Status and Future Prospects for the Pacific Ocean Perch Resource in Waters off Washington and Oregon as Assessed in 2005

by

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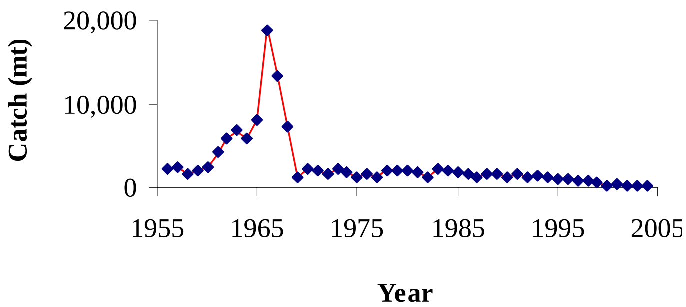
This assessment applies to the Pacific ocean perch (*Sebastes alutus*) (POP) species of rockfish for the combined US Vancouver and Columbia INPFC areas. Catches are characterized by large removals of between 5,000 and 20,000 mt during the mid-1960's, primarily by foreign vessels. The fishery proceeded 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 2004.

Catch history from 1956-2005



Catch estimates for past 10 years including discard

Year	*Catch*
1995	*965*
1996	*938*
1997	*751*
1998	*739*
1999	*593*
2000	*171*
2001	*307*
2002	*179*
2003	*155*
2004	*145*

This assessment is an update and uses the same model as in the 2003 assessment, a forward projection age-structured model (Hamel et al. 2003).

New data and changes to the data used in the previous assessment include new or updated data as follows. Catch data for 2002 was updated, and new catch data and fishery age compositions were added for 2003-2004. Fishery length compositions from 1981-1998 were updated, with new 1990 and 1991 length compositions and 1994 age compositions. The 2004 Triennial survey biomass index was added, while data from all years were limited to the 55-366 meter range. The 1995 Triennial survey age composition data was available and used instead of the length composition data for that year. All age and length composition data from the triennial survey from years with water haul issues not previously resolved (prior to 1998) were updated to account for water hauls. The 2003 and 2004 NWFSC slope survey biomass indices and age compositions were added, as well as the 2001 age composition, and all slope survey indices and age compositions were recalculated based upon changes in stratum area estimates and updates in the database.

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 upon alternative model structures / data set choices suggested that the overall uncertainty may be greater than that predicted by a single model specification, as was the case in the 2003 assessment. 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; gender differences in growth and survival; a possible non-linear relationship between individual spawner biomass and effective spawning output and more complicated relationship between age and maturity.

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.

Retrospective of past 10 years

Year	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Total Catch	965	938	751	739	593	171	307	179	155	145	
Discards	155	150	120	118	95	27	49	29	25	23	
Landings	810	788	631	621	498	144	258	150	130	122	
ABC					695	713	1541	640	689	980	988
OY (HG)	(1300)	(750)	(750)	(750)	595	270	303	350	377	444	447
F	0.0509	0.0503	0.0398	0.0388	0.0301	0.0084	0.0147	0.0084	0.0071	0.0065	*0.0197**
Expl. Rate	0.0498	0.0497	0.0397	0.0387	0.0315	0.0091	0.0162	0.0090	0.0073	0.0067	*0.0199**
3+ Biomass	19362	18878	18931	19071	18850	18689	18972	19958	21091	21792	22440
Biom. sd	2393	2411	2403	2586	2623	2652	2690	2875	3086	3231	3386
Biom. cv	0.12	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15
Sp Biomass	7652	7578	7607	7763	7902	7925	8012	8222	8640	8846	8846
Sp Bio. sd	956	982	1021	1065	1109	1131	1137	1170	1228	1259	1262
Sp Bio. cv	0.12	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Recruitment	0.50	0.59	4.18	2.78	0.37	0.49	1.21	6.54	5.09	1.39	
Rec. sd	0.30	0.33	0.98	0.76	0.22	0.25	0.49	1.88	1.80	0.86	
Rec. cv	0.60	0.56	0.23	0.27	0.59	0.51	0.40	0.29	0.35	0.62	
Depletion	0.202	0.200	0.201	0.205	0.209	0.209	0.212	0.217	0.228	0.234	0.234
Depl. sd	0.032	0.033	0.034	0.035	0.036	0.036	0.037	0.038	0.040	0.041	0.041
Depl. cv	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18

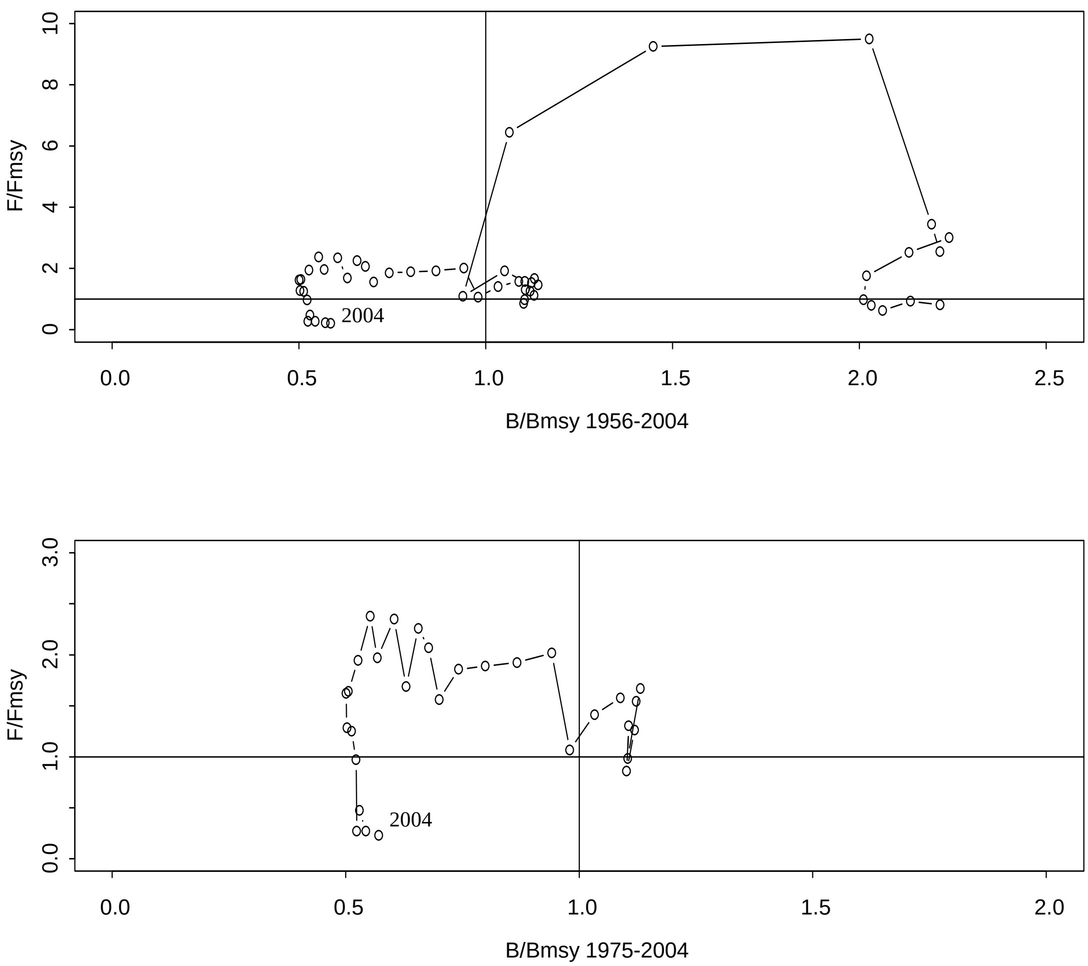
* If OY is reached

The point estimate (maximum of the posterior density function, MPD) for the depletion of the spawning biomass at the start of 2005 is 23.4%. The ABC for 2007 based on the MPD point estimate is 746 mt. The OY for 2007 based upon the 40-10 rule, is 352 mt. For West Coast rockfish, a stock is considered overfished when it is below 25% of virgin spawning biomass, and recovered when it reaches 40% of virgin spawning biomass. Overfishing for POP is considered to be occurring when F is above Fmsy = 0.0310 according to the current assessment base model.

POP are essentially managed on a regional basis, as they occur almost exclusively off of Oregon and Washington for the West Coast. Better management might be possible in cooperation with British Columbia, as the stock extends northward into Canadian waters.

Major quantities from assessment

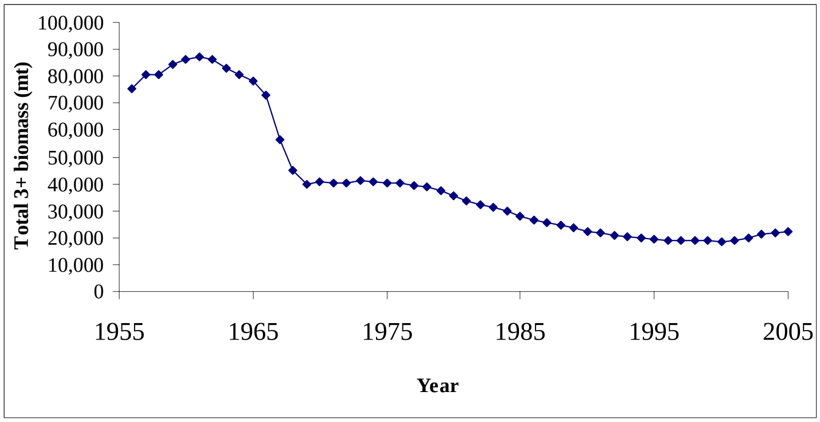
	Value	*sd*	*cv*
SB_0	37,838	4,942	0.13
B_0	83,218	11,103	0.13
R_0	4.92	0.95	0.19
SBmsy	15,135	2,509	0.17
Fmsy	0.0310	0.0110	0.35
Basis for above	F at equilibrium 40% biomass with S-R curve		
Exploitation rate at MSY	0.0324	0.0104	0.32
MSY	1181	348	0.29



F/Fmsy versus B/Bmsy for all years of catch data and the last 30 years

The point estimates of current biomass are relatively flat over the past ten years, although there is some indication of an increasing trend in biomass in the most recent years.

