia areas POP trip limit be reduced to 5,000 pounds or 20 percent by weight of all fish on board, whichever is less. Landings of POP less than 1,000 pounds will be unrestricted. The fishery for this species will close when the OY in each area is reached.
June 10, 1985	Recommended landings of POP up to 1,000 pounds per trip will be unrestricted regardless of the percentage of these fish on board.
January 1, 1986	Recommended the POP limit in the area north of Cape Blanco (42 degrees, 50 minutes N) should be 20 percent (by weight) of all fish on board or 10,000 pounds whichever is less; landings of POP should be unrestricted if less than 1,000 pounds regardless of percentage on board; Vancouver area OY = 600 t; Columbia area OY = 950 t.
December 1, 1986	OY quota for POP reached in the Vancouver area; fishery closed until January 1, 1987.
January 1, 1987	Recommended the coastwide POP limit should be 20 percent of all legal fish on board or 5,000 pounds whichever is less (in round weight); landings of POP unrestricted if less than 1,000 pounds regardless of percentage on board; Vancouver area OY = 500 t; Columbia area OY = 800 t.
January 1, 1988	Recommended the coastwide POP trip limit should be 20 percent (by weight) of all fish on board or 5,000 pounds, whichever is less; landings of POP be unrestricted if less than 1,000 pounds regardless of percentage on board; Vancouver area OY = 500 t; Columbia area OY = 800 t.
January 1, 1989	Established the coastwide POP trip limit at 20 percent (by weight) of all fish on board or 5,000 pounds whichever is less; landings of POP unrestricted if less than 1,000 pounds regardless of percentage on board (Vancouver area OY = 500 t; Columbia area OY = 800 t).
July 26, 1989	Reduced the coastwide trip limit for POP to 2,000 pounds or 20 percent of all fish on board, whichever is less, with no trip frequency restriction. Increased the Columbia area POP OY from 800 to 1,040 t.
December 13, 1989	Closed the POP fishery in the Columbia area because 1,040 t OY reached.
January 1, 1990	Established the coastwide POP trip limit at 20 percent (by weight) of all fish on board or 3,000 pounds whichever is less; landings of POP be unrestricted if less than 1,000 pounds regardless of percentage on board. (Vancouver area OY = 500 t; Columbia area OY = 1,040 t).
January 1, 1991	Established the coastwide POP trip limit at 20 percent (by weight) of all fish on board or 3,000 pounds whichever is less; landings of POP be unrestricted if less than 1,000 pounds regardless of percentage on board (harvest guideline for combined Vancouver and Columbia areas = 1,000 t).
January 1, 1992	Established the coastwide POP trip limit at 20 percent (by weight) of all groundfish on board or 3,000 pounds whichever is less; landings of POP be unrestricted if less than 1,000 pounds regardless of percentage on board (harvest guideline for combined Vancouver and Columbia areas = 1,550 mt).
January 1, 1993	Continued the coastwide POP trip limit at 20 percent (by weight) of all groundfish on board or 3,000 pounds whichever is less; landings of POP be unrestricted if less than 1,000 pounds regardless of percentage on board (harvest guideline for combined Vancouver and Columbia areas = 1,550 mt).
January 1, 1994	Adopted the following management measure for the limited entry fishery in 1994: POP: Trip limit of 3,000 pounds or 20 percent of all fish on board, whichever is less, in landings of POP above 1,000 pounds. Adopted the following management measure for open access gear except trawls in 1994: Rockfish: Limit of 10,000 pounds per vessel per trip, not to exceed 40,000 pounds cumulative per month, and the limits for any rockfish species or complex in the limited entry longline or pot fishery must not be exceeded.
May 1, 1994	Changed trip limit for rockfish taken with setnet gear off California. The 10,000 pound trip limit for rockfish caught with setnets, which applied to each trip, was removed. The 40,000 pound cumulative limit that applies per calendar month remains in effect.
January 1, 1995	Established cumulative trip limits of 6,000 pounds per month.
January 1, 1996	Established cumulative trip limits of 10,000 pounds every two months.
July 1, 1996	Reduced cumulative 2-month trip limit to 8,000 pounds.
January 1, 1997	Established cumulative trip limits of 10,000 pounds every two months.
January 1998	Harvest guidelines reduced from 750 mt to 650 mt with ABC=0. Limited entry fishery under 8,000 pounds per two-months until September with monthly limits of 4,000 pounds
January 1999	Monthly cumulative trip limit of 4,000 pounds for limited entry fishery. A 100 pound per month limit established for open access fishery.
January 2000	Monthly cumulative trip limit of 2,500 pounds (May-October) and 500 pounds (November-April) for limited entry fishery.
January 2001	Monthly cumulative trip limit of 2,500 pounds (May-October) and 1,500 pounds (November-April) for limited entry fishery
June 2001	Monthly cumulative trip limit increased to 3,500 pounds for limited entry fishery beginning July 1, 2001.
September 2001	POP limited entry and open access fisheries closed starting October 1, 2001 through the end of 2001.
January 2002	Monthly cumulative trip limit of 4,000 pounds (April-October) and 2,000 pounds (November-March) for limited entry fishery.
January 2003	Two-month cumulative trip limit of 3,000 pounds for limited entry trawl fishery and 1,800 pounds for limited entry fixed gear fishery throughout year.

Table 2. Pacific ocean perch landings and estimated total catch in metric tons (including estimated discards) from the US Vancouver and Columbia INPFC areas by foreign and domestic vessels.

Year	*Foreign catch*	*Domestic landings*	*Domestic catch including discard*	*Total*
1956		2.119	2.231	2.231
1957		2,320	2,442	2,442
1958		1,580	1,587	1,587
1959		1,860	1,958	1,958
1960		2,246	2,364	2,364
1961		3,924	4,149	4,149
1962		5,530	5,793	5,793
1963		6,449	6,788	6,788
1964		5,517	5,807	5,807
1965		7,660	8,063	8,063
1966	15,561	3,039	3,200	18,761
1967	12,357	885	932	13,289
1968	6,639	592	623	7,262
1969	469	692	728	1,197
1970	441	1,649	1,736	2,177
1971	902	997	1,049	1,951
1972	950	578	608	1,558
1973	1,773	353	372	2,145
1974	1,457	326	343	1,800
1975	496	623	656	1,152
1976	239	1,366	1,438	1,677
1977		1,180	1,242	1,242
1978		2,014	2,120	2,120
1979		1,854	1,952	1,952
1980		1,867	1,965	1,965
1981		1,445	1,720	1,720
1982		1,043	1,242	1,242
1983		1,860	2,215	2,215
1984		1,645	1,959	1,959
1985		1,506	1,792	1,792
1986		1,389	1,653	1,653
1987		1,096	1,305	1,305
1988		1,382	1,645	1,645
1989		1,433	1,706	1,706
1990		1,032	1,230	1,230
1991		1,433	1,659	1,659
1992		1,097	1,306	1,306
1993		1,260	1,500	1,500
1994		988	1,176	1,176
1995		810	965	965
1996		788	938	938
1997		631	751	751
1998		621	739	739
1999		498	593	593
2000		144	171	171
2001		258	307	307
2002		201	239*	239*

1 Average of two previous years

Table 3. Table 3. Age-composition data for the domestic fishery catch in Vancouver and Columbia areas combined based on surface ageing (1966-80; from Gunderson, 1981). The data for ages 14 and older are grouped in a single "plus-group" when fitting the model to avoid potential problems with ageing bias.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
3	0	0	0	0	6	0	0	2	0	0	0	0	0	0	0
4	0	0	19	0	0	0	4	9	0	0	0	4	2	0	0
5	12	44	29	18	22	0	31	29	6	87	200	7	23	8	4
6	24	61	559	7	233	12	65	44	14	88	1,353	91	48	17	23
7	82	543	1,206	64	319	117	142	70	15	105	425	529	95	34	53
8	294	872	1,648	109	711	291	277	110	28	67	289	144	333	87	159
9	353	1,580	1,191	97	1,459	956	540	311	94	101	201	118	183	257	345
10	801	2,780	1,667	230	1,081	1,640	990	709	241	218	316	98	195	191	351
11	1,401	4,989	2,484	578	907	1,083	1,511	1,170	402	321	420	155	208	166	214
12	2,731	8,115	4,142	1,267	904	798	620	1,326	505	373	403	157	279	195	189
13	1,648	6,322	3,845	1,369	937	686	402	564	370	390	297	141	264	178	197
14	1,201	5,496	3,130	1,103	807	652	420	279	142	351	248	122	296	170	200
15	1,425	4,523	2,703	1,060	818	667	426	242	106	97	133	83	215	164	176
16	1,342	3,595	2,051	586	700	572	402	218	79	77	62	71	170	146	166
17	812	2,501	1,317	215	390	538	377	233	66	86	61	42	106	124	146
18	589	1,326	938	184	269	252	271	187	65	70	60	37	68	99	107
19	259	992	651	71	148	220	137	146	41	54	45	36	33	73	60
20	118	379	520	7	74	149	90	105	37	32	49	27	30	44	69
21	35	115	248	0	27	75	58	72	34	23	15	12	17	32	39
22	12	141	146	4	0	21	31	25	25	12	25	2	11	21	23
23	12	44	34	0	0	0	6	10	14	8	15	5	3	18	16
24	0	27	0	0	0	0	0	0	5	3	16	1	0	2	20
25	0	0	0	0	0	0	0	0	0	0	0	0	0	4	12

Table 4. Age–compositions data for the domestic fishery catch in the US Vancouver and Columbia INFPC areas combined based on the break-and-burn method (1999-2002).

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1999	0	0	4	2	20	19	49	33	21	8	14	9	11	12	10	8	8	9	7	4	5	1	52
2000	0	0	18	1	7	30	47	65	59	37	47	39	44	22	27	7	11	8	8	11	6	1	101
2001	0	10	25	40	21	30	57	77	95	81	42	32	33	25	29	14	19	13	5	14	10	16	188
2002	0	2	8	69	65	35	45	85	78	85	59	31	32	13	19	23	12	10	7	12	11	17	104

Table 5. Size-composition data (categories in centimeters) for the domestic fishery catch in Vancouver and Columbia areas.

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40+
1981	0	0	0	0	0	0	0	0	0	0	0	2	2	5	20	11	16	39	86	154	177	214	217	941
1982	0	0	0	0	0	0	0	0	1	0	2	0	3	1	3	5	22	39	72	115	160	202	223	951
1983	0	0	0	0	0	0	0	0	0	0	0	2	6	7	15	26	74	107	175	245	288	317	312	1156
1984	0	0	0	0	0	0	0	0	1	0	1	2	8	12	27	56	84	159	234	306	413	450	369	981
1985	0	1	0	0	0	0	0	0	1	0	3	9	4	25	35	52	127	207	344	389	413	464	492	1943
1986	0	0	0	0	0	0	0	0	0	1	3	1	7	7	22	40	55	161	248	357	369	430	463	1840
1987	0	0	0	0	0	0	0	0	0	0	1	1	2	13	21	48	82	141	223	303	372	400	302	1196
1988	0	0	0	0	0	0	0	0	0	0	1	1	1	4	7	9	6	11	20	44	61	59	51	241
1989	0	0	0	0	0	0	0	0	0	0	1	0	0	2	10	12	23	33	61	82	115	120	105	234
1994	0	0	0	0	0	0	0	0	0	0	0	1	4	13	25	47	45	68	72	95	100	115	75	238
1995	0	0	0	0	0	0	0	0	0	0	0	2	2	10	24	33	35	63	87	128	114	107	65	186
1996	0	0	0	0	0	0	0	1	1	2	7	11	14	42	58	55	94	121	146	143	150	142	121	455
1997	0	0	0	0	0	0	0	4	3	9	13	35	54	107	101	133	164	181	177	209	208	200	173	424
1998	0	0	0	0	1	2	0	1	4	4	14	20	23	27	60	98	123	151	147	135	139	119	101	307

Table 6. Survey age-composition data for the combined Vancouver and Columbia areas. Note that the data for ages 1 and 2 are not used when fitting the model, nor are the data from 1977-1980, the latter because of low sample size and the use of surface rather than break-and-burn ageing methods.

Age	**1977**	**1979**	**1980**	**1985**	**1989**	**1992**	**1998**	**2001**	**2002**
1	0	0	0	0	46,138			201,713	-
2	18,214	2,556	0	21,200	254,816	38,718		540,828	-
3	84,582	13,231	0	122,477	89,226	798,759	2,056,539	335,665	112,483
4	119,793	228,325	295,155	332,342	3,176,682	3,368,042	3,457,344	142,091	37,169
5	125,448	667,058	702,456	731,141	1,219,343	2,750,737	363,980	148,375	25,395
6	460,779	652,383	591,543	1,017,246	656,796	1,076,992	501,087	858,304	54,531
7	2,631,845	870,267	350,490	418,657	833,499	1,255,653	1,114,104	755,694	288,843
8	745,320	2,341,122	514,736	290,206	2,353,474	1,020,789	1,164,323	191,718	367,913
9	474,994	3,722,415	576,100	294,572	928,618	627,615	617,259	70,412	179,019
10	383,316	1,663,880	268,615	603,853	748,928	540,627	474,097	46,313	228,546
11	455,394	1,148,334	253,944	523,611	573,984	2,472,883	496,022	111,504	266,186
12	900,039	1,169,177	371,575	301,193	416,323	1,229,444	331,823	200,846	369,018
13	888,055	1,004,988	403,092	405,146	353,090	668,764	588,042	92,684	296,681
14	1,251,141	1,080,766	224,522	553,271	219,216	306,908	384,535	93,131	266,709
15	1,013,324	933,723	365,190	554,201	24,770	390,237	583,973	72,108	253,579
16	1,036,159	914,997	240,000	290,312	129,282	541,074	442,703	49,274	220,007
17	551,481	738,255	192,922	210,758	20,177	47,713	442,686	71,836	148,661
18	939,938	592,137	220,671	284,327	9,974	130,796	339,970	69,013	213,617
19	976,370	418,312	0	189,918	36,992	82,358	407,549	64,931	98,155
20	768,559	320,882	0	265,433	20,936	213,467	49,590	66,921	85,925
21	406,035	171,105	64,715	263,709	49,188	148,865	223,090	45,266	110,451
22	139,400	108,387	0	213,783	23,570	105,234	94,158	36,720	94,398
23	98,700	58,304	0	217,418	119,073	77,359	205,193	38,776	90,737
24	7,982	17,428	0	200,765	132,707	142,147	39,458	50,639	72,252
25	54,337	15,899	0	3,163,096	2,195,421	1,725,477	3,439,282	647,245	983,431

Table 7. POP, triennial and AFSC survey size composition data (numbers (1977-1995) and proportions(1996-2000)).

	1977	1979	1980	1983	1986	1995	1996	1997	1999	2000
17	2,584	3,117	0	1,473	6,506	2,906	0.0005	0.0029	0	0.0022
18	6,140	7,630	3,679	23,991	53,295	11,052	0.0016	0	0	0.0012
19	43,904	0	2,620	81,723	41,690	15,612	0.0121	0.0071	0	0.0012
20	27,326	5,123	4,929	112,702	104,521	12,741	0.013	0.013	0.0027	0.0166
21	39,782	5,490	1,602	39,004	83,053	13,768	0.0092	0.0453	0	0.0104
22	60,688	14,459	19,007	48,154	33,164	15,787	0.0033	0.0471	0.0042	0
23	111,235	27,669	16,276	66,084	41,216	41,237	0.0009	0.1149	0.0027	0.0006
24	76,141	62,293	70,625	89,355	36,240	55,680	0.0006	0.1715	0.0116	0.0019
25	67,469	75,040	58,952	61,353	55,261	150,256	0.0011	0.226	0.0174	0.0006
26	71,551	113,413	75,296	92,155	101,218	295,345	0.0025	0.076	0.0137	0
27	123,024	164,058	112,373	59,602	289,455	282,386	0.0036	0.0236	0.0261	0
28	137,833	285,927	112,882	56,398	248,178	220,504	0.0081	0.0059	0.0228	0.0012
29	147,907	325,469	185,941	34,134	276,130	114,244	0.0506	0.0049	0.024	0.0019
30	188,555	251,458	317,137	57,269	341,303	193,641	0.0442	0.0157	0.0289	0.0019
31	434,441	443,636	291,127	55,976	272,989	142,663	0.0818	0.0203	0.0198	0.0278
32	787,543	725,956	423,489	44,155	184,777	149,017	0.0317	0.0384	0.0249	0.0382
33	1,065,585	1,366,737	217,998	84,491	229,861	111,459	0.0416	0.0202	0.0647	0.0902
34	924,884	2,156,232	237,176	91,813	170,925	169,644	0.0365	0.0128	0.1102	0.1714
35	641,234	2,242,299	293,713	179,254	264,174	205,715	0.0603	0.0365	0.1415	0.1304
36	649,319	2,073,524	267,499	264,220	96,217	369,945	0.0753	0.029	0.16	0.122
37	764,075	1,642,703	377,084	358,488	138,885	497,226	0.0958	0.0251	0.1045	0.1684
38	788,588	1,525,133	365,442	456,473	190,770	553,446	0.1081	0.0252	0.1018	0.0915
39	938,366	1,436,646	360,172	592,849	172,037	385,388	0.1128	0.0167	0.0524	0.0381
40+	7,431,350	3,916,376	2,902,115	4,300,601	860,253	1,828,881	0.2049	0.022	0.0628	0.0821

Table 8. Biomass indices (and associated coefficients of variance, expressed as percentages) from the triennial surveys by INPFC area (1977-2001).

Area/Year	Depth (m)	Biomass Estimates	Sampling CV
US Vancouver			
1977	91-366	7,589	64.8%
1980	55-366	3,128	53.7%
1983	55-366	3,786	37.6%
1986	55-366	1,214	38.3%
1989	55-366	7,719	55.3%
1992	55-366	5,358	65.4%
1995	55-500	3,555	63.0%
1998	55-500	4,495	45.0%
2001	55-500	1,110	49.0%
Columbia			
1977	91-366	6,656	22.5%
1980	55-366	3,340	81.4%
1983	55-366	2,947	43.4%
1986	55-366	1,583	69.8%
1989	55-366	1,536	53.9%
1992	55-366	2,243	45.7%
1995	55-500	761	28.0%
1998	55-500	3,084	43.0%
2001	55-500	1,710	56.2%

Table 9. Biomass indices (and associated coefficients of variance, expressed as percentages) from slope groundfish surveys for combined US Vancouver and Columbia INPFC areas (1979-2002).

Year/Survey	Depth (m)	Biomass Estimates	Sampling CV
1979 POP	165-475	16,044	29.6%
1985 POP	165-475	10,696	20.1%
"1992" AFSC	183-1280	6,971	37.7%
1996 AFSC	183-1280	4,730	30.5%
1997 AFSC	183-1280	2,146	38.5%
1999 AFSC	183-1280	8,857	50.9%
2000 AFSC	183-1280	2,465	51.9%
2001 AFSC	183-1280	9,675	78.0%
1999 NWFSC	183-1280	2,651	51.0%
2000 NWFSC	183-1280	2,556	56.7%
2001 NWFSC	183-1280	5,269	45.8%
2002 NWFSC	183-1280	3,770	55.4%

Table 10. List of the data sources and associated time periods used in present assessment.

Data Source	Years
Fishery Catch	1956-2002
Fishery age-composition data	1966-80 (biased); 1999-2002 (unbiased)
Fishery size-composition data	1981-99, 1994-98
Fishery CPUE	1956-73
Biomass estimates	
Triennial survey	1977,1980,1983,1986,1989,1992,1995,1998,2001
POP/Rockfish survey	1979,1985
AFSC slope survey	"1992", 1996, 1997, 1999-2001
NWFSC slope survey	1999-2002
Survey age-composition data	
Triennial survey	1989, 1992, 1998, 2001
POP / NWFSC slope surveys	1985, 2002
Survey size-composition data	
Triennial survey	1977, 1980, 1983, 1986, 1995
POP / NWFSC / AFSC slope surveys	1979, 1996, 1997, 1999, 2000

Table 11. Model parameters, equations, and likelihood components. The symbols i, j and k_i denote year (1956-2002), age (3-25) and the selectivity group (0-8) to which year i relates.

(a) The "free" parameters of the population dynamics model, the prior distributions assumed for them, and their ADMB phase. For parameters that are vectors, the length of the parameter vector is given. Priors indicated by asterisks are modified in the tests of sensitivity.

Parameter	Symbol	Length	Prior	Phase
Average recruitment	$\bar{R}$		Log-Uniform(-∞,∞)	1
Unfished equilibrium recruitment	R_0		Log-Uniform(-∞,∞)	1
CPUE catchability	q^f		Log-Uniform(-∞,∞)	1
Triennial survey catchability	q^T		Log-Uniform(-∞,∞)	6
POP survey catchability	q^P		Log-Uniform(-∞,∞)	6
AFSC survey catchability	q^A		Log-Uniform(-∞,∞)	6
NWFSC survey catchability	q^N		Log-Uniform(-∞,∞)	6
Natural mortality	M		Lognormal(.5,.1)	6
Stock-recruitment steepness	h		Uniform(.21,0.99)	7
Average fishing mortality	$\bar{F}$		Log-Uniform(-∞,∞)	1
Recruitment deviation	ε_i^R	68	Log-Uniform(-10,10)	3
Fishing mortality deviation	ε_i^F	47	Log-Uniform(-10,10)	2
Triennial survey selectivity-at-age	s_j^T	10	Log-Uniform(-∞,∞)	4
Slope survey selectivity-at-age	s_j^{Sl}	10	Log-Uniform(-∞,∞)	4
Fishery selectivity-at-age in first year of fishery	$s_{1956,j}^F$	12	Log-Uniform(-∞,∞)	2
Fishery selectivity deviations (every 6 years)	$\varsigma_{k_i,j}^F$	96 (12*8)	Log-Uniform(-5,5)	3

(Table 11 Continued).

(b) The pre-specified parameters of the model (baseline model). Values indicated by asterisks are modified in the tests of sensitivity.

Parameter	Symbol	Value
Plus-group age	$a_{\max}$	25
Age beyond which fishery selectivity is constant	a_S^F	14*
Age beyond which survey selectivity is constant	a_S^S	12
Probability an animal of age *j* is in length-class	$A_{j,l}$	Fig. 8
Probability an animal of age *j* is aged to be *j*'.	$B_{j,j'}$	Fig. 9*
Weight-at-age	W_j	Fig. 7
Age-at-50%-maturity	μ	8*
Extent of auto-correlation in recruitment	ρ	0*
Extent of variability in recruitment	σ_R	1.0*
Number of years in a grouping for time-varying fishery selectivity	g	6*
Weighting factors		
CPUE cv	τ	0.2
Catch biomass weight	λ_1	100
Age/size data weight	λ_3	1
Fishing mortality regularity weight	λ_5	0.1
Selectivity prior overall weight	λ_6	1
Fishery selectivity dome-shapedness penalty	λ_8	20
Fishery selectivity temporal penalty	λ_9	20
Selectivity curvature penalty	λ_{10}	20
Effective sample size		
Fishery age-composition	n_i^F	50
Fishery size-composition	m_i^F	50
Survey age-composition	n_i^S	50
Survey size-composition	m_i^S	25

(Table 11 Continued)

(c) The derived quantities

Quantity	Equation
Virgin Biomass	$B_0 = R_0(1, e^{-M}, e^{-2M}, \ldots, e^{-21M}, \frac{e^{-22M}}{1-e^{-M}}) \cdot \vec{W}$
Fishery selectivity-at-age	$s^F_{i,j} = s^F_{1956,j} \varsigma^F_{k_i,j}$
Fishing mortality rate	$F_{i,j} = \overline{F} \varepsilon^F_i s^F_{i,j}$
Total mortality rate	$Z_{i,j} = F_{i,j} + M$
Annual survival rate	$S_{i,j} = e^{-Z_{i,j}}$
Number at age	$N_{i,j} = \begin{cases} \overline{R} \varepsilon^R_i & j = 3 \\ N_{i-1,j-1} S_{i-1,j-1} & 4 \le j \le 23 \\ N_{i-1,24} S_{i-1,24} + N_{i-1,25} S_{i-1,25} & j = 25 \end{cases}$
Maturity-at-age	$\theta_j = 0.5[1 + \exp(-2(j + 2 - \mu))]^{-1}$
Spawning biomass	$B_i = \sum_{j=3}^{x} N_{i,j} \theta_j W_j$
Predicted recruitment	$\hat{R}_i = \frac{B_{i-3}}{\alpha + \beta B_{i-3}}; \qquad \alpha = \frac{B_0}{R_0} \frac{1-h}{4h}; \beta = \frac{5h-1}{4hR_0}$
Recruitment anomaly	$\xi_i = \ln(\frac{N_{i,3} + 0.00000001^*}{\hat{R}_i + 0.00000001})$

* constants added to avoid ln(0) or dividing by 0.

(Table 11 Continued)

(d) Model predictions

Data Type	**Symbol**	**Model prediction**
Triennial survey abundance index i=1977,80,83,86,89,92,95,98,2001	Y_i^T	$\hat{Y}_i^T = q^T \sum_{j=3}^{x} s_{i,j}^T W_j N_{i,j}$
POP survey index i = 1979, 1985	Y_i^P	$\hat{Y}_i^P = q^P \sum_{j=3}^{x} s_{i,j}^{Sl} W_j N_{i,j}$
AFSC slope survey index i= 1992, 96, 97, 99, 2000, 2001	Y_i^A	$\hat{Y}_i^A = q^A \sum_{j=3}^{x} s_{i,j}^{Sl} W_j N_{i,j}$
NWFSC slope survey index i= 1999, 2000, 2001, 2002	Y_i^N	$\hat{Y}_i^N = q^N \sum_{j=3}^{x} s_{i,j}^N W_j N_{i,j}$
Historical CPUE index i = 1956, 1957, ... 1973	Y_i^f	$\hat{Y}_i^f = q^f \sum_{j=3}^{x} s_{i,j}^F W_j N_{i,j}$
Catch biomass i=1956, …, 2002	C_i	$\hat{C}_i = \sum_{j=3}^{x} W_j N_{i,j} \frac{F_{i,j}}{Z_{i,j}} (1 - e^{-Z_{i,j}})$
Proportions at age (fishery or survey)	$P_{i,j}^{F/S}$	$\hat{P}_{i,j}^l = \frac{\sum_{j'=3}^{x} N_{i,j} s_{i,j'}^{F/S} B_{j,j'}}{\sum_{j''=3}^{x} N_{i,j''} s_{i,j''}^{F/S}}$
Proportions at length (fishery or survey)	$L_{i,j}^{F/S}$	$\hat{L}_{i,j}^l = \frac{\sum_{j'=3}^{x} N_{i,j} s_{i,j'}^{F/S} A_{j',l}}{\sum_{j''=3}^{x} N_{i,j''} s_{i,j''}^{F/S}}$

(Table 11 Continued)

(e) Components of the objective function (data-related); *v* denotes the number of years for which each data-type is available.

Component	**Data type**
$L_1 = \tfrac{v}{2}\ln(\pi/\lambda_1) + \lambda_1 \sum_i \ln((C_i + 0.01^*)/(\hat{C}_i + 0.01))^2$	Catch biomass
$L_2 = \tfrac{1}{2}(v\ln(2\pi\tau^2) + \sum_i \ln(Y_i^f / \hat{Y}_i^f)^2 \tau^{-2})$	Cpue index
$L_3 = \tfrac{1}{2} \sum_{t=T,P,A,N} \sum_i \left(\ln(2\pi \ln(1 + (\tfrac{\sigma_i^t}{Y_i^t})^2)^2) + \dfrac{\ln(Y_i^t / \hat{Y}_i^t)^2}{\ln(1 + (\tfrac{\sigma_i^t}{Y_i^t})^2)^2} \right)$	Survey index (by survey type)
$L_5 = \tfrac{1}{2}\sum_{i,j} n_i^{F/S} \{\ln(\pi/\lambda_3) + \ln(\tfrac{0.1}{23} + \hat{P}_{i,j}^{F/S}(1 - \hat{P}_{i,j}^{F/S}))\} + \lambda_3 \sum_{i,j} \ln\left[\exp\left(\dfrac{n_i (P_{i,j}^{F/S} - \hat{P}_{i,j}^{F/S})^2}{2(\tfrac{0.1}{23} + \hat{P}_{i,j}^{F/S}(1 - \hat{P}_{i,j}^{F/S}))} \right) + 0.01 \right]^{**}$	Fishery and survey age data
$L_5 = \tfrac{1}{2}\sum_{i,j} m_i^{F/S} \{\ln(\pi/\lambda_3) + \ln(\tfrac{0.1}{24} + \hat{L}_{i,j}^{F/S}(1 - \hat{L}_{i,j}^{F/S}))\} + \lambda_3 \sum_{i,j} \ln\left[\exp\left(\dfrac{n_i (L_{i,j}^{F/S} - \hat{L}_{i,j}^{F/S})^2}{2(\tfrac{0.1}{24} + \hat{L}_{i,j}^{F/S}(1 - \hat{L}_{i,j}^{F/S}))} \right) + 0.01 \right]^{**}$	Fishery and survey size data

* constants added to avoid ln(0) or dividing by 0.

** This formulation is that of Fournier et al. (1990) which is different than that of Fournier et al (1998), as we use the expected proportions instead of the observed proportions for calculating the variance. This reflects the unused robust likelihood code in the 2000 assessment. Only a small difference exists between the results using this formulation and using that of Fournier et al. (1998). While the current formulation has been used in other stock assessments, we recommend investigating the two variance calculations in preparation for future West Coast Pacific ocean perch assessments.

(Table 11 Continued)

(f) Components of the objective function (priors)

Component	**Parameter**
$P_1 = \frac{n}{2}\ln(2\pi\sigma_R^2) + \sum_{i \geq 1935} \frac{(\xi_i - \rho\xi_{i-1})^2}{2(1-\rho^2)\sigma_R^2}$	Recruitment anomalies
$P_2 = 0.001\lambda_5 \sum_i \ln(\varepsilon_i^F)^2$	Fishing Mortality regularity
$P_{3a} = \lambda_6\lambda_{10} \sum_{w=T,Sl} \sum_j \ln\left(\frac{s_j^w s_{j+2}^w}{(s_{j+1}^w)^2}\right)^2$ $P_{3b} = \frac{\lambda_6\lambda_{10}}{9} \sum_k \sum_j \ln\left(\frac{s_{k,j}^F s_{k,j+2}^F}{(s_{k,j+1}^F)^2}\right)^2$ $P_{3c} = \lambda_6\lambda_8 \sum_k \sum_{j=3}^{a_m^s - 1} \min(0, \ln(s_{k,j}^F / s_{k,j+1}^F)^2$ $P_{3c} = \frac{\lambda_6\lambda_9}{g} \sum_{k=1}^{8} \sum_j \ln(s_{k-1,j}^F / s_{k,j}^F)^2$	Selectivity curvature penalty for survey selectivities Selectivity curvature penalty for fishery selectivities Penalty for fishery selectivity dome-shapedness Penalty for changes between groups of (*m*) years for fishery selectivity
$P_4 = \frac{\ln(2\pi)}{2} + \ln(0.1) + \frac{(\ln(M/0.05))^2}{0.02}$	Natural mortality