3+ Biomass Levels from 1956 to 2005



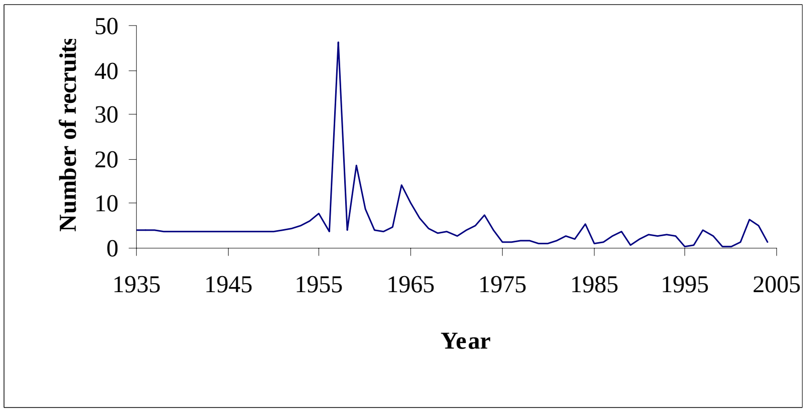
Biomass estimates for the past 10 years

Year	Total 3+ biomass(mt)
1996	*18878*
1997	*18931*
1998	*19071*
1999	*18850*
2000	*18689*
2001	*18972*
2002	*19958*
2003	*21091*
2004	*21792*
2005	*22440*

The recruitment pattern for POP is similar to that of many rockfish species. Recent decades have provided rather poor year-classes compared with the 1950s and 1960s, although the 1999 and 2000 year classes (2002 and 2003 recruitment years) appear to be larger than have been seen since the early 1970s.

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 (1995-2004 in the table below) estimates of recruitment are highly variable by year, and lower on average than those for 1960-74, though higher on average than those for 1975-1994. The estimate of recruitment for 2004 is based on very limited information.

Recruitment estimates (1935-2002)

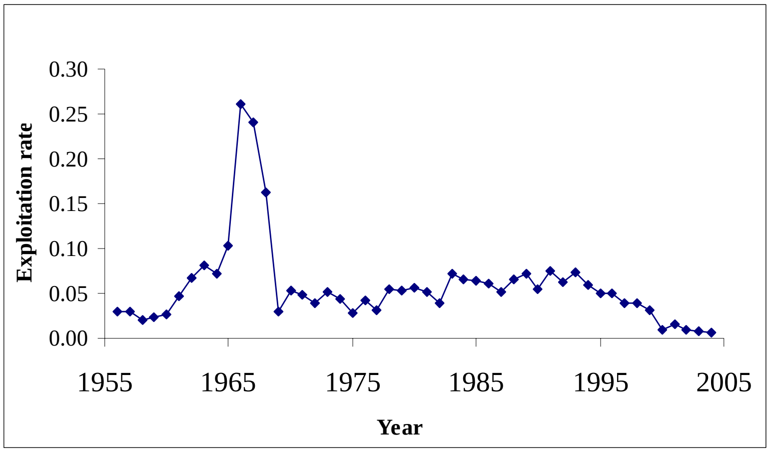


Recruitment estimates for the past 10 years (millions of recruits)

Year	Recruitment
1995	*0.50*
1996	*0.59*
1997	*4.18*
1998	*2.78*
1999	*0.37*
2000	*0.49*
2001	*1.21*
2002	*6.54*
2003	*5.09*
2004	*1.39*

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 nearly 5% to well under 1%.

Exploitation rate estimates (1956-2005)



Exploitation estimates for the past 10 years

Year	*Exploitation rate*
1995	*0.0498*
1996	*0.0497*
1997	*0.0397*
1998	*0.0387*
1999	*0.0315*
2000	*0.0091*
2001	*0.0162*
2002	*0.0090*
2003	*0.0073*
2004	*0.0067*

Near term projections show a slow monotonic increase in exploitable biomass. These were calculated with a new module within the assessment model using fishing mortality rates of 0.01 and 0.02, after assuming catches of the OY of 447 mt in each of 2005 and 2006. This module projects recruitment from the estimated spawner recruit curve. To create three different possible states of nature for the two fishing mortality rates, we took the medians of the lowest 25%, the middle 50% and the highest 25% for each quantity and year from the 2400 saved model runs from the MCMC analysis.

Catch, Spawning Biomass and Depletion projections with F = 0.01

	Catch (mt)			Spawning biomass			Depletion		
	0-25%	25-75%	75-100%	0-25%	25-75%	75-100%	0-25%	25-75%	75-100%
2007	207	247	301	7898	9322	11253	0.212	0.266	0.325
2008	215	258	314	7818	9257	11190	0.209	0.264	0.324
2009	227	272	332	8093	9679	11782	0.218	0.276	0.341
2010	239	288	357	8748	10484	12841	0.236	0.299	0.370
2011	247	301	374	9173	11028	13534	0.247	0.314	0.391
2012	252	308	385	9396	11339	14018	0.254	0.324	0.405
2013	256	314	397	9630	11660	14585	0.259	0.334	0.420
2014	261	322	410	9808	11997	15186	0.265	0.344	0.436
2015	268	332	423	10046	12371	15704	0.274	0.355	0.450
2016	276	342	433	10308	12733	16139	0.280	0.366	0.462

Catch, Spawning Biomass and Depletion projections with F = 0.02

	Catch (mt)			Spawning biomass			Depletion		
	0-25%	25-75%	75-100%	0-25%	25-75%	75-100%	0-25%	25-75%	75-100%
2007	412	492	598	7898	9322	11253	0.212	0.266	0.325
2008	423	507	616	7818	9257	11190	0.209	0.264	0.324
2009	441	527	644	8093	9679	11782	0.218	0.276	0.341
2010	458	553	687	8647	10363	12691	0.233	0.295	0.366
2011	469	572	710	8965	10777	13241	0.242	0.307	0.382
2012	474	579	726	9082	10980	13570	0.246	0.313	0.392
2013	475	585	745	9208	11162	14001	0.247	0.320	0.402
2014	482	597	761	9276	11378	14434	0.251	0.326	0.415
2015	492	610	778	9421	11633	14770	0.257	0.333	0.424
2016	502	623	791	9598	11866	15082	0.261	0.341	0.431

These projections are based upon the estimated spawner recruit curve and current spawning biomass and age composition estimates. The more thorough analysis which will be done for the rebuilding analysis, upon which management actions will be based, will likely result in different projections than those seen here.

A comparison of Bayesian and frequentist parametric 90% intervals was made in an attempt to ascertain what is gained in understanding of uncertainty by constructing Bayesian posterior distributions. The intervals are quite similar for both methods, and are plotted for 7 quantities of interest in the Appendix. A useful next step would involve the comparison of the distribution of projected quantities using the Bayesian posteriors and parametric uncertainty estimates.

Research and data needs for future assessments include information on the relationship of individual female age and biomass to maturity, fecundity and survival of offspring; information on the accuracy of POP ageing; information on the relative density of POP in trawlable and untrawlable areas and difference in age and/or length compositions between those areas; and information on the status of the British Columbia stock of POP and its relationship to that off of Oregon and Washington.

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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 update, 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. Size-composition data for these areas indicate 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 based upon a 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.

Prior to 1977, 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. 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).

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 1977-2004. The inter-annual variability of these ten triennial 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.

Two slope surveys have been conducted on the west coast in recent years, one using the research vessel Millar Freeman, which ended in 2001, and another a cooperative survey using commercial fishing vessels which began in 1998.

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). 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 West Coast fishery observer data from 2001-2003 gives an average discard rate of 14-15%.

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 estimated to be aged 14 years and older are pooled into a “plus-group” to reduce the impact of this bias. Fishery age-composition data based on the break-and-burn technique are available for 1994 and 1999-2004 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 composition to the expected observed age composition given aging error. This is accomplished by using an ageing-error matrix (which specifies the probability that a fish of given actual age will be given any estimated 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 PacFIN for available years not including those years for which age data was used. This includes 1981-1991 and 1995-1998. No data was available for 1992-1993. The model is fitted to the size-composition data (17-40cm, where 40cm is a plus-group) from the commercial fishery for these years. 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 8; 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 8; Tables 6-9).

1. The triennial shelf survey that was conducted every third year from 1977-2004 (Although for many species to be assessed in 2005, the 1977 triennial survey biomass index will not be used, the reasons for its omission do not apply to Pacific ocean perch. Still, this survey point is omitted for sensitivity analysis in model 1h).
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 1999-2004.

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 AFSC slope survey or for the NWFSC slope survey prior to 2001.

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 $0.15yr^{-1}$ 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 $0.05yr^{-1}$. 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 $0.059yr^{-1}$. In this assessment update we place a fairly tight base-case prior distribution on natural mortality (lognormal with median $0.05yr^{-1}$ 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. 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 minor (within 5% of 1:1) so 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 3. As part of the sensitivity analysis, a model run was conducted with a different maturity function based upon a recent maturity study (Hannah and Parker 2005).

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 4).

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 5).