Table 12. Point estimates of the numbers at age (millions of fish) for the US west coast population of Pacific ocean perch (1956-2003) based on Model 1.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1956	3.90	6.94	5.58	4.56	3.84	3.35	3.02	2.80	2.65	2.54	2.43	2.32	2.21	2.11	2.01	1.91	1.82	1.74	1.65	1.58	1.51	1.44	32.34
1957	46.84	3.70	6.58	5.29	4.32	3.63	3.16	2.83	2.60	2.44	2.33	2.23	2.13	2.03	1.93	1.84	1.75	1.67	1.59	1.52	1.45	1.38	30.96
1958	4.41	44.43	3.51	6.24	5.01	4.08	3.42	2.95	2.62	2.38	2.23	2.12	2.03	1.94	1.85	1.76	1.68	1.60	1.52	1.45	1.38	1.32	29.50
1959	19.18	4.18	42.15	3.33	5.92	4.74	3.85	3.21	2.75	2.43	2.20	2.05	1.96	1.88	1.79	1.71	1.63	1.55	1.48	1.41	1.34	1.28	28.49
1960	9.26	18.20	3.97	39.97	3.15	5.60	4.47	3.61	2.99	2.54	2.22	2.02	1.89	1.80	1.73	1.65	1.57	1.50	1.42	1.36	1.29	1.23	27.32
1961	4.42	8.78	17.26	3.76	37.86	2.98	5.27	4.18	3.34	2.73	2.31	2.02	1.84	1.72	1.64	1.57	1.50	1.43	1.36	1.30	1.24	1.18	26.00
1962	3.82	4.19	8.33	16.36	3.56	35.69	2.79	4.86	3.79	2.97	2.40	2.03	1.78	1.62	1.51	1.45	1.39	1.32	1.26	1.20	1.14	1.09	23.95
1963	5.20	3.62	3.97	7.89	15.46	3.35	33.17	2.54	4.33	3.27	2.53	2.04	1.73	1.52	1.38	1.29	1.23	1.18	1.13	1.08	1.03	0.98	21.38
1964	15.43	4.93	3.44	3.76	7.45	14.50	3.09	30.05	2.24	3.66	2.70	2.09	1.71	1.45	1.27	1.16	1.08	1.03	0.99	0.94	0.90	0.86	18.72
1965	11.16	14.63	4.67	3.25	3.55	7.00	13.46	2.82	26.77	1.93	3.08	2.28	1.79	1.46	1.24	1.09	0.99	0.92	0.88	0.84	0.81	0.77	16.69
1966	7.29	10.59	13.87	4.43	3.07	3.33	6.45	12.11	2.46	22.23	1.56	2.50	1.88	1.47	1.20	1.02	0.89	0.81	0.76	0.72	0.69	0.66	14.35
1967	4.95	6.92	10.03	13.09	4.14	2.81	2.91	5.29	9.10	1.62	13.57	0.96	1.60	1.20	0.94	0.77	0.65	0.57	0.52	0.48	0.46	0.44	9.60
1968	3.64	4.70	6.55	9.46	12.24	3.79	2.47	2.41	4.02	6.09	1.01	8.56	0.63	1.04	0.78	0.61	0.50	0.42	0.37	0.34	0.32	0.30	6.54
1969	4.14	3.45	4.45	6.19	8.89	11.33	3.41	2.13	1.96	3.01	4.34	0.72	6.28	0.46	0.76	0.57	0.45	0.37	0.31	0.27	0.25	0.23	5.02
1970	2.98	3.93	3.28	4.22	5.86	8.39	10.63	3.16	1.94	1.75	2.69	3.91	0.66	5.74	0.42	0.70	0.52	0.41	0.33	0.28	0.25	0.23	4.80
1971	4.07	2.83	3.72	3.10	3.99	5.50	7.80	9.69	2.79	1.66	1.50	2.33	3.48	0.59	5.10	0.37	0.62	0.47	0.36	0.30	0.25	0.22	4.46
1972	5.33	3.86	2.68	3.53	2.93	3.75	5.14	7.16	8.66	2.43	1.44	1.32	2.10	3.12	0.53	4.58	0.34	0.56	0.42	0.33	0.27	0.23	4.21
1973	7.58	5.06	3.66	2.54	3.34	2.77	3.52	4.76	6.51	7.73	2.17	1.30	1.20	1.91	2.85	0.48	4.18	0.31	0.51	0.38	0.30	0.24	4.05
1974	4.10	7.19	4.79	3.47	2.40	3.15	2.59	3.24	4.27	5.70	6.76	1.92	1.17	1.09	1.73	2.57	0.43	3.77	0.28	0.46	0.34	0.27	3.87
1975	1.33	3.88	6.82	4.54	3.28	2.27	2.94	2.39	2.93	3.78	5.04	6.06	1.75	1.06	0.99	1.57	2.34	0.40	3.43	0.25	0.42	0.31	3.76
1976	1.15	1.26	3.68	6.47	4.30	3.09	2.11	2.70	2.17	2.64	3.43	4.61	5.60	1.61	0.98	0.91	1.45	2.16	0.37	3.17	0.23	0.39	3.77
1977	1.38	1.09	1.20	3.49	6.10	4.02	2.84	1.90	2.40	1.91	2.33	3.07	4.21	5.11	1.47	0.90	0.83	1.32	1.97	0.33	2.89	0.21	3.79
1978	1.81	1.31	1.03	1.13	3.30	5.73	3.73	2.60	1.71	2.15	1.71	2.12	2.83	3.87	4.70	1.36	0.83	0.77	1.22	1.81	0.31	2.66	3.68
1979	1.12	1.71	1.24	0.98	1.07	3.07	5.23	3.31	2.26	1.48	1.86	1.51	1.92	2.55	3.49	4.24	1.22	0.75	0.69	1.10	1.64	0.28	5.72
1980	0.88	1.06	1.62	1.17	0.92	1.00	2.81	4.67	2.90	1.96	1.29	1.65	1.37	1.73	2.31	3.16	3.84	1.11	0.67	0.63	0.99	1.48	5.43
1981	1.45	0.83	1.01	1.54	1.11	0.86	0.91	2.51	4.08	2.51	1.70	1.14	1.49	1.24	1.57	2.09	2.86	3.47	1.00	0.61	0.57	0.90	6.25
1982	2.76	1.38	0.79	0.96	1.45	1.04	0.80	0.83	2.28	3.70	2.28	1.54	1.02	1.34	1.11	1.41	1.87	2.57	3.12	0.90	0.55	0.51	6.41
1983	2.18	2.62	1.31	0.75	0.91	1.37	0.97	0.74	0.77	2.09	3.40	2.09	1.40	0.93	1.22	1.01	1.28	1.70	2.33	2.83	0.82	0.50	6.30
1984	5.18	2.07	2.48	1.24	0.70	0.85	1.26	0.88	0.66	0.68	1.86	3.02	1.83	1.23	0.81	1.07	0.89	1.12	1.49	2.05	2.48	0.72	5.96
1985	1.02	4.91	1.97	2.35	1.17	0.66	0.78	1.15	0.79	0.59	0.61	1.66	2.66	1.61	1.08	0.72	0.94	0.78	0.99	1.32	1.80	2.19	5.88
1986	1.19	0.96	4.66	1.86	2.22	1.10	0.61	0.71	1.03	0.70	0.53	0.55	1.47	2.35	1.42	0.95	0.63	0.83	0.69	0.87	1.16	1.59	7.11
1987	2.13	1.13	0.91	4.41	1.76	2.09	1.02	0.55	0.64	0.92	0.63	0.47	0.48	1.29	2.07	1.25	0.84	0.56	0.73	0.61	0.77	1.02	7.68
1988	4.80	2.02	1.07	0.87	4.17	1.65	1.93	0.92	0.50	0.57	0.83	0.57	0.42	0.43	1.16	1.85	1.12	0.75	0.50	0.65	0.54	0.69	7.79
1989	0.74	4.55	1.92	1.01	0.82	3.89	1.51	1.73	0.82	0.44	0.50	0.73	0.50	0.37	0.38	1.02	1.62	0.98	0.66	0.44	0.57	0.48	7.43
1990	2.65	0.71	4.31	1.82	0.96	0.76	3.56	1.35	1.52	0.71	0.38	0.44	0.63	0.43	0.32	0.33	0.88	1.41	0.86	0.58	0.38	0.50	6.89
1991	3.13	2.51	0.67	4.09	1.71	0.90	0.70	3.23	1.21	1.36	0.64	0.34	0.39	0.56	0.38	0.29	0.29	0.79	1.26	0.76	0.51	0.34	6.57
1992	1.38	2.97	2.38	0.63	3.85	1.60	0.82	0.63	2.82	1.05	1.18	0.56	0.30	0.34	0.49	0.33	0.25	0.25	0.68	1.09	0.66	0.44	5.99
1993	6.30	1.31	2.82	2.25	0.60	3.60	1.47	0.74	0.55	2.49	0.93	1.04	0.49	0.26	0.30	0.43	0.29	0.22	0.22	0.60	0.96	0.58	5.65
1994	2.15	5.98	1.24	2.67	2.11	0.55	3.19	1.27	0.63	0.47	2.14	0.81	0.91	0.43	0.23	0.26	0.38	0.26	0.19	0.20	0.52	0.84	5.46
1995	1.65	2.04	5.67	1.17	2.51	1.95	0.49	2.80	1.10	0.55	0.42	1.89	0.72	0.81	0.38	0.20	0.23	0.33	0.23	0.17	0.17	0.47	5.59
1996	0.66	1.56	1.93	5.37	1.10	2.33	1.77	0.44	2.47	0.97	0.48	0.37	1.70	0.64	0.73	0.34	0.18	0.21	0.30	0.20	0.15	0.16	5.44
1997	5.06	0.62	1.48	1.83	5.05	1.02	2.11	1.58	0.39	2.19	0.87	0.43	0.33	1.53	0.58	0.66	0.31	0.16	0.19	0.27	0.18	0.14	5.03
1998	4.28	4.80	0.59	1.40	1.73	4.71	0.94	1.91	1.41	0.35	1.97	0.78	0.39	0.30	1.39	0.53	0.60	0.28	0.15	0.17	0.25	0.17	4.70
1999	0.67	4.06	4.56	0.56	1.32	1.61	4.33	0.85	1.71	1.27	0.31	1.79	0.71	0.36	0.28	1.27	0.48	0.54	0.25	0.14	0.16	0.22	4.44
2000	0.80	0.64	3.85	4.32	0.53	1.24	1.49	3.95	0.77	1.56	1.16	0.29	1.65	0.66	0.33	0.25	1.16	0.44	0.50	0.23	0.13	0.14	4.29
2001	1.89	0.76	0.60	3.65	4.09	0.50	1.17	1.40	3.70	0.72	1.46	1.09	0.27	1.55	0.62	0.31	0.24	1.10	0.42	0.47	0.22	0.12	4.17
2002	2.46	1.79	0.72	0.57	3.45	3.85	0.47	1.09	1.30	3.44	0.67	1.36	1.02	0.25	1.45	0.58	0.29	0.22	1.02	0.39	0.44	0.21	4.01
2003	2.46	2.34	1.70	0.68	0.54	3.26	3.62	0.44	1.02	1.21	3.21	0.63	1.28	0.96	0.24	1.36	0.54	0.27	0.21	0.96	0.36	0.41	3.95

Table 13. Point estimates of the catch-at-age (millions of fish) for the US west coast population of Pacific ocean perch (1956-2002) based on Model 1.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1956	0.000	0.001	0.002	0.005	0.011	0.021	0.035	0.053	0.070	0.080	0.080	0.077	0.073	0.070	0.067	0.063	0.060	0.058	0.055	0.052	0.050	0.048	1.073
1957	0.003	0.001	0.003	0.007	0.015	0.027	0.044	0.065	0.086	0.095	0.090	0.083	0.079	0.076	0.072	0.069	0.065	0.062	0.059	0.057	0.054	0.052	1.157
1958	0.000	0.006	0.001	0.006	0.011	0.020	0.032	0.046	0.058	0.062	0.058	0.054	0.051	0.049	0.047	0.045	0.042	0.040	0.038	0.037	0.035	0.033	0.745
1959	0.001	0.001	0.019	0.004	0.017	0.030	0.046	0.063	0.077	0.080	0.072	0.065	0.062	0.060	0.057	0.054	0.052	0.049	0.047	0.045	0.043	0.041	0.905
1960	0.001	0.004	0.002	0.059	0.011	0.043	0.065	0.087	0.103	0.103	0.090	0.079	0.074	0.070	0.067	0.064	0.061	0.058	0.056	0.053	0.050	0.048	1.066
1961	0.001	0.003	0.017	0.010	0.243	0.041	0.137	0.179	0.204	0.196	0.165	0.140	0.127	0.119	0.113	0.109	0.103	0.099	0.094	0.090	0.085	0.081	1.795
1962	0.001	0.002	0.012	0.062	0.033	0.706	0.104	0.297	0.327	0.301	0.242	0.198	0.174	0.158	0.148	0.141	0.135	0.129	0.123	0.117	0.112	0.106	2.339
1963	0.001	0.002	0.007	0.037	0.177	0.082	1.457	0.177	0.461	0.417	0.312	0.234	0.199	0.175	0.158	0.148	0.142	0.136	0.129	0.123	0.118	0.112	2.451
1964	0.003	0.003	0.005	0.015	0.073	0.303	0.116	1.788	0.205	0.401	0.287	0.206	0.168	0.143	0.126	0.114	0.107	0.102	0.098	0.093	0.089	0.085	1.843
1965	0.003	0.010	0.009	0.017	0.047	0.196	0.677	0.224	3.253	0.279	0.433	0.298	0.233	0.191	0.162	0.142	0.129	0.120	0.115	0.110	0.105	0.100	2.180
1966	0.005	0.020	0.075	0.064	0.109	0.249	0.850	2.455	0.733	7.740	0.527	0.794	0.596	0.466	0.381	0.323	0.284	0.258	0.241	0.230	0.220	0.210	4.559
1967	0.003	0.013	0.052	0.181	0.141	0.201	0.368	1.030	2.612	0.544	4.435	0.295	0.489	0.367	0.287	0.235	0.199	0.175	0.159	0.148	0.142	0.136	2.939
1968	0.002	0.006	0.023	0.089	0.285	0.187	0.217	0.330	0.828	1.483	0.239	1.888	0.138	0.230	0.172	0.135	0.110	0.093	0.082	0.074	0.070	0.067	1.443
1969	0.000	0.001	0.004	0.014	0.048	0.127	0.076	0.083	0.112	0.171	0.207	0.026	0.227	0.017	0.028	0.021	0.016	0.013	0.011	0.010	0.009	0.008	0.181
1970	0.000	0.002	0.005	0.017	0.056	0.164	0.411	0.214	0.190	0.171	0.221	0.245	0.041	0.359	0.026	0.044	0.033	0.026	0.021	0.018	0.016	0.014	0.300
1971	0.001	0.001	0.004	0.010	0.031	0.088	0.247	0.541	0.226	0.134	0.101	0.120	0.179	0.030	0.262	0.019	0.032	0.024	0.019	0.015	0.013	0.011	0.230
1972	0.000	0.001	0.002	0.008	0.016	0.043	0.117	0.287	0.504	0.141	0.070	0.049	0.077	0.115	0.019	0.169	0.012	0.021	0.015	0.012	0.010	0.008	0.155
1973	0.001	0.002	0.004	0.008	0.024	0.041	0.104	0.248	0.491	0.582	0.137	0.062	0.058	0.092	0.137	0.023	0.200	0.015	0.024	0.018	0.014	0.012	0.194
1974	0.000	0.002	0.005	0.009	0.015	0.040	0.066	0.145	0.279	0.371	0.370	0.080	0.048	0.045	0.071	0.106	0.018	0.156	0.011	0.019	0.014	0.011	0.160
1975	0.000	0.001	0.007	0.015	0.029	0.044	0.094	0.102	0.139	0.169	0.180	0.151	0.044	0.027	0.025	0.039	0.058	0.010	0.085	0.006	0.010	0.008	0.094
1976	0.000	0.001	0.006	0.032	0.058	0.090	0.101	0.173	0.154	0.177	0.183	0.173	0.210	0.061	0.037	0.034	0.054	0.081	0.014	0.119	0.009	0.014	0.141
1977	0.000	0.000	0.001	0.013	0.062	0.088	0.103	0.092	0.129	0.097	0.095	0.087	0.119	0.145	0.042	0.025	0.024	0.038	0.056	0.009	0.082	0.006	0.108
1978	0.000	0.001	0.002	0.007	0.057	0.213	0.228	0.211	0.155	0.183	0.117	0.102	0.136	0.186	0.226	0.065	0.040	0.037	0.058	0.087	0.015	0.128	0.177
1979	0.000	0.001	0.002	0.006	0.017	0.106	0.297	0.251	0.190	0.117	0.118	0.067	0.085	0.114	0.156	0.189	0.055	0.033	0.031	0.049	0.073	0.012	0.255
1980	0.000	0.001	0.003	0.007	0.015	0.035	0.164	0.363	0.250	0.159	0.084	0.076	0.063	0.079	0.106	0.145	0.176	0.051	0.031	0.029	0.046	0.068	0.249
1981	0.000	0.000	0.001	0.005	0.009	0.017	0.030	0.105	0.172	0.105	0.075	0.060	0.079	0.066	0.083	0.111	0.152	0.184	0.053	0.032	0.030	0.048	0.331
1982	0.000	0.000	0.001	0.002	0.009	0.015	0.020	0.026	0.073	0.117	0.076	0.062	0.041	0.054	0.045	0.057	0.075	0.103	0.126	0.036	0.022	0.020	0.258
1983	0.000	0.001	0.002	0.003	0.011	0.037	0.045	0.043	0.045	0.122	0.210	0.155	0.104	0.069	0.090	0.075	0.095	0.126	0.173	0.210	0.061	0.037	0.466
1984	0.001	0.001	0.003	0.005	0.008	0.022	0.056	0.048	0.037	0.038	0.109	0.211	0.128	0.086	0.057	0.075	0.062	0.078	0.105	0.143	0.174	0.050	0.417
1985	0.000	0.002	0.003	0.010	0.013	0.017	0.034	0.062	0.043	0.032	0.035	0.114	0.182	0.110	0.074	0.049	0.064	0.053	0.068	0.090	0.123	0.150	0.402
1986	0.000	0.000	0.006	0.008	0.024	0.027	0.026	0.038	0.055	0.038	0.030	0.037	0.099	0.159	0.096	0.065	0.043	0.056	0.047	0.059	0.078	0.107	0.481
1987	0.000	0.000	0.001	0.018	0.020	0.050	0.040	0.028	0.034	0.049	0.033	0.027	0.027	0.073	0.116	0.070	0.047	0.031	0.041	0.034	0.043	0.057	0.431
1988	0.001	0.001	0.002	0.005	0.061	0.052	0.101	0.062	0.035	0.040	0.057	0.042	0.031	0.032	0.085	0.136	0.082	0.055	0.037	0.048	0.040	0.050	0.571
1989	0.000	0.003	0.004	0.006	0.013	0.133	0.086	0.126	0.062	0.033	0.038	0.058	0.040	0.030	0.030	0.081	0.130	0.078	0.053	0.035	0.046	0.038	0.593
1990	0.000	0.000	0.006	0.008	0.012	0.020	0.154	0.075	0.088	0.041	0.022	0.027	0.038	0.026	0.020	0.020	0.054	0.086	0.052	0.035	0.023	0.030	0.418
1991	0.001	0.002	0.001	0.026	0.029	0.032	0.042	0.250	0.098	0.108	0.051	0.029	0.033	0.048	0.033	0.024	0.025	0.067	0.106	0.064	0.043	0.029	0.556
1992	0.000	0.002	0.004	0.003	0.055	0.049	0.042	0.041	0.194	0.071	0.080	0.040	0.021	0.024	0.035	0.024	0.018	0.018	0.049	0.078	0.047	0.032	0.430
1993	0.001	0.001	0.008	0.024	0.019	0.227	0.131	0.073	0.053	0.226	0.078	0.079	0.037	0.020	0.023	0.032	0.022	0.017	0.017	0.045	0.073	0.044	0.428
1994	0.000	0.004	0.003	0.023	0.054	0.028	0.233	0.103	0.049	0.035	0.146	0.050	0.056	0.026	0.014	0.016	0.023	0.016	0.012	0.012	0.032	0.052	0.337
1995	0.000	0.001	0.012	0.008	0.054	0.085	0.030	0.193	0.073	0.034	0.024	0.098	0.037	0.042	0.020	0.011	0.012	0.017	0.012	0.009	0.009	0.024	0.291
1996	0.000	0.001	0.004	0.038	0.023	0.099	0.107	0.030	0.161	0.060	0.027	0.019	0.086	0.033	0.037	0.017	0.009	0.011	0.015	0.010	0.008	0.008	0.277
1997	0.001	0.000	0.002	0.010	0.083	0.034	0.100	0.083	0.020	0.105	0.038	0.017	0.013	0.061	0.023	0.026	0.012	0.007	0.007	0.011	0.007	0.005	0.201
1998	0.000	0.002	0.001	0.007	0.027	0.150	0.043	0.097	0.070	0.016	0.084	0.030	0.015	0.012	0.053	0.020	0.023	0.011	0.006	0.007	0.009	0.006	0.181
1999	0.000	0.001	0.006	0.003	0.017	0.040	0.159	0.036	0.071	0.050	0.011	0.052	0.021	0.010	0.008	0.037	0.014	0.016	0.007	0.004	0.005	0.007	0.129
2000	0.000	0.000	0.001	0.006	0.002	0.009	0.015	0.047	0.009	0.017	0.011	0.002	0.014	0.005	0.003	0.002	0.010	0.004	0.004	0.002	0.001	0.001	0.035
2001	0.000	0.000	0.000	0.008	0.026	0.006	0.021	0.029	0.076	0.014	0.025	0.016	0.004	0.022	0.009	0.004	0.003	0.016	0.006	0.007	0.003	0.002	0.060
2002	0.000	0.000	0.000	0.001	0.016	0.035	0.006	0.017	0.020	0.050	0.009	0.015	0.011	0.003	0.016	0.006	0.003	0.002	0.011	0.004	0.005	0.002	0.044

Table 14: Estimates of model parameters, output statistics and fit diagnostics for Model 1 and for the 17 tests of sensitivity.

Derived Quantities of Interest	Model 1	Model 1b	Model 1c	Model 1d	Model 1e	Model 1f	Model 1g	Model 1h	Model 1i	Model 1j	Model 1k
Depletion	0.253	0.249	0.272	0.298	0.253	0.214	0.255	0.237	0.279	0.233	0.242
2003 spawning biomass	9,946	9,754	10,262	9,467	10,114	10,152	10,516	10,054	11,097	8,573	10,249
Unfished spawning biomass	39,291	39,133	37,670	31,767	39,906	47,388	41,172	42,464	39,835	36,789	42,305
B_{MSY}	13,516	13,476	10,511	8,638	15,841	17,750	15,327	14,936	12,831	11,775	13,878
MSY	1,172	1,159	1,507	1,267	822	1,115	1,129	1,238	1,355	1,238	1,406
MSYL	0.344	0.344	0.279	0.272	0.397	0.375	0.372	0.352	0.322	0.320	0.328
F_{MSY}	0.035	0.034	0.056	0.057	0.021	0.026	0.029	0.033	0.042	0.037	0.040
F_{2002}/F_{MSY}	0.284	0.291	0.170	0.180	0.458	0.377	0.315	0.289	0.212	0.264	0.238
Likelihoods											
Objective function	279.19	280.50	282.06	273.99	269.08	273.29	279.66	308.77	270.04	279.49	281.98
Triennial survey biomass likelihood	36.15	36.21	36.21	36.04	36.41	36.42	36.00	36.38	36.68	36.15	36.64
POP survey biomass likelihood	0.16	0.14	0.21	0.15	0.21	0.06	0.15	0.14	0.22	0.17	0.21
AFSC survey biomass likelihood	26.65	26.58	26.90	26.58	26.64	26.58	26.60	26.47	26.87	26.72	26.85
NWFSC survey biomass likelihood	3.26	3.26	3.21	3.24	3.28	3.24	3.31	3.10	3.10	3.25	3.25
CPUE likelihood	12.13	12.08	11.98	11.05	12.57	8.34	12.57	8.18	12.02	12.11	12.09
Triennial survey age likelihood	-33.09	-33.10	-32.82	-31.56	-32.10	-34.31	-32.93	-31.87	-37.29	-33.01	-30.73
POP/slope survey age likelihood	9.61	9.63	9.86	10.28	9.45	7.34	9.83	10.91	6.96	9.63	10.10
Fishery biased age likelihood	53.24	53.24	53.00	51.89	53.80	53.32	53.04	74.71	54.38	53.29	49.89
Fishery unbiased age likelihood	19.55	19.56	19.48	19.49	19.52	18.50	19.64	20.90	19.74	19.53	20.74
Triennial survey size likelihood	39.92	39.97	39.69	40.25	40.53	36.53	40.23	40.06	31.27	39.84	40.70
POP/slope survey size likelihood	39.57	39.44	39.64	39.62	40.01	39.80	39.50	38.81	37.73	39.60	41.11
Fishery size likelihood	31.43	31.43	31.52	32.44	31.12	31.62	31.63	47.09	29.95	31.41	32.38
Priors											
Catch fit prior	0.23	0.23	0.21	0.25	0.20	0.15	0.24	0.13	0.23	0.22	0.20
Fdevs prior	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fishery selectivity dome prior	6.69	6.70	6.48	5.45	7.07	10.76	6.41	0.00	9.17	6.72	7.88
Fishery selectivity time change prior	8.77	8.76	8.77	8.88	9.02	12.58	8.76	0.00	14.33	8.75	8.89
Fishery selectivity curvature prior	6.65	6.64	6.60	6.29	6.72	6.39	6.65	15.62	9.16	6.65	6.60
Survey selectivity curvature prior	2.14	2.23	2.14	2.21	2.17	2.23	2.08	1.96	0.06	2.13	2.44
Rho/SigmaR sp-rec prior	17.40	17.46	17.79	12.82	3.54	15.08	16.38	17.33	16.72	17.61	13.88
Natural mortality prior	-1.25	-1.28	-1.34	-1.38	-1.09	-1.36	-0.43	-1.15	-1.25	-1.27	-1.14
Steepness prior	0.00	0.00	2.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Catchability prior	0.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parameters											
Natural mortality	0.053	0.052	0.052	0.050	0.054	0.051	0.059	0.054	0.053	0.052	0.054
Steepness	0.532	0.531	0.714	0.734	0.396	0.449	0.457	0.508	0.593	0.586	0.577
Rho	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sigma R	1.000	1.000	1.000	1.000	0.760	1.000	1.000	1.000	1.000	1.000	1.000
Triennial survey catchability	0.253	0.258	0.250	0.267	0.246	0.245	0.233	0.251	0.233	0.252	0.239
POP survey catchability	0.454	0.466	0.456	0.476	0.447	0.456	0.416	0.439	0.337	0.454	0.442
NWFSC survey catchability	0.211	0.219	0.206	0.224	0.207	0.212	0.196	0.207	0.142	0.210	0.204
AFSC survey catchability	0.271	0.280	0.267	0.287	0.264	0.273	0.250	0.272	0.192	0.270	0.261

Table 14 (continued): Estimates of model parameters, output statistics and fit diagnostics for Model 1 and for the 17 tests of sensitivity.

Derived Quantities of Interest	Model 1	Model 1l	Model 1m	Model 1n	Model 1o	Model 1p	Model 1q	Model 1r	Model 1 posterior median
Depletion	0.253	0.238	0.288	0.084	0.258	0.288	0.252	0.243	0.274
2003 spawning biomass	9,946	9,298	11,159	3,073	10,150	11,445	9,910	10,332	10,231
Unfished spawning biomass	39,291	39,131	38,806	36,381	39,304	39,732	39,402	42,473	37,269
B_{MSY}	13,516	13,323	10,774	15,200	13,390	12,794	13,705	15,040	
MSY	1,172	1,208	1,647	598	1,194	1,334	1,150	1,199	
MSYL	0.344	0.340	0.278	0.418	0.341	0.322	0.348	0.354	
F_{MSY}	0.035	0.036	0.061	0.016	0.036	0.041	0.034	0.032	
F_{2002}/F_{MSY}	0.284	0.368	0.101	1.983	0.271	0.207	0.294	0.296	
Likelihoods									
Objective function	279.19	268.84	262.74	236.04	279.00	251.92	275.91	264.60	
Triennial survey biomass likelihood	36.15	36.75	25.62	0.00	36.12	35.63	36.04	35.93	
POP survey biomass likelihood	0.16	0.05	0.10	0.09	0.00	0.22	0.15	0.20	
AFSC survey biomass likelihood	26.65	26.94	28.85	21.77	26.72	0.00	26.65	26.76	
NWFSC survey biomass likelihood	3.26	3.23	0.02	3.69	3.24	3.25	0.00	3.28	
CPUE likelihood	12.13	12.01	11.73	11.06	12.16	12.32	12.17	0.00	
Triennial survey age likelihood	-33.09	-33.86	-19.20	-31.68	-33.03	-32.55	-33.12	-33.10	
POP/slope survey age likelihood	9.61	6.80	6.42	10.17	9.58	9.50	9.50	10.22	
Fishery biased age likelihood	53.24	53.45	54.00	53.73	53.12	53.35	53.23	50.82	
Fishery unbiased age likelihood	19.55	12.92	8.90	19.44	19.53	19.61	19.56	19.44	
Triennial survey size likelihood	39.92	38.36	36.51	36.82	40.01	39.39	40.02	40.05	
POP/slope survey size likelihood	39.57	39.37	37.96	39.99	39.80	39.27	39.46	39.63	
Fishery size likelihood	31.43	31.49	31.47	30.36	31.40	31.42	31.50	31.73	
Priors									
Catch fit prior	0.23	0.22	0.21	0.15	0.21	0.20	0.23	0.09	
Fdevs prior	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Fishery selectivity dome prior	6.69	6.67	6.63	7.21	6.61	6.67	6.69	5.61	
Fishery selectivity time change prior	8.77	8.84	8.89	8.62	8.78	8.71	8.80	10.07	
Fishery selectivity curvature prior	6.65	6.81	7.03	6.34	6.64	6.65	6.66	6.28	
Survey selectivity curvature prior	2.14	2.62	2.05	2.04	2.00	2.20	2.24	2.20	
Rho/SigmaR sp-rec prior	17.40	17.39	16.78	17.46	17.36	17.37	17.39	16.57	
Natural mortality prior	-1.25	-1.23	-1.22	-1.21	-1.26	-1.28	-1.23	-1.19	
Steepness prior	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Catchability prior	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Parameters									
Natural mortality	0.053	0.053	0.053	0.053	0.053	0.052	0.053	0.053	.054
Steepness	0.532	0.543	0.723	0.348	0.541	0.593	0.521	0.504	0.532
Rho	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Sigma R	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Triennial survey catchability	0.253	0.254	0.247	0.366	0.249	0.232	0.253	0.246	0.247
POP survey catchability	0.454	0.502	0.495	0.580	0.465	0.448	0.459	0.444	0.438
NWFSC survey catchability	0.211	0.224	0.129	0.621	0.204	0.188	0.160	0.204	0.203
AFSC survey catchability	0.271	0.290	0.242	0.612	0.262	0.380	0.273	0.262	0.265

Table 15. MPD and Posterior median estimates for spawning biomass and recruitment.

	MPD estimates		Posterior Medians	
Year	SpBiomass	Recruits	SpBiomass	Recruits
1956	35,119	3.90	32,727	6.90
1957	33,896	46.84	31,637	39.17
1958	32,733	4.41	30,548	7.49
1959	32,215	19.18	30,259	16.28
1960	31,789	9.26	30,160	9.69
1961	31,817	4.42	30,852	4.10
1962	33,501	3.82	32,637	3.70
1963	35,107	5.20	34,128	4.92
1964	34,744	15.43	33,978	16.32
1965	34,427	11.16	33,607	11.15
1966	31,909	7.29	31,138	7.43
1967	23,135	4.95	22,360	4.94
1968	17,328	3.64	16,636	3.75
1969	15,549	4.14	14,933	4.04
1970	17,377	2.98	16,853	2.94
1971	18,321	4.07	17,862	4.29
1972	18,779	5.33	18,389	5.00
1973	18,995	7.58	18,670	8.32
1974	18,695	4.10	18,420	3.87
1975	18,446	1.33	18,232	1.32
1976	18,501	1.15	18,313	1.12
1977	18,459	1.38	18,315	1.31
1978	18,847	1.81	18,772	1.72
1979	18,680	1.12	18,648	1.09
1980	18,097	0.88	18,099	0.87
1981	17,154	1.45	17,201	1.64
1982	16,238	2.76	16,305	1.88
1983	15,567	2.18	15,646	2.15
1984	14,384	5.18	14,471	5.38
1985	13,285	1.02	13,380	0.92
1986	12,317	1.19	12,435	1.14
1987	11,581	2.13	11,671	2.13
1988	11,166	4.80	11,196	4.70
1989	10,762	0.74	10,794	0.71
1990	10,283	2.65	10,331	2.66
1991	9,813	3.13	9,859	3.12
1992	9,190	1.38	9,239	1.42
1993	8,965	6.30	8,995	6.60
1994	8,629	2.15	8,664	2.21
1995	8,342	1.65	8,362	1.64
1996	8,259	0.66	8,272	0.65
1997	8,218	5.06	8,234	5.39
1998	8,468	4.28	8,517	4.51
1999	8,776	0.67	8,890	0.68
2000	8,872	0.80	9,022	0.78
2001	9,052	1.89	9,210	1.90
2002	9,372	2.46	9,592	2.16
2003	9,946	2.46	10,241	2.16

1.7. Figures

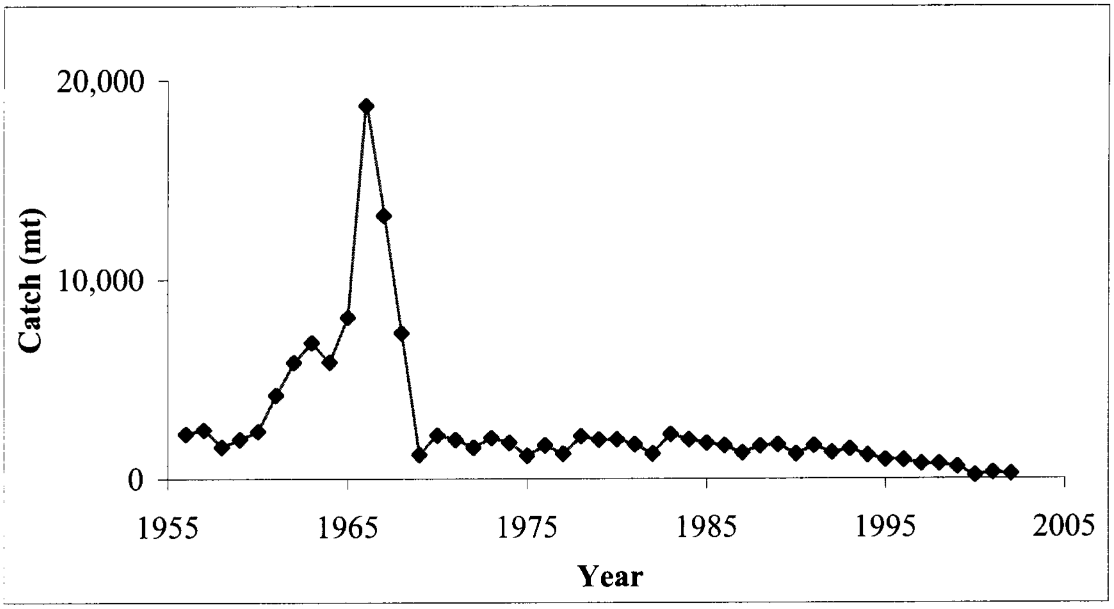


Figure 1. Catch history of Pacific ocean perch (domestic and foreign fleets combined).

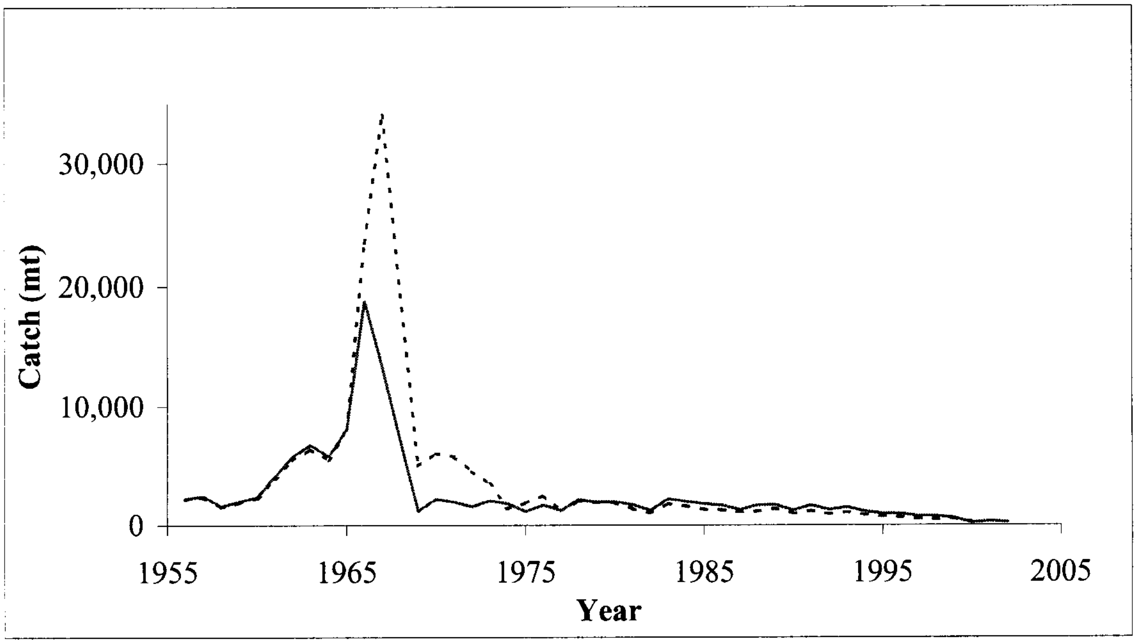


Figure 2. Pacific ocean perch catch data used in the 2000 (dotted line) and the 2003 (solid line) assessments.