1.2.4 Changes in data from the 2003 assessment

The 2003 and 2004 catch data and fishery age compositions are included in this assessment, along with updated 2002 catch data. Also the 1981-1989 and 1995-1998 length compositions have been updated, and new length compositions for 1990 and 1991, and new age compositions for 1994 have been added. This data was extracted on May 3, 2005.

This update includes the biomass index and age-composition data for the 2004 triennial shelf survey, and in addition the original data was re-analyzed for the triennial shelf survey from 1977-1995 with water hauls removed, for both biomass indices and composition data. The biomass index data was limited in all years from 55 to 366 meters, which was the limit of the survey in many years, while 1977 remained the same at 91 to 366 meters. Age composition data was available for this update for the 1995 triennial survey, so this data replaced the length composition data previously used. This data was extracted on March 28, 2005.

Biomass indices and age compositions for the NWFSC slope survey for the years 2003 and 2004 were used in the assessment, and the entire time series was re-calculated based upon new stratum area estimates and updates to the database. The 2001 age composition data was available and used in this update as well. This data was extracted on March 9, 2005 (biomass indices) and March 28, 2005 (age composition data).

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).

The survey design used for the 1985 POP survey was similar to that used in 1979 (Wilkins and 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). The 2003 assessment used a revised, corrected and updated version of the 2000 model (Hamel et al. 2003).

1.3.2. Changes between the 2003 assessment model and the current model

No changes to the estimating model have been made since the last assessment. However, the F necessary to achieve B_{40} is calculated in a new manner, calculating the fishing rate at constant recruitment at an equilibrium spawning biomass of B_{40}, and including the S-R curve in the calculation, rather than using F_{50}. The exploitation rate associated with this F at equilibrium is reported as well.

A new projection module has been added to the code, allowing projections at specified F levels out 10 years or more. Given an F value the model now deterministically projects catch and recruitment as well as biomass, spawning biomass and age composition. This involves applying the F through the fishery selectivity function for the last year of the fitted model, and projecting recruits from the spawner-recruit curve and the spawning biomass (with a 3-year time lag). The projection module is used in the MCMC realization to compare 3 states of nature arrived at by taking the median of the lowest 25%, the middle 50% and the highest 25% of each quantity of interest for each year (tables in executive summary).

1.3.3. Model features unchanged from the 2003 assessment model

The population dynamics model used in the present assessment is the same as the 2003 assessment model, 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 2003 assessment, a prior probability distribution was placed on natural mortality instead of assuming a constant fixed value. Fishery selectivity is allowed to be a smooth function of age, and to vary over time. The prior distributions for natural mortality, R_0 and the recruitment residuals remain unchanged.

The same parameterization of the Beverton-Holt stock-recruitment relationship was used in this assessment as was the case for the 2003 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 unfished level (Francis 1992)[1], so that:

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

[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.

where $\widetilde{B}_0$ 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.

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 2,400 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 14,000,000 cycles of the MCMC algorithm, discarding the first 2,000,000 as a burn-in period and selecting every 5,000$^{\text{th}}$ 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

14,000,000, 2,000,000 and 2,400 was based on generating a sample which showed no noteworthy signs of lack of convergence to the posterior distribution. We evaluated whether convergence occurred by 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.

1.36 Comparison of Bayesian and frequentist uncertainty estimates

Given the long computation time necessary to run MCMC analysis and analyze the results, there is some question as the whether the information gained is significant enough to warrant generating posterior densities by this method in many cases. As one metric for ascertaining differences between Bayesian and frequentist parametric estimates of uncertainty, a comparison was made between the Bayesian 90% intervals and the 90% confidence intervals calculated using the standard deviation estimates from the Hessian and assuming either normal or lognormal distributions. Comparisons of the confidence intervals (and median values) for 7 quantities of interest are plotted in the Appendix. These are: depletion (Figure A1); 2005 spawning biomass (Figure A2); unfished spawning biomass (Figure A3); steepness (Figure A4); triennial survey catchability (Figure A5); natural mortality (Figure A6); and MSY (Figure A7).

A useful next step would involve the comparison of the distribution of projected quantities using the Bayesian posteriors and parametric uncertainty estimates.

1.4. Results

1.4.1. Model selection and evaluation

The initial *a priori* model (Model 1) identical to the model used in the 2003 assessment, which included the following features:

1. The standard deviation of the fluctuations about the stock-recruitment relationship, σ_R, was set at 1.0.
2. A uniform prior was assumed for steepness.
3. Uniform priors were assumed for survey catchability.
4. The oldest age for which fishery selectivity was estimated was 14 years while the oldest age for which survey selectivity was estimated was 12 years.
5. Fishery selectivity was allowed to change every 6^{th} year.
6. Survey selectivity for age 10 was set to 1.0 rather than imposing a constraint that average selectivity across ages equals 1.0 or setting the maximum selectivity to 1.0.

1.4.2. Reference model results

Figure 7 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 2) 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 29% in 1966-67 and stabilized between 3 and 8% from 1969-1999, averaging 5% over that period. Over the past three years, the fishing mortality rate has been less than 1%.

The fits of the model 1 to the various indices are summarized in Figure 8 (survey biomass indices and fishery CPUE data), Figures 9 and 10 (fishery age-composition data), Figures 11 and 12 (survey age-composition data), Figure 13 (fishery size-composition data) and Figure 14 (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 15). 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 pattern for both the triennial survey exhibits a dome shape, while for the slope survey selectivity increases monotonically to age 12, beyond which selectivity is forced to be flat (Figure 16). 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 23.4% of its unfished equilibrium level of 37,838 mt in 2005 (Table 14). In terms of exploitable (age 3+) biomass, the depletion is 26.4% of unfished equilibrium level of 83,218 mt. The estimate of M is 0.051 yr^{-1} while steepness is estimated at 0.551. The estimate of *MSY* is 1,181 mt, which is smaller than all but two of the annual catches (including discard) from 1956-93 and overfishing ($F > F_{MSY}$) occurred in almost all years throughout this period. The fishing mortality in 2000 - 2004 was less than F_{MSY}.

1.4.3. Sensitivity analysis

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

1) Model 1b: Decrease the age at which the maturity curve has an inflection point (i.e. the age-at-50%-maturity) from age 8 to age 6 (Based upon Hannah and Parker (2005)).
2) Model 1c: Do not allow the fishery selectivity to change over time.
3) Model 1d: Decrease the mean of the prior on natural mortality to 0.04.
4) Model 1e: Increase the mean of the prior on natural mortality to 0.06.
5) Model 1f: Omit the NWFSC slope survey indices from the likelihood function.
6) Model 1g: Omit the triennial survey indices from the likelihood function.
7) Model 1h: Omit the 1977 triennial survey index from the likelihood function.
8) Retro 2003: Retrospective analysis – ignore the assessment data for 2003 and 2004 (as if assessment were conducted in 2003)

The results of the sensitivity analyses do not indicate great variation in results from the reference model (Model 1). Depletion levels for all but two of the sensitivity tests lie between 0.198 and 0.240. The exceptions are Models 1g and 1h, where either all the triennial survey indices are excluded from the assessment, or just the 1977 index is excluded. For these, the estimated depletion level and *MSY* drop to 0.143 and 880 mt or increase to 0.281 and 1,371 mt, 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. The 1977 index is substantially higher than the other indices, and therefore its exclusion removes evidence of decline in subsequent years. On the other hand, the triennial survey index is relatively flat from

1986 on, despite substantial variance, and therefore its inclusion supports relatively little change in depletion over that past 20 years.

Ignoring the data for 2003 and 2004 (Retrospective for comparison to the 2003 assessment) has a moderate impact on current spawning biomass and depletion. This is because the 2001 triennial survey index is fairly low and influential. Note that the depletion level of 0.215 for the Retrospective 2003 model should be compared to the estimated depletion in Model 1 for 2003 of 0.228, and to the estimated depletion level of 0.253 the 2003 assessment.

1.4.4. Markov-Chain Monte Carlo results

Evaluation of convergence

Convergence was demonstrated in the 2003 assessment and similar results of the tests of convergence were achieved for the 2005 MCMC run. Figure 25 shows the trace, moving average, autocorrelation at lag 1 and posterior for depletion. Figures were similar for the other parameters Figure 26 shows MCMC diagnostics for 26 key parameters and derived quantities, Figure 27 shows MCMC diagnostics for the spawning biomass time series, and , Figure 27 shows MCMC diagnostics for the recruitment time series.

The posteriors

The posterior probability that the 2005 spawning biomass is less than $0.25B_0$ is 0.373 (One can interpret this to indicate a 37.3% probability that Pacific ocean perch is currently overfished). The posterior probability that the 2005 spawning biomass is less than half of B_{40} is ~0.08.

Figures 17 and 18 show the posterior densities of spawning biomass and recruitment for the years 1956 to 2005. These represent the uncertainty in individual years, but also the uncertainty in the trajectories of the values. Posterior densities for recent and projected spawning biomass under fishing regimes of F = 0.01 and F=0.02 are displayed in figures 19 and 20. The projections for each MCMC realization were done by assuming recruitment from the spawner-recruit curve for each projected year. The uncertainty in future spawning biomass increases the further out from the present one goes, with the large jump in the upper tail in 2011 representing the maturing of the unobserved recruits from 2005 and later.

The posterior distribution for steepness is relatively wide (Figure 21). This confirms the expectation that the data are relatively uninformative about the shape of stock-recruitment relationship. In addition, the stock-recruitment relationship may have changed since the 1940s and 1950s, possibly due to climate change, fishery selectivity, or both.

The posterior distribution for natural mortality is relatively tight, reflecting the prior distribution, but shifted to slightly higher values (figure 22). The posterior distributions for 2007 spawning biomass and depletion are shown in Figures 23 and 24.

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.

Research on the relationship of individual female age and biomass to maturity, fecundity and survival of offspring

Further research on the accuracy of POP ageing, as well as the magnitude of bias in surface ageing compared to break-and-burn ageing.

Research on the relative density of POP in trawlable and untrawlable areas and difference in age and/or length compositions between those areas.

Research on the status of the British Columbia stock of POP and its relationship to that off of Oregon and Washington.

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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	Limited entry trip limit of 4,000 pounds/month (May-June), 4,000 pounds/2 months (July-October) or 2,000 pounds/month (November-March)
.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 the year.

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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*	*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		150	179	179
2003		130	155	155
2004		122	145	145

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 (1994,1999-2004).

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1994	0	0	0	5	2	5	17	23	13	26	28	24	8	9	8	3	7	2	2	3	4	3	46
1999	0	0	2	2	6	29	41	71	52	31	16	17	14	17	14	12	10	9	10	8	3	5	70
2000	0	0	5	13	1	7	30	47	66	60	36	49	39	44	21	25	7	11	8	8	11	6	102
2001	0	2	9	30	51	35	36	75	97	104	93	46	38	40	28	32	15	20	19	7	16	12	234
2002	0	1	0	8	82	74	44	56	93	95	99	82	48	41	24	26	26	17	19	12	17	12	163
2003	0	4	3	1	14	36	40	33	34	58	51	53	43	25	32	21	12	19	11	9	8	5	124
2004	0	0	2	0	2	7	9	11	5	2	15	17	15	7	12	16	10	9	9	9	7	4	61

Table 5. Size-composition data (categories in centimeters) for the domestic fishery catch in Vancouver and Columbia areas 1981-1991,1995-1998)

	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	3	2	9	30	52	77	190	291	421	411	409	407	1620
1982	0	0	0	0	0	0	0	0	1	0	2	2	7	10	27	45	134	221	334	459	448	503	546	2085
1983	0	0	0	0	0	0	0	0	0	0	0	3	7	7	20	38	92	164	240	334	379	394	422	1844
1984	0	0	0	0	0	0	0	0	1	0	1	2	8	12	27	56	84	159	234	306	413	449	369	982
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	1841
1987	0	0	0	0	0	0	0	0	0	0	1	1	3	13	21	48	82	141	223	298	365	390	293	1177
1988	0	0	0	0	0	0	0	0	0	0	1	1	1	4	7	9	7	11	23	47	70	65	58	298
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
1990	0	0	0	0	0	0	0	0	0	0	0	1	4	5	3	13	19	36	49	64	66	91	68	180
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	12	6	20	29	26	25	22	73
1995	0	0	0	0	0	0	0	0	0	0	0	2	4	19	47	68	94	149	283	391	457	423	311	913
1996	0	0	0	0	0	0	0	0	0	0	6	6	7	26	36	35	89	149	233	328	374	394	316	1086
1997	0	0	0	0	0	1	1	0	0	0	0	4	14	40	70	152	173	239	297	361	429	418	362	1053
1998	0	0	0	0	0	0	1	0	0	1	0	0	11	15	53	149	227	268	279	334	334	329	312	1137

Table 6. Survey age-composition data for the combined Vancouver and Columbia areas. POP survey: 1985. Triennial Survey: 1989, 1992, 1995, 1998, 2001, 2004. NWFSC Survey: 2001-2004.

Age	1985	1989	1992	1995	1998	2001	2004	2001	2002	2003	2004
3	122,477	185837	235691	28977	2056539	335,665	381063	0.0000	0.0453	0.0255	0.0238
4	332,342	3072003	1309142	679084	3457344	142,091	1565515	0.0000	0.0171	0.0707	0.1088
5	731,141	1630881	1261446	323207	363980	148,375	2268166	0.0000	0.0129	0.0075	0.0935
6	1,017,246	750624	522824	156044	501087	858,304	718472	0.0000	0.0229	0.0023	0.0077
7	418,657	829380	712930	155517	1114104	755,694	90781	0.0023	0.0737	0.0109	0.0299
8	290,206	2352749	624739	162745	1164323	191,718	163816	0.0069	0.0876	0.0978	0.0109
9	294,572	820937	360284	107115	617259	70,412	413599	0.0000	0.0365	0.0740	0.0112
10	603,853	812617	346103	115033	474097	46,313	306772	0.0408	0.0565	0.0666	0.0232
11	523,611	884372	1351217	138796	496022	111,504	251889	0.0026	0.0570	0.0499	0.0048
12	301,193	659494	665580	101593	331823	200,846	147871	0.0750	0.0923	0.0993	0.0202
13	405,146	273415	493037	155176	588042	92,684	246107	0.0908	0.0663	0.0962	0.0478
14	553,271	257562	214071	226419	384535	93,131	338846	0.0247	0.0374	0.0854	0.0688
15	554,201	105087	267540	188697	583973	72,108	185017	0.0471	0.0581	0.0578	0.0704
16	290,312	78270	330121	201449	442703	49,274	347284	0.0924	0.0554	0.0826	0.0867
17	210,758	88692	37384	126352	442686	71,836	213816	0.0886	0.0346	0.0126	0.0285
18	284,327	143052	108532	133602	339970	69,013	111383	0.0770	0.0348	0.0275	0.0254
19	189,918	157849	56544	127269	407549	64,931	237379	0.0547	0.0169	0.0083	0.0484
20	265,433	82410	0	55619	49590	66,921	119860	0.0461	0.0090	0.0069	0.0274
21	263,709	101508	129949	54256	223090	45,266	269919	0.0691	0.0156	0.0236	0.0529
22	213,783	80334	111067	47732	94158	36,720	107435	0.0085	0.0209	0.0129	0.1073
23	217,418	107953	71190	87274	205193	38,776	57046	0.0388	0.0203	0.0100	0.0106
24	200,765	181983	61804	59850	39458	50,639	80912	0.0080	0.0112	0.0005	0.0218
25	3,163,096	1886400	1177248	1287009	3439282	647,245	1506318	0.2265	0.1176	0.0712	0.0700

Table 7. POP(1979), triennial (1977-1986), and AFSC slope survey (1996-2000) size composition data.

	1977	1979	1980	1983	1986	1996	1997	1999	2000
17	2584	3,117	0	1473	5736	0.0005	0.0029	0	0.0022
18	6467	7,630	7357	23990	47058	0.0016	0	0	0.0012
19	38364	0	2620	81720	36811	0.0121	0.0071	0	0.0012
20	25567	5,123	4929	112695	93738	0.013	0.013	0.0027	0.0166
21	18575	5,490	1602	39263	73738	0.0092	0.0453	0	0.0104
22	41654	14,459	27080	48412	29864	0.0033	0.0471	0.0042	0
23	81803	27,669	27311	65048	37357	0.0009	0.1149	0.0027	0.0006
24	48390	62,293	138618	89875	34172	0.0006	0.1715	0.0116	0.0019
25	27669	75,040	129445	63206	50693	0.0011	0.226	0.0174	0.0006
26	39117	113,413	209275	88923	93667	0.0025	0.076	0.0137	0
27	62771	164,058	304862	58278	264244	0.0036	0.0236	0.0261	0
28	45894	285,927	235861	57232	226472	0.0081	0.0059	0.0228	0.0012
29	85183	325,469	417038	29597	252731	0.0506	0.0049	0.024	0.0019
30	155001	251,458	693664	46408	309120	0.0442	0.0157	0.0289	0.0019
31	423459	443,636	670202	49020	244611	0.0818	0.0203	0.0198	0.0278
32	743104	725,956	1138242	41128	165931	0.0317	0.0384	0.0249	0.0382
33	1028825	1,366,737	566302	64475	206263	0.0416	0.0202	0.0647	0.0902
34	927484	2,156,232	568183	70924	154355	0.0365	0.0128	0.1102	0.1714
35	648449	2,242,299	564382	152161	237612	0.0603	0.0365	0.1415	0.1304
36	662100	2,073,524	400455	201342	88275	0.0753	0.029	0.16	0.122
37	780754	1,642,703	558378	233651	125937	0.0958	0.0251	0.1045	0.1684
38	820832	1,525,133	519617	369834	173686	0.1081	0.0252	0.1018	0.0915
39	963049	1,436,646	457938	541827	155814	0.1128	0.0167	0.0524	0.0381
40+	7582173	3,916,376	3529329	4151022	800873	0.2049	0.022	0.0628	0.0821

Table 8. Biomass indices (and associated coefficients of variance, expressed as percentages) from the triennial surveys for the US-Vancouver and Columbia areas combined (1977-2004).

Year	Depth (m)	Biomass Estimates	Sampling CV
US Vancouver			
1977	91-366	14,519	35.5%
1980	55-366	9,628	41.6%
1983	55-366	6,710	28.2%
1986	55-366	2,569	41.5%
1989	55-366	9,427	46.3%
1992	55-366	7,603	48.0%
1995	55-366	3,772	59.6%
1998	55-366	7,310	32.9%
2001	55-366	2,509	43.8%
2004	55-366	5,835	43.4%

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	3,602	43.3%
2000 NWFSC	183-1280	4,627	52.4%
2001 NWFSC	183-1280	6,338	47.4%
2002 NWFSC	183-1280	4,465	57.8%
2003 NWFSC	183-1280	33,087	40.7%
2004 NWFSC	183-1280	10,471	85.3%

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

Data Source	Years
Fishery Catch	1956-2004
Fishery age-composition data	1966-80 (biased); 1994, 1999-2004 (unbiased)
Fishery size-composition data	1981-1991, 1995-98
Fishery CPUE	1956-73
Biomass estimates	
Triennial survey	1977,1980,1983,1986,1989,1992,1995,1998,2001,2004
POP/Rockfish survey	1979,1985
AFSC slope survey	1992*, 1996, 1997, 1999-2001
NWFSC slope survey	1999-2004
Survey age-composition data	
Triennial survey	1989, 1992, 1995, 1998, 2001, 2004
POP / NWFSC slope surveys	1985, 2001-2004
Survey size-composition data	
Triennial survey	1977, 1980, 1983, 1986
POP / NWFSC / AFSC slope surveys	1979, 1996, 1997, 1999, 2000

*Super year, for which data from different areas from the years 1992 and 1993 are combined in order to have adequate coverage of the US-Vancouver and Columbia INPFC areas.