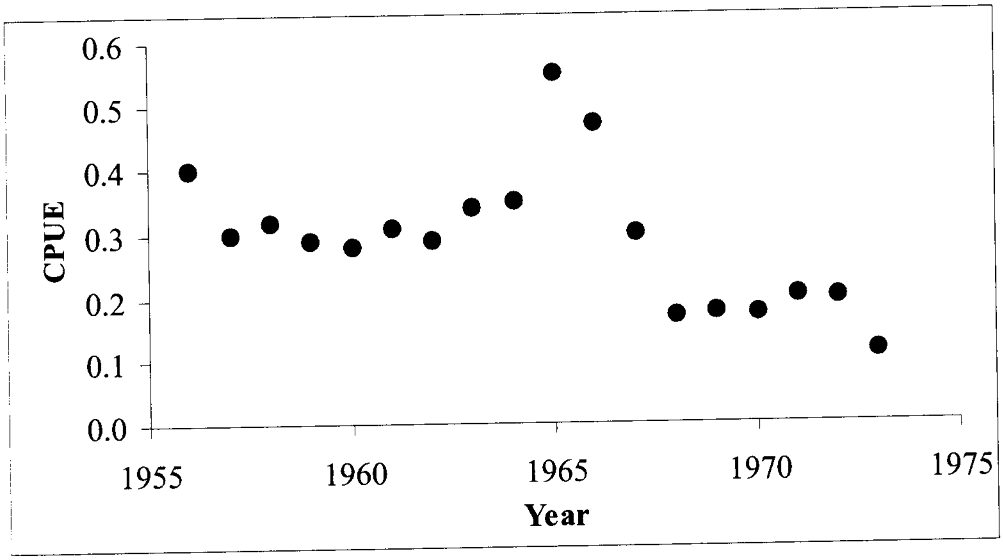
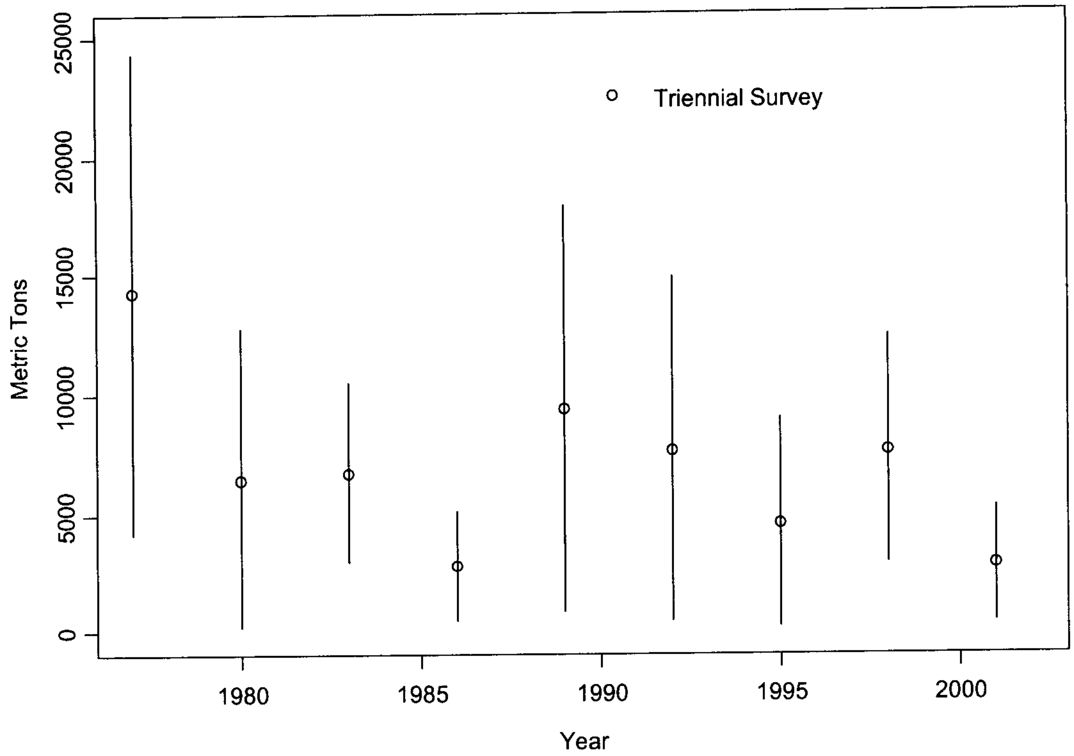


Figure 3. Pacific ocean perch catch-per-unit-of-effort data for the domestic fishery in the US-Vancouver and Columbia INPFC areas combined



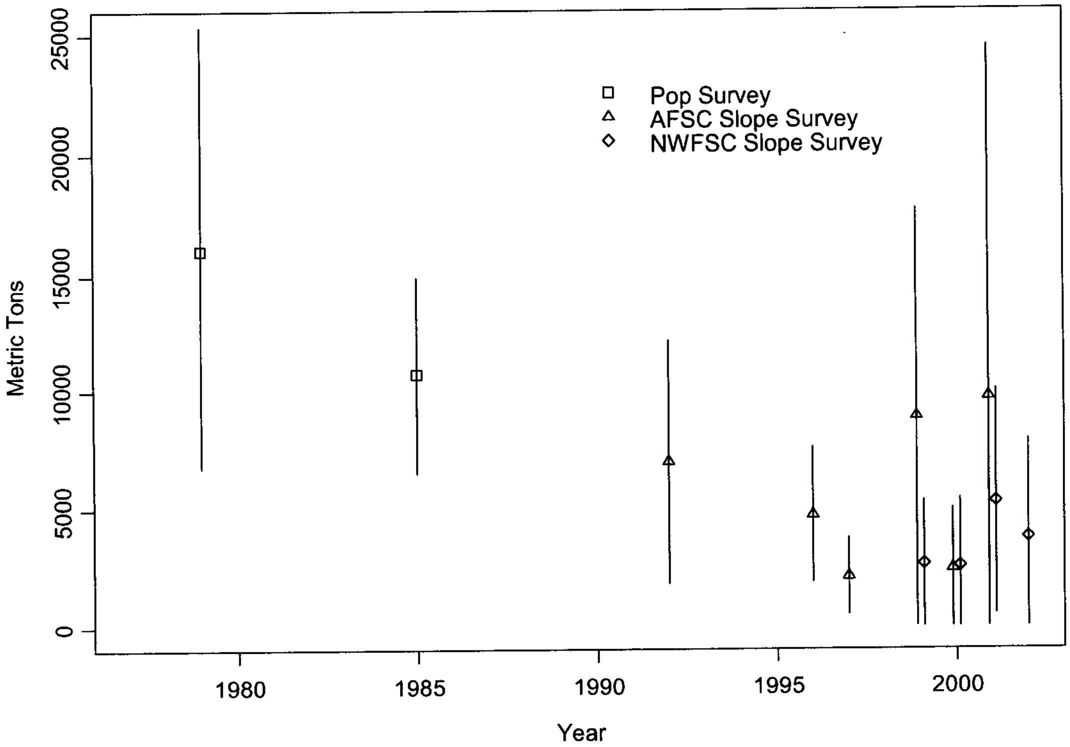


Figure 4. Survey biomass indices with their associated 95% confidence intervals for Pacific ocean perch (1977-2002)

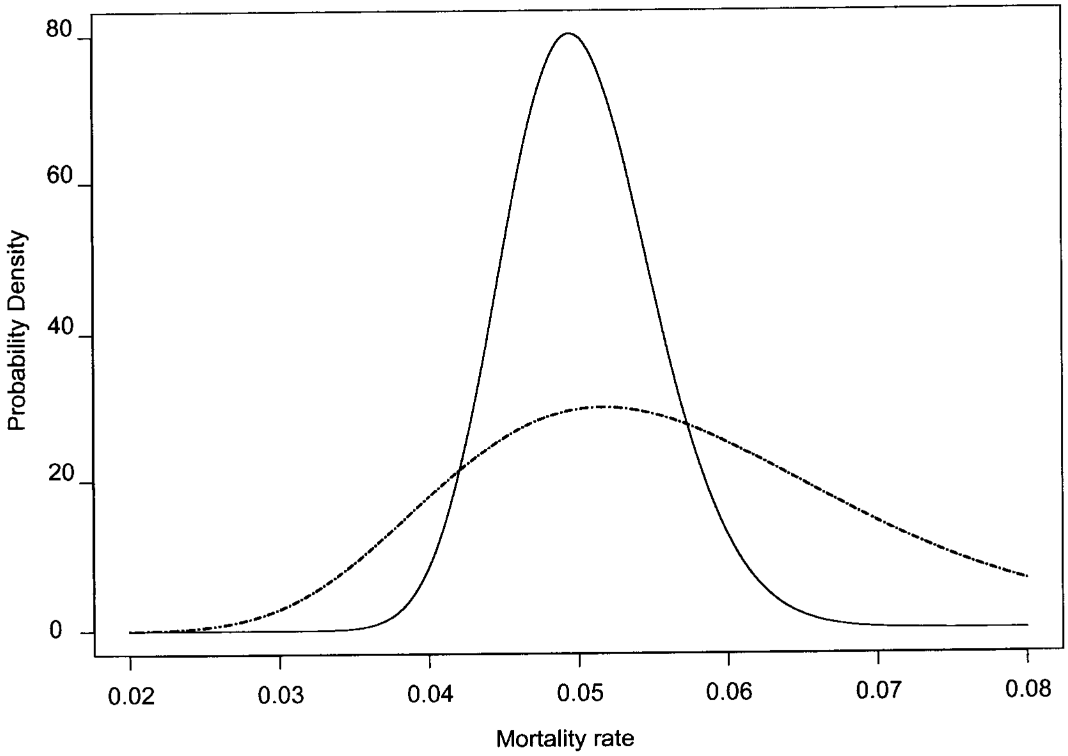


Figure 5. Base-case prior distribution assumed for natural mortality (solid line) and the alternative (diffuse) prior (dashed line).

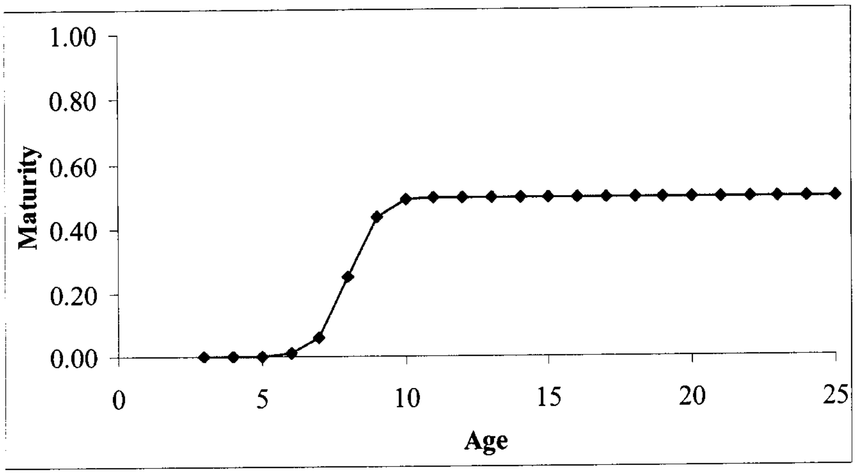


Figure 6. Modeled proportion of Pacific ocean perch that are mature females by age.

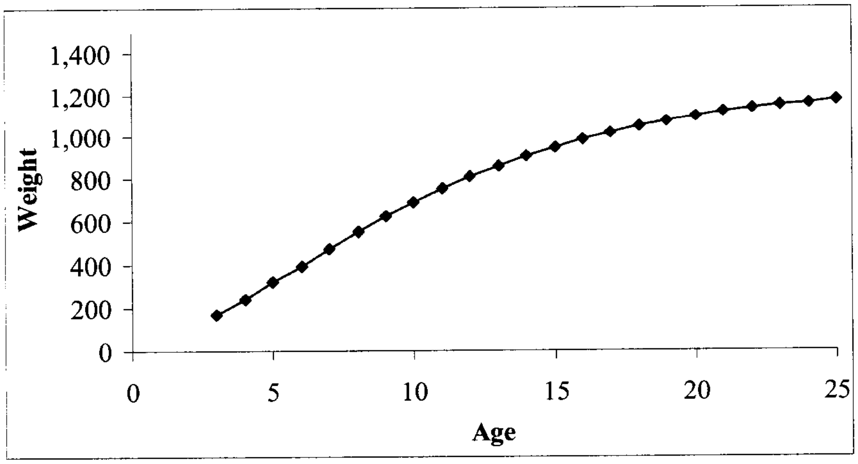


Figure 7. Weight at age (grams) for Pacific ocean perch used in the assessment model.

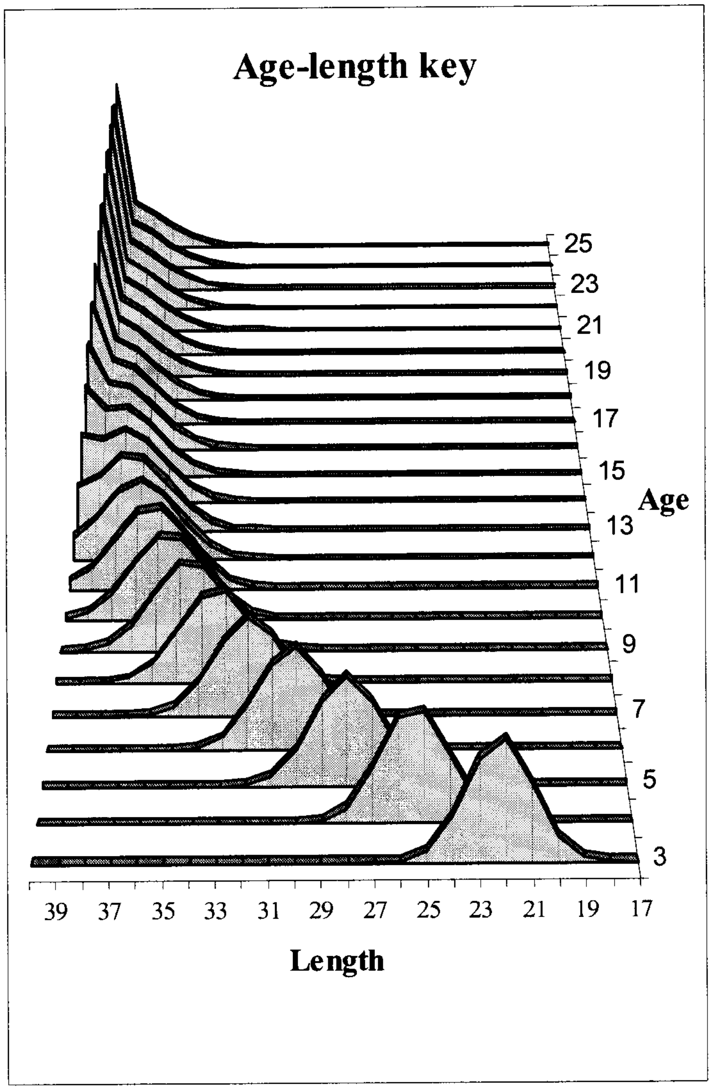


Figure 8. Length distributions by age used in the age-length transition matrix.

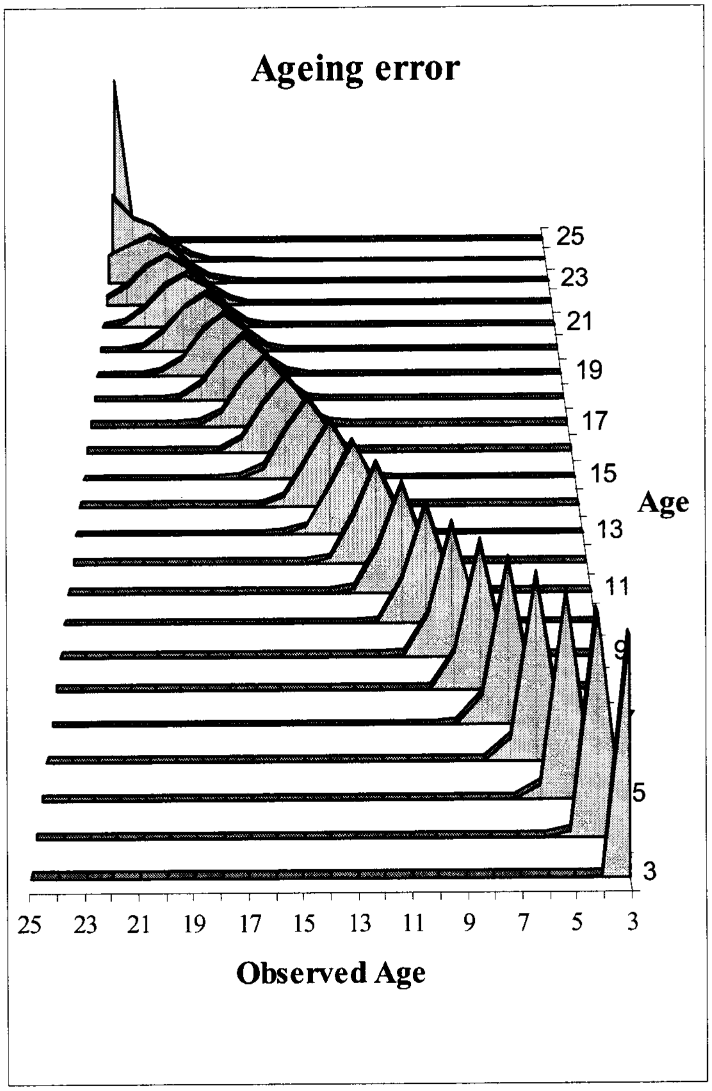


Figure 9. Assumed relationship between observed age and true age used as an ageing error matrix.

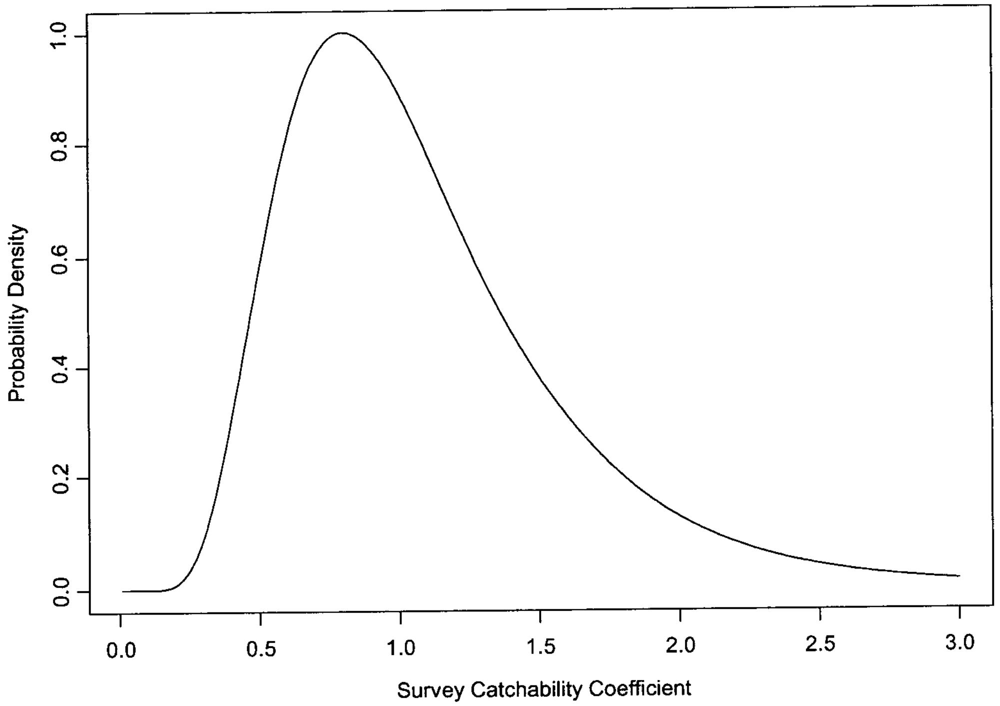


Figure 10. Alternative informative prior for survey catchability.

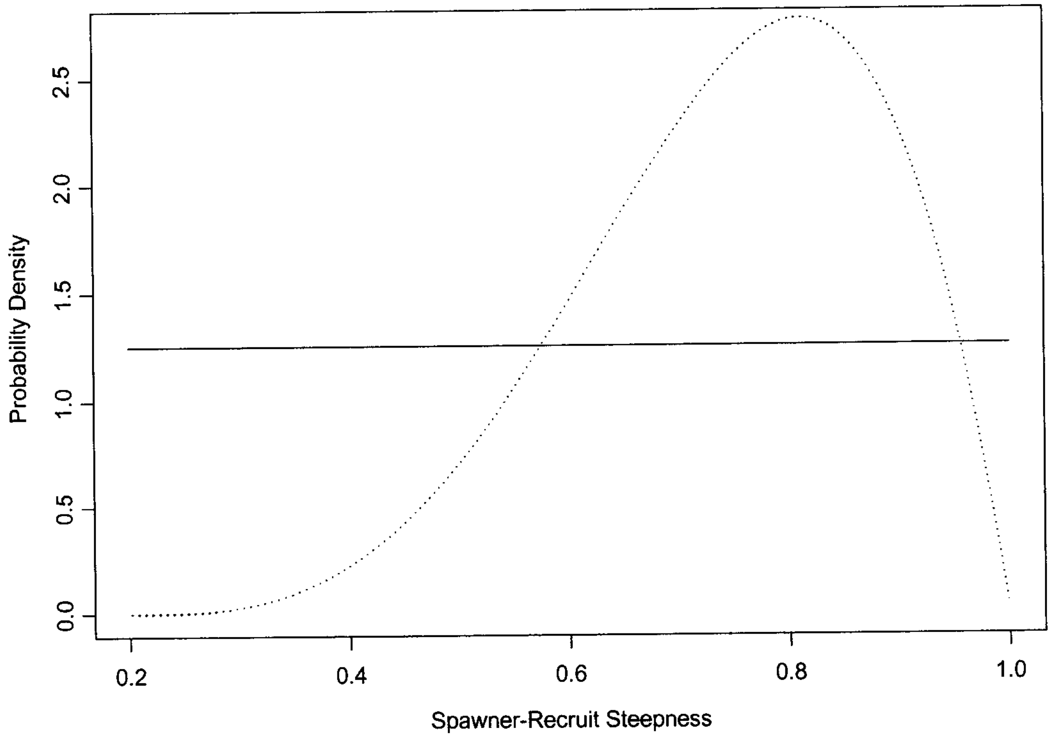


Figure 11. Uniform prior distribution assumed for steepness (solid line) and the more informative prior for steepness based on Dorn's (2000, and Minte-Vera et al. 2003) meta-analysis (dotted line).

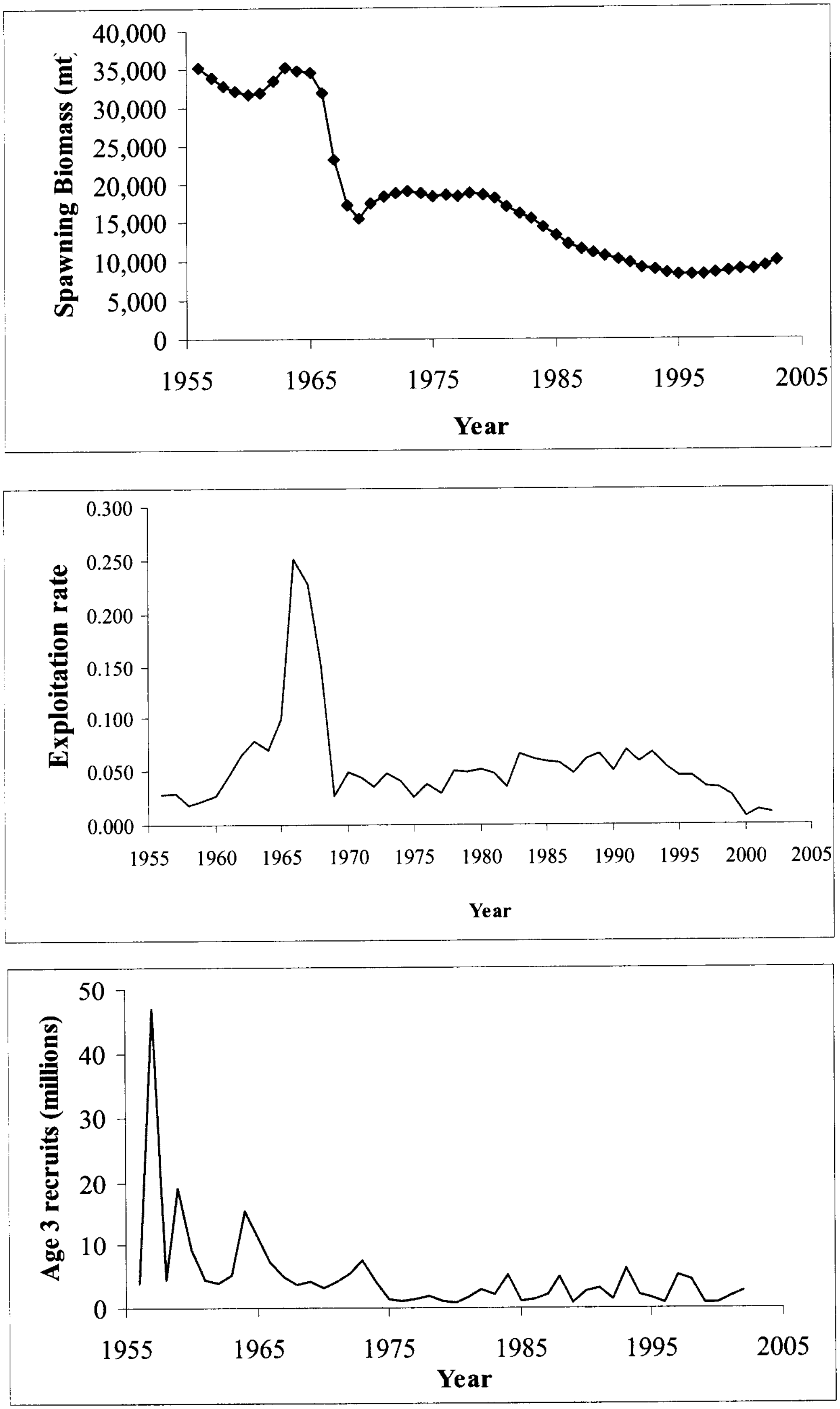


Figure 12. Time series of spawning biomass, exploitation rate and recruitment.

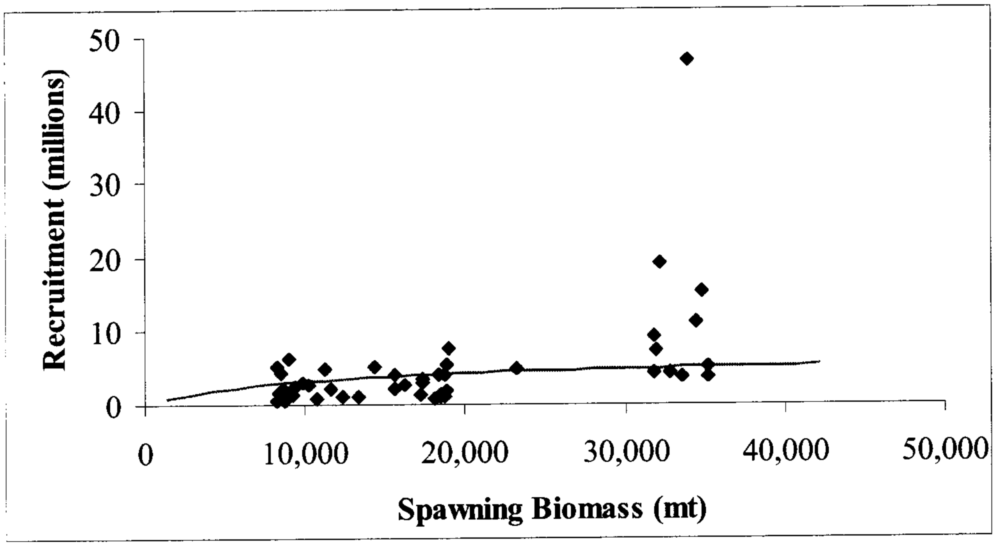


Figure 13: Fit of the deterministic stock-recruitment relationship to the spawning stock biomass and recruitment data.

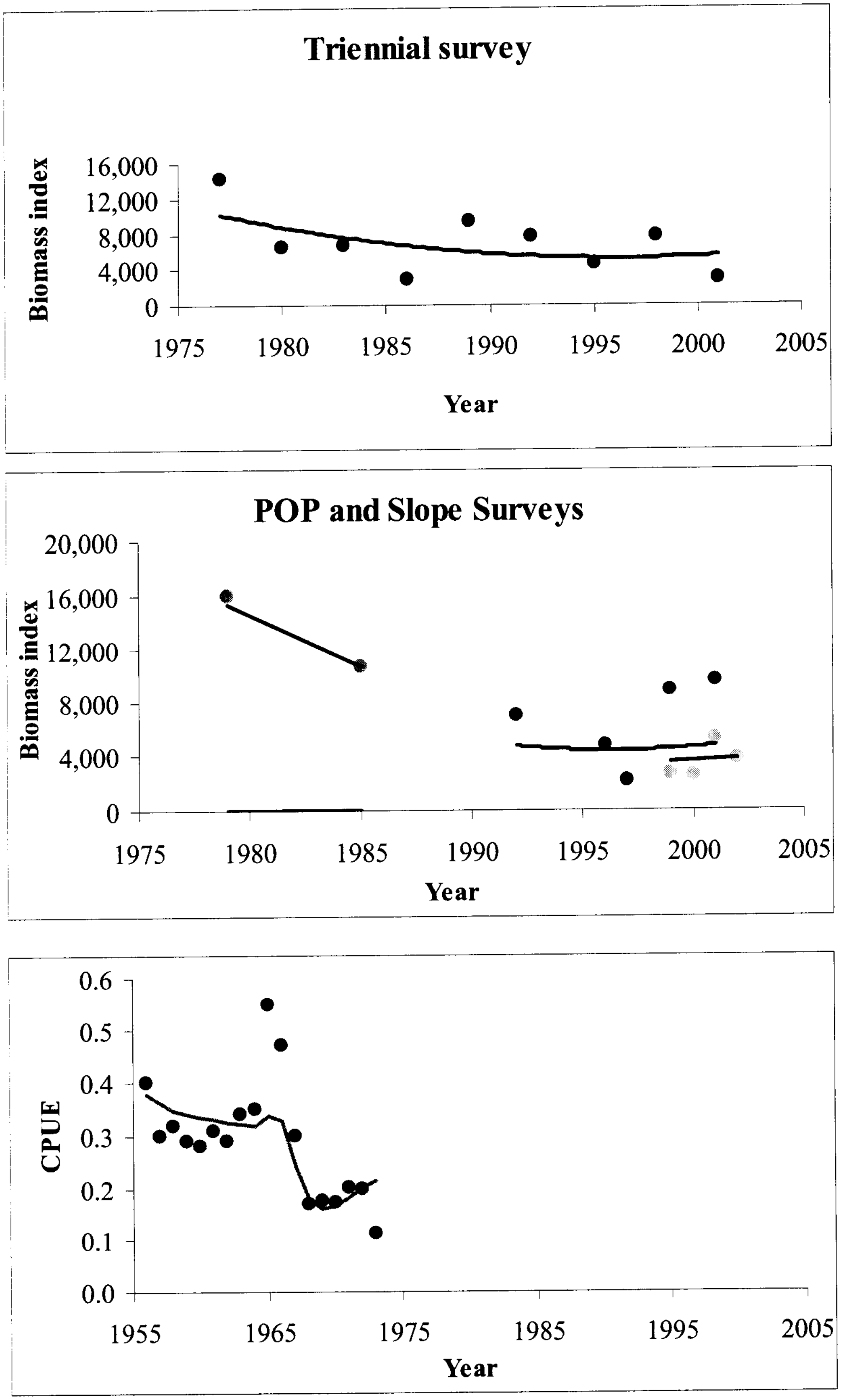


Figure 14. Fit of Model 1 to the survey biomass indices and to the fishery CPUE data. Note that each survey has a unique catchability coefficient so that there is a separate trajectory of survey-selected biomass for each survey; the curves shown are only through expected biomass indices for the years of data.

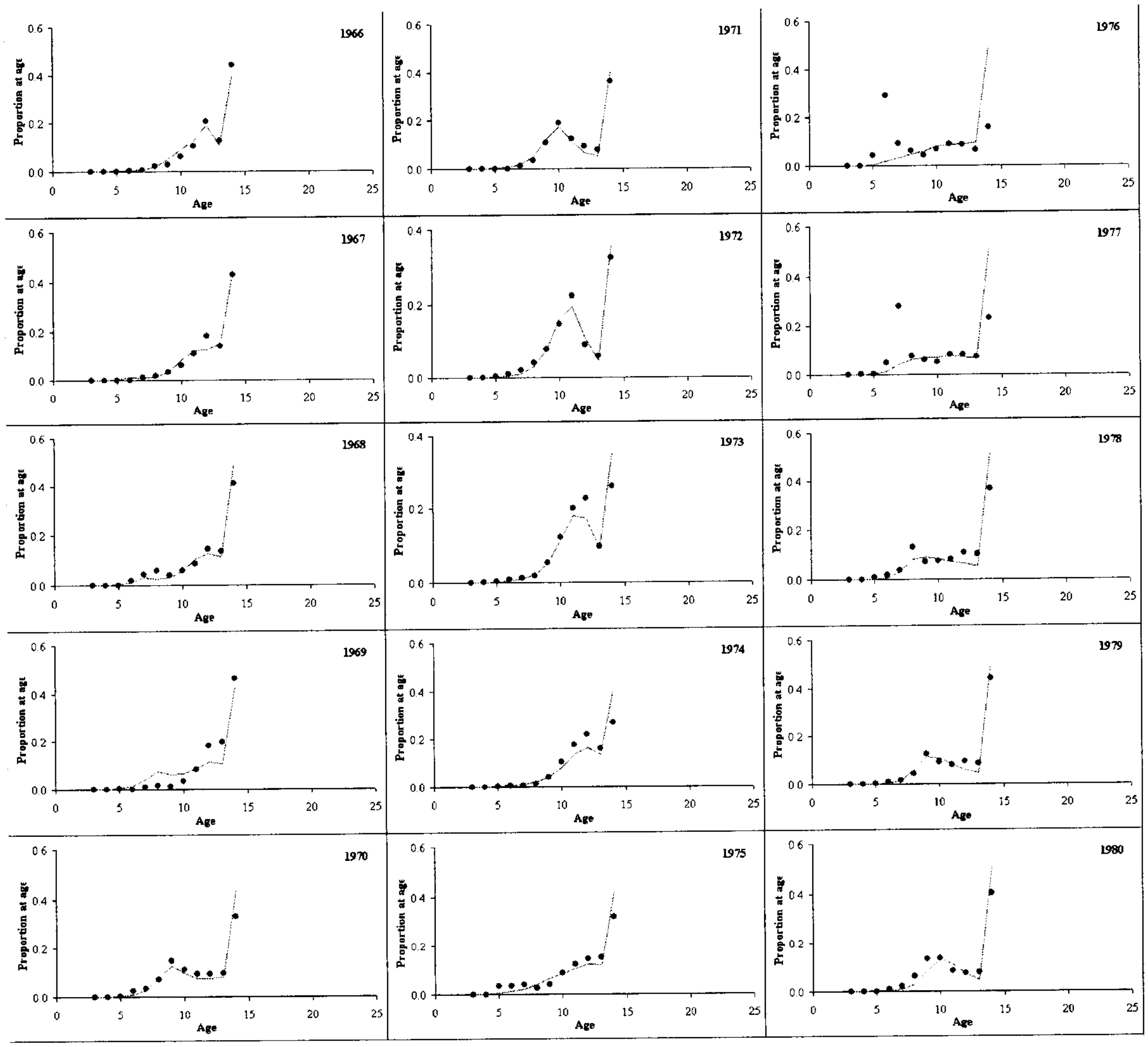


Figure 15. Fit of model 1 to the "biased" (1966-80) fishery age-composition data.

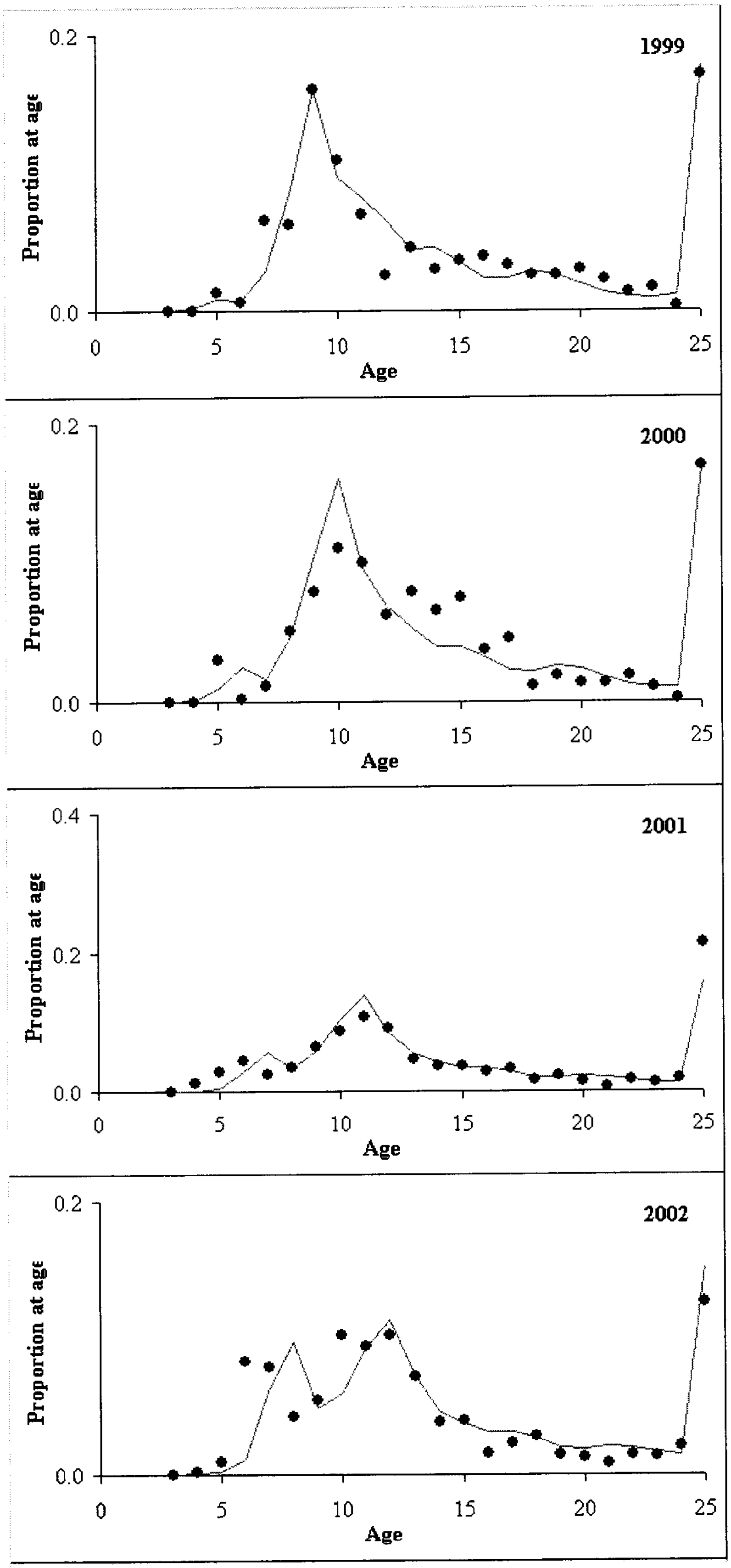


Figure 16. Fit of Model 1 to the "unbiased" (1999-2002) fishery age-composition data.

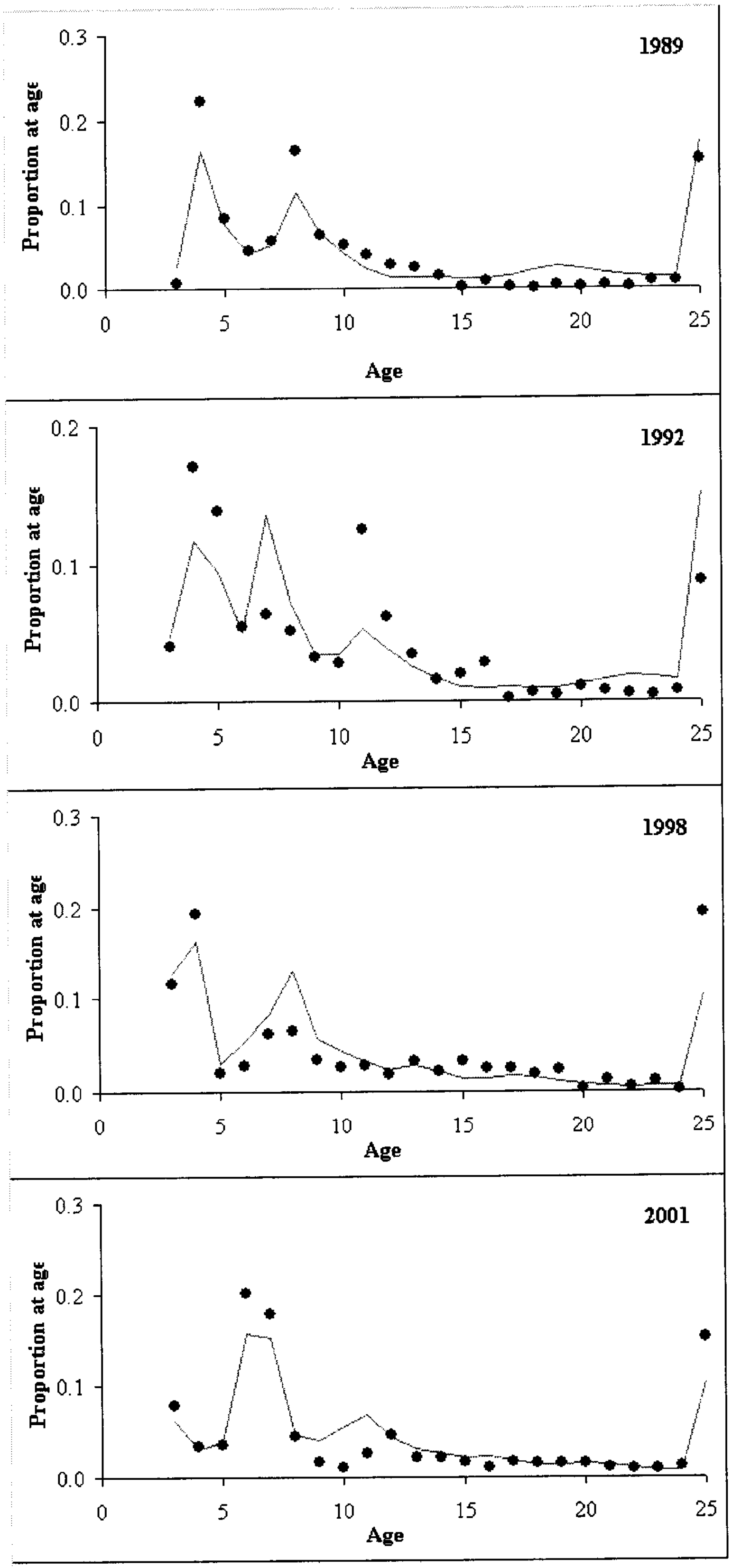


Figure 17. Fit of model 1 to triennial survey age-composition data.

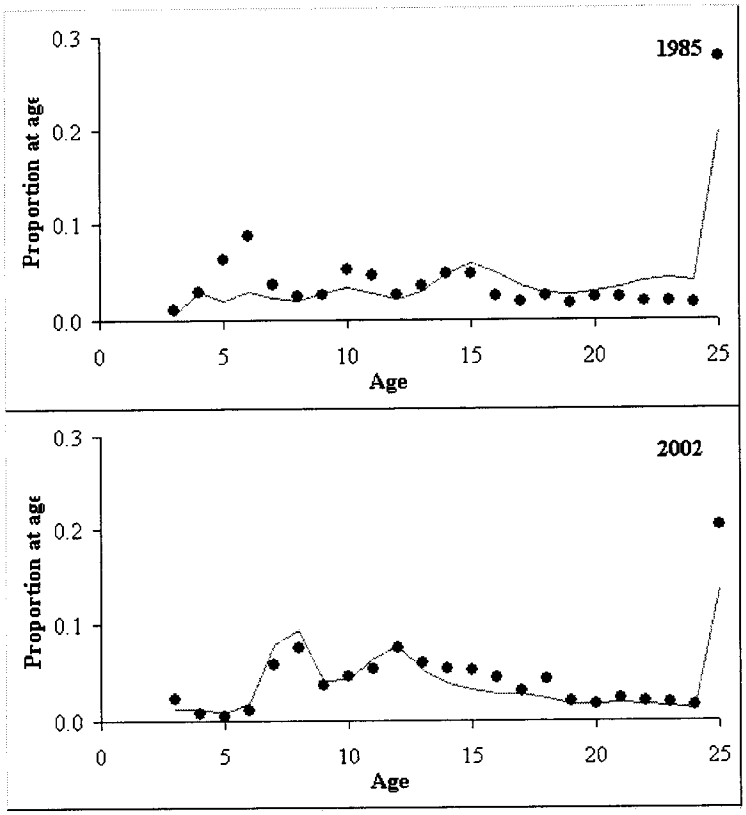


Figure 18. Fit of Model 1 to POP and slope survey age-composition data.

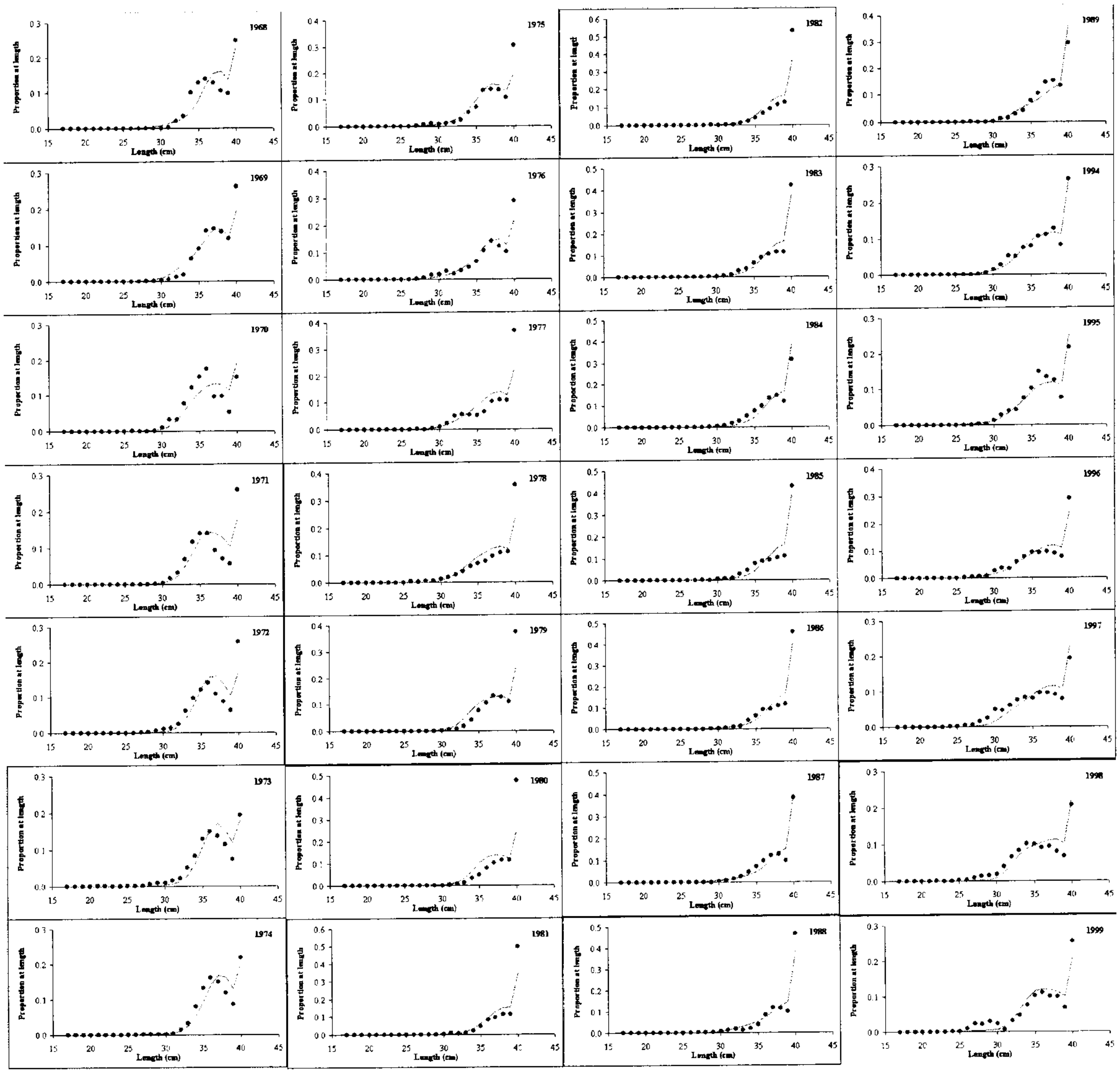


Figure 19. Fit of Model 1 to fishery size-composition data (1968-1989,1994-1999). Note that the data for 1968-1980 and for 1999 are not used when fitting the model.

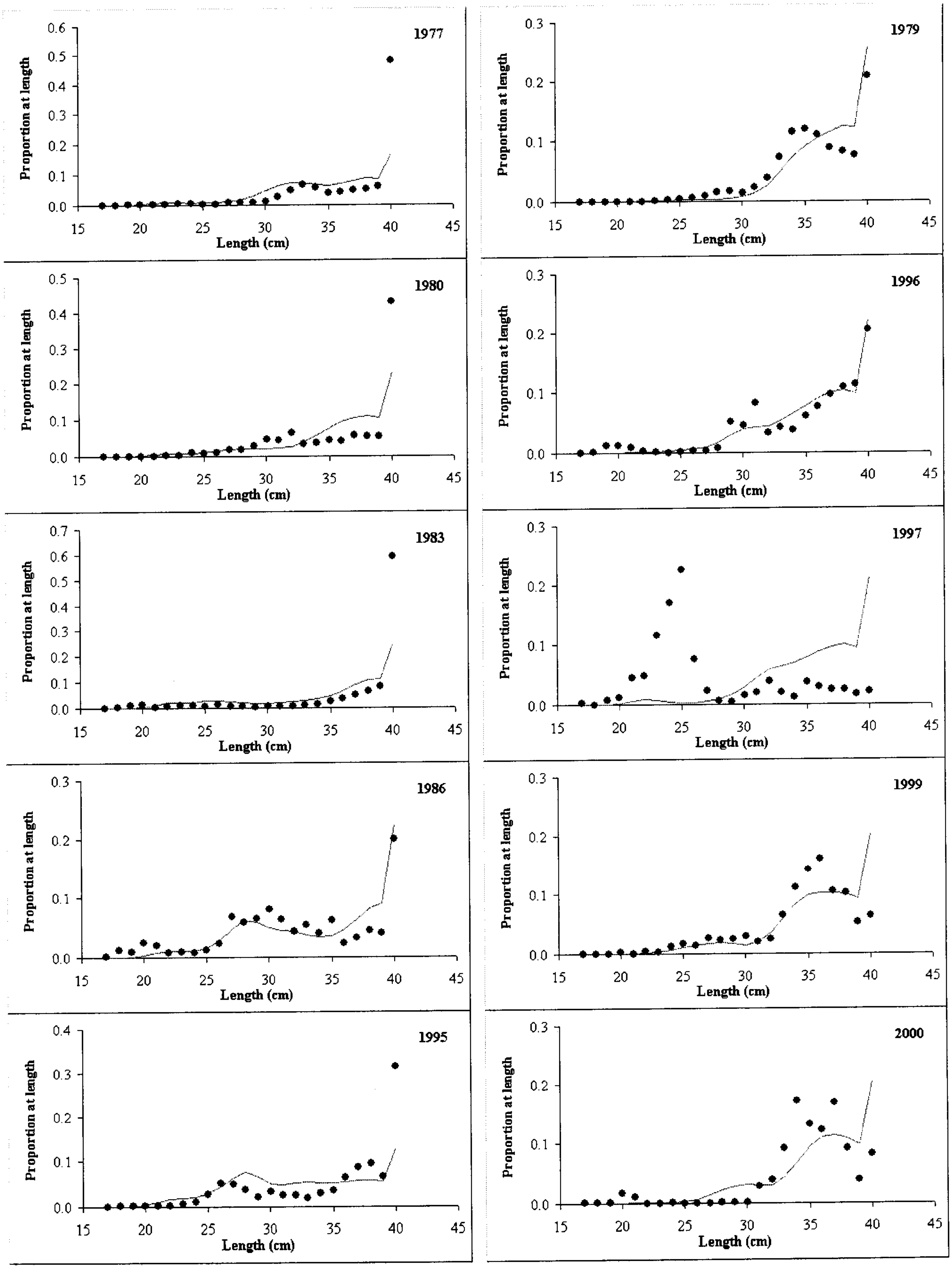


Figure 20. Fit of Model 1 to triennial and slope survey size-composition data.

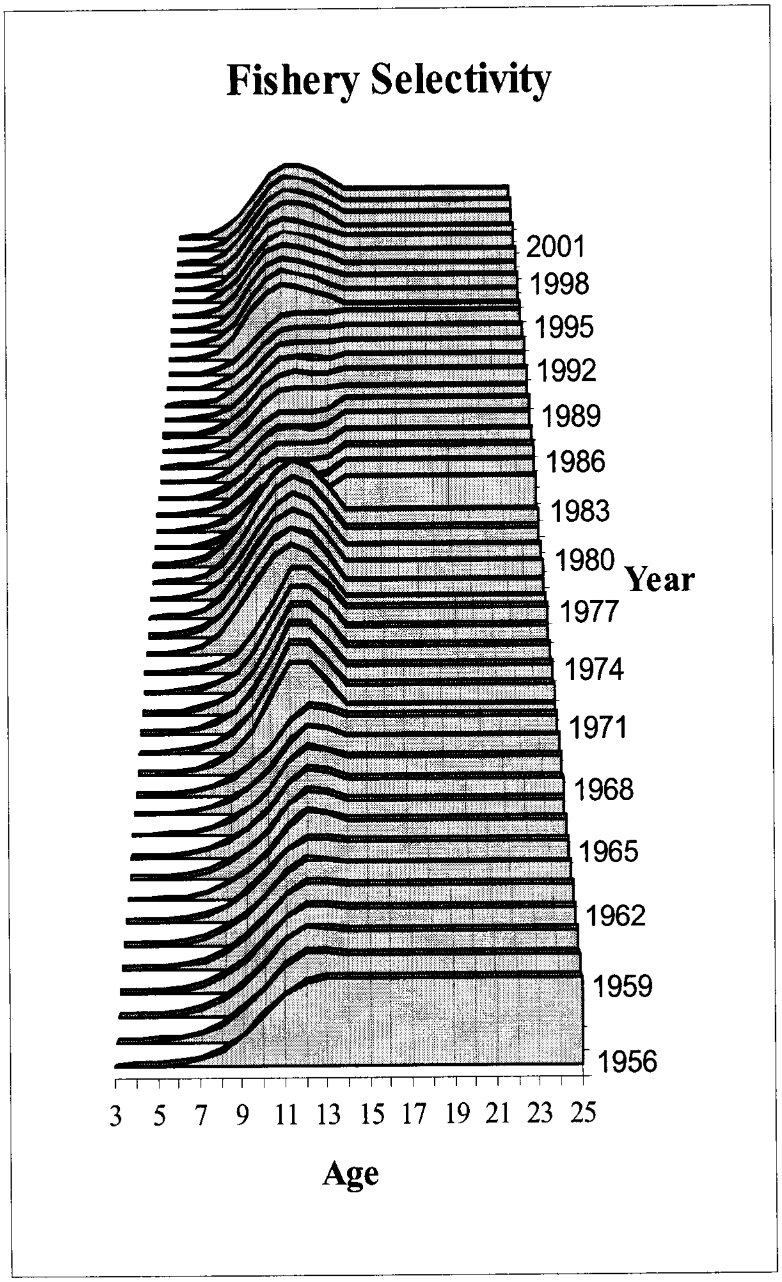
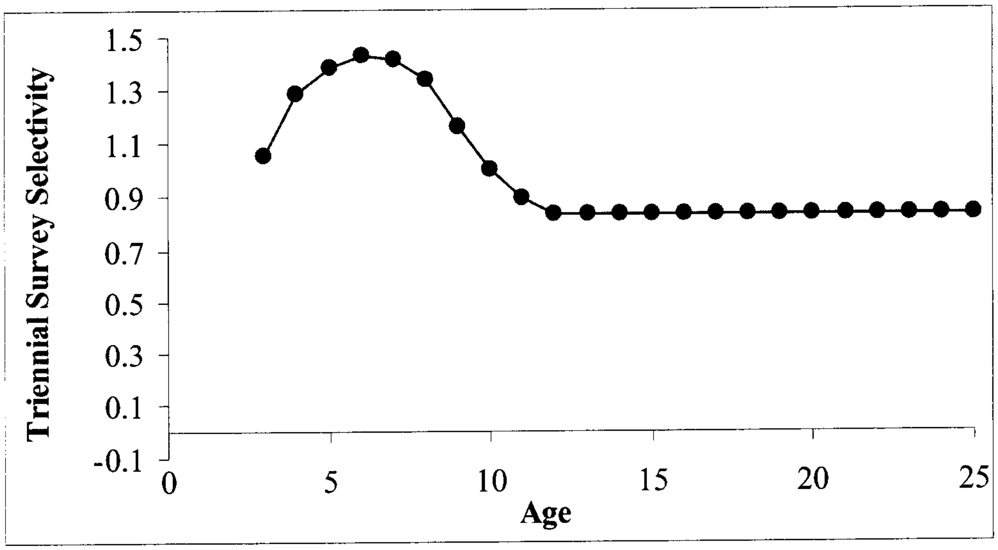


Figure 21. Fishery selectivity patterns (1956-2002).



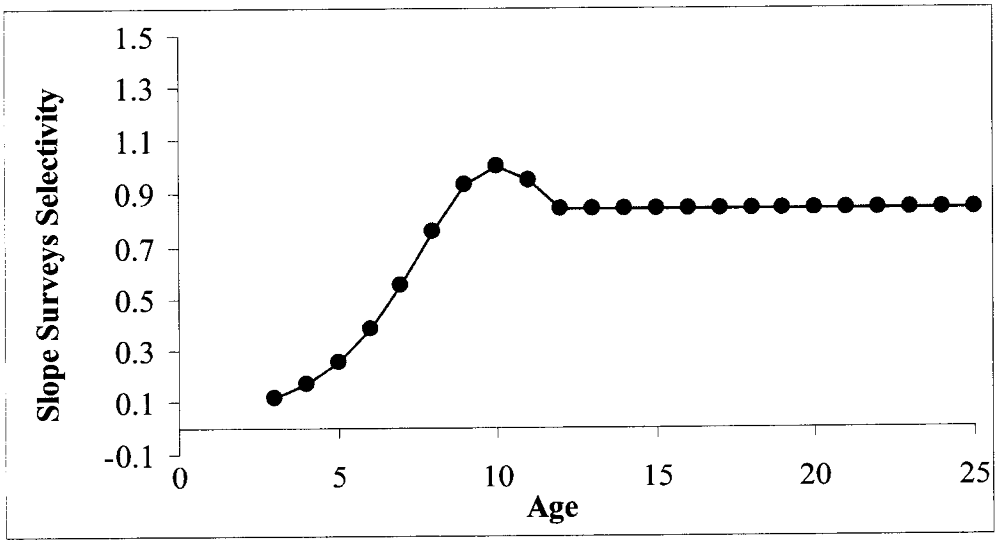


Figure 22. Selectivity patterns for the triennial and slope surveys.

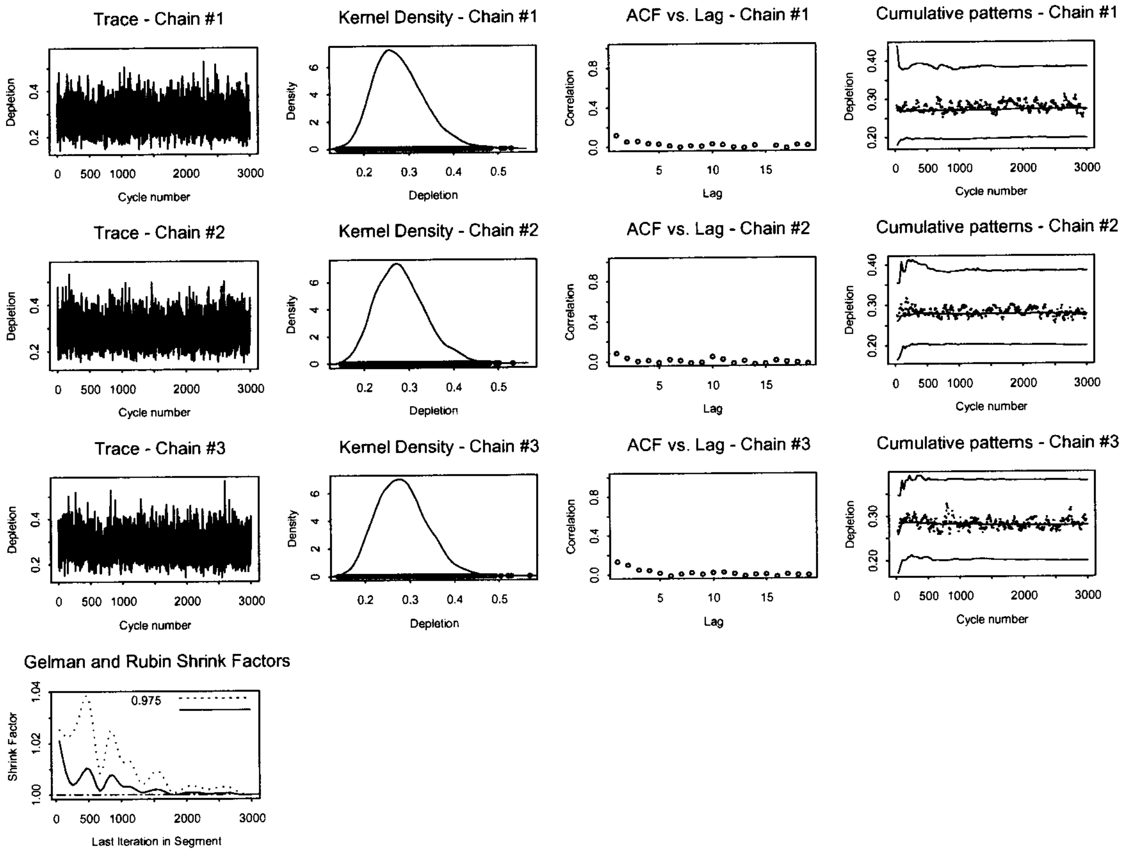


Figure 23a. MCMC diagnostics for depletion.

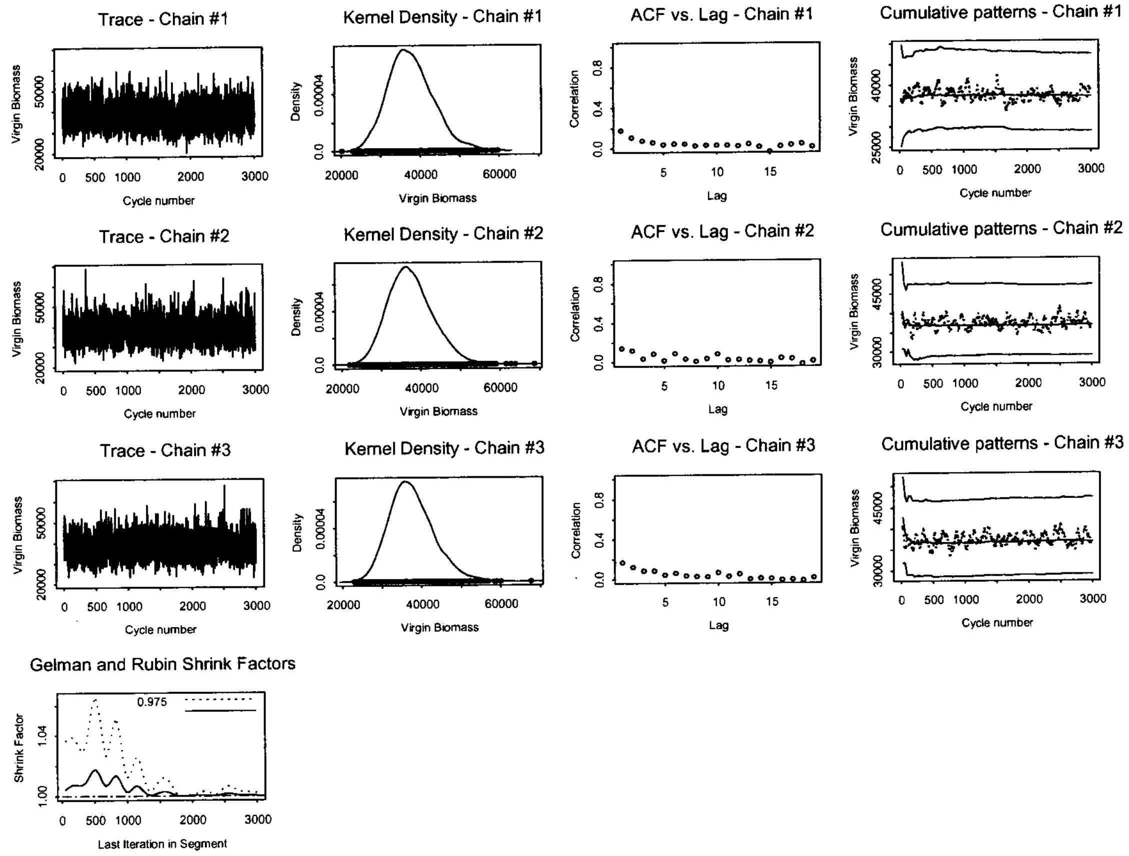


Figure 23b. MCMC diagnostics for virgin biomass.

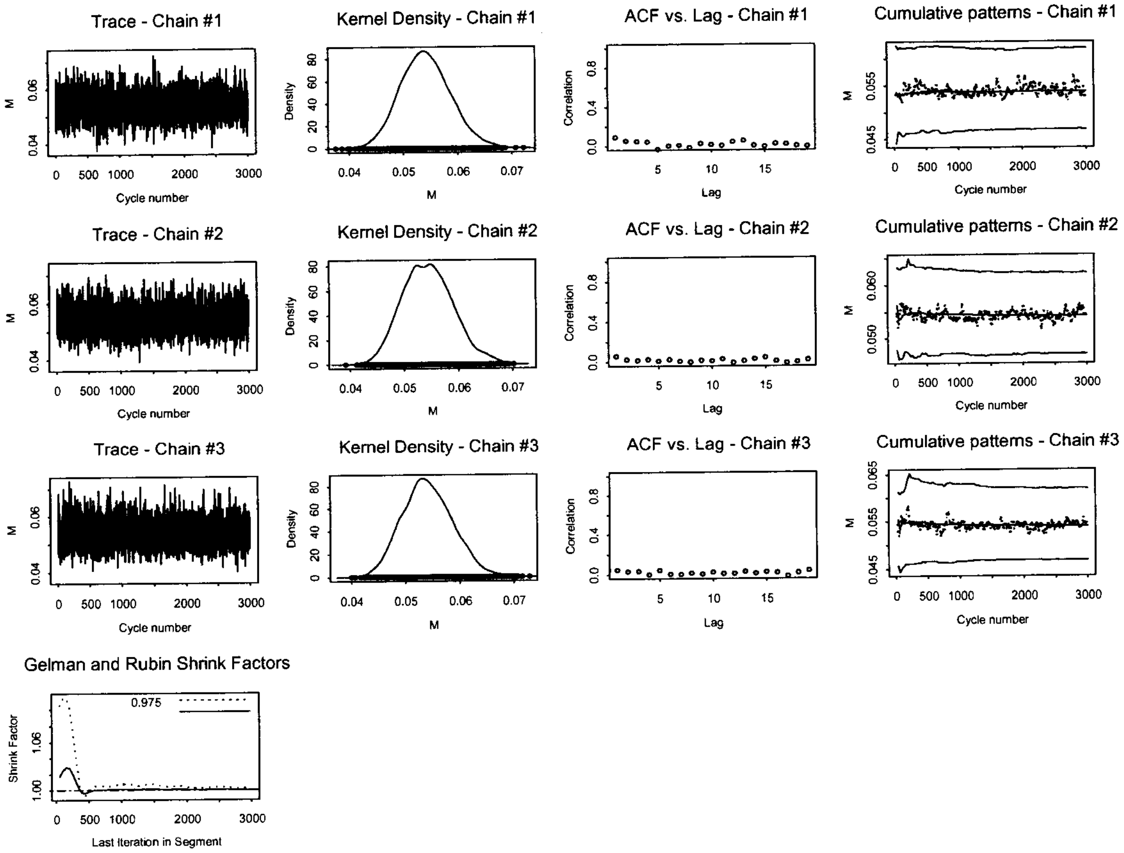


Figure 23c. MCMC diagnostics for natural mortality.

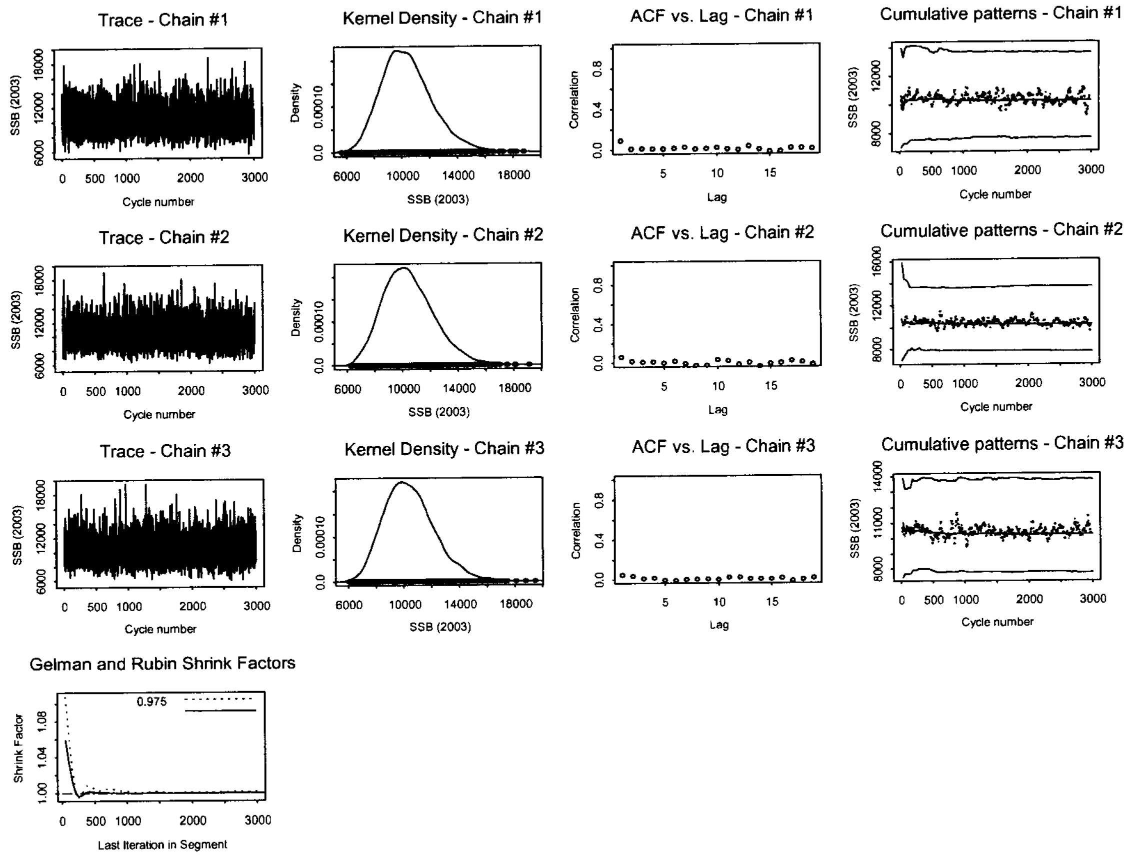


Figure 23d. MCMC diagnostics for current spawning biomass.