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	Priors or Penalty functions	Phase
Average recruitment	$\overline{R}$		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	$\overline{F}$		Log-Uniform(-∞,∞)	1
Recruitment deviation	ε_i^R	70	Log-Uniform(-10,10)	3
Fishing mortality deviation	ε_i^F	49	Log-Normal(-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	0.0
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	$B_0 = R_0(1, e^{-M}, e^{-2M}, ..., e^{-21M}, \frac{e^{-22M}}{1-e^{-M}}) \cdot \vec{W}$
Fishery selectivity-at-age	$s_{i,j}^F = s_{1956,j}^F \varsigma_{k_i,j}^F$
Fishing mortality rate	$F_{i,j} = \bar{F} \varepsilon_i^F s_{i,j}^F$
Total mortality rate	$Z_{i,j} = F_{i,j} + M$
Annual survival rate	$S_{i,j} = e^{-Z_{i,j}}$
Number at age	$N_{i,j} = \begin{cases} \bar{R}\varepsilon_i^R & j = 3 \\ N_{i-1,j-1}S_{i-1,j-1} & 4 \le j \le 23 \\ N_{i-1,24}S_{i-1,24} + N_{i-1,25}S_{i-1,25} & j = 25 \end{cases}$
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=1977,80,83,86,89,92,95,98,2001,2004	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= 1999-2004	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, …, 2004	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
$L_1 = \frac{v}{2}\ln(\pi/\lambda_1) + \lambda_1 \sum_i \ln((C_i + 0.01^*)/(\hat{C}_i + 0.01))^2$	Catch biomass
$L_2 = \frac{1}{2}(v\ln(2\pi\tau^2) + \sum_i \ln(Y_i^f / \hat{Y}_i^f)^2 \tau^{-2})$	Cpue index
$L_3 = \frac{1}{2} \sum_{t=T,P,A,N} \sum_i \left(\ln(2\pi \ln(1+(\frac{\sigma_i^t}{Y_i^t})^2)^2) + \frac{\ln(Y_i^t / \hat{Y}_i^t)^2}{\ln(1+(\frac{\sigma_i^t}{Y_i^t})^2)^2} \right)$	Survey index (by survey type)
$L_5 = \frac{1}{2}\sum_{i,j} n_i^{F/S}\{\ln(\pi/\lambda_3) + \ln(\frac{0.1}{23} + \hat{P}_{i,j}^{F/S}(1-\hat{P}_{i,j}^{F/S}))\} + \lambda_3 \sum_{i,j} \ln\left[\exp\left(\frac{n_i(P_{i,j}^{F/S} - \hat{P}_{i,j}^{F/S})^2}{2(\frac{0.1}{23} + \hat{P}_{i,j}^{F/S}(1-\hat{P}_{i,j}^{F/S}))}\right) + 0.01\right]^{**}$	Fishery and survey age data
$L_5 = \frac{1}{2}\sum_{i,j} m_i^{F/S}\{\ln(\pi/\lambda_3) + \ln(\frac{0.1}{24} + \hat{L}_{i,j}^{F/S}(1-\hat{L}_{i,j}^{F/S}))\} + \lambda_3 \sum_{i,j} \ln\left[\exp\left(\frac{n_i(L_{i,j}^{F/S} - \hat{L}_{i,j}^{F/S})^2}{2(\frac{0.1}{24} + \hat{L}_{i,j}^{F/S}(1-\hat{L}_{i,j}^{F/S}))}\right) + 0.01\right]^{**}$	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
$P_{3a} = \lambda_6\lambda_{10} \sum_{w=T,Sl} \sum_j \ln\left(\frac{s_j^w s_{j+2}^w}{(s_{j+1}^w)^2}\right)^2$	Selectivity curvature penalty for survey selectivities
$P_{3b} = \frac{\lambda_6\lambda_{10}}{9} \sum_k \sum_j \ln\left(\frac{s_{k,j}^F s_{k,j+2}^F}{(s_{k,j+1}^F)^2}\right)^2$	Selectivity curvature penalty for fishery selectivities
$P_{3c} = \lambda_6\lambda_8 \sum_k \sum_{j=3}^{a_m^s - 1} \min(0, \ln(s_{k,j}^F / s_{k,j+1}^F)^2$	Penalty for fishery selectivity dome-shapedness
$P_{3c} = \frac{\lambda_6\lambda_9}{g} \sum_{k=1}^{8} \sum_j \ln(s_{k-1,j}^F / s_{k,j}^F)^2$	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 (1956-2005) 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	3.70	7.30	5.61	4.42	3.65	3.14	2.80	2.58	2.44	2.34	2.24	2.13	2.04	1.94	1.85	1.77	1.68	1.61	1.53	1.47	1.40	1.34	31.70
1957	46.18	3.52	6.93	5.33	4.20	3.46	2.96	2.63	2.40	2.25	2.14	2.05	1.96	1.87	1.78	1.70	1.62	1.54	1.47	1.41	1.34	1.29	30.27
1958	4.03	43.87	3.34	6.58	5.06	3.98	3.26	2.77	2.44	2.20	2.05	1.95	1.87	1.78	1.70	1.62	1.55	1.47	1.41	1.34	1.28	1.23	28.77
1959	18.50	3.82	41.67	3.17	6.25	4.79	3.76	3.06	2.59	2.26	2.03	1.89	1.80	1.73	1.65	1.57	1.50	1.43	1.36	1.30	1.24	1.18	27.72
1960	8.78	17.57	3.63	39.56	3.01	5.92	4.52	3.52	2.85	2.39	2.07	1.86	1.73	1.65	1.58	1.51	1.44	1.38	1.31	1.25	1.19	1.14	26.52
1961	4.15	8.34	16.69	3.45	37.53	2.85	5.58	4.23	3.26	2.61	2.17	1.88	1.69	1.58	1.51	1.44	1.38	1.31	1.25	1.19	1.14	1.09	25.17
1962	3.55	3.94	7.92	15.84	3.27	35.44	2.67	5.15	3.83	2.89	2.28	1.90	1.65	1.49	1.39	1.32	1.27	1.21	1.15	1.10	1.05	1.00	23.09
1963	4.87	3.38	3.74	7.52	15.00	3.08	32.98	2.43	4.57	3.30	2.45	1.93	1.62	1.41	1.27	1.18	1.13	1.08	1.03	0.98	0.94	0.89	20.48
1964	14.22	4.63	3.20	3.55	7.11	14.09	2.85	29.87	2.14	3.85	2.71	2.02	1.61	1.35	1.17	1.06	0.98	0.94	0.90	0.86	0.82	0.78	17.81
1965	10.18	13.51	4.39	3.04	3.36	6.69	13.10	2.60	26.58	1.84	3.23	2.28	1.72	1.37	1.14	1.00	0.90	0.84	0.80	0.76	0.73	0.69	15.80
1966	6.75	9.67	12.83	4.17	2.88	3.15	6.18	11.78	2.26	22.00	1.48	2.61	1.87	1.40	1.12	0.94	0.81	0.73	0.68	0.65	0.62	0.60	13.49
1967	4.43	6.41	9.17	12.13	3.91	2.64	2.76	5.05	8.78	1.47	13.21	0.90	1.64	1.17	0.88	0.70	0.59	0.51	0.46	0.43	0.41	0.39	8.84
1968	3.38	4.21	6.08	8.67	11.38	3.59	2.32	2.27	3.78	5.76	0.89	8.12	0.57	1.04	0.74	0.56	0.45	0.37	0.32	0.29	0.27	0.26	5.86
1969	3.80	3.21	4.00	5.76	8.17	10.56	3.23	1.99	1.83	2.78	4.01	0.63	5.83	0.41	0.75	0.53	0.40	0.32	0.27	0.23	0.21	0.20	4.39
1970	2.78	3.61	3.05	3.79	5.46	7.72	9.91	2.99	1.81	1.63	2.47	3.60	0.57	5.31	0.37	0.68	0.49	0.37	0.29	0.24	0.21	0.19	4.18
1971	3.98	2.64	3.42	2.89	3.59	5.14	7.18	9.01	2.63	1.53	1.37	2.13	3.18	0.50	4.69	0.33	0.60	0.43	0.32	0.26	0.22	0.19	3.86
1972	4.99	3.78	2.51	3.25	2.74	3.38	4.80	6.58	8.03	2.27	1.32	1.21	1.90	2.84	0.45	4.19	0.29	0.54	0.38	0.29	0.23	0.19	3.62
1973	7.39	4.74	3.59	2.38	3.08	2.59	3.17	4.44	5.97	7.13	2.01	1.18	1.10	1.73	2.59	0.41	3.81	0.27	0.49	0.35	0.26	0.21	3.47
1974	3.97	7.02	4.50	3.41	2.26	2.90	2.42	2.92	3.97	5.19	6.20	1.78	1.06	0.99	1.56	2.32	0.37	3.43	0.24	0.44	0.31	0.24	3.30
1975	1.47	3.77	6.66	4.28	3.23	2.13	2.72	2.23	2.63	3.50	4.57	5.52	1.61	0.96	0.89	1.41	2.10	0.33	3.10	0.22	0.40	0.28	3.20
1976	1.46	1.39	3.58	6.32	4.05	3.05	1.99	2.50	2.02	2.36	3.15	4.16	5.09	1.48	0.89	0.82	1.30	1.94	0.31	2.86	0.20	0.37	3.22
1977	1.59	1.39	1.32	3.40	5.98	3.80	2.81	1.79	2.20	1.77	2.07	2.81	3.78	4.63	1.35	0.81	0.75	1.18	1.76	0.28	2.60	0.18	3.26
1978	1.64	1.51	1.32	1.26	3.22	5.63	3.53	2.56	1.61	1.97	1.58	1.88	2.58	3.48	4.25	1.24	0.74	0.69	1.09	1.62	0.26	2.39	3.16
1979	1.11	1.55	1.43	1.25	1.19	3.01	5.15	3.14	2.22	1.37	1.69	1.38	1.69	2.32	3.12	3.82	1.11	0.67	0.62	0.97	1.45	0.23	4.98
1980	0.94	1.05	1.48	1.36	1.18	1.11	2.76	4.60	2.73	1.91	1.19	1.49	1.25	1.52	2.09	2.81	3.44	1.00	0.60	0.56	0.88	1.31	4.70
1981	1.85	0.89	1.00	1.40	1.28	1.11	1.02	2.46	4.00	2.34	1.65	1.04	1.34	1.12	1.37	1.88	2.53	3.10	0.90	0.54	0.50	0.79	5.41
1982	2.80	1.76	0.85	0.95	1.33	1.21	1.03	0.93	2.21	3.58	2.10	1.48	0.93	1.20	1.01	1.23	1.69	2.27	2.77	0.81	0.48	0.45	5.55
1983	2.05	2.66	1.67	0.80	0.90	1.25	1.13	0.95	0.85	2.01	3.26	1.91	1.34	0.85	1.09	0.91	1.11	1.53	2.06	2.52	0.73	0.44	5.45
1984	5.32	1.94	2.53	1.59	0.76	0.85	1.16	1.02	0.84	0.74	1.76	2.85	1.67	1.17	0.74	0.95	0.80	0.97	1.34	1.80	2.20	0.64	5.14
1985	1.10	5.05	1.85	2.40	1.50	0.72	0.78	1.05	0.90	0.74	0.65	1.55	2.50	1.46	1.03	0.65	0.83	0.70	0.85	1.17	1.57	1.92	5.06
1986	1.21	1.04	4.80	1.75	2.27	1.41	0.66	0.71	0.93	0.79	0.65	0.58	1.36	2.19	1.28	0.90	0.57	0.73	0.61	0.75	1.03	1.38	6.13
1987	2.59	1.15	0.99	4.55	1.66	2.14	1.31	0.60	0.63	0.81	0.70	0.57	0.51	1.19	1.93	1.13	0.79	0.50	0.64	0.54	0.66	0.90	6.59
1988	3.66	2.46	1.10	0.94	4.32	1.57	2.00	1.20	0.54	0.56	0.72	0.62	0.51	0.45	1.06	1.71	1.00	0.70	0.44	0.57	0.48	0.58	6.66
1989	0.63	3.48	2.34	1.04	0.89	4.06	1.45	1.81	1.06	0.47	0.48	0.63	0.54	0.44	0.39	0.92	1.49	0.87	0.61	0.39	0.50	0.42	6.30
1990	2.10	0.60	3.30	2.22	0.98	0.84	3.76	1.31	1.59	0.92	0.40	0.42	0.54	0.47	0.38	0.34	0.80	1.28	0.75	0.53	0.33	0.43	5.80
1991	3.15	2.00	0.57	3.13	2.10	0.93	0.78	3.44	1.17	1.40	0.81	0.36	0.37	0.48	0.41	0.34	0.30	0.70	1.14	0.66	0.47	0.29	5.50
1992	2.58	2.99	1.89	0.54	2.97	1.98	0.86	0.70	3.01	1.01	1.21	0.70	0.31	0.32	0.41	0.35	0.29	0.26	0.60	0.98	0.57	0.40	4.98
1993	3.13	2.45	2.84	1.80	0.51	2.79	1.84	0.78	0.62	2.63	0.88	1.05	0.61	0.27	0.28	0.36	0.31	0.25	0.22	0.53	0.85	0.50	4.70
1994	2.84	2.98	2.33	2.70	1.70	0.48	2.57	1.65	0.68	0.53	2.24	0.75	0.91	0.52	0.23	0.24	0.31	0.27	0.22	0.19	0.45	0.73	4.47
1995	0.50	2.69	2.83	2.21	2.55	1.60	0.45	2.33	1.46	0.59	0.46	1.96	0.66	0.79	0.46	0.20	0.21	0.27	0.23	0.19	0.17	0.40	4.56
1996	0.59	0.48	2.56	2.68	2.09	2.41	1.49	0.41	2.08	1.29	0.52	0.41	1.73	0.59	0.71	0.41	0.18	0.19	0.24	0.21	0.17	0.15	4.40
1997	4.18	0.56	0.45	2.43	2.54	1.97	2.24	1.36	0.37	1.85	1.14	0.46	0.36	1.54	0.52	0.63	0.36	0.16	0.16	0.21	0.18	0.15	4.04
1998	2.78	3.97	0.53	0.43	2.30	2.40	1.84	2.06	1.23	0.33	1.66	1.02	0.42	0.33	1.39	0.47	0.56	0.33	0.14	0.15	0.19	0.17	3.77
1999	0.37	2.64	3.77	0.51	0.41	2.17	2.24	1.70	1.87	1.11	0.29	1.49	0.92	0.38	0.30	1.25	0.42	0.51	0.29	0.13	0.13	0.17	3.55
2000	0.49	0.35	2.51	3.58	0.48	0.38	2.03	2.07	1.55	1.70	1.01	0.27	1.36	0.84	0.34	0.27	1.14	0.39	0.46	0.27	0.12	0.12	3.41
2001	1.21	0.47	0.34	2.39	3.40	0.45	0.36	1.91	1.95	1.46	1.59	0.94	0.25	1.28	0.79	0.32	0.25	1.07	0.36	0.44	0.25	0.11	3.31
2002	6.54	1.15	0.44	0.32	2.26	3.22	0.43	0.34	1.78	1.81	1.35	1.48	0.88	0.24	1.19	0.74	0.30	0.24	1.00	0.34	0.41	0.23	3.19
2003	5.09	6.22	1.09	0.42	0.30	2.15	3.04	0.40	0.32	1.67	1.70	1.27	1.39	0.83	0.22	1.12	0.69	0.28	0.22	0.94	0.32	0.38	3.22
2004	1.39	4.84	5.90	1.03	0.40	0.29	2.03	2.87	0.38	0.30	1.57	1.60	1.20	1.31	0.78	0.21	1.05	0.65	0.27	0.21	0.88	0.30	3.39
2005	1.39	1.32	4.60	5.61	0.98	0.38	0.27	1.92	2.70	0.36	0.28	1.48	1.50	1.13	1.23	0.73	0.20	0.99	0.61	0.25	0.20	0.83	3.48