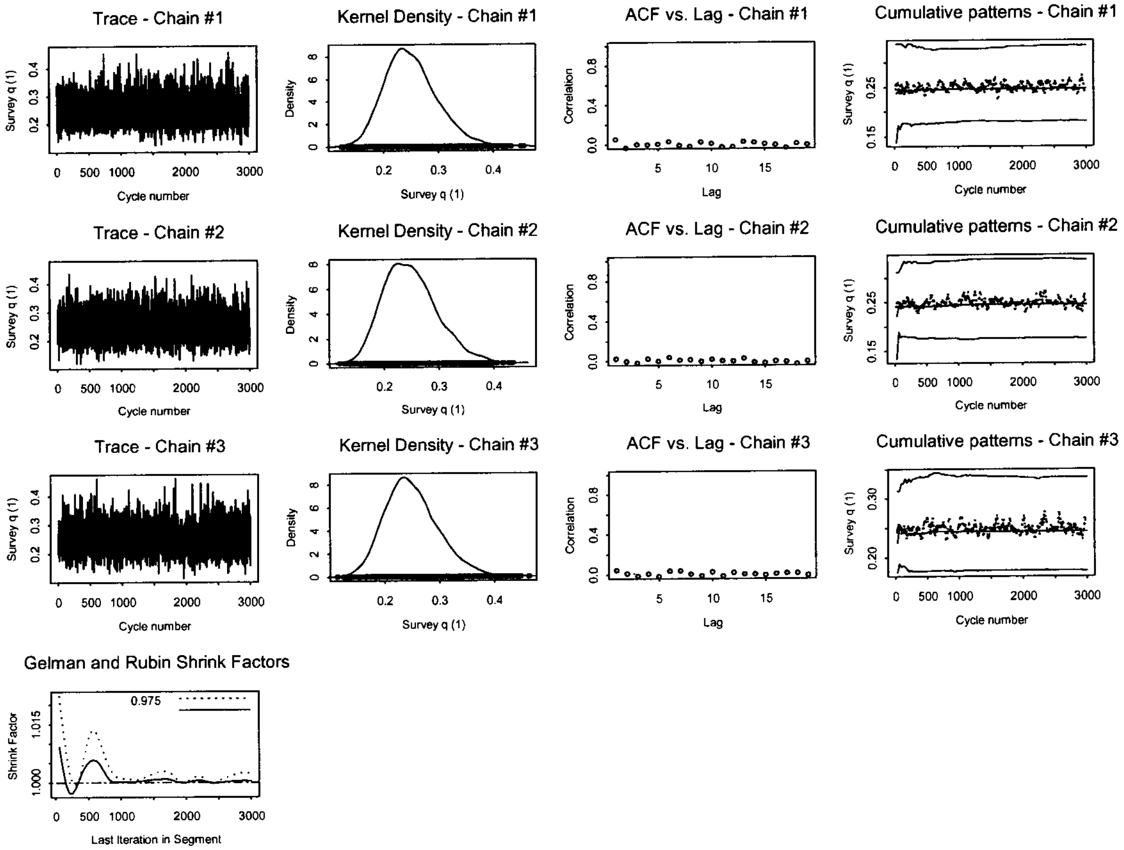
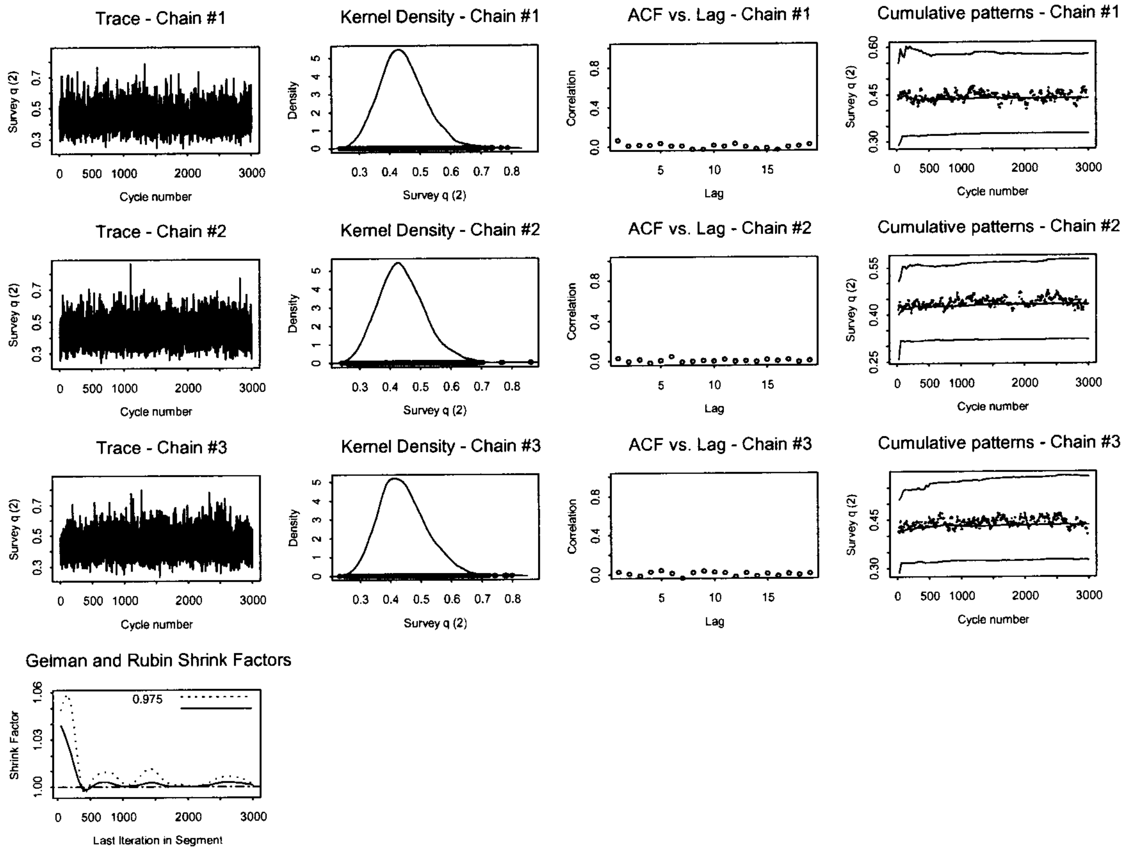


Figure 23e. MCMC diagnostics for triennial survey catchability.


Trace - Chain #1

Kernel Density - Chain #1

ACF vs. Lag - Chain #1

Cumulative patterns - Chain #1

Trace - Chain #2

Kernel Density - Chain #2

ACF vs. Lag - Chain #2

Cumulative patterns - Chain #2

Trace - Chain #3

Kernel Density - Chain #3

ACF vs. Lag - Chain #3

Cumulative patterns - Chain #3

Gelman and Rubin Shrink Factors

Figure 23f. MCMC diagnostics for POP survey catchability.

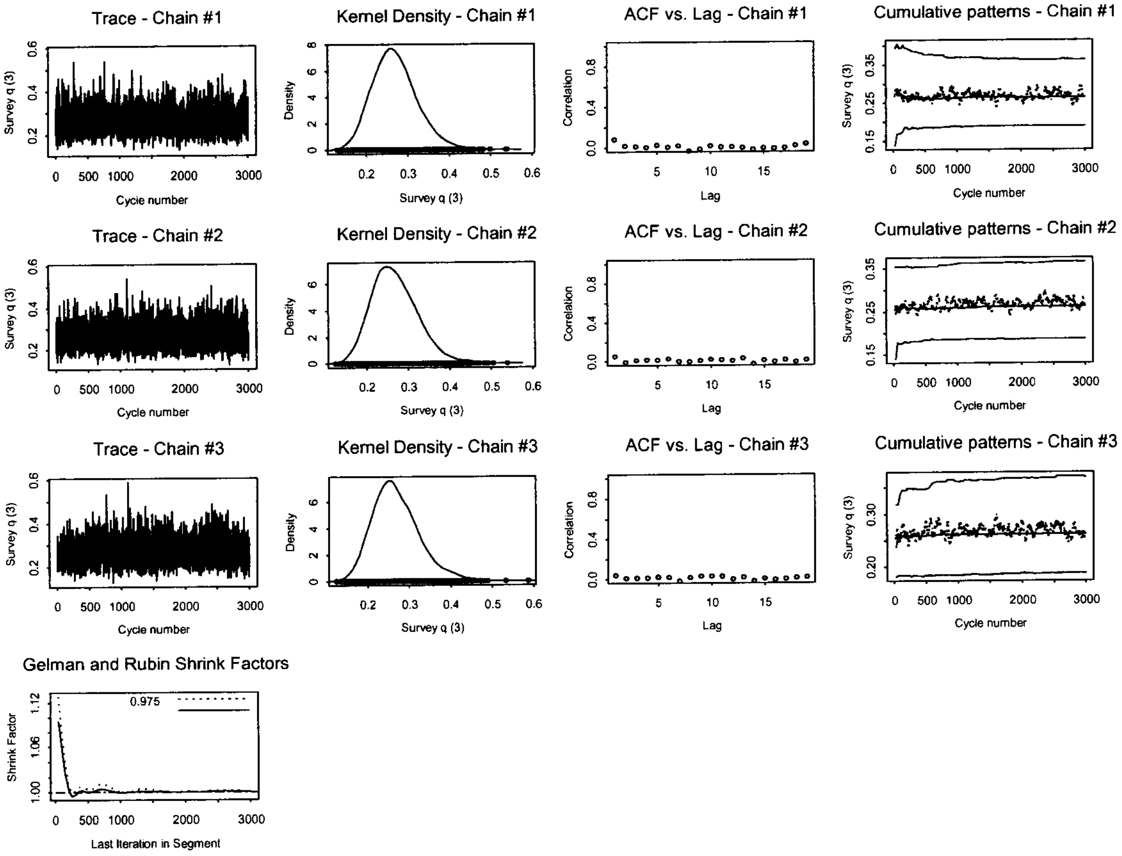


Figure 23g. MCMC diagnostics for AFSC slope survey catchability.

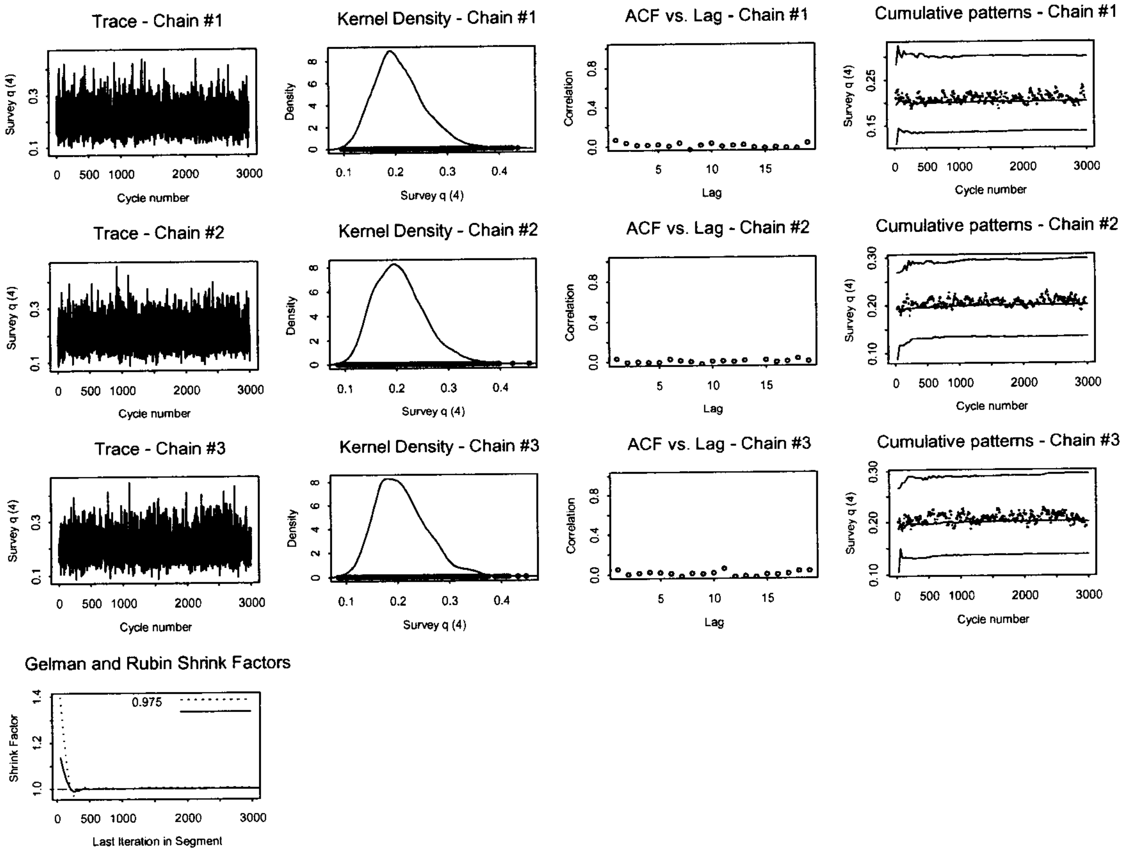


Figure 23h. MCMC diagnostics for NWFSC slope survey catchability.

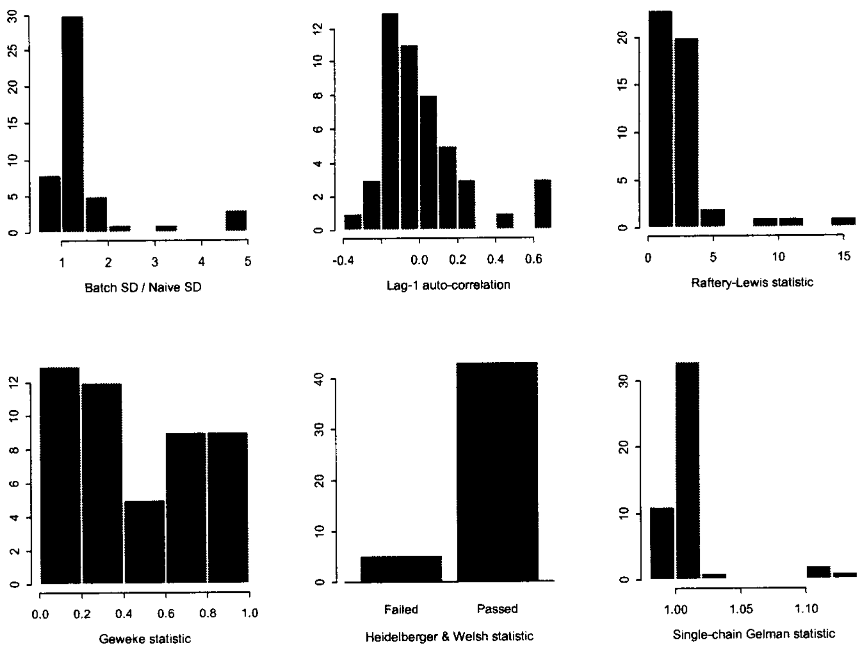


Figure 24a. Summary of six diagnostic statistics for the 48 annual recruitments.

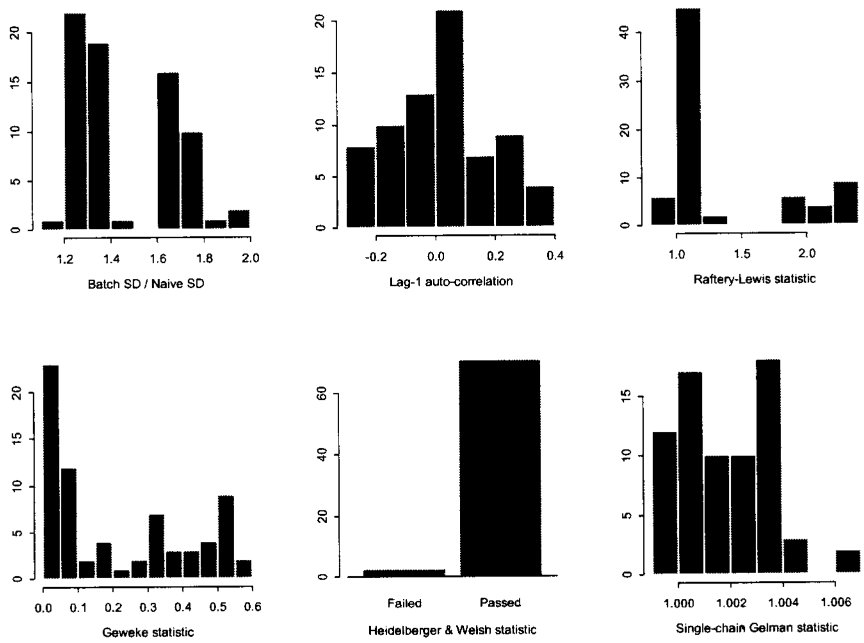


Figure 24b. Summary of six diagnostic statistics for the 72 annual estimates of spawning biomass.

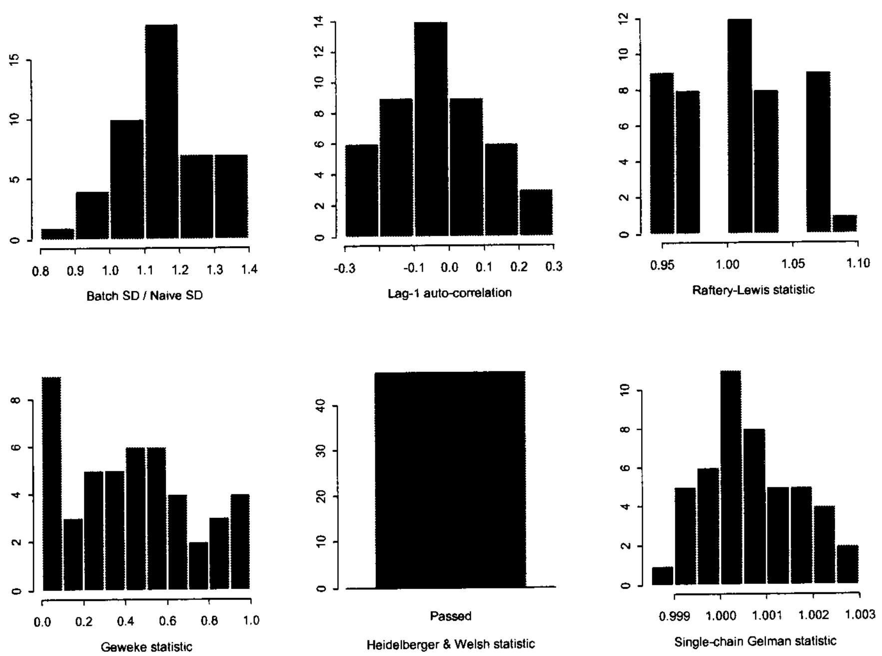


Figure 24c. Summary of six diagnostic statistics for the 47 fully-selected fishing mortalities.

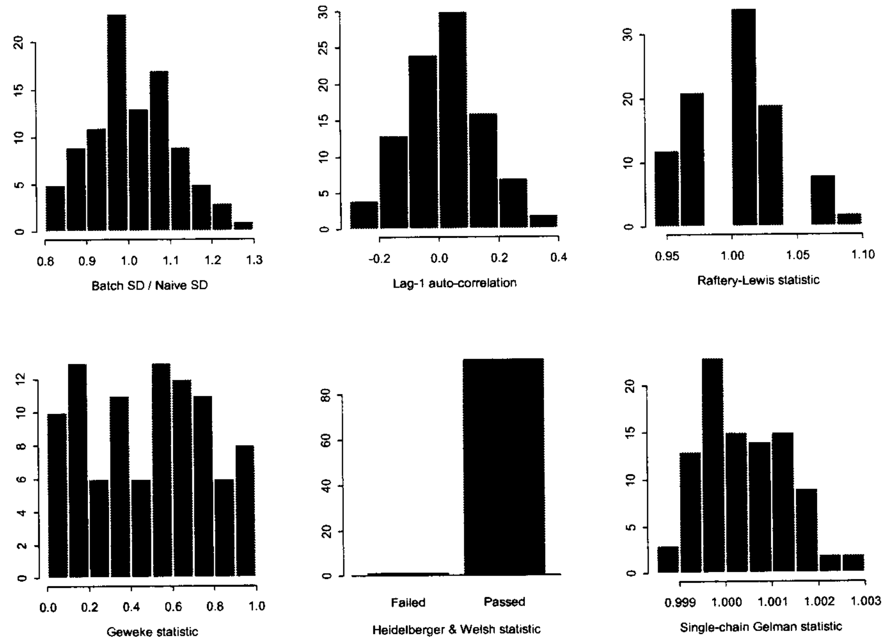


Figure 24d. Summary of six diagnostic statistics for the 96 selectivity deviations.

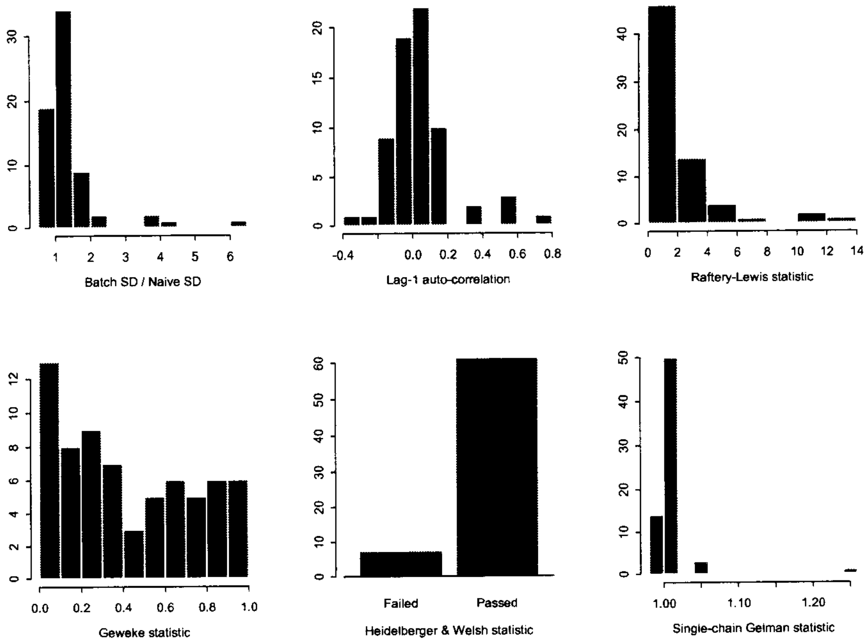


Figure 24e. Summary of six diagnostic statistics for the 68 recruitment residuals.

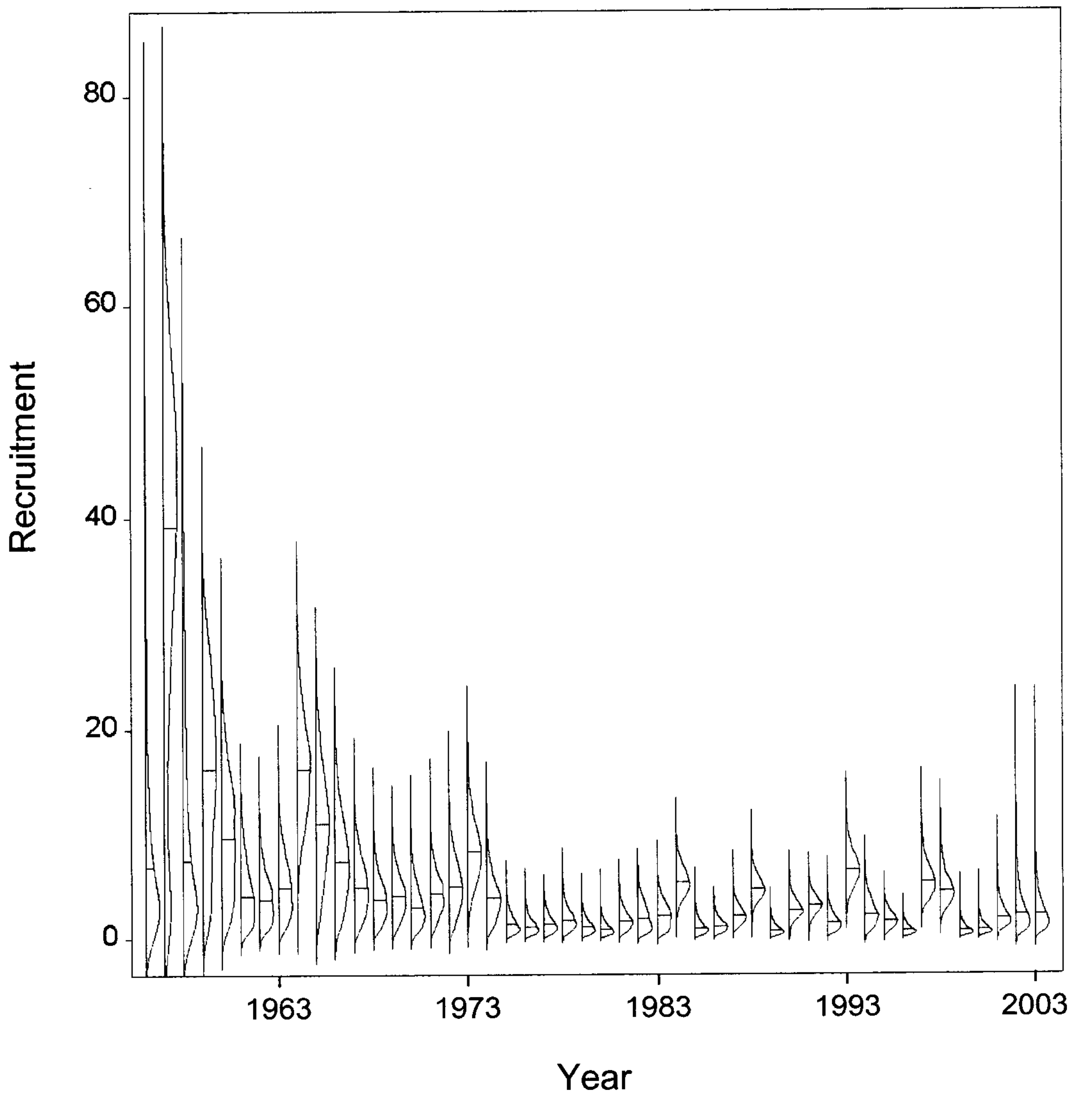


Figure 25. Smoothed posterior densities for estimated recruitment (1956-2003). Horizontal lines indicate the medians, vertical lines the ranges.

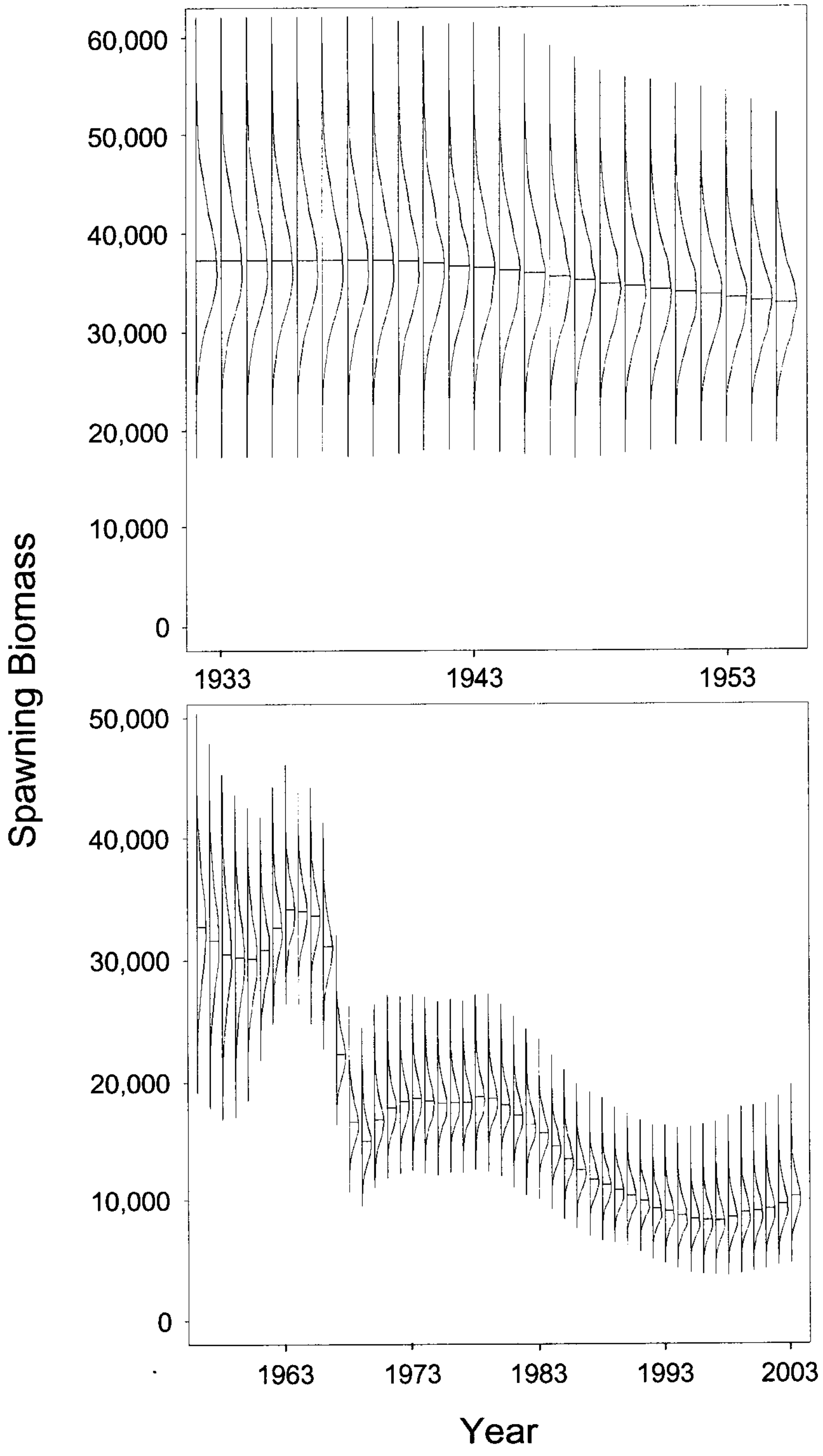


Figure 26. Smoothed posterior densities for estimated spawning biomass for the years prior to exploitation (1932-1955) and thereafter (1956-2003). Horizontal lines indicate the medians, vertical lines the ranges.

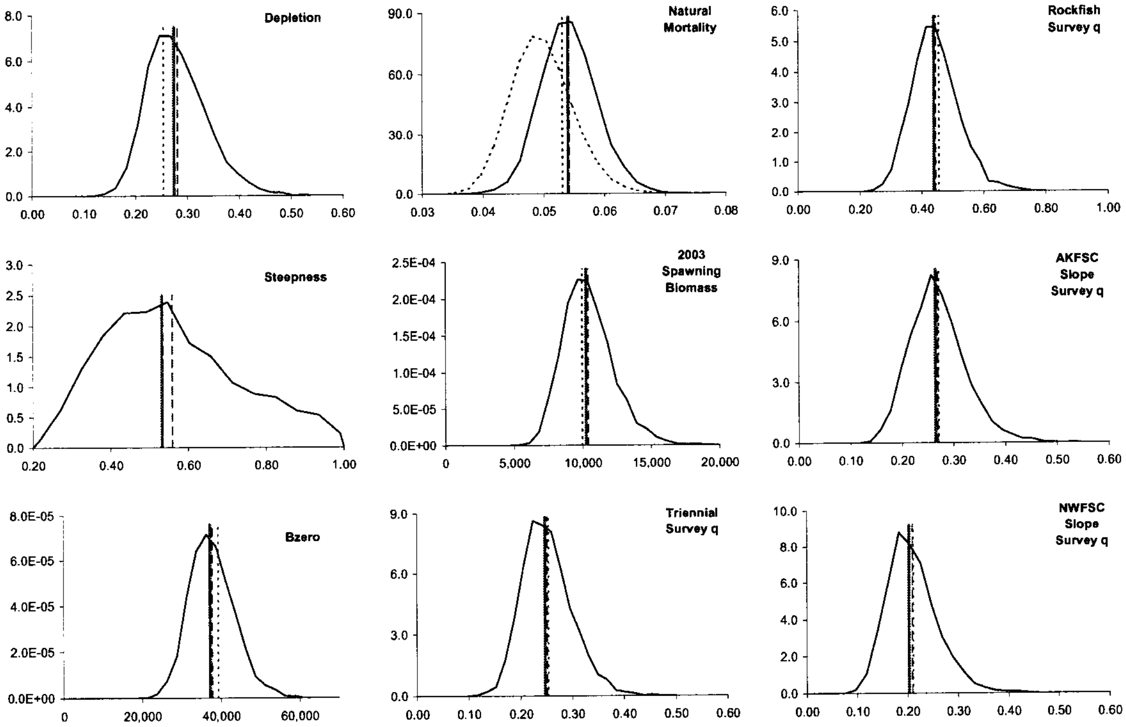


Figure 27. Posterior distributions for key parameters and derived quantities. The solid and dotted lines indicate respectively the medians and means of the posterior distributions. The short dashes indicate the MPD estimates. For natural mortality, the informative prior, lognormal(0.05,0.1), is shown as a dashed curve.

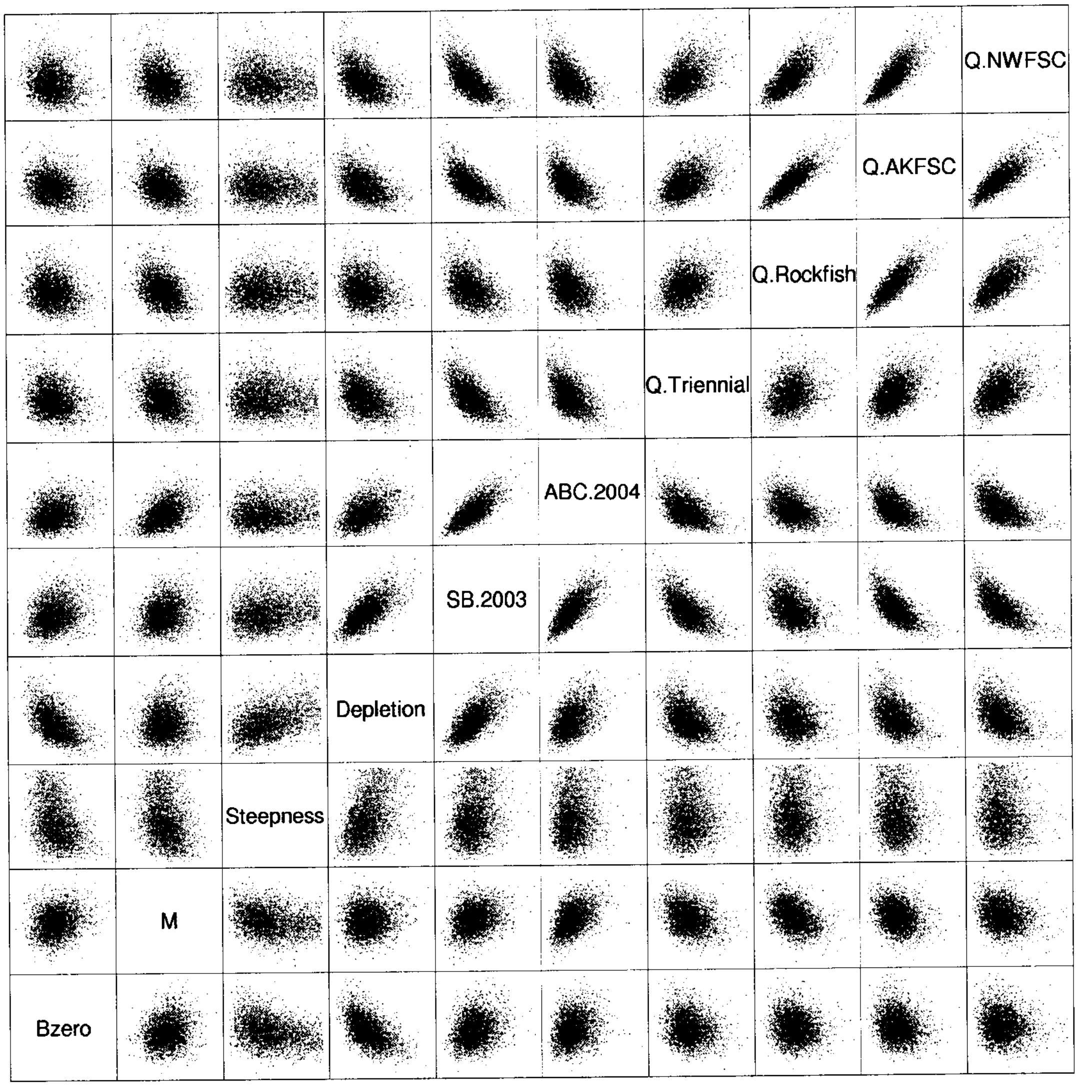


Figure 28. Correlation of key parameters and derived quantities based on 4,000 draws from the posterior distribution.