Table 13. Point estimates of the catch-at-age (millions of fish) for the US west coast population of Pacific ocean perch (1956-2004) 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	0.004	0.010	0.019	0.034	0.052	0.069	0.078	0.078	0.074	0.071	0.067	0.064	0.061	0.058	0.056	0.053	0.051	0.049	0.047	1.100
1957	0.002	0.000	0.003	0.006	0.013	0.025	0.043	0.064	0.084	0.092	0.087	0.080	0.077	0.073	0.070	0.066	0.063	0.060	0.058	0.055	0.053	0.050	1.186
1958	0.000	0.004	0.001	0.005	0.011	0.020	0.032	0.045	0.057	0.061	0.056	0.052	0.050	0.047	0.045	0.043	0.041	0.039	0.037	0.036	0.034	0.032	0.763
1959	0.001	0.000	0.014	0.003	0.017	0.030	0.046	0.063	0.077	0.079	0.070	0.063	0.060	0.058	0.055	0.052	0.050	0.048	0.045	0.043	0.041	0.040	0.925
1960	0.000	0.002	0.002	0.050	0.010	0.046	0.069	0.090	0.104	0.102	0.088	0.076	0.071	0.068	0.065	0.062	0.059	0.056	0.054	0.051	0.049	0.047	1.087
1961	0.000	0.002	0.013	0.008	0.225	0.039	0.151	0.191	0.210	0.197	0.163	0.136	0.123	0.114	0.109	0.104	0.100	0.095	0.091	0.086	0.082	0.079	1.822
1962	0.000	0.001	0.009	0.051	0.028	0.700	0.103	0.331	0.349	0.308	0.242	0.194	0.169	0.152	0.142	0.135	0.130	0.124	0.118	0.112	0.107	0.102	2.358
1963	0.001	0.001	0.005	0.029	0.160	0.075	1.494	0.176	0.505	0.435	0.315	0.232	0.193	0.168	0.152	0.141	0.135	0.129	0.123	0.117	0.112	0.107	2.453
1964	0.001	0.002	0.004	0.012	0.065	0.293	0.110	1.843	0.203	0.436	0.299	0.207	0.166	0.138	0.120	0.108	0.101	0.096	0.092	0.088	0.084	0.080	1.830
1965	0.001	0.006	0.007	0.014	0.041	0.187	0.678	0.214	3.337	0.275	0.472	0.311	0.233	0.186	0.156	0.135	0.122	0.114	0.108	0.104	0.099	0.094	2.149
1966	0.003	0.012	0.052	0.051	0.096	0.237	0.841	2.480	0.697	7.903	0.519	0.864	0.618	0.464	0.370	0.309	0.269	0.243	0.226	0.216	0.207	0.197	4.461
1967	0.002	0.008	0.037	0.146	0.127	0.193	0.367	1.038	2.650	0.517	4.548	0.291	0.531	0.380	0.285	0.228	0.190	0.166	0.149	0.139	0.133	0.127	2.864
1968	0.001	0.004	0.017	0.073	0.259	0.185	0.219	0.336	0.839	1.504	0.228	1.941	0.136	0.249	0.178	0.134	0.107	0.089	0.078	0.070	0.065	0.062	1.401
1969	0.000	0.001	0.003	0.011	0.043	0.123	0.077	0.085	0.114	0.173	0.211	0.025	0.233	0.016	0.030	0.021	0.016	0.013	0.011	0.009	0.008	0.008	0.175
1970	0.000	0.001	0.003	0.013	0.050	0.157	0.414	0.221	0.193	0.174	0.223	0.249	0.039	0.367	0.026	0.047	0.034	0.025	0.020	0.017	0.015	0.013	0.289
1971	0.000	0.001	0.003	0.008	0.027	0.086	0.246	0.549	0.232	0.135	0.103	0.121	0.181	0.029	0.267	0.019	0.034	0.024	0.018	0.015	0.012	0.011	0.220
1972	0.000	0.001	0.002	0.007	0.015	0.040	0.118	0.288	0.511	0.145	0.071	0.049	0.078	0.116	0.018	0.171	0.012	0.022	0.016	0.012	0.009	0.008	0.148
1973	0.001	0.001	0.003	0.006	0.022	0.040	0.102	0.253	0.492	0.589	0.141	0.063	0.058	0.092	0.138	0.022	0.203	0.014	0.026	0.019	0.014	0.011	0.184
1974	0.000	0.002	0.003	0.008	0.014	0.039	0.067	0.144	0.284	0.372	0.375	0.082	0.049	0.045	0.072	0.107	0.017	0.158	0.011	0.020	0.014	0.011	0.152
1975	0.000	0.001	0.005	0.011	0.025	0.040	0.090	0.103	0.138	0.174	0.181	0.155	0.045	0.027	0.025	0.039	0.059	0.009	0.087	0.006	0.011	0.008	0.090
1976	0.000	0.000	0.004	0.024	0.048	0.087	0.099	0.172	0.159	0.176	0.188	0.175	0.215	0.063	0.037	0.035	0.055	0.082	0.013	0.121	0.008	0.015	0.135
1977	0.000	0.000	0.001	0.010	0.054	0.082	0.106	0.094	0.132	0.100	0.094	0.090	0.121	0.148	0.043	0.026	0.024	0.038	0.056	0.009	0.083	0.006	0.104
1978	0.000	0.001	0.002	0.006	0.049	0.205	0.224	0.224	0.160	0.185	0.119	0.101	0.139	0.186	0.228	0.066	0.040	0.037	0.058	0.087	0.014	0.128	0.169
1979	0.000	0.001	0.002	0.006	0.017	0.101	0.303	0.254	0.205	0.120	0.118	0.069	0.084	0.115	0.155	0.190	0.055	0.033	0.031	0.048	0.072	0.011	0.247
1980	0.000	0.000	0.002	0.006	0.017	0.038	0.165	0.381	0.258	0.170	0.085	0.075	0.063	0.077	0.106	0.143	0.175	0.051	0.030	0.028	0.045	0.067	0.238
1981	0.000	0.000	0.001	0.003	0.009	0.020	0.036	0.125	0.222	0.127	0.088	0.059	0.076	0.063	0.077	0.106	0.143	0.175	0.051	0.031	0.028	0.045	0.306
1982	0.000	0.000	0.000	0.002	0.007	0.016	0.028	0.036	0.093	0.148	0.086	0.063	0.040	0.051	0.043	0.053	0.072	0.097	0.119	0.035	0.021	0.019	0.238
1983	0.000	0.001	0.002	0.003	0.009	0.032	0.057	0.068	0.067	0.154	0.246	0.152	0.107	0.068	0.087	0.073	0.089	0.122	0.164	0.200	0.058	0.035	0.433
1984	0.000	0.001	0.002	0.005	0.007	0.021	0.055	0.070	0.063	0.054	0.127	0.217	0.127	0.089	0.056	0.072	0.061	0.074	0.102	0.137	0.167	0.049	0.391
1985	0.000	0.001	0.002	0.007	0.014	0.017	0.037	0.071	0.066	0.053	0.046	0.116	0.187	0.109	0.077	0.048	0.062	0.052	0.064	0.087	0.118	0.144	0.378
1986	0.000	0.000	0.004	0.005	0.021	0.033	0.031	0.047	0.067	0.056	0.045	0.042	0.100	0.161	0.094	0.066	0.042	0.054	0.045	0.055	0.075	0.102	0.451
1987	0.000	0.000	0.001	0.010	0.011	0.036	0.044	0.031	0.039	0.051	0.043	0.036	0.032	0.075	0.121	0.071	0.049	0.031	0.040	0.034	0.041	0.056	0.413
1988	0.000	0.001	0.001	0.003	0.038	0.035	0.089	0.083	0.044	0.046	0.059	0.051	0.042	0.037	0.087	0.141	0.082	0.058	0.036	0.047	0.039	0.048	0.547
1989	0.000	0.001	0.002	0.003	0.008	0.098	0.070	0.135	0.094	0.042	0.043	0.056	0.048	0.039	0.035	0.082	0.133	0.078	0.055	0.034	0.044	0.037	0.563
1990	0.000	0.000	0.002	0.005	0.007	0.015	0.137	0.074	0.107	0.062	0.027	0.028	0.037	0.031	0.026	0.023	0.054	0.087	0.051	0.036	0.023	0.029	0.392
1991	0.000	0.001	0.001	0.010	0.021	0.023	0.039	0.267	0.108	0.130	0.075	0.033	0.034	0.045	0.038	0.031	0.028	0.065	0.105	0.062	0.043	0.027	0.510
1992	0.000	0.001	0.002	0.002	0.025	0.042	0.036	0.046	0.235	0.079	0.094	0.055	0.024	0.025	0.032	0.028	0.023	0.020	0.047	0.077	0.045	0.031	0.391
1993	0.000	0.001	0.003	0.007	0.006	0.084	0.102	0.063	0.059	0.260	0.086	0.097	0.056	0.025	0.026	0.033	0.028	0.023	0.021	0.049	0.078	0.046	0.432
1994	0.000	0.001	0.002	0.009	0.017	0.012	0.117	0.109	0.053	0.044	0.181	0.057	0.069	0.040	0.018	0.018	0.024	0.020	0.016	0.015	0.034	0.056	0.339
1995	0.000	0.001	0.002	0.006	0.021	0.033	0.017	0.131	0.097	0.041	0.032	0.126	0.042	0.051	0.030	0.013	0.013	0.018	0.015	0.012	0.011	0.026	0.294
1996	0.000	0.000	0.002	0.007	0.017	0.049	0.057	0.023	0.137	0.088	0.036	0.026	0.110	0.037	0.045	0.026	0.011	0.012	0.015	0.013	0.011	0.010	0.280
1997	0.000	0.000	0.000	0.005	0.017	0.032	0.068	0.060	0.019	0.101	0.061	0.023	0.018	0.078	0.026	0.032	0.018	0.008	0.008	0.011	0.009	0.008	0.205
1998	0.000	0.001	0.000	0.001	0.015	0.038	0.054	0.089	0.063	0.018	0.087	0.051	0.021	0.016	0.069	0.023	0.028	0.016	0.007	0.007	0.010	0.008	0.186
1999	0.000	0.000	0.002	0.001	0.003	0.036	0.058	0.060	0.081	0.048	0.012	0.056	0.034	0.014	0.011	0.047	0.016	0.019	0.011	0.005	0.005	0.006	0.133
2000	0.000	0.000	0.000	0.002	0.001	0.002	0.015	0.021	0.019	0.021	0.012	0.003	0.014	0.009	0.004	0.003	0.012	0.004	0.005	0.003	0.001	0.001	0.036
2001	0.000	0.000	0.000	0.002	0.012	0.004	0.005	0.033	0.042	0.031	0.032	0.017	0.005	0.024	0.015	0.006	0.005	0.020	0.007	0.008	0.005	0.002	0.061
2002	0.000	0.000	0.000	0.000	0.005	0.015	0.003	0.003	0.022	0.022	0.015	0.016	0.009	0.002	0.013	0.008	0.003	0.002	0.011	0.004	0.004	0.002	0.034
2003	0.000	0.000	0.000	0.000	0.001	0.009	0.019	0.003	0.003	0.017	0.017	0.011	0.013	0.007	0.002	0.010	0.006	0.003	0.002	0.008	0.003	0.003	0.029
2004	0.000	0.000	0.001	0.000	0.001	0.001	0.012	0.022	0.004	0.003	0.014	0.013	0.010	0.011	0.006	0.002	0.009	0.005	0.002	0.002	0.007	0.002	0.028