Appendix 1 Code and input files

Assessment model code

```
  // 2003 West Coast Pacific ocean perch Assessment Model code
  // Compiled April 28, 2003, cleaned up for publication July 15, 2003
//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

DATA_SECTION

  !!CLASS ofstream report1("params.dat",ios::app);
  !!CLASS ofstream report2("spbiomass.dat",ios::app);
  !!CLASS ofstream report3("recruitment.dat",ios::app);
  !!CLASS ofstream report4("surv_sel.dat",ios::app);
  //!!CLASS ofstream report5("fish_sel.dat",ios::app);

  !!ad_comm::change_datafile_name("pop1.ctl");
  int Do_Fmort;

  init_int      styr;         // first year of fishery data
  init_int      endyr;        // last year of fishery data
  init_int      recage;       // age at recruitment
  init_int      nages;        // number of ages modeled
  init_number   mat_inflctn; //at age, not by age-index

  int styr_rec;             // first year recruitment modeled (styr -
nages + 2)
  int styr_sp;                      //first year of spawning modeled
(styr_rec - recage)
  int endyr_sp;                     //last year of spawning modeled
(endyr-recage)
  // moved beta steepness prior values
  init_vector   wt(1,nages); // weight at age for age classes modeled
  init_vector   obs_catch(styr,endyr);    // fishery catch for years of
data

  // +==+==+==+ Triennial survey Biomass +==+==+==+ +==+==+==+
  init_int      nyrs_surv; // number of years of triennial survey data
  init_ivector  yrs_surv(1,nyrs_surv);  // actual years of data
  init_vector   obs_surv_biom(1,nyrs_surv); // calculated biomass from
survey
  init_vector   obs_surv_se(1,nyrs_surv); // Standard deviations of
survey obs

  // +==+==+==+ POP survey Biomass +==+==+==+ +==+==+==+
  init_int      nyrs_surv2;         // number of years of POP+slope
survey
  init_ivector  yrs_surv2(1,nyrs_surv2); // actual years survey done
  init_vector   obs_surv_biom2(1,nyrs_surv2); // calc biomass from
survey
  init_vector   obs_surv_se2(1,nyrs_surv2); // Standard devs of survey
obs

  // +==+==+==+ AFSC Slope survey Biomass +==+==+==+ +==+==+==+
  init_int      nyrs_surv3;         // number of years of POP+slope
survey
```

```
  init_ivector  yrs_surv3(1,nyrs_surv3); // actual years survey done
  init_vector   obs_surv_biom3(1,nyrs_surv3); // calc biomass from
survey
  init_vector   obs_surv_se3(1,nyrs_surv3); // Standard devs of survey
obs

  // +==+==+==+ NWFSC Slope survey Biomass +==+==+==+ +==+==+==+
  init_int      nyrs_surv4;         // number of years of POP+slope
survey
  init_ivector  yrs_surv4(1,nyrs_surv4); // actual years survey done
  init_vector   obs_surv_biom4(1,nyrs_surv4); // calc biomass from
survey
  init_vector   obs_surv_se4(1,nyrs_surv4); // Standard devs of survey
obs

  // +==+==+==+ Old CPUE data  +==+==+==+ +==+==+==+
  init_int      nyrs_cpue; // number of years of catch per unit effort
data
  init_ivector  yrs_cpue(1,nyrs_cpue); // actual years of cpue data
  init_vector   obs_cpue(1,nyrs_cpue); // calculated cpue

  // Read in fishery Biased (old) age composition data
  init_int      nyrs_fish_age; // number of years of fishery age data
  init_ivector  yrs_fish_age(1,nyrs_fish_age); // actual years of age
data
  init_vector   nsamples_fish_age(1,nyrs_fish_age); // sample size by
year
  init_matrix   oac_fish(1,nyrs_fish_age,1,12); // observed age
composition

  // Read in new (1999+) fishery age composition data
  init_int      nyrs_fish2_age; // number of years of new fishery age
data
  init_ivector  yrs_fish2_age(1,nyrs_fish2_age); // actual years of age
data
  init_vector   nsamples_fish2_age(1,nyrs_fish2_age); // sample size by
year
  init_matrix   oac_fish2(1,nyrs_fish2_age,1,nages); // observed age
composition

  // Read in Triennial Survey age composition data
  init_int      nyrs_surv_age; // number of years of survey age data
  init_ivector  yrs_surv_age(1,nyrs_surv_age); // actual years of data
  init_vector   nsamples_surv_age(1,nyrs_surv_age); // sample size by
year
  init_matrix   oac_surv(1,nyrs_surv_age,1,nages); // observed age
composition

  // Read in pop and Slope Survey age composition data
  init_int      nyrs_surv2_age; // number of years of survey age data
  init_ivector  yrs_surv2_age(1,nyrs_surv2_age); // actual years of
data
  init_vector   nsamples_surv2_age(1,nyrs_surv2_age); // sample size by
year
  init_matrix   oac_surv2(1,nyrs_surv2_age,1,nages); // observed age
comp

  // Read in fishery size composition data
  init_int      nlenbins; // number of length classes
  init_int      nyrs_fish_size; //number of years of fishery size data
```

```
  init_ivector  yrs_fish_size(1,nyrs_fish_size); // actual years of
size data
  init_vector   nsamples_fish_size(1,nyrs_fish_size); // sample size by
year
  init_matrix   osc_fish(1,nyrs_fish_size,1,nlenbins); // observed size
comp

  // Read in unused fishery size compostion data for comparison
  init_int      nyrs_ufish_size; //number of years of unused fishery
size data
  init_ivector  yrs_ufish_size(1,nyrs_ufish_size); // actual years
unused data
  init_matrix   osc_ufish(1,nyrs_ufish_size,1,nlenbins); // observed
size comp

  // Read in Triennial Survey size composition data
  init_int      nyrs_surv_size; // number of years of survey size data
  init_ivector  yrs_surv_size(1,nyrs_surv_size); // actual years of
data
  init_vector   nsamples_surv_size(1,nyrs_surv_size); // sample size by
year
  init_matrix   osc_surv(1,nyrs_surv_size,1,nlenbins);  //observed size
comp

  // Read in Rockfish and Slope Survey size composition data
  init_int      nyrs_surv2_size; // number of years of survey size data
  init_ivector  yrs_surv2_size(1,nyrs_surv2_size); // actual years of
data
  init_vector   nsamples_surv2_size(1,nyrs_surv2_size); // sample size
by year
  init_matrix   osc_surv2(1,nyrs_surv2_size,1,nlenbins);  //observed
size comp
  init_matrix   sizeage(1,nages,1,nlenbins); // age to length
transition matrix
  init_matrix   ageage(1,nages,1,nages); // empirical ageing error
matrix

  int dim_sel;  // number of selectivity curve changes over years of
data
  int i;
  int ii;
  int j;
  number pii;
  int phase_F55;  // phase to estimate various spawner per recruit
fishing levels

  // =+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=
  // Read in control file stuff
  !! ad_comm::change_datafile_name("pop2.ctl"); // another data file

  // switch for combined (=0) or split (=1) survey selectivity
  // for Triennial vs. Rockfish and Slope surveys.
  // init_int    surv_split; // switch for combined (=0) or split (=1)

  init_int    plusgrp; // fishery age plus group switch, 0 or 1
(1=include)
  init_number cv_cpue; // CV for CPUE index
  init_int    SrType;               // Ricker = 1; B-Holt = 2
  init_number srprior_a;           // parameter for beta steepness
prior
```

```
  init_number srprior_b ;           // parameter for beta steepness
prior
  init_int    steeppriorswitch; // 1 for beta (above), 0 for no prior
  init_int    max_sel_age;      // age class beyond which fishery
selectivity curve flat
  init_int    max_sel_age_surv; // age class beyond which survey
selectivity curve flat
  init_int    Do_Robust_Phase;  // phase at which robust age likelihood
done
  init_int    ph_steepness;     // phase to estimate steepness
  init_number rho;              // rho (serial recruitment correlation)
  init_number sigr;             // SD for S-R relationship
  init_int    ph_M;             // phase to estimate natural mortality
  init_int    ph_sigmar;        // phase to estimate recruitment
variability
  init_int    ph_Fdev;          // phase to estimate deviance in
fishing morality
  init_int    ph_recdev;        // phase to estimate recruitment
deviances

  // selectivity stuff
  init_int surv_switch;             // Type of survey selectivity to
use
  init_int    ph_seldev_fish;   // phase to estimate fishery
selectivity devs
  init_int    ph_surv_sel;      // phase to estimate survey selectivity

  // the following selectivity phases are given values in the local
calcs section
  int         ph_surv_sel_type1 // phase to estimate option 1
selectivity mean
  int         ph_seldev_surv;   // phase to estimate survey selectivity
devs
  int         ph_asym_sel;      // phase to estimate asymptotic
selectivity for survey

  init_int    ph_fish_sel;      // phase to estimate fishery
selectivity
  init_int    ph_surv_q;        // phase to estimate triennial survey
catchability
  init_int    group_num;        // number of years between changes in
estimated selectivity curve
  init_number natmortprior;     // mean natural mortality prior value
  init_number cvnatmortprior;   // cv ""
  init_number qprior;           // mean catchability prior value
  init_number cvqprior;         // cv ""
  init_int qpriortype;        // prior type - 0 = noninformative, 1 =
normal, 2 = lognormal.
  init_int qprior_switch;     // determines if on triennial (0) or all
(1)

  vector M_prior(1,6);
  vector q_prior(1,6);

  init_vector lambda(1,20);
  int jj;
//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

 LOCAL_CALCS
```

```
  // selectivity stuff
  int ii=0;

  // this counts the number of groups over the time series
  for (i=styr;i<endyr;i++)
    {
        if (!(i%group_num))
        {
            ii++;
        }
    };
  dim_sel=ii;  // dim_sel now carries the correct number of groups for
the entire time-series

  styr_rec  = styr - nages + 2;    // corrected(old = styr-
nages+recage-1)
  styr_sp   = styr_rec - recage ;  // First year of spawning biomass
  endyr_sp  = endyr - recage - 1;  // endyr year of (main) spawning
biomass
  phase_F55 = 6;

  // selectivity stuff
  // For now, this is where you turn on and off parameters
  // and select phases within selectivity options
  // this could be moved to the control file

  // Set up the parameter phases for the selectivity option
  if (surv_switch == 1)
    {
      //  turn on the parameters to be used
        ph_surv_sel_type1 = ph_surv_sel;
        //  turn off the parameters for other options
        ph_seldev_surv = -5;
      ph_asym_sel = -5;
  }
  if (surv_switch == 2)
    {
      //  turn on the parameters to be used
        ph_surv_sel_type1 = ph_surv_sel;
        ph_seldev_surv = ph_surv_sel + 2;
        //  turn off the parameters for other options
      ph_asym_sel = -5;
  }

  if (surv_switch == 3)
    {
        //  turn on the parameters to be used
      ph_asym_sel = ph_surv_sel;
        //  turn off the parameters for other options
        ph_surv_sel_type1 = -5;
        ph_seldev_surv = -5;
  }


//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

 END_CALCS

INITIALIZATION_SECTION
```

```
  sel_slp_surv   -0.5
  sel_a50_surv    2.0
  steepness       0.5
  log_Rzero       1.8
  log_avg_rec     1.8
  natmort          .05
  log_avg_F      -1.6
  fish_sel_coffs  -.10



//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

PARAMETER_SECTION

  init_number            log_avg_rec(1);            // log of average
recruitment
  init_number            log_Rzero(1);                    // Unfish
equil recruitment (logged)
  init_number            log_q_cpue(1);             // Log fishery
catchability
  init_number            log_q_surv(ph_surv_q);     // Log survey1
catchability
  init_number            log_q_surv2(ph_surv_q);    // Log survey2
catchability
  init_number            log_q_surv3(ph_surv_q);    // Log survey3
catchability
  init_number            log_q_surv4(ph_surv_q);    // Log survey4
catchability
  init_bounded_number    natmort(0.01,.2,ph_M);   // Natural
mortality
  init_bounded_number    steepness(0.21,0.99,ph_steepness); // Bounded
SR shape parameter
  //init_bounded_number    sigr(0.1,2.,ph_sigmar);   // SR variance
parameter
  //init_bounded_number    rho(0.0,0.9,ph_rho); // Bounded SR serial
correlation parameter
  init_number            log_avg_F(1);                    // Average
Fishing mortality

  // Deviations from recruitment model in each year
  init_bounded_dev_vector   log_rec_dev(styr_rec,endyr,-
10,10,ph_recdev);

  // Annual effect on fishing (effort implied)
  init_bounded_dev_vector   log_F_devs(styr,endyr,-10,10,ph_Fdev);

  // Selectivity parameters
  // for shelf (triennial) survey
  // options 1 and 2
  // these are actually in log-space
  init_vector     surv_sel_coffs(1,max_sel_age_surv,ph_surv_sel_type1);
// Sel at age coefficients

  // option 2

  // Time changes in survey selectivity
  init_bounded_matrix  sel_devs_surv(1,dim_sel,1,max_sel_age_surv,-
5.,5.,ph_seldev_surv);
```

```
  //option 3
  init_bounded_number  sel_slp_surv(-500,3,ph_asym_sel);  // Asymptotic
Selectivity Coef
  init_bounded_number  sel_a50_surv(-500,3.3,ph_asym_sel);  //
Asymptotic Sel Coef

  //selectivity parameters for slope and POP survey

  //options 1 and 2
  // these are actually in log-space
  init_vector
surv2_sel_coffs(1,max_sel_age_surv,ph_surv_sel_type1);
  // Sel at age coefficients

  // option 2
  // there are more of these than needed

  // Time changes in survey selectivity
  init_bounded_matrix  sel_devs_surv2(1,dim_sel,1,max_sel_age_surv,-
5.,5.,ph_seldev_surv);


  //option 3
  init_bounded_number  sel_slp_surv2(-500,3,ph_asym_sel);  //
Asymptotic Selectivity Coef
  init_bounded_number  sel_a50_surv2(-500,3.3,ph_asym_sel);  //
Asymptotic Sel Coef


    // Fishery Selectivity
  init_bounded_matrix sel_devs_fish(1,dim_sel,1,max_sel_age,-
5.,5.,ph_seldev_fish);
  init_vector  fish_sel_coffs(1,max_sel_age,ph_fish_sel);  //Fishery
sel at age coefs

  matrix esc_surv(1,nyrs_surv_size,1,nlenbins); //--Exp prop at size in
Survey
  matrix eac_surv(1,nyrs_surv_age,1,nages);     //--Exp prop at age in
Survey
  matrix esc_surv2(1,nyrs_surv2_size,1,nlenbins);//--Exp prop at size
in Survey2
  matrix eac_surv2(1,nyrs_surv2_age,1,nages);     //--Exp prop at age
in Survey2
  matrix esc_fish(1,nyrs_fish_size,1,nlenbins); //--Exp prop at size in
Fishery
  matrix esc_ufish(1,nyrs_ufish_size,1,nlenbins); // Exp prop at size
in Fishery
  matrix eac_fish1(1,nyrs_fish_age,1,nages);    // -- Exp prop at age
in Fishery
  matrix eac_fish(1,nyrs_fish_age,1,12);        //-- "" - truncated
  matrix eac_fish2(1,nyrs_fish2_age,1,nages);   //-- """" - 1999+

  vector Fmort(styr,endyr);
  matrix catage(styr,endyr,1,nages);
  vector pred_catch(styr,endyr);
  vector seltmp(1,nages);
  vector p_mature(1,nages);
  vector sp_biom(styr_sp,endyr+1);
  vector tot_biom(styr,endyr+1);
  matrix natage(styr,endyr+1,1,nages);
  matrix Z(styr,endyr,1,nages);
```

```
  matrix F(styr,endyr,1,nages);
  matrix S(styr,endyr,1,nages);
  matrix log_surv_sel(styr,endyr,1,nages);
  matrix surv_sel(styr,endyr,1,nages); // this maintains survey
selectivity for years with no survey...
  matrix log_surv2_sel(styr,endyr,1,nages);// added for survey 2
  matrix surv2_sel(styr,endyr,1,nages); // added for survey 2
  matrix log_fish_sel(styr,endyr,1,nages);
  matrix fish_sel(styr,endyr,1,nages);

  number ssqcatch;
  number avgfishsel;
  number avgsurvsel;
  number avgsurv2sel; // added for survey 2
  number alpha;
  number beta;
  number Rzero;
  number surv;

  vector sel_like(1,5);
  vector surv_like(1,5);
  vector age_like(1,7);
  vector rec_like(1,4);
  vector fmort_like(1,3);
  vector Priors(1,6);
  vector offset(1,7); // Offsets for Multinomial age likelihood
  vector offset2(1,7); // Offsets for Robust Likelihood
  number sumtmp;

  vector pred_cpue(1,nyrs_cpue);
  vector pred_surv(1,nyrs_surv);
  vector pred_surv2(1,nyrs_surv2);
  vector pred_surv3(1,nyrs_surv3);
  vector pred_surv4(1,nyrs_surv4);
  vector SRec_Spawn(1,20);
  vector SRec_Rec(1,20);

  // Parameters for computing SPR rates
  init_bounded_number F55(0.01,1.,phase_F55);
  init_bounded_number F50(0.01,1.,phase_F55);
  init_bounded_number F40(0.01,1.,phase_F55);
  number ABC;

  // Stuff for SPR and yield projections
  number sigmaRsq;
  number SB0;
  number SBF55;
  number SBF50;
  number SBF40;
  number sprpen;
  matrix Nspr(1,4,1,nages);

  sdreport_number endbiom;
  sdreport_number q_surv;
  sdreport_number q_surv2;
  sdreport_number q_surv3;
  sdreport_number q_surv4;
  sdreport_number q_cpue;
  sdreport_number begbiom;
  sdreport_number Depletion;
  sdreport_number MSY;
```

```
  sdreport_number MSYL;
  sdreport_number Fmsy;
  sdreport_number Fmsy_Fend;
  sdreport_number Rmsy;
  sdreport_number Bmsy;
  sdreport_number Bcur_Bmsy;
  sdreport_number Bzero;
  number Btotzero; // added 4/28/03 to report total "initial" biomass

  number phizero;
  number qfix_surv; // added 3/19/03 fix at 1.0 at age 10
  number qfix_surv2;
  number qfix_surv3;
  number qfix_surv4;

  sdreport_vector est_rec(styr_rec,endyr);
  sdreport_vector est_spb(styr_rec,endyr);
  sdreport_vector pred_sd_rec(styr_rec,endyr);

  vector pred_rec(styr_rec,endyr);
  vector chi(styr_rec,endyr);

  objective_function_value obj_fun;

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

PRELIMINARY_CALCS_SECTION

  // Get maturity vector
  // NOTE Females only
  for (j=1; j<=nages; j++)
    {
      //old version
        //p_mature(j)= 0.5/(1.+ mfexp(-2.*(double(j)-
mat_inflctn+recage-1.)));
        //Ian's rewrite to compile in VCC
      p_mature(j)= 0.5 / (1. + mfexp(-2. * (double(j) - mat_inflctn +
double(recage) - 1.)));
    }

  //--Caculate offsets for multinomial and robust likelihoods----------
---
  pii = 3.14159265358979;
  for (i=1; i<=nyrs_surv_age; i++)
    {
      // First make sure that they data are in proportions...
      oac_surv(i)/=sum(oac_surv(i));
      offset=0.;
      offset2=0.;
      // the multinomial value (-LnL) for a perfect fit...
      offset(1) -= nsamples_surv_age(i)*(oac_surv(i) + 0.001) *
log(oac_surv(i) + 0.001 ) ;
      offset2(1) -= nages*log(1.01);
      offset2(1) += 0.5*sum(log(2*pii*(oac_surv(i)-square(oac_surv(i))
+ (0.1/nages))));
    }
  for (i=1; i<=nyrs_surv2_age; i++)
    {
      // First make sure that they data are in proportions...
      oac_surv2(i)/=sum(oac_surv2(i));
```

```
      // the multinomial value (-LnL) for a perfect fit...
      offset(2) -= nsamples_surv2_age(i)*(oac_surv2(i) + 0.001) *
log(oac_surv2(i) + 0.001 ) ;
      offset2(2) -= nages*log(1.01);
      offset2(2) += 0.5*sum(log(2*pii*(oac_surv2(i)-
square(oac_surv2(i)) + (0.1/nages))));
    }
  for (i=1; i<=nyrs_fish_age; i++)
    {
    if(plusgrp==1)
      {
      oac_fish(i)/=sum(oac_fish(i));
      offset(3) -= nsamples_fish_age(i)* ((oac_fish(i) + 0.001) *
log(oac_fish(i) + 0.001 )) ;
      offset2(3) -= 12*log(1.01);
      offset2(3) += 0.5*sum(log(2*pii*(oac_fish(i)-square(oac_fish(i))
+ (0.1/12))));// all fixed for including plus group
      }
    else
      {
      oac_fish(i)(1,11)/=sum(oac_fish(i)(1,11));
      oac_fish(i)(12) = 0;
      offset(3) -= nsamples_fish_age(i)* ((oac_fish(i)(1,11) + 0.001) *
log(oac_fish(i)(1,11) + 0.001 )) ;
      offset2(3) -= 11*log(1.01);
      offset2(3) += 0.5*sum(log(2*pii*(oac_fish(i)(1,11)-
square(oac_fish(i)(1,11)) + (0.1/11))));
      }
    }
  for (i=1; i<=nyrs_surv_size; i++)
    {
      osc_surv(i)/=sum(osc_surv(i));
      offset(4) -= nsamples_surv_size(i)* ((osc_surv(i) + 0.001) *
log(osc_surv(i) + 0.001 )) ;
      offset2(4) -= nlenbins*log(1.01);
      offset2(4) += 0.5*sum(log(2*pii*(osc_surv(i)-square(osc_surv(i))
+ (0.1/nlenbins))));
    }
  for (i=1; i<=nyrs_surv2_size; i++)
    {
      osc_surv2(i)/=sum(osc_surv2(i));
      offset(5) -= nsamples_surv2_size(i)* ((osc_surv2(i) + 0.001) *
log(osc_surv2(i) + 0.001 )) ;
      offset2(5) -= nlenbins*log(1.01);
      offset2(5) += 0.5*sum(log(2*pii*(osc_surv2(i)-
square(osc_surv2(i)) + (0.1/nlenbins))));
    }

  for (i=1; i<=nyrs_fish_size; i++)
    {
      osc_fish(i)/=sum(osc_fish(i));
      offset(6) -= nsamples_fish_size(i)* ((osc_fish(i) + 0.001) *
log(osc_fish(i) + 0.001 )) ;
      offset2(6) -= nlenbins*log(1.01);
      offset2(6) += 0.5*sum(log(2*pii*(osc_fish(i)-square(osc_fish(i))
+ (0.1/nlenbins))));
    }

  for (i=1; i<=nyrs_fish_size; i++)
    {
      osc_ufish(i)/=sum(osc_ufish(i));
```

```
    }

  for (i=1; i<=nyrs_fish2_age; i++)
    {
      oac_fish2(i)/=sum(oac_fish2(i));
      offset(7) -= nsamples_fish2_age(i)* ((oac_fish2(i) + 0.001) *
log(oac_fish2(i) + 0.001 )) ;
      offset2(7) -= nages*log(1.01);
      offset2(7) += 0.5*sum(log(2*pii*(oac_fish2(i)-
square(oac_fish2(i)) + (0.1/nages))));
    }

  // Calculations moved from the Data and Parameter sections by Owen:
  Do_Fmort=0;
  q_prior(4)=qpriortype;
  q_prior(5)=qprior;
  q_prior(6)=cvqprior;
  M_prior(4)=2;
  M_prior(5)=natmortprior;
  M_prior(6)=cvnatmortprior;


  if (ph_surv_q<0) log_q_surv = log(qprior);
  //if (ph_rho <0) rho = 0.; // added 3/3/2003

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

RUNTIME_SECTION

   maximum_function_evaluations 100,150,300,4000
   convergence_criteria .01,.0001,1e-7

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

PROCEDURE_SECTION

  Get_Bzero();
  Get_Selectivity();
  Get_Mortality_Rates();
  Get_Numbers_At_Age();
  Get_Catch_at_Age();
  Get_Predicted_Values();
  if (active(F55))
    {
      compute_spr_rates();
      ABC = ((Depletion-
0.10)/0.30)*F50*fish_sel(endyr)*(elem_prod(natage(endyr+1),wt));

    }
  if(last_phase())
    {
      get_msy();
      Fmsy_Fend=Fmort(endyr)/Fmsy;
    }
  if (Do_Fmort==1)
    {
      Profile_Fmort();
      exit(1);
    }
```

```
  Evaluate_Objective_Function();
  if (mceval_phase())
    {
      MCWrite();
    }

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION Get_Bzero

  Rzero     =  mfexp(log_Rzero);
  surv      = mfexp(-natmort);
  dvar_matrix natagetmp(styr_rec,styr,1,nages);
  natagetmp(styr_rec,1) = Rzero;

  for (j=2; j<=nages; j++)
    {
      natagetmp(styr_rec,j) = natagetmp(styr_rec,j-1) * surv;
    };

  natagetmp(styr_rec,nages) /= (1.-surv);
  Bzero  = elem_prod(wt,p_mature)*natagetmp(styr_rec);
  Btotzero = natagetmp(styr_rec)*wt;

  if (SrType==1)  // Ricker
    {
      alpha = log(-4.*steepness/(steepness-1.));
      phizero = Bzero/Rzero;
    }
  else                         // Beverton-Holt
    {
      alpha  =  Bzero * (1. - (steepness - 0.2) / (0.8*steepness) ) /
Rzero;
      beta   = (5. * steepness - 1.) / (4. * steepness * Rzero);
    };

  sp_biom.initialize();
  sp_biom(styr_sp,styr_rec-1) = Bzero;

  for (i=styr_rec;i<styr;i++)
    {
      sp_biom(i) = elem_prod(natagetmp(i), wt) * p_mature;
      natagetmp(i,1)    = mfexp(log_rec_dev(i) + log_Rzero);
      natagetmp(i+1)(2,nages) = ++(natagetmp(i)(1,nages-1)*mfexp(-
natmort ));
      natagetmp(i+1,nages) += natagetmp(i,nages)*mfexp(-natmort);
    };

  natagetmp(styr,1)    = mfexp(log_rec_dev(styr) + log_Rzero); // tried
log_avg_rec - should not make a deifference
  est_rec(styr_rec,styr) = column(natagetmp,1);
  natage(styr)   = natagetmp(styr);
  sp_biom(styr) = elem_prod(natage(styr), wt) * p_mature;

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION Get_Selectivity

  // Shelf (Triennial) survey
```

```
  // which survey selectivity option is turned on?

  if (surv_switch == 1)
    {
      // original Ianelli selectivity function used in model 1c
        // time invariant selectivity function
      avgsurvsel  = log(mean(mfexp(surv_sel_coffs))); //for penalty
used in likelihood
      log_surv_sel(styr)(1,max_sel_age_surv) = surv_sel_coffs;
//assigns coeffs up to max age
        log_surv_sel(styr)(max_sel_age_surv,nages) =
surv_sel_coffs(max_sel_age_surv); //assigns older ages the same as max
age
      log_surv_sel(styr)-=log(mean(mfexp(log_surv_sel(styr))));
//turns these into residuals

      for (i=styr;i<endyr;i++)
          {
          log_surv_sel(i+1)=log_surv_sel(i); // paste values across
years
        };
      surv_sel=mfexp(log_surv_sel); // exponentiate for use in model
    };

  if (surv_switch == 2)
    {
      // Original Ianelli selectivity model -- time varying
        avgsurvsel  = log(mean(mfexp(surv_sel_coffs))); //for penalty
used in likelihood
      log_surv_sel(styr)(1,max_sel_age_surv) = surv_sel_coffs;
//assigns coeffs up to max age
        log_surv_sel(styr)(max_sel_age_surv,nages) =
surv_sel_coffs(max_sel_age_surv); //assigns older ages the same as max
age
      int ii;
      log_surv_sel(styr)-=log(mean(mfexp(log_surv_sel(styr)))); //turns
these into residuals
        if (active(sel_devs_surv))
        {
          ii=1;
          for (i=styr;i<endyr;i++)
            {
              if (!(i%group_num))
                {

log_surv_sel(i+1)(1,max_sel_age_surv)=log_surv_sel(i)(1,max_sel_age_sur
v)+sel_devs_surv(ii);

log_surv_sel(i+1)(max_sel_age_surv,nages)=log_surv_sel(i+1,max_sel_age_
surv);
                  ii++;
                  log_surv_sel(i+1)-
=log(mean(mfexp(log_surv_sel(i+1))));
                }
              else
                {
                  log_surv_sel(i+1) =log_surv_sel(i);
                  log_surv_sel(i+1)-
=log(mean(mfexp(log_surv_sel(i+1))));
                };
            };
```

```
        };
      surv_sel=mfexp(log_surv_sel);
      };

  if (surv_switch == 3)  // Ianelli asymptotic selectivity function
    {
      for (j=1; j<=nages; j++)  //calculate the value over ages
          {
              //calculates the vector of selectivity coefficients for
the first year
              surv_sel(styr,j)=1./(1.+mfexp(-1.*mfexp(sel_slp_surv)*
(double(j)-mfexp(sel_a50_surv))));
        }
        for (i=styr;i<endyr;i++) //copy this value to all years
            {
              //assigns all the subsequent years the same vector of
coefficients
          surv_sel(i+1)=surv_sel(i);
        }
    };




  // NWFSC, AKFSC Slope + POP survey
  // which survey selectivity option is turned on?

  if (surv_switch == 1)
    {
      // Ianelli selectivity function used in model 1c
        // time invariant selectivity function
      avgsurv2sel  = log(mean(mfexp(surv2_sel_coffs))); //for penalty
used in likelihood
      log_surv2_sel(styr)(1,max_sel_age_surv) = surv2_sel_coffs;
//assigns coeffs up to max age
        log_surv2_sel(styr)(max_sel_age_surv,nages) =
surv2_sel_coffs(max_sel_age_surv); //assigns older ages the same as max
age
      log_surv2_sel(styr)-=log(mean(mfexp(log_surv2_sel(styr))));
//turns these into residuals
      for (i=styr;i<endyr;i++)
          {
          log_surv2_sel(i+1)=log_surv2_sel(i); //paste values across
years
        };
      surv2_sel=mfexp(log_surv2_sel);
    };

  if (surv_switch == 2)
    {
      //original Ianelli selectivity model -- time varying
        avgsurv2sel  = log(mean(mfexp(surv2_sel_coffs))); //for penalty
used in likelihood
      log_surv2_sel(styr)(1,max_sel_age_surv) = surv2_sel_coffs;
//assigns coeffs up to max age
        log_surv2_sel(styr)(max_sel_age_surv,nages) =
surv2_sel_coffs(max_sel_age_surv); //assigns older ages the same as max
age
      int ii;
      log_surv2_sel(styr)-=log(mean(mfexp(log_surv2_sel(styr))));
//turns these into residuals
```

```
        if (active(sel_devs_surv2))
        {
          ii=1;
          for (i=styr;i<endyr;i++)
            {
              if (!(i%group_num))
                {

log_surv2_sel(i+1)(1,max_sel_age_surv)=log_surv2_sel(i)(1,max_sel_age_s
urv)+sel_devs_surv2(ii);

log_surv2_sel(i+1)(max_sel_age_surv,nages)=log_surv2_sel(i+1,max_sel_ag
e_surv);
                  ii++;
                  log_surv2_sel(i+1)-
=log(mean(mfexp(log_surv2_sel(i+1))));
                }
              else
                {
                  log_surv2_sel(i+1) =log_surv2_sel(i);
                  log_surv2_sel(i+1)-
=log(mean(mfexp(log_surv2_sel(i+1))));
                };
            };
        };
      surv2_sel=mfexp(log_surv2_sel);
      };

  if (surv_switch == 3)  //this is the Ianelli asymptotic selectivity
function
    {
      for (j=1; j<=nages; j++)  //calculate the value over ages
          {
              //calculates the vector of selectivity coefficients for
the first year
              surv2_sel(styr,j)=1./(1.+mfexp(-1.*mfexp(sel_slp_surv2)*
(double(j)-mfexp(sel_a50_surv2))));
        }
        for (i=styr;i<endyr;i++) //copy this value to all years
            {
              //assigns all the subsequent years the same vector of
coefficients
          surv2_sel(i+1)=surv2_sel(i);
        }
    };



  // Fishery selectivity function
  avgfishsel                             =
log(mean(mfexp(fish_sel_coffs)));
  log_fish_sel(styr)(1,max_sel_age)      = fish_sel_coffs;
  log_fish_sel(styr)(max_sel_age,nages)  = fish_sel_coffs(max_sel_age);
  log_fish_sel(styr)                    -=
log(mean(mfexp(log_fish_sel(styr))));
  if (active(sel_devs_fish))
    {
      ii=1;
      for (i=styr;i<endyr;i++)
        {
          if (!(i%group_num))
```

```
            {
              log_fish_sel(i+1)(1,max_sel_age)     =
log_fish_sel(i)(1,max_sel_age)+sel_devs_fish(ii);
              log_fish_sel(i+1)(max_sel_age,nages) =
log_fish_sel(i+1,max_sel_age);
              ii++;
              log_fish_sel(i+1) -= log(mean(mfexp(log_fish_sel(i+1))));
            }
          else
            {
              log_fish_sel(i+1)    = log_fish_sel(i);
              log_fish_sel(i+1)  -=
log(mean(mfexp(log_fish_sel(i+1))));
            }
        }
    }
  else
    {
      for (i=styr;i<endyr;i++)

          {
          log_fish_sel(i+1)=log_fish_sel(i);
        }
    }
  fish_sel=mfexp(log_fish_sel);

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION Get_Mortality_Rates

  Fmort =  mfexp(log_avg_F +  log_F_devs);
  //F     = outer_prod(Fmort , fish_sel);
  for (i=styr; i<=endyr; i++)
    F(i) = Fmort(i) * fish_sel(i) ;
  Z=F+natmort;
  S=mfexp(-1.0*Z);

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+


FUNCTION Get_Numbers_At_Age

  // Now do for next several years
  for (i = styr; i <= endyr; i++)
  {
    natage(i,1)  = mfexp(log_avg_rec + log_rec_dev(i));
    est_rec(i)   = natage(i,1);
    sp_biom(i)   = elem_prod(natage(i),p_mature) * wt;
    tot_biom(i)    = natage(i)*wt;    // Added April 28 to get age 3+
biomass

    // Now graduate for the next year....
    natage(i+1)(2,nages) = ++elem_prod(natage(i)(1,nages-
1),S(i)(1,nages-1));
    natage(i+1,nages)   += natage(i,nages)*S(i,nages);
  }

  natage(endyr+1,1)   = mfexp(log_avg_rec + log_rec_dev(endyr)) ;
  sp_biom(endyr+1)    = elem_prod(natage(endyr+1),p_mature) * wt;
```

```
  tot_biom(endyr+1)  = natage(endyr+1)*wt;
  dvar_vector Stmp(styr_rec, endyr) ;
  Stmp = sp_biom(styr_rec-recage, endyr-recage).shift(styr_rec);
  est_spb = Stmp;
  pred_rec = SRecruit(Stmp);

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+


FUNCTION Get_Catch_at_Age

  for (i=styr; i<=endyr; i++)
  {
    pred_catch(i)=0.;

    //--Baranov equation here
    for (j = 1 ; j<= nages; j++)
      catage(i,j) = natage(i,j)*F(i,j)*(1.-S(i,j))/Z(i,j);
    pred_catch(i) = catage(i)*wt;
  }

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION Get_Predicted_Values

  q_surv=mfexp(log_q_surv);
  q_surv2=mfexp(log_q_surv2);
  q_surv3=mfexp(log_q_surv3);
  q_surv4=mfexp(log_q_surv4);
  q_cpue=mfexp(log_q_cpue);

  for (i=1;i<=nyrs_surv;i++)
    {
      pred_surv(i)=q_surv * elem_prod(surv_sel(yrs_surv(i)),
natage(yrs_surv(i))) * wt;
    };

  for (i=1;i<=nyrs_cpue;i++)
    pred_cpue(i)=q_cpue * elem_prod(fish_sel(yrs_cpue(i)),
natage(yrs_cpue(i))) * wt;

  for (i=1;i<=nyrs_surv2;i++)
    pred_surv2(i)=q_surv2 * elem_prod(surv2_sel(yrs_surv2(i)),
natage(yrs_surv2(i))) * wt;

  for (i=1;i<=nyrs_surv3;i++)
    pred_surv3(i)=q_surv3 * elem_prod(surv2_sel(yrs_surv3(i)),
natage(yrs_surv3(i))) * wt;

  for (i=1;i<=nyrs_surv4;i++)
    pred_surv4(i)=q_surv4 * elem_prod(surv2_sel(yrs_surv4(i)),
natage(yrs_surv4(i))) * wt;

  for ( i=1;i<=nyrs_surv_age;i++)
    eac_surv(i) =
elem_prod(surv_sel(yrs_surv_age(i)),natage(yrs_surv_age(i)))/
    (surv_sel(yrs_surv_age(i)) * natage(yrs_surv_age(i)))*ageage ;

  for ( i=1;i<=nyrs_surv_size;i++)
```

```
    esc_surv(i) =
elem_prod(surv_sel(yrs_surv_size(i)),natage(yrs_surv_size(i)))/
    (surv_sel(yrs_surv_size(i)) * natage(yrs_surv_size(i))) * sizeage;

  for ( i=1;i<=nyrs_surv2_age;i++)
    eac_surv2(i) =
elem_prod(surv2_sel(yrs_surv2_age(i)),natage(yrs_surv2_age(i)))/
    (surv_sel(yrs_surv2_age(i)) * natage(yrs_surv2_age(i)))*ageage ;

  for ( i=1;i<=nyrs_surv2_size;i++)
    esc_surv2(i) =
elem_prod(surv2_sel(yrs_surv2_size(i)),natage(yrs_surv2_size(i)))/
                              (surv2_sel(yrs_surv2_size(i)) *
natage(yrs_surv2_size(i))) * sizeage;

  for ( i=1;i<=nyrs_fish_age;i++) // changed this to accommodate
ageerror matrix
    {
    eac_fish1(i)=
catage(yrs_fish_age(i))/sum(catage(yrs_fish_age(i)))*ageage;
      if(plusgrp==1)
        {
          eac_fish(i)(1,11) = eac_fish1(i)(1,11);
          eac_fish(i)(12) = sum(eac_fish1(i)(12,23));
        }
      else
        {
          eac_fish(i)(1,11) =
eac_fish1(i)(1,11)/sum(eac_fish(i)(1,11));
        }
    }
  for ( i=1;i<=nyrs_fish_size;i++)
    esc_fish(i)  =
catage(yrs_fish_size(i))/sum(catage(yrs_fish_size(i))) * sizeage;

  for ( i=1;i<=nyrs_ufish_size;i++)
    esc_ufish(i)  =
catage(yrs_ufish_size(i))/sum(catage(yrs_ufish_size(i))) * sizeage;

  for ( i=1;i<=nyrs_fish2_age;i++)
    eac_fish2(i)  =
catage(yrs_fish2_age(i))/sum(catage(yrs_fish2_age(i))) * ageage;

  begbiom  = natage(styr)*wt;
  endbiom  = natage(endyr)*wt;
  Depletion=sp_biom(endyr+1)/Bzero; // - changed from /sp_biom(styr)

  if(sd_phase())
    {
      for ( j=1;j<nages;j++)
        {
          i = styr+1-j;
          pred_sd_rec(i) = natage(styr,j)*mfexp(natmort*double(j-1));
        }
      // natage(styr,nages) = mfexp(log_Rzero - natmort * (nages-1) ) /
 (1. - surv);
      for ( i=styr;i<=endyr;i++)
        {
          pred_sd_rec(i) = natage(i,1);
        }
    }
```

```
  qfix_surv = q_surv*surv_sel(2000,8);
  qfix_surv2 = q_surv2*surv2_sel(2000,8);
  qfix_surv3 = q_surv3*surv2_sel(2000,8);
  qfix_surv4 = q_surv4*surv2_sel(2000,8);


//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION compute_spr_rates

  // Compute SPR Rates and add them to the likelihood for Females
  SB0=0.;
  SBF55=0.;
  SBF50=0.;
  SBF40=0.;
  for (i=1;i<=4;i++)
    Nspr(i,1)=1.;

  for (j=2;j<nages;j++)
    {
      Nspr(1,j) = Nspr(1,j-1)*mfexp(-1.*natmort);
      Nspr(2,j) = Nspr(2,j-1)*mfexp(-1.*(natmort+F55*fish_sel(endyr,j-
1)));
      Nspr(3,j) = Nspr(3,j-1)*mfexp(-1.*(natmort+F50*fish_sel(endyr,j-
1)));
      Nspr(4,j) = Nspr(4,j-1)*mfexp(-1.*(natmort+F40*fish_sel(endyr,j-
1)));
    }

  Nspr(1,nages) = Nspr(1,nages-1)*mfexp(-1.*natmort)/(1.-mfexp(-
1.*natmort));
  Nspr(2,nages) = Nspr(2,nages-1)*mfexp(-1.*
(natmort+F55*fish_sel(endyr,nages-1)))/
                              (1.-mfexp(-
1.*(natmort+F55*fish_sel(endyr,nages))));
  Nspr(3,nages) = Nspr(3,nages-1)*mfexp(-1.*
(natmort+F50*fish_sel(endyr,nages-1)))/
                              (1.-mfexp(-
1.*(natmort+F50*fish_sel(endyr,nages))));
  Nspr(4,nages) = Nspr(4,nages-1)*mfexp(-1.*
(natmort+F40*fish_sel(endyr,nages-1)))/
                              (1.-mfexp(-
1.*(natmort+F40*fish_sel(endyr,nages))));

  for (j=1;j<=nages;j++)
    {
      // Kill them off till april (0.25)
      SB0    += Nspr(1,j)*p_mature(j)*wt(j)*mfexp(-0.25*natmort);
      SBF55  += Nspr(2,j)*p_mature(j)*wt(j)*mfexp(-
0.25*(natmort+F55*fish_sel(endyr,j)));
      SBF50  += Nspr(3,j)*p_mature(j)*wt(j)*mfexp(-
0.25*(natmort+F50*fish_sel(endyr,j)));
      SBF40  += Nspr(4,j)*p_mature(j)*wt(j)*mfexp(-
0.25*(natmort+F40*fish_sel(endyr,j)));
    }

  sprpen    = 300.*square(SBF55/SB0-0.55);
  sprpen   += 300.*square(SBF50/SB0-0.5);
  sprpen   += 300.*square(SBF40/SB0-0.4);
```

```
  //
+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+=
=+

FUNCTION Surv_Likelihood

  // -Likelihood due to survey biomass index-
  surv_like=0.;
  // change to a log_normal likelihood for the survey biomass series
fitting

  for (i=1; i<=nyrs_surv; i++)
    // the old normal likelihood
    //surv_like(1)+=lambda(13)*square((obs_surv_biom(i)-pred_surv(i)
))/
  //(2.*obs_surv_se(i)*obs_surv_se(i));
      // the lognormal likelihood
    surv_like(1)+=lambda(13)*square((log(obs_surv_biom(i))-
log(pred_surv(i))))/
                   (2.*
(log(1+(obs_surv_se(i)/obs_surv_biom(i))*(obs_surv_se(i)/obs_surv_biom(
i))))*

(log(1+(obs_surv_se(i)/obs_surv_biom(i))*(obs_surv_se(i)/obs_surv_biom(
i)))));

  for (i=1; i<=nyrs_surv2; i++)
    // the old normal likelihood
    //surv_like(2)+=lambda(14)*square((obs_surv_biom2(i)-pred_surv2(i)
))/
  //(2.*obs_surv_se2(i)*obs_surv_se2(i));
      // the lognormal likelihood
      surv_like(2)+=lambda(14)*square((log(obs_surv_biom2(i))-
log(pred_surv2(i))))/
                   (2.*
(log(1+(obs_surv_se2(i)/obs_surv_biom2(i))*(obs_surv_se2(i)/obs_surv_bi
om2(i))))*

(log(1+(obs_surv_se2(i)/obs_surv_biom2(i))*(obs_surv_se2(i)/obs_surv_bi
om2(i)))));

  for (i=1; i<=nyrs_surv3; i++)// added in surv3 without changing param
    // the old normal likelihood
    // surv_like(3)+=lambda(14)*square((obs_surv_biom3(i)-pred_surv3(i)
))/
  //(2.*obs_surv_se3(i)*obs_surv_se3(i));
      // the lognormal likelihood
    surv_like(3)+=lambda(14)*square((log(obs_surv_biom3(i))-
log(pred_surv3(i))))/
                   (2.*
(log(1+(obs_surv_se3(i)/obs_surv_biom3(i))*(obs_surv_se3(i)/obs_surv_bi
om3(i))))*

(log(1+(obs_surv_se3(i)/obs_surv_biom3(i))*(obs_surv_se3(i)/obs_surv_bi
om3(i)))));

  for (i=1; i<=nyrs_surv4; i++)// added in surv4 without changing param
    // the old normal likelihood
```

```
    //surv_like(4)+=lambda(14)*square((obs_surv_biom4(i)-pred_surv4(i)
))/
  //(2.*obs_surv_se4(i)*obs_surv_se4(i));
      // the lognormal likelihood
    surv_like(4)+=lambda(14)*square((log(obs_surv_biom4(i))-
log(pred_surv4(i))))/
                   (2.*
(log(1+(obs_surv_se4(i)/obs_surv_biom4(i))*(obs_surv_se4(i)/obs_surv_bi
om4(i))))*

(log(1+(obs_surv_se4(i)/obs_surv_biom4(i))*(obs_surv_se4(i)/obs_surv_bi
om4(i)))));


  for (i=1; i<=nyrs_cpue; i++)
    // got rid of log(cv_cpue) so not neg

      surv_like(5)+=lambda(15)*square((log(obs_cpue(i))-
log(pred_cpue(i)) ))/ (2.*cv_cpue*cv_cpue);
    // logLike=square(log(observed)-log(expected))/(2*square(cv)) +
log(cv)+  0.5*log(2*pi);
  //
+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+=
=+

FUNCTION Multinomial_Likelihood

  //-Likelihood due to Age compositions--------------------------------
  age_like=0.;
  for (i=1; i <= nyrs_surv_age; i++)
    age_like(1) -= nsamples_surv_age(i)*(oac_surv(i) + 0.001) *
log(eac_surv(i) + 0.001);
  for (i=1; i <= nyrs_surv2_age; i++)
    age_like(2) -= nsamples_surv2_age(i)*(oac_surv2(i) + 0.001) *
log(eac_surv2(i) + 0.001 ) ; // added for slope survey
  for (i=1; i <= nyrs_fish_age; i++)
    {
    if(plusgrp==1)
      {
      age_like(3) -= nsamples_fish_age(i)*(oac_fish(i) + 0.001) *
log(eac_fish(i) + 0.001 ) ; // fixed for plus group inclusion
    }
    else
      {
      age_like(3) -= nsamples_fish_age(i)*(oac_fish(i)(1,11) + 0.001) *
log(eac_fish(i)(1,11) + 0.001 ) ;
    }
  }

  //-Likelihood due to survey size compositions------------------------
--------
  for (i=1; i <= nyrs_surv_size; i++)
    age_like(4) -= nsamples_surv_size(i)*(osc_surv(i) + 0.001) *
log(esc_surv(i) + 0.001 ) ;
  for (i=1; i <= nyrs_surv2_size; i++)
    age_like(5) -= nsamples_surv2_size(i)*(osc_surv2(i) + 0.001) *
log(esc_surv2(i) + 0.001 ) ; // added for slope survey

  //-Likelihood due to fishery size compositions-----------------------
---------
  for (i=1; i <= nyrs_fish_size; i++)
```

```
    age_like(6) -= nsamples_fish_size(i)*(osc_fish(i) + 0.001) *
log(esc_fish(i) + 0.001 ) ;

  // - Likelihood due to fishery new (1999+) age compostions----------
--------
  for (i=1; i <= nyrs_fish2_age; i++)
    age_like(7) -= nsamples_fish2_age(i)*(oac_fish2(i) + 0.001) *
log(eac_fish2(i) + 0.001 ) ;

  age_like(1)-=offset(1);
  age_like(2)-=offset(2);
  age_like(3)-=offset(3);
  age_like(4)-=offset(4);
  age_like(5)-=offset(5);
  age_like(6)-=offset(6);
  age_like(7)-=offset(7);
  //
+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+=
=+

FUNCTION Compute_Rec_Like

  rec_like.initialize();
  sigmaRsq    = sigr*sigr;
  chi = log(est_rec+1e-8)- log(pred_rec+1e-8);
  //chi += sigmaRsq/2. ;// To adjust for bias...
  if (rho>0)
  {
    for (i=styr_rec;i<styr;i++)
      rec_like(1)    += (square( chi(i) ) / (2*sigmaRsq)) + log(sigr);
    chi += sigmaRsq/2. ;// To adjust for bias...
    for (i=styr;i<=endyr;i++)
      rec_like(1) += square(chi(i)- rho*chi(i-1)) /sqrt(1.-
rho*rho)/(2.*sigmaRsq) + log(sigr);
  }
  else
  {
    for (i=styr_rec;i<styr;i++)
      rec_like(1)    += (square( chi(i) ) / (2*sigmaRsq)) + log(sigr);
    chi += sigmaRsq/2. ;// To adjust for bias...
    for (i=styr;i<=endyr;i++)
      rec_like(1)    += (square( chi(i)) / (2*sigmaRsq)) + log(sigr);
  }
  if (!last_phase() ) // Recruitment variability: EARLY PHASES ONLY
    rec_like(2)  = 1. * norm2(log_rec_dev) ;
  else
  {
    rec_like(1) *= lambda(4) ;
    rec_like(2)  = 0.0 * norm2(log_rec_dev) ;
  }


//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION Sel_Like

  sel_like.initialize(); //Set vector equal to zero for initialization

  //this will only be turned on in options 1 and 2
  if((surv_switch == 1) || (surv_switch == 2))
```

```
    {
      if (surv_switch == 2) //If time changes on, then do 2nd
differencing for curvature penalty on subsequent years
        {
          //--This is for limiting the dome-shapedness
          for (i=1978;i<= endyr;i++) //may need to remove specific year
                {
              if (!(i%group_num))
                for (j=1;j<nages;j++)
                  if (log_surv_sel(i,j)>log_surv_sel(i,j+1))
                    sel_like(1) +=lambda(8)*square(log_surv_sel(i,j)-
log_surv_sel(i,j+1));
            };
          sel_like(2) +=lambda(9)/group_num*norm2(sel_devs_surv);
          sel_like(3)
+=lambda(10)/dim_sel*norm2(first_difference(first_difference(log_surv_s
el(styr))));
          for (i=styr;i<endyr;i++)
            if (!(i%group_num))
                    {
                sel_like(4)
+=lambda(10)/dim_sel*norm2(first_difference(first_difference(log_surv_s
el(i+1))));
              };
            }
      else  //otherwise only first year mtr
        {
          sel_like(3)
+=lambda(10)*norm2(first_difference(first_difference(log_surv_sel(styr)
)));
        };
    };

  // Now for surv2
  if((surv_switch == 1) || (surv_switch == 2))
    {
      if (surv_switch == 2) //If time changes on, then do 2nd
differencing for curvature penalty on subsequent years
        {
          //--This is for limiting the dome-shapedness
          for (i=1978;i<= endyr;i++) //may need to remove specific year
                {
              if (!(i%group_num))
                for (j=1;j<nages;j++)
                  if (log_surv2_sel(i,j)>log_surv2_sel(i,j+1))
                    sel_like(1) +=lambda(8)*square(log_surv2_sel(i,j)-
log_surv2_sel(i,j+1));
            };
          sel_like(2) +=lambda(9)/group_num*norm2(sel_devs_surv2);
          sel_like(3)
+=lambda(10)/dim_sel*norm2(first_difference(first_difference(log_surv2_
sel(styr))));
          for (i=styr;i<endyr;i++)
            if (!(i%group_num))
                    {
                sel_like(4)
+=lambda(10)/dim_sel*norm2(first_difference(first_difference(log_surv2_
sel(i+1))));
              };
            }
      else  //otherwise only first year mtr
```

```
        {
          sel_like(3)
+=lambda(10)*norm2(first_difference(first_difference(log_surv2_sel(styr
))));
        };
    };

  // Fishery selectivity
  if (active(sel_devs_fish))
    {
      //--This is for limiting the dome-shapedness
      for (i=styr;i<= endyr;i++)
        {
              if (!(i%group_num))
            {
              for (j=8;j<nages;j++)
                {
                  if (log_fish_sel(i,j)>log_fish_sel(i,j+1))
                        {
                      sel_like(1) +=lambda(8)*square(log_fish_sel(i,j)-
log_fish_sel(i,j+1));
                    };
                };
                };
        };
      sel_like(2) +=lambda(9)/group_num*norm2(sel_devs_fish);
      sel_like(4)
+=lambda(10)/dim_sel*norm2(first_difference(first_difference(log_fish_s
el(styr))));

      for (i=styr;i<endyr;i++)
      if (!(i%group_num))
        {
          sel_like(4)
+=lambda(10)/dim_sel*norm2(first_difference(first_difference(log_fish_s
el(i+1))));
        };
    }
  else
    {
      sel_like(4)
+=lambda(11)*norm2(first_difference(first_difference(log_fish_sel(styr)
)));
    };

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION Fmort_likelihood

  fmort_like.initialize();
  fmort_like(1) = .001 * lambda(5) *  norm2(log_F_devs);

  //This is to make the initial comp not stray too far from then
subsequent (early phases)
  if (current_phase()<3 )
    {
      fmort_like(2) = 10.0*norm2(Fmort-.2);
    };
```

```
//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION Evaluate_Objective_Function

  //-Likelihood function------------------------------------------------
  Surv_Likelihood();          //-surv Deviations
  Sel_Like();                         // Call likelihood due to
selectivity penalties
                                            // this gets called
regardless of selectivity option
  Fmort_likelihood();
  ssqcatch  = norm2(log(obs_catch+.01)- log(pred_catch+.01));    //
Total catch biomass
  Compute_Rec_Like();

  if (current_phase() < Do_Robust_Phase)
    Multinomial_Likelihood(); // Age and Size Likelihoods
  else
    Robust_Likelihood(); // Robust Age and Size Likelihoods

  //--Priors -------------------------------------------
  if (active(natmort))
    Priors(1) = prior(natmort,   M_prior);

  // Beta prior on steepness...
  if (active(steepness))
    {
      if(steeppriorswitch == 1)
      {
        dvariable steeptmp;
        steeptmp = (steepness - .199999999) /.80000001;
        Priors(2) = -((srprior_a-1.)*log(steeptmp) + (srprior_b-
1)*log(1.-steeptmp));
      }
  }

  if (active(log_q_surv))
      {
      if(surv_switch==1)
            {
            if(qprior_switch==0)
                  Priors(3) = prior(qfix_surv,    q_prior);
            else
                  Priors(3) = .25*(prior(qfix_surv, q_prior)+
prior(qfix_surv2, q_prior)+ prior(qfix_surv3, q_prior)+
prior(qfix_surv4, q_prior));
      }
      else
            {
            if(qprior_switch==0)
                  Priors(3) = prior(q_surv,    q_prior);
            else
                  Priors(3) = .25*(prior(q_surv, q_prior)+
prior(q_surv2, q_prior)+ prior(q_surv3, q_prior)+ prior(q_surv4,
q_prior));
      }
  }

  // Put all components together
```

```
  obj_fun += lambda(1) *  ssqcatch ;
  obj_fun += lambda(3) *  sum(age_like);
  obj_fun += lambda(2) *  sum(surv_like);
  obj_fun += sum(rec_like);
  obj_fun += sum(fmort_like);
  obj_fun += lambda(6) *  sum(sel_like);  //add all the sel_like
components mult by lambda(6) = 1
  obj_fun += sum(Priors);
  obj_fun += 10. *square(avgfishsel);

  // this ensures the coefficients average to zero (in log space), so
the avg original sel is = 1
  // the code seems to run without this constraint, the difference
absorbed in q?
  if ((surv_switch == 1) || (surv_switch == 2)) // only use this in
selectivity switch 1 or 2
    {
      obj_fun += 10. *(square(avgsurvsel)+square(avgsurv2sel));
    };

  obj_fun += sprpen;


//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION Robust_Likelihood

  // following Coleraine model following Fournier et al. (1998,1990)
  age_like.initialize();
  double rf      = .1/nages;
  double nlb     = .1/nlenbins; // for sizes
  dvar_matrix vc = rf+elem_prod(eac_surv,1-eac_surv);
  dvar_matrix lc = mfexp(-
mean(nsamples_surv_age)*elem_div(square(eac_surv-oac_surv),2*vc));
  age_like(1)    -= sum(log(lc+.01));
  age_like(1)    += 0.5*sum(log(2*pii*vc));
  dvar_matrix vc2 = rf+elem_prod(eac_surv2,1-eac_surv2);
  dvar_matrix lc2 = mfexp(-
mean(nsamples_surv2_age)*elem_div(square(eac_surv2-oac_surv2),2*vc2));
  age_like(2)    -= sum(log(lc2+.01));
  age_like(2)    += 0.5*sum(log(2*pii*vc2));

  //age_like(1)    -=
0.5*nyrs_surv_age*nages*log(mean(nsamples_surv_age));
  //age_like(2)    -=
0.5*nyrs_surv_age*nages*log(mean(nsamples_surv2_age));
  dvar_matrix vfc(1,nyrs_fish_age,1,12);
  dvar_matrix lfc(1,nyrs_fish_age,1,12);
  if(plusgrp==1)
    {
    vfc = (0.1/12)+elem_prod(eac_fish,1-eac_fish);// fixed to include
plus group
    lfc = mfexp(-mean(nsamples_fish_age)*elem_div(square(eac_fish-
oac_fish),2*vfc));
    }
  else
    {
    for(i=1;i<=nyrs_fish_age;i++)
      {
```

```
      vfc(i)(1,11) = (0.1/11)+elem_prod(eac_fish(i)(1,11),1-
eac_fish(i)(1,11));
        vfc(i)(12) = 1/(2*pii);
      lfc(i)(1,11) = mfexp(-
mean(nsamples_fish_age)*elem_div(square(eac_fish(i)(1,11)-
oac_fish(i)(1,11)),2*vfc(i)(1,11)));
      lfc(i)(12) = .99;
      }
    }
  age_like(3)    -= sum(log(lfc+.01));
  age_like(3)    += 0.5*sum(log(2*pii*vfc));
  //age_like(3)    -=
0.5*nyrs_fish_age*11.*log(mean(nsamples_fish_age));
  dvar_matrix vss = nlb+elem_prod(esc_surv,1-esc_surv);
  dvar_matrix lss = mfexp(-
mean(nsamples_surv_size)*elem_div(square(esc_surv-osc_surv),2*vss));
  age_like(4)    -= sum(log(lss+.01));
  age_like(4)    += 0.5*sum(log(2*pii*vss));
  dvar_matrix vss2 = nlb+elem_prod(esc_surv2,1-esc_surv2);
  dvar_matrix lss2 = mfexp(-
mean(nsamples_surv2_size)*elem_div(square(esc_surv2-
osc_surv2),2*vss2));
  age_like(5)    -= sum(log(lss2+.01));
  age_like(5)    += 0.5*sum(log(2*pii*vss2));
  //age_like(5)    -=
0.5*nyrs_surv_size*nlenbins*log(mean(nsamples_surv_size));
  dvar_matrix vs = nlb+elem_prod(esc_fish,1-esc_fish);
  dvar_matrix ls = mfexp(-
mean(nsamples_fish_size)*elem_div(square(esc_fish-osc_fish),2*vs));
  age_like(6)    -= sum(log(ls+.01));
  age_like(6)    += 0.5*sum(log(2*pii*vs));
  //age_like(6)    -=
0.5*nyrs_fish_size*nlenbins*log(mean(nsamples_fish_size));
  dvar_matrix vfc2 = rf+elem_prod(eac_fish2,1-eac_fish2);
  dvar_matrix lfc2 = mfexp(-
mean(nsamples_fish2_age)*elem_div(square(eac_fish2-oac_fish2),2*vfc2));
  age_like(7)    -= sum(log(lfc2+.01));
  age_like(7)    += 0.5*sum(log(2*pii*vfc2));

  age_like(1)    -= offset2(1);
  age_like(2)    -= offset2(2);
  age_like(3)    -= offset2(3);
  age_like(4)    -= offset2(4);
  age_like(5)    -= offset2(5);
  age_like(6)    -= offset2(6);
  age_like(7)    -= offset2(7);

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION get_msy

  /*Function calculates used in calculating MSY and MSYL for a
designated component
  of the population, given values for stock recruitment and
selectivity...
  Fmsy is the trial value of MSY example of the use of "funnel" to
reduce the amount
  of storage for derivative calculations */
  dvariable Fdmsy;
  dvariable Stmp;
```

```
  dvariable Rtmp;
  double df=1.e-5;
  dvariable F1=log(.03);
  dvariable F2;
  dvariable F3;
  dvariable FF;
  dvariable yld1;
  dvariable yld2;
  dvariable yld3;
  dvariable dyld;
  dvariable dyldp;
  seltmp =  fish_sel(endyr);
  // Newton Raphson stuff to go here

  for (int ii=1;ii<=15;ii++)
    {
      F2     = F1 + df*.5;
      F3     = F2 - df;
      //F1    = double(ii)/400;
      FF = mfexp(F1);
      yld1   = msy(FF, Stmp,Rtmp);
      FF = mfexp(F2);
      yld2   = msy(FF,Stmp,Rtmp);
      FF = mfexp(F3);
      yld3   = msy(FF,Stmp,Rtmp);
      dyld   = (yld2 - yld3)/df;                      // First
derivative (to find the root of this)
      dyldp  = (yld2 + yld3 - 2.*yld1)/(.25*df*df);   // Second
derivative (for Newton Raphson)
      if (dyldp!=0.)
        F1    -= dyld/dyldp;
    }

  // Reset funnel variable
  Fdmsy    = mfexp(F1);
  Fmsy     = Fdmsy;
  MSY      = msy(Fmsy,Stmp,Rtmp);
  Bmsy     = Stmp;
  MSYL     = Stmp/Bzero;
  Bcur_Bmsy= sp_biom(endyr+1)/Bmsy;
  Rmsy     = Rtmp;

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION Profile_Fmort

  // population, given values for stock recruitment and selectivity...
  // Fmsy is the trial value of MSY example of the use of "funnel" to
reduce
  // the amount of storage for derivative calculations
  dvariable Stmp;
  dvariable Rtmp;
  dvariable F1;
  dvariable yld1;
  seltmp =  fish_sel(endyr);

    for (jj=3;jj>=-3;jj--)
  {
    for (int kk=1;kk<=nages;kk++)
      if (kk+jj>=1 && kk+jj<=nages) seltmp(kk) = fish_sel(endyr,kk+jj);
```

```
  // Re normalize seltmp to have mean value of 1...
  seltmp /= mean(seltmp);
  for (int ii=1;ii<=100;ii++)
   {
    F1    = double(ii-1)/750.;
    yld1   = msy(F1, Stmp,Rtmp);
    if (yld1<0)
     cout <<-jj<<" " <<F1<<" "<< 0 <<" "<<0<<" "<<0<<" "<< endl;
    else
     cout <<-jj<<" " <<F1<<" "<< Stmp <<" "<<yld1<<" "<<Rtmp<<"
"<< endl;
   }
 }

 seltmp =  fish_sel(endyr);
 log_avg_rec = 0.;
 SrType=3;
 for (int jj=3;jj>=-3;jj--)
 {
  for (int kk=1;kk<=nages;kk++)
   if (kk+jj>=1 && kk+jj<=nages) seltmp(kk) = fish_sel(endyr,kk+jj);
  // Re normalize seltmp to have mean value of 1...
  seltmp /= mean(seltmp);
  for (int ii=1;ii<=100;ii++)
  {
   F1    = double(ii-1)/750.;
   yld1   = msy(F1, Stmp,Rtmp);
   if (yld1<0)
    cout <<-jj<<" " <<F1<<" "<< 0 <<" "<<0<<" "<<0<<" "<< endl;
   else
    cout <<-jj<<" " <<F1<<" "<< Stmp <<" "<<yld1<<" "<<Rtmp<<" "<<
endl;
  }
 }

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION dvariable msy(dvariable& Ftmp, dvariable& Stmp,dvariable&
Rtmp)


 dvariable yield;
 dvariable phi;
 dvariable Req;
 dvar_vector Ntmp(1,nages);
 dvar_vector Ctmp(1,nages);

 // dvar_vector seltmp  = fish_sel(endyr);
 dvar_vector Fatmp    = Ftmp*seltmp;
 dvar_vector Ztmp     = Fatmp+ natmort;
 dvar_vector survtmp = mfexp(-Ztmp);
 Ntmp(1) = 1.;
 for ( j=1 ; j < nages; j++ )
  Ntmp(j+1)  =   Ntmp(j) * survtmp(j); // Begin numbers in the next
year/age class
 Ntmp(nages)  /= (1.- survtmp(nages));
 //for ( j=1 ; j <= nages; j++ ) Ctmp(j)     = Ntmp(j) * Fatmp(j) *
(1. - survtmp(j)) / Ztmp(j);
 Ctmp     = elem_prod(Ntmp , elem_div(elem_prod(Fatmp , (1. -
survtmp)) , Ztmp));
```

```
  yield   = wt * Ctmp; //phi     = elem_prod(Ntmp , wttmp) * p_mature; //
Kill these off till april as well!

  phi     = elem_prod(  Ntmp , p_mature ) * wt; // Equilibrium
Spawners/Recruit at this Fishing mortality //Req     = Requil(phi);
  Req     = Requil(phi);
  yield *= Req;
  Stmp    = phi*Req;
  Rtmp    = Req;
  return yield;

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION dvariable Requil(dvariable& phi)

  dvariable RecTmp;
  switch (SrType)
    {
      case 1:
        //RecTmp =  (log(phi)+alpha) / (beta*phi); //RecTmp =
(log(phi)/alpha + 1.)*beta/phi;
        cout << "phi,phizero " << phi << " " << phizero << endl;
        RecTmp =  Bzero * (alpha + log(phi) - log(phizero) ) /
(alpha*phi);
        break;
      case 2:
        RecTmp =  (phi-alpha)/(beta*phi);
        break;
      case 3:
        RecTmp =  mfexp(log_avg_rec);
        break;
    }
  return RecTmp;

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION MCWrite

  report1 << obj_fun << " " << steepness << " " << rho << " " <<
natmort <<
                    " " << q_surv << " " << Bcur_Bmsy << " " <<
Depletion <<
                    " " << MSY <<" "<< MSYL << " " << Fmsy << " " <<
Bmsy  <<
                    " " << q_surv2 << " " << q_surv3 << " " << q_surv4
<< " " <<
                    endbiom << " " << begbiom << " " << sp_biom(endyr)
<< " " <<
              Bzero << " " << sigr << " " << Rzero << " " <<
log_avg_rec <<
                    " " << F55 << " " << F50 << " " << F40 << " " <<
endl;

  report2 << sp_biom << endl;

  report3 << column(natage,1) << endl;

  report4 << extract_row(surv_sel,1956) << " " <<
extract_row(surv2_sel,1956) << endl;
```

```
  //report5 << extract_row(fish_sel,1956) << endl;

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION dvariable SRecruit(const dvariable& Stmp)
  RETURN_ARRAYS_INCREMENT();
  dvariable RecTmp;
  switch (SrType)
    {
      case 1:
        //RecTmp = Stmp * mfexp( alpha  - Stmp * beta) ; //Ricker form
        RecTmp = (Stmp / phizero) * mfexp( alpha * ( 1. - Stmp / Bzero
)) ; //Ricker form from Dorn
        break;
      case 2:
        RecTmp = Stmp / ( alpha + beta * Stmp);        //Beverton-Holt
form
        break;
      case 3:
        RecTmp = mfexp(log_avg_rec);                      //Avg
recruitment
        break;
    }
  RETURN_ARRAYS_DECREMENT();
  return RecTmp;

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

FUNCTION dvar_vector SRecruit(const dvar_vector& Stmp)

  RETURN_ARRAYS_INCREMENT();
  dvar_vector RecTmp(Stmp.indexmin(),Stmp.indexmax());
  switch (SrType)
    {
      case 1:
        //RecTmp = elem_prod(Stmp ,mfexp( alpha - Stmp * beta));
//Ricker form
        RecTmp = elem_prod((Stmp / phizero) , mfexp( alpha * ( 1. -
Stmp / Bzero  ))) ; //Ricker form from Dor
        break;
      case 2:
        RecTmp = elem_prod(Stmp , 1. / ( alpha + beta * Stmp));
//Beverton-Holt form
        break;
      case 3:
        RecTmp = mfexp(log_avg_rec);   //Avg recruitment
        break;
    }

  RETURN_ARRAYS_DECREMENT();
  //cout <<RecTmp<<endl;
  return RecTmp;

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

REPORT_SECTION
```

```
  report << "Estimated Catch and Observed" << endl;
  report << pred_catch << endl;
  report << obs_catch << endl << endl;

  report << "Estimated Survival at age" << endl;
  report << S << endl;
  report << "Estimated N at age" << endl;
  report << natage << endl;
  report << "selectivity survey, fishery" << endl;
  if(surv_switch==1)
    {
    report << surv_sel/surv_sel(2000,8) << endl << endl;
    report << surv2_sel/surv2_sel(2000,8)  << endl << endl;
  }
  else
    {
    report << surv_sel << endl << endl;
    report << surv2_sel  << endl << endl;
  }
  report << endl << fish_sel << endl << endl;

  report << "observed fishery P at size and unused observed fishery p
at size" << endl;
  report << yrs_ufish_size(1,13) << " ; " << yrs_fish_size << " ; "<<
yrs_ufish_size(14) << endl;
  for (i=1;i<=13;i++)
      {
      report << osc_ufish(i) << endl;
      }
  report << osc_fish << endl;
  report << osc_ufish(14) << endl;
  report << "Predicted fishery P at size" << endl;
  for (i=1;i<=13;i++)
      {
      report << esc_ufish(i) << endl;
      }
  report << esc_fish << endl;
  report << esc_ufish(14)  << endl << endl;

  report << "Fishery Observed P at age"<< endl;
  report << yrs_fish_age << endl;
  for (i=1;i<=nyrs_fish_age;i++)
    if(plusgrp==1)
      {
        report << oac_fish(i)<< endl;
      }
    else
      {
        report << oac_fish(i)(1,11) << endl;
      }
  report << "Fishery Predicted P at age" << endl;
  for (i=1;i<=nyrs_fish_age;i++)
    if(plusgrp==1)
      {
        report << eac_fish(i) << endl;
      }
    else
      {
        report << eac_fish(i)(1,11) << endl;
      }
  report << "Survey Observed P at age" << endl;
```

```
  report << yrs_surv_age << endl;
  report << oac_surv << endl;
  report << "Survey Predicted P at age" << endl;
  report << eac_surv << endl << endl;

  report << "observed Triennial survey P at size" << endl;
  report << yrs_surv_size << endl;
  report << osc_surv << endl;
  report << "Predicted survey P at size" << endl;
  report << esc_surv << endl << endl;

  report << "observed POP and Slope survey P at size" << endl;
  report << yrs_surv2_size << endl;
  report << osc_surv2 << endl;
  report << "Predicted survey P at size" << endl;
  report << esc_surv2 << endl << endl;

  report << "Triennial Survey Biomass " << endl;
  report << "Year:     ";
  report << yrs_surv << endl;
  report << "Predicted:   ";
  report << pred_surv << endl;
  report << "Observed:   ";
  report << obs_surv_biom << endl << endl;

  report << "POP and Slope Survey Biomass " << endl;
  report << "Year:     ";
  report << yrs_surv2 << endl;
  report << yrs_surv3 << endl;
  report << yrs_surv4 << endl;
  report << "Predicted:   ";
  report << pred_surv2 << endl;
  report << pred_surv3 << endl;
  report << pred_surv4 << endl;
  report << "Observed:   ";
  report << obs_surv_biom2 << endl;
  report << obs_surv_biom3 << endl;
  report << obs_surv_biom4 << endl << endl;

  report << "CPUE Index ";
  report << yrs_cpue  << endl;
  report << "Predicted:  CPUE ";
  report << pred_cpue << endl;
  report << "Observed:   ";
  report << obs_cpue  << endl << endl;

  report << "Fmort " << endl;
  report << Fmort << endl;
  report << "Spawners " << endl;
  report << sp_biom(styr,endyr+1) << endl;
  report << "Proportion Mature, Avg wt " << endl;
  report << p_mature << endl << wt << endl;
  report << "Catch_wt_likelihood "<< lambda(1)*ssqcatch << endl;
  report << "Survey_Likelihood "<< lambda(2)*surv_like(1) << endl;
  report << "Survey_Likelihood "<< lambda(2)*surv_like(2)  << endl;
  report << "Survey_Likelihood "<< lambda(2)*surv_like(3) << endl;
  report << "Survey_Likelihood "<< lambda(2)*surv_like(4) << endl; //
added
  report << "Survey_Likelihood "<< lambda(2)*surv_like(5) << endl; //
added
  report << "Age_Likelihood    "<< lambda(3)*age_like(1) << endl;
```

```
  report << "Age_Likelihood    "<< lambda(3)*age_like(2) << endl;
  report << "Age_Likelihood    "<< lambda(3)*age_like(3) << endl;
  report << "Age_Likelihood    "<< lambda(3)*age_like(4) << endl;
  report << "Age_Likelihood    "<< lambda(3)*age_like(5) << endl;
  report << "Sel_Likelihood    "<< lambda(6)*sel_like(1) << endl;
  report << "Sel_Likelihood    "<< lambda(6)*sel_like(2) << endl;
  report << "Sel_Likelihood    "<< lambda(6)*sel_like(3) << endl;
  report << "Sel_Likelihood    "<< lambda(6)*sel_like(4) << endl;
  report << "Sel_Likelihood    "<< lambda(6)*sel_like(5) << endl;
  report << "Fmort_Likelihood  "<< fmort_like(1) << endl;
  report << "Fmort_Likelihood  "<< fmort_like(2) << endl;
  report << "Fmort_Likelihood  "<< fmort_like(3) << endl;
  report << "Rec_Likelihood    "<< lambda(4)*rec_like(1) << endl;
  report << "Rec_Likelihood    "<< lambda(4)*rec_like(2) << endl;
  report << "Rec_Likelihood    "<< lambda(4)*rec_like(3) << endl;
  report << "Rec_Likelihood    "<< lambda(4)*rec_like(4) << endl;
  report << "Prior_Likelihood  "<< Priors(1) << endl;
  report << "Prior_Likelihood  "<< Priors(2) << endl;
  report << "Prior_Likelihood  "<< Priors(3) << endl;

  //--Priors -------------------------------------------
  report << "Stock Recruit "<< endl << " 0 0 " << endl;
  for (i=1;i<=30;i++)
    {
      sumtmp=double(i)*Bzero/28;
      report << sumtmp<<" "<< SRecruit(sumtmp) << endl;
    }
  dvar_vector yrs_rec(styr_rec,endyr);
  yrs_rec.fill_seqadd(double(styr_rec),1);

  report << yrs_rec << endl;
  report << sp_biom(styr_rec-recage,endyr-recage) << endl;
  report << est_rec << endl << pred_rec << endl;
  if (last_phase())
    {
      report << "Fmsy MSY MSYL Bmsy" << endl;
      report << Fmsy << " " << MSY << " " << MSYL << " " << Bmsy << " "
<< endl;
      report << "Alpha and Beta" << endl;
      report << alpha << " " << beta << " " << Bmsy << " " << endl;
    }
  report << "SBF0 SBF55 Spawners, recruits" << endl;
  report << SB0 << " " << SBF55 << endl << Bzero << " " <<
sp_biom(styr-2,endyr-3) << endl;
  for (i=styr;i<=endyr;i++)
      report << " " << natage(i,1) << " ";
  report << endl;

  report << "2003 spawning biomass " << sp_biom(endyr+1) << endl;
  report << "Unfished spawning biomass " << Bzero << endl;
  report << "Bmsy " << Bmsy << endl;
  report << "msy " << MSY << endl;
  report << "msyl " << MSYL << endl;
  report << "F2002/Fmsy " << Fmsy_Fend << endl;
  report << "Natural Mortality " << natmort << endl;
  report << "Steepness " << steepness << endl;
  report << "Rho " << rho << endl;
  if(surv_switch==1)
    report << "survey q's " << qfix_surv << " " << qfix_surv2 << " " <<
qfix_surv3 << " " << qfix_surv4 << endl;
  else
```

```
    report << "survey q's " << q_surv << " " << q_surv2 << " " <<
q_surv3 << " " << q_surv4 << endl;

  report << "ssq catch " << ssqcatch << endl;
  report << "age likelihoods " << age_like << endl;
  report << "survey likelihoods " << surv_like << endl;
  report << "recruitment likelihoods " << rec_like << endl;
  report << "fishery mortality likelihood " << fmort_like << endl;
  report << "selectivity likelihoods " << sel_like << endl;
  report << "probabilities from priors " << Priors << endl;
  report << "log average fishery selectivity " << avgfishsel << endl;
  report << "log average shelf survey selectivity " << avgsurvsel <<
endl;
  report << "log average slope survey selectivity " << avgsurv2sel <<
endl;
  report << "sprpen " << sprpen << endl;
  report << "Depletion " << Depletion << endl;
  report << "Multinomial offsets" << offset << endl;
  report << "Robust offsets" << offset2 << endl;
  report << "Type of survey selectivity " << surv_switch << endl;
  report << "Years of slope ages" << endl;
  report << yrs_surv2_age << endl;
  report << "Observed slope ages" << endl;
  report << oac_surv2 << endl;
  report << "Predicted slope ages" << endl;
  report << eac_surv2 << endl;
  report << "Objective_function " << obj_fun << endl;
  report << "Plus_group_switch " << plusgrp << endl;
  report << "S-R_Function_switch " << SrType << endl;
  report << "Q_Prior_Type " << qpriortype << endl;
  report << "SigmaR " << sigr << endl;

  report << "years of new fishery age data " << yrs_fish2_age << endl;
  report << "expected and observed new fishery age data" << endl;
  report << eac_fish2 << endl << endl;
  report << oac_fish2 << endl << endl;

  report << "total target biomass " << endl << Btotzero << endl;
  report << "beginning biomass " << endl << begbiom << endl;
  report << "ending biomass " << endl << endbiom << endl;
  report << "3+ biomass 1956-2003 " << endl << tot_biom << endl;
  report << "catch at age 1956-2002 " << endl << catage << endl;
  report << "ABC" << endl << ABC << endl;

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

TOP_OF_MAIN_SECTION

  gradient_structure::set_MAX_NVAR_OFFSET(1000);  //maximum number of
depdendent variables of 400 exceeded
  gradient_structure::set_NUM_DEPENDENT_VARIABLES(800);
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(100000);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(1000000);
  arrmblsize=900000;

//+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==+==
+==+

GLOBALS_SECTION
```

```
  #include <admodel.h>

  //=+=+=+=+=+=+=+=+=+=+=+ PRIOR GENERAL FUNCTION
=+=+=+=+=+=+=+=+=+=+=+
  dvariable prior (dvariable parameter_value, dvector& prior_dat)
  {
  RETURN_ARRAYS_INCREMENT();
  dvariable prior_value;
  int switch_temp=prior_dat(4);
  double pi = 3.1415926358979;
  switch (switch_temp)
    {
      case 0: //uniform
        //do nothing
        prior_value=0;
        break;
      case 1: //normal
        //check if really log normal
        if (prior_dat(5)==0)
              prior_value = square((prior_dat(5))-(parameter_value))/
                             (2*square(prior_dat(6))) +
log(prior_dat(6))+  0.5*log(2*pi);
        else
              prior_value = square((prior_dat(5))-(parameter_value))/

      (2*square(prior_dat(6)*prior_dat(5))) +
log(prior_dat(6)*prior_dat(5))+  0.5*log(2*pi);
        break;
      case 2: //lognormal
        prior_value = square(log(prior_dat(5))-log(parameter_value))/
                                (2*square(prior_dat(6)))+
log(prior_dat(6))+  0.5*log(2*pi);
        break;
      default:
        cout << "No such prior: "<< prior_dat(4) << " Will be uniform";
        break;
    }
  RETURN_ARRAYS_DECREMENT();
  return(prior_value);
  }
```

Input file 1

```
# Westcoast POP data file  April 28, 2003

# Begin year, endyr
1956  2002

# Recrument lag (age  of  first age group)
3

# Number  of  age groups
23

# Maturity  inflection  age   (8)
8

# Wts at age 3 4 5 6 7 8 9 10  11  12  13  14  15  16  17  18  19  20
21  22  23  24  25
169.1051  240.6028  317.2732  395.9663  474.1622  549.9697  622.0596
689.5722  752.0223
809.21  861.1457  907.9877  949.9927  987.4781  1020.7938 1050.301
1076.3584 1099.3113
1119.4864 1137.1872 1152.6927 1166.2567 1178.1084

# Catch
# 1956  1957  1958  1959  1960  1961  1962  1963  1964  1965  1966
1967  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  2000  2001  2002
# Include nom. and unsp. POP; assume 16% of catch bycatch for 1981-
present, and
# 5% of domestic previously. Use Jean Rogers' updated estimates of
foreign catch # 1965-1976.
# Estimate of 2002 catch = average of two previous years.
2231 2442 1587 1958 2364 4149 5793 6788 5807 8063 18761 13289 7262
1197 2177 1951 1558 2145 1800 1152 1677 1242 2120 1952  1965  1720
1242 2215 1959 1792 1653 1305 1645 1706 1230 1659 1306  1500  1176
965  938  751  739  593  171  307  239

# Triennial survey
# Number  of  surveys (added 2001)
9

# Years of survey
1977  1980  1983  1986  1989  1992  1995  1998  2001

# Observed survey biomass and standard errors
14245     6468      6733      2797      9384      7669    4603    7668
2853
5140.652  3195.805  1913.711  1198.778  4361.926  3688.12 2255.47
2411.934899 1257.5

# all equal
# 2000 2000 2000 2000 2000 2000 2000 2000 2000
```

```
# Number of POP
2

# Years of POP survey
1979  1985

# Observed POP survey biomass and standard errors
16044  10696
4744.941 2146.44

# all equal
# 2000 2000

# AFSC Slope  Surveys
# Number  of AFSC Slope  Surveys
6

# Years of  survey
1992 1996 1997 1999 2000 2001

# Observed AFSC survey biomass and standard errors
6971    4730    2146   8857    2465    9675
2627.4  1443.8  826.4  4509.1  1278.3  7546.5

# all equal
#2000 2000 2000 2000 2000 2000


# Number  of NWFSC Slope  Surveys
4

# Years of NWFSC survey
1999 2000 2001 2002

# Observed NWFSC survey biomass and standard errors
2651    2556    5269    3770
1353.1  1448.7  2414.1  2089.0

# all equal
# 2000 2000 2000 2000

# Number of fishery CPUE years
18

# CPUE  Index Years
1956  1957  1958  1959  1960  1961  1962  1963  1964  1965  1966
1967  1968  1969  1970  1971  1972  1973

# CPUE Index 2000000
0.4    0.3    0.32  0.29  0.28  0.31  0.29  0.34  0.35  0.55  0.47
0.3    0.17   0.178 0.175 0.203390321 0.19840584  0.114393158

# Fishery
# Number of years fishery Age comp data available
15

# Years
1966  1967  1968  1969  1970  1971  1972  1973  1974  1975  1976  1977
1978  1979  1980
```

```
# Sample  Size
50  50  50  50  50  50  50  50  50  50  50  50  50  50  50

# Fishery  Biased  Age Comps
# 3  4 5 6 7 8 9 10  11  12  13  14+
0 0 11773 23546 82412 294327  353192  800569  1400996 2731353 1648231
5804127
0 0 44025 61344 542701  871749  1579703 2779859 4988854 8114900 6321905
19138901
0 19445 29168 559050  1205606 1647984 1190985 1667342 2483964 4141526
3844974 11738633
0 0 18329 7332  63903 109478  96896 230148  577996  1266660 1369303
3228934
6061 0 22418 232718  318736  711292  1458647 1080697 907494  903918
937291  3232452
0 0 0 11530 116730  290514  955934  1640367 1082769 798318  686227
3145259
0 4041 30635 65310 141704  277291  539727  990170  1511001 620434
402448  2218553
2192 8770  29248 43873 70205 110415  311165  708651  1169763 1326243
563832  1518129
0 0 6051  14004 14752 27601 94155 241437  402419  505346  370164
614418
0 0 86936 87829 104809  66539 101331  218006  320522  372778  389814
812795
0 0 200233  1352729 425060  288616  201398  316326  419943  402556
297460  727954
203 3556 7024  90826 528924  143630  117648  97600 155403  156922
141183  436808
0 2163 22657 48246 94670 332951  182756  195130  208480  278606  263716
949239
0 461 7838 17163 34203 87284 256599  191345  165525  195499  178333
897075
0 0 3613 23207 53012 159388  345493  351055  214443  189135  197499
1034480


# Number of years of new fishery Age comp data
4

# Years
1999 2000 2001 2002

# Sample Size
50 50 50 50

#Fishery "unbiased" age comps
# 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

0 0 4 2 20 19 49 33 21 8 14 9 11 12 10 8 8 9 7 4 5 1 52
0 0 18 1 7 30 47 65 59 37 47 39 44 22 27 7 11 8 8 11 6 1 101
0 10 25 40 21 30 57 77 95 81 42 32 33 25 29 14 19 13 5 14 10 16 188
0 2 8 69 65 35 45 85 78 85 59 31 32 13 19 23 12 10 7 12 11 17 104

# Number  of  Triennial Survey  Age comp  years
4

# Years of  Triennial Survey  Age comp  data
1989  1992  1998 2001
```

```
# Sample  Size
# to test effect 500  500  500  500
50  50  50  50

# Triennial survey age comps
# 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25+

89226 3176682 1219343 656796  833499  2353474 928618  748928  573984
416323  353090  219216  24770 129282  20177 9974  36992 20936 49188
23570 119073  132707  2195421
798758.917  3368042.48  2750736.95  1076991.98  1255653 1020788.99
627615.278  540627.06 2472883.1 1229443.9 668763.817  306908.324
390237.276  541074.14 47713.2941  130796.409  82358 213467  148865.216
105233.883  77359.2941  142147.091  1725477.199
2056539.051 3457344.093 363980.3206 501086.5161 1114104.047 1164322.744
617258.5934 474097.492  496022.3963 331823.4085 588042.2259 384535.3644
583972.5132 442703.0598 442685.5361 339970.1398 407548.9212 49589.83333
223090.3369 94157.57143 205192.9163 39458.18182 3439282.363

# 2001 data from pacfin
# 201713.2879 540827.805 (1 and 2 years old)
335664.7393 142090.6679 148375.1889 858304.4052 755693.9964 191717.5054
70412.70346 46312.89167 111504.4177 200846.3658 92684.10963 93130.94058
72107.84488 49273.5895 71835.77148 69012.5556 64930.84995 66920.51399
45266.49407 36720.70682 38776.32115 50639.23902 647245.0888

# Number of slope survey age comp years
2

# years
1985 2002

# sample size
50 50

# data
122477.  332342.  731141.  1017246. 418657.  290206.  294572.  603853.
523611.  301193.  405146.  553271.  554201.  290312.  210758.  284327.
189918.  265433.  263709.  213783.  217418.  200765.  3163096.

# 2002 FRAM survey age comps (from length dist and a-l transition
matrix)
# 59653.67 (2 years old)
112483.2  37169.3 25395.1 54531.0 288842.9 367912.8 179018.7 228545.8
266185.9 369017.9 296680.8 266709.0 253579.0 220006.7 148661.6 213616.6
98155.5 85925.0 110451.2 94398.4 90736.9 72251.5 983430.6

# Number of length Bins
24

# Number of size comp years
14

# Years of  size  comp  data
1981 1982 1983 1984 1985 1986 1987
1988 1989 1994 1995 1996 1997 1998

# Sample  Size
50  50  50  50  50  50  50  50  50  50  50  50  50  50

# Fishery size  comp  data
```

```
# 17 28 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
40
0 0 0 0 0 0 0 0 0 0 0 2 2 5 20  11  16  39  86  154 177 214 217 941
0 0 0 0 0 0 0 0 1 0 2 0 3 1 3 5 22  39  72  115 160 202 223 951
0 0 0 0 0 0 0 0 0 0 0 2 6 7 15  26  74  107 175 245 288 317 312 1156
0 0 0 0 0 0 0 0 1 0 1 2 8 12  27  56  84  159 234 306 413 450 369 981
0 1 0 0 0 0 0 0 1 0 3 9 4 25  35  52  127 207 344 389 413 464 492 1943
0 0 0 0 0 0 0 0 0 1 3 1 7 7 22  40  55  161 248 357 369 430 463 1840
0 0 0 0 0 0 0 0 0 0 1 1 2 13  21  48  82  141 223 303 372 400 302 1196
0 0 0 0 0 0 0 0 0 0 1 1 1 4 7 9 6 11  20  44  61  59  51  241
0 0 0 0 0 0 0 0 0 0 1 0 0 2 10  12  23  33  61  82  115 120 105 234
0 0 0 0 0 0 0 0 0 0 0 1 4 13  25  47  45  68  72  95  100 115 75  238
0 0 0 0 0 0 0 0 0 0 0 2 2 10  24  33  35  63  87  128 114 107 65  186
0 0 0 0 0 0 0 1 1 2 7 11  14  42  58  55  94  121 146 143 150 142 121
455
0 0 0 0 0 0 0 4 3 9 13  35  54  107 101 133 164 181 177 209 208 200 173
424
0 0 0 0 1 2 0 1 4 4 14  20  23  27  60  98  123 151 147 135 139 119 101
307

#Unused Fishery size data (where exists age data) for comparison to
fits
#Number of years of data
14


#Years of data
1968 1969 1970 1971 1972 1973 1974 1975 1976  1977 1978 1979 1980
1999


#comparison data
0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 8 13  39  50  54  50  41  38  97
0 0 0 0 0 0 0 0 0 0 0 1 1 4 7 15  22  77  110 170 177 167 144 318
0 0 0 0 0 0 0 0 0 1 0 0 1 10  31  31  74  116 146 168 91  92  50  144
0 0 0 0 0 0 0 0 0 1 1 0 8 9 60  118 259 431 517 516 347 265 212 961
0 1 0 0 0 1 2 1 2 2 7 13  22  41  53  89  226 356 448 526 402 322 232
955
0 0 0 0 3 4 0 2 6 7 7 19  34  34  51  74  177 285 446 516 474 393 258
669
0 0 0 0 0 0 0 1 2 3 8 4 4 4 11  60  135 341 562 687 634 506 365 931
0 0 0 0 0 0 0 0 1 1 6 15  30  22  30  39  64  146 200 379 388 386 300
876
0 0 0 0 0 0 1 0 2 1 4 14  41  47  79  50  83  112 164 272 357 309 262
732
0 0 0 0 0 0 1 2 1 1 4 3 15  31  70  146 163 159 151 193 308 323 319
1105
0 0 0 0 0 1 0 1 2 14  10  27  26  57  86  130 188 270 316 353 438 494
509 1616
0 0 0 0 0 0 0 0 0 0 1 2 1 3 14  19  41  92  171 233 292 282 241 835
0 0 0 0 0 1 0 0 0 0 1 1 1 3 8 28  39  106 160 258 329 373 370 1523
0 0 0 0 0 0 1 2 2 13  33  31  41  34  9 43  66  107 145 159 143 140 97
365

# Number  of Triennial survey size  comp  years
5


# Years
1977 1980 1983 1986 1995
```

```
# Sample  Size
25 25 25 25 25

# data
2584  6140  43904 27326 39782 60688 111235  76141 67469 71551 123024
137833  147907  188555  434441  787543  1065585 924884  641234  649319
764075  788588  938366  7431350
0 3679  2620  4929  1602  19007 16276 70625 58952 75296 112373  112882
185941  317137  291127  423489  217998  237176  293713  267499  377084
365442  360172  2902115
1473  23991 81723 112702  39004 48154 66084 89355 61353 92155 59602
56398 34134 57269 55976 44155 84491 91813 179254  264220  358488
456473  592849  4300601
6506  53295 41690 104521  83053 33164 41216 36240 55261 101218  289455
248178  276130  341303  272989  184777  229861  170925  264174  96217
138885  190770  172037  860253
2906 11052 15612 12741 13768 15787 41237 55680 150256  295345  282386
220504  114244  193641  142663  149017  111459  169644  205715  369945
497226  553446  385388  1828881


# Number of slope survey size comp years
5


# years 1xpop, 4xAFSC
1979 1996 1997 1999 2000

# sample size
25 25 25 25 25


#data
3117  7630  0 5123  5490  14459 27669 62293 75040 113413  164058
285927  325469  251458  443636  725956  1366737 2156232 2242299 2073524
1642703 1525133 1436646 3916376
0.000545883 0.001587818 0.012074275 0.012952897 0.009216671 0.003261842
      0.000929738 0.000624344 0.001057719 0.002473756 0.003559574
      0.008113279 0.050649006 0.044189142 0.081811212 0.031712932
      0.041568258 0.036459437 0.060271182 0.075347444 0.095830634
      0.108081505 0.1128124   0.204869054
0.002945144 0     0.007085336 0.012975624 0.045278491 0.047122312
      0.114912033 0.171458375 0.225992313 0.076018705 0.023561156
      0.005890289 0.004863574 0.015743406 0.020306108 0.038435209
      0.020168079 0.012769241 0.036505619 0.028982356 0.025075904
      0.025156636 0.01670957  0.022044518
0     0     0     0.002672647 0     0.004230858 0.002672647 0.011552594
      0.017440576 0.013737546 0.026112599 0.022837714 0.024021736
      0.028888425 0.019831463 0.024863938 0.064659819 0.110150525
      0.141455973 0.159970542 0.104483774 0.101755315 0.052362501
      0.062764155
0.002194043 0.001244728 0.001244728 0.016627654 0.01038538  0
      0.000648547 0.001858893 0.000648547 0     0     0.001210346
      0.001945641 0.001858893 0.02783832  0.038168572 0.090194851
      0.171351924 0.130416005 0.122006234 0.168400319 0.091497348
      0.038125381 0.082133645

# Size  age transition
9.2109E-06  0.001079748 0.011657379 0.066160987 0.198036027 0.313395584
0.262498953 0.116321595 0.02721869  0.003353133 0.000216721 7.32235E-06
1.28881E-07 1.17798E-09 5.57554E-12 1.36557E-14 0 0 0 0 0 0 0 0
```

```
1.82275E-11 2.72482E-08 1.66962E-06 5.58508E-05 0.001022726 0.010281257
0.056899331 0.173802131 0.293597363 0.274556239 0.142113922 0.040665725
0.006419035 0.000557461 2.65604E-05 6.92306E-07 9.84541E-09 7.62039E-11
3.20299E-13 0 0 0 0 0
0 2.63567E-13 5.29131E-11 6.02374E-09 3.89691E-07 1.43548E-05
0.000301749 0.00362788  0.025003452 0.098994015 0.225567713 0.296167575
0.224168686 0.097768925 0.02454019  0.003538401 0.000292459 1.38252E-05
3.72938E-07 5.72817E-09 4.99961E-11 2.4758E-13  0 0
0 0 2.9976E-15  7.6128E-13  1.15133E-10 1.02732E-08 5.41676E-07
1.69059E-05 0.000312885 0.003440158 0.022511263 0.087817158 0.204528475
0.284686142 0.23691735  0.11785397  0.035013738 0.00620419  0.000654599
4.10524E-05 1.52749E-06 3.36591E-08 4.3849E-10  3.38718E-12
0 0 0 3.33067E-16 8.10463E-14 1.2881E-11  1.24979E-09 7.41568E-08
2.69453E-06 6.0043E-05  0.000821753 0.006917715 0.035870485 0.114715784
0.226511451 0.276332572 0.208323571 0.097024917 0.027895724 0.004945508
0.000539926 3.62485E-05 1.49428E-06 3.83568E-08
0 0 0 0 2.22045E-16 4.75175E-14 6.74749E-12 6.04234E-10 3.41475E-08
1.21927E-06 2.75389E-05 0.000393946 0.003573514 0.020579011 0.075315455
0.17534042  0.259846513 0.245204886 0.147332292 0.056343226 0.013703326
0.002117516 0.000207669 1.34319E-05
0 0 0 0 0 5.55112E-16 1.03806E-13 1.18362E-11 8.76158E-10 4.2126E-08
1.31685E-06 2.679E-05 0.000355066 0.003068824 0.017312826 0.063806999
0.153746899 0.242347668 0.249976695 0.168731913 0.074510376 0.021513844
0.004058589 0.000542151
0 0 0 0 0 0 4.55191E-15 5.77427E-13 4.93773E-11 2.81337E-09 1.06894E-07
2.71064E-06 4.59143E-05 0.000519932 0.003939293 0.019984169 0.067927405
0.154796267 0.236610675 0.242644147 0.166944752 0.077046435 0.023840708
0.005697482
0 0 0 0 0 0 4.44089E-16 6.52811E-14 5.88396E-12 3.61953E-10 1.51992E-08
4.35988E-07 8.5491E-06  0.000114674 0.00105296  0.006622695 0.02854887
0.084392974 0.171156731 0.238230634 0.227606206 0.149260276 0.067172692
0.025832286
0 0 0 0 0 0 1.11022E-16 1.52101E-14 1.35369E-12 8.40635E-11 3.64111E-09
1.10065E-07 2.32337E-06 3.42687E-05 0.000353381 0.002549135 0.012869562
0.045493893 0.112652853 0.195472902 0.237727193 0.202653901 0.121083536
0.069106938
0 0 0 0 0 0 0 6.43929E-15 5.40012E-13 3.22701E-11 1.37201E-09 4.15229E-
08 8.94974E-07 1.37451E-05 0.000150493 0.001175212 0.006548412
0.026045994 0.073974823 0.150074244 0.217526622 0.225296993 0.166740067
0.132452456
0 0 0 0 0 0 0 4.44089E-15 3.36065E-13 1.86916E-11 7.53224E-10 2.20034E-
08 4.66158E-07 7.16543E-06 7.9947E-05  0.000647716 0.00381195
0.016301602 0.050671228 0.114514624 0.188205485 0.224974761 0.195609414
0.20517562
0 0 0 0 0 0 0 4.32987E-15 2.96874E-13 1.5016E-11  5.59804E-10 1.53856E-
08 3.11858E-07 4.66361E-06 5.14717E-05 0.000419412 0.002523912
0.011219811 0.036853693 0.089466632 0.160553249 0.213018096 0.208969127
0.276919605
0 0 0 0 0 0 1.11022E-16 5.66214E-15 3.42948E-13 1.55483E-11 5.27637E-10
1.34074E-08 2.55185E-07 3.63919E-06 3.88981E-05 0.000311709 0.001873183
0.00844345  0.028553309 0.072455732 0.137990604 0.197263643 0.211687571
0.341377993
0 0 0 0 0 0 1.11022E-16 9.21485E-15 4.84723E-13 1.95146E-11 5.96649E-10
1.38579E-08 2.44579E-07 3.28099E-06 3.34632E-05 0.000259545 0.001531208
0.006872501 0.023470767 0.061001445 0.120676214 0.1817308 0.208347755
0.396072763
0 0 0 0 0 0 3.33067E-16 1.70974E-14 7.93698E-13 2.82361E-11 7.73215E-10
1.63014E-08 2.64659E-07 3.30967E-06 3.18874E-05 0.000236743 0.001354688
0.005975487 0.020320727 0.053283574 0.107744023 0.168031217 0.202120402
0.440897658
```

```
0 0 0 0 0 0 6.66134E-16 3.58602E-14 1.44162E-12 4.52461E-11 1.10669E-09
2.11006E-08 3.13676E-07 3.63642E-06 3.28817E-05 0.000231952 0.00127665
0.005483168 0.018379195 0.048084258 0.098199474 0.156563528 0.194882067
0.476862854
0 0 0 0 0 0 1.77636E-15 7.99361E-14 2.80875E-12 7.77943E-11 1.69882E-09
2.92546E-08 3.97342E-07 4.25733E-06 3.59901E-05 0.000240084 0.00126396
0.005252191 0.017227582 0.044609041 0.091196203 0.147206074 0.187625621
0.505338568
0 0 0 0 0 1.11022E-16 4.77396E-15 1.86073E-13 5.71732E-12 1.40028E-10
2.7333E-09  4.25289E-08 5.27565E-07 5.21827E-06 4.11619E-05 0.000258962
0.001299557 0.005202466 0.016615406 0.042338133 0.086080662 0.139658512
0.18081613  0.527683219
0 0 0 0 0 3.33067E-16 1.32117E-14 4.41536E-13 1.19189E-11 2.58919E-10
4.52819E-09 6.37641E-08 7.23067E-07 6.60372E-06 4.858E-05 0.000287891
0.001374479 0.00528712  0.016386906 0.040925794 0.082366103 0.133592323
0.174628019 0.54509539
0 0 0 0 0 9.99201E-16 3.59712E-14 1.05316E-12 2.50663E-11 4.84807E-10
7.62019E-09 9.73502E-08 1.01096E-06 8.53497E-06 5.8585E-05  0.000326982
0.00148404  0.005477404 0.016441184 0.040136691 0.079693834 0.128709039
0.169087051 0.558575539
0 0 0 0 1.11022E-16 3.10862E-15 9.68114E-14 2.49312E-12 5.25903E-11
9.09413E-10 1.28933E-08 1.49887E-07 1.4289E-06  1.11717E-05 7.16395E-05
0.000376819 0.001625865 0.005754759 0.01671005  0.039806445 0.077799194
0.124757327 0.164149725 0.568935411
0 0 0 0 3.33067E-16 9.21485E-15 2.55684E-13 5.81091E-12 1.09176E-10
1.69553E-09 2.17679E-08 2.31049E-07 2.02771E-06 1.4715E-05  8.83062E-05
0.000438256 0.001798828 0.006106491 0.017145386 0.039817187 0.076485602
0.121533218 0.159745484 0.576824244

# Normal ageing error matrix
0.9954      0.0046      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000
0.0254      0.9492      0.0254      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000
0.0000      0.0591      0.8818      0.0591      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000
0.0000      0.0000      0.0964      0.8071      0.0964      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000
0.0000      0.0000      0.0004      0.1318      0.7356      0.1318
      0.0004      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000
0.0000      0.0000      0.0000      0.0017      0.1627      0.6712
      0.1627      0.0017      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000
```

```
0.0000        0.0000        0.0000        0.0000        0.0046        0.1881
       0.6146        0.1881        0.0046        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0095
       0.2078        0.5653        0.2078        0.0095        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0002
       0.0164        0.2222        0.5224        0.2222        0.0164
       0.0002        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0000
       0.0006        0.0248        0.2321        0.4850        0.2321
       0.0248        0.0006        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0013        0.0344        0.2382        0.4521
       0.2382        0.0344        0.0013        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0026        0.0444        0.2414
       0.4232        0.2414        0.0444        0.0026        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0001        0.0045        0.0545
       0.2422        0.3975        0.2422        0.0545        0.0045
       0.0001        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0003        0.0070
       0.0642        0.2412        0.3746        0.2412        0.0642
       0.0070        0.0003        0.0000        0.0000        0.0000
       0.0000        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0006
       0.0101        0.0732        0.2389        0.3542        0.2389
       0.0732        0.0101        0.0006        0.0000        0.0000
       0.0000        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0011        0.0138        0.0814        0.2357        0.3357
       0.2357        0.0814        0.0138        0.0011        0.0000
       0.0000        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0001        0.0019        0.0179        0.0888        0.2318
       0.3191        0.2318        0.0888        0.0179        0.0019
       0.0001        0.0000
0.0000        0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0000        0.0000        0.0000        0.0000
       0.0000        0.0002        0.0029        0.0223        0.0952
       0.2274        0.3039        0.2274        0.0952        0.0223
       0.0029        0.0002
```

```
0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0000    0.0004    0.0042    0.0268
     0.1008    0.2227    0.2901    0.2227    0.1008
     0.0268    0.0046
0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0000    0.0000    0.0006    0.0058
     0.0314    0.1055    0.2179    0.2775    0.2179
     0.1055    0.0379
0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0000    0.0000    0.0001    0.0010
     0.0076    0.0360    0.1094    0.2130    0.2659
     0.2130    0.1541
0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0000    0.0000    0.0000    0.0002
     0.0015    0.0096    0.0405    0.1126    0.2080
     0.2552    0.3724
0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0000    0.0000    0.0000    0.0000
     0.0000    0.0003    0.0015    0.0062    0.0177
     0.0371    0.9372
```

Input file 2

```
# April 28, 2003 version pop2.ctl

# Fishery age plus group inclusion - 1 = yes, 0 = no
1

# cv for CPUE (old = 0.2)
0.2

# SR function - 1 = Ricker, 2 = Bev-Holt
2

# beta parameters for steepness prior
# old(2.01,2.07),base(2,2), new Bev-holt (4.33,2.03), new Ricker
(2.32,3.00)
4.33 2.03

#steepness prior switch - 0 = uniform prior, 1 = beta prior (above)
0

# Max selectivity age class for fishery (base = 12, old = 20)
12

# Max selectivity age class for survey (base = 10, old = 8)
10

# Phase to do robust age and size likelihood if phase reached (changed
to 7)
7

# steepness phase (7)
7


# Rho value (0.0, other - 0.5)
0.0

#Sigma R value (1.0, other = 0.76 = old)
1.0

# natural mortality M phase (6)
6

# sigma r (recruitment variance) phase
-1

# F deviance phase
2

# Recruitment deviance phase (3)
3

# Survey selectivity type switch -> 1 = Original Ianelli, with no
selectivity change over time
#                                                      2 = Original
Ianelli, with time-varying deviations
#                                                      3 = Original
Ianelli, asymptotic selectivity function
#
```

```
1

# selectivity deviance phase (fish)
3

# survey selectivity phase -- This is the phase to begin whatever
selectivity option is turned on
4

# fishery selectivity phase
2

# survey catchability phase (5)
5

# groupnum (changed to 6 so last 2 years in a larger group of 4)
6

# Natural mortality prior mean (.05, other = .55)
0.05

# Natural mortality prior cv (0.1, other = 0.25)
0.1

# q prior mean (base = 0.79 other = 0.98)
0.98

#q prior cv (base = 0.68 other = 0.45)
0.45

#q prior type = 0 = uniform in log space, 1 = normal, 2 = lognormal
(old =2)
0

# q prior switch - 0 = on triennial (shelf) survey only, 1 = on all
0

# Vector of lambdas (100 1 1 1 0.0 1 12 20 20 20 50 20 1 1 1 1 1 1 1 1)
100 1 1 1 0.1 1 12 20 20 20 50 20 1 1 1 1 1 1 1 1
```