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

Derived Quantities of Interest	Model 1	Model 1b	Model 1c	Model 1d	Model 1e	Model 1f	Model 1g	Model 1h	Retro 2003	Model 2003	Bayesian Medians
Depletion in 2005 (or 2003)	0.234	0.244	0.232	0.230	0.236	0.222	0.143	0.281	(0.219)	(0.253)	0.266
2005 spawning biomass (or 2003)	8,846	9,689	9,069	8,332	9,368	8,537	5,178	10,717	(8,481)	(9,946)	9,322
Unfished spawning biomass	37,838	39,706	39,168	36,154	39,724	38,509	36,213	38,115	38,734	39,283	35,371
B_{MSY}	15,135	15,883	15,667	14,462	15,890	15,404	14,485	15,246	15,494	15,713	13,767
MSY	1,181	1,161	1,208	1,164	1,166	1,064	880	1,371	986	1,160	1,266
MSYL	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
F_{MSY}	0.031	0.032	0.031	0.032	0.029	0.027	0.024	0.036	0.026	0.030	0.037
Exploitation rate at MSY	0.032	0.033	0.032	0.034	0.030	0.029	0.026	0.037	0.027	0.031	0.038
F_{2004}/F_{MSY} (or F_{2002}/F_{MSY})	0.211	0.206	0.210	0.219	0.211	0.246	0.465	0.151	(0.344)	(0.332)	
Likelihoods											
Objective function	347.39	347.24	370.53	348.61	347.35	292.28	301.22	341.33	273.60	272.82	
Triennial survey biomass likelihood	43.16	43.16	43.33	43.54	42.87	42.63	0.00	36.68	43.11	36.13	
POP survey biomass likelihood	0.48	0.48	0.63	0.51	0.46	0.37	0.15	0.81	0.28	0.16	
AFSC survey biomass likelihood	25.99	25.96	25.84	25.92	26.02	25.78	23.22	27.03	25.25	26.65	
NWFSC survey biomass likelihood	54.15	54.19	54.18	53.28	54.91	0.00	55.46	53.47	2.19	3.26	
CPUE likelihood	11.56	11.57	8.98	11.47	11.89	11.69	11.14	11.77	11.75	12.14	
Triennial survey age likelihood	-54.92	-54.99	-56.47	-55.17	-54.69	-54.54	-56.84	-55.61	-43.45	-33.38	
POP/slope survey age likelihood	55.08	55.13	58.20	54.83	55.33	54.59	55.51	55.26	31.70	9.54	
Fishery biased age likelihood	52.59	52.55	71.02	52.95	52.34	52.40	52.59	52.51	52.60	52.65	
Triennial survey size likelihood	33.24	33.26	33.80	33.06	33.39	33.80	33.03	33.39	33.98	39.26	
POP/slope survey size likelihood	40.82	40.83	40.83	40.84	40.80	40.36	41.18	40.98	41.16	38.64	
Fishery size likelihood	21.65	21.66	29.83	21.34	21.94	21.88	21.32	21.67	21.95	27.78	
Fishery unbiased age likelihood	24.13	24.13	25.68	24.01	24.26	23.79	24.30	24.31	14.64	19.22	
Priors											
Catch fit prior	0.24	0.24	0.17	0.25	0.24	0.24	0.15	0.20	0.23	0.23	
Fdevs prior	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Fishery selectivity dome prior	6.31	6.27	0.00	6.75	5.98	6.33	6.25	6.09	6.13	6.68	
Fishery selectivity change prior	6.70	6.70	0.00	6.72	6.67	6.81	6.62	6.68	6.86	8.77	
Fishery selectivity curvature prior	1.21	1.21	1.21	1.21	1.21	1.25	1.97	1.22	1.59	2.16	
Survey selectivity curvature prior	6.76	6.75	14.89	6.79	6.76	6.77	6.61	6.78	6.98	6.72	
Rho/SigmaR sp-rec prior	19.58	19.47	19.73	21.37	18.32	19.28	19.93	19.46	17.74	17.47	
Natural mortality prior	-1.35	-1.34	-1.32	-1.06	-1.35	-1.14	-1.36	-1.37	-1.09	-1.25	
Steepness prior	0.00	0.00	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	0.00	0.00	
Parameters											
Natural mortality	0.051	0.051	0.052	0.043	0.059	0.054	0.051	0.051	0.054	0.053	0.054
Steepness	0.551	0.520	0.541	0.671	0.469	0.479	0.446	0.645	0.454	0.531	0.596
Triennial survey catchability	0.252	0.252	0.247	0.277	0.229	0.253		0.210	0.260	0.253	0.256
POP survey catchability	0.393	0.393	0.387	0.435	0.357	0.415	0.439	0.374	0.442	0.455	0.347
NWFSC survey catchability	0.465	0.467	0.460	0.510	0.428		0.761	0.389	0.290	0.212	0.401
AFSC survey catchability	0.242	0.243	0.238	0.269	0.220	0.256	0.354	0.210	0.273	0.271	0.212

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

	MPD estimates		Posterior Medians	
Year	SpBiomass	Recruits	SpBiomass	Recruits
1956	33537	3.70	31278	4.68
1957	32332	46.18	30207	42.27
1958	31204	4.03	29366	5.65
1959	30754	18.50	29232	16.55
1960	30435	8.78	29294	9.33
1961	30558	4.15	29756	3.89
1962	32282	3.55	31572	3.50
1963	33901	4.87	33245	4.68
1964	33527	14.22	33021	15.24
1965	33191	10.18	32642	10.64
1966	30670	6.75	30145	6.94
1967	21919	4.43	21412	4.50
1968	16088	3.38	15619	3.59
1969	14210	3.80	13831	3.80
1970	15892	2.78	15650	2.94
1971	16714	3.98	16529	4.15
1972	17089	4.99	16970	4.77
1973	17255	7.39	17199	8.40
1974	16928	3.97	16920	3.77
1975	16669	1.47	16732	1.49
1976	16736	1.46	16843	1.45
1977	16708	1.59	16823	1.59
1978	17112	1.64	17275	1.62
1979	16983	1.11	17189	1.09
1980	16470	0.94	16718	0.97
1981	15632	1.85	15885	2.08
1982	14828	2.80	15098	2.28
1983	14243	2.05	14517	2.21
1984	13121	5.32	13388	5.63
1985	12094	1.10	12382	1.03
1986	11228	1.21	11519	1.17
1987	10597	2.59	10883	2.70
1988	10254	3.66	10515	3.71
1989	9921	0.63	10187	0.63
1990	9527	2.10	9780	2.18
1991	9139	3.15	9406	3.43
1992	8592	2.58	8863	2.65
1993	8365	3.13	8625	3.42
1994	7970	2.84	8221	3.04
1995	7652	0.50	7903	0.53
1996	7578	0.59	7845	0.61
1997	7607	4.18	7891	4.65
1998	7763	2.78	8054	3.03
1999	7902	0.37	8227	0.39
2000	7925	0.49	8275	0.51
2001	8012	1.21	8373	1.26
2002	8222	6.54	8607	7.14
2003	8640	5.09	9100	4.66
2004	8846	1.39	9331	1.42
2005	8846	1.39	9322	1.87

1.7. Figures

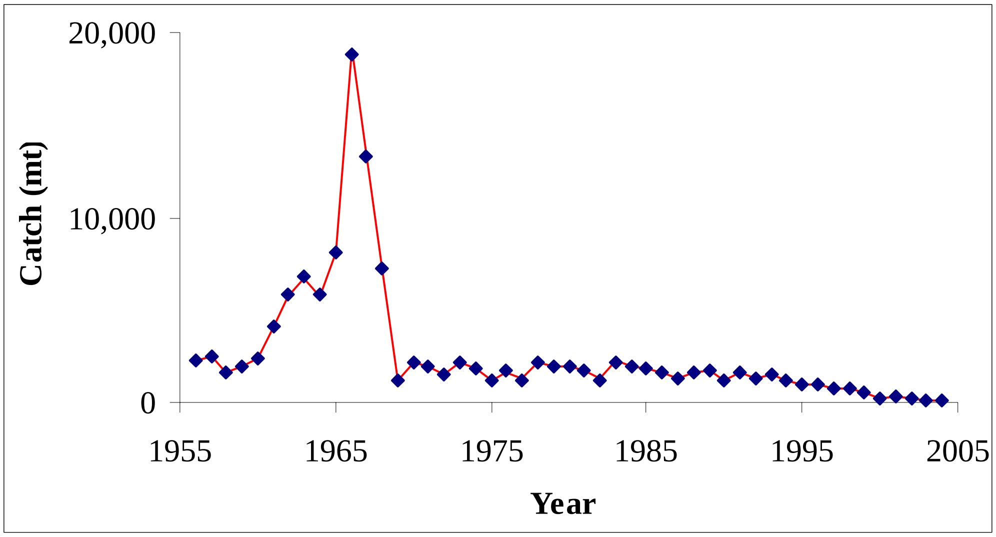


Figure 1. Catch history of Pacific ocean perch (domestic and foreign fleets combined).

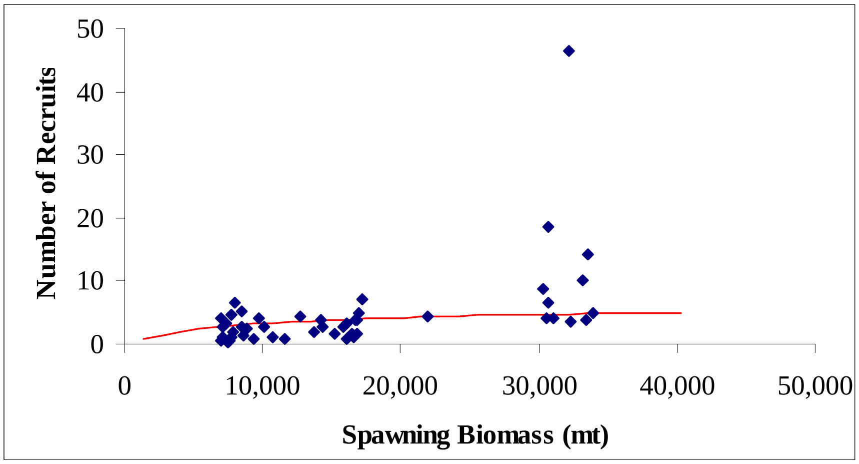


Figure 2: Fit of the deterministic stock-recruitment relationship to the spawning stock biomass and recruitment estimates.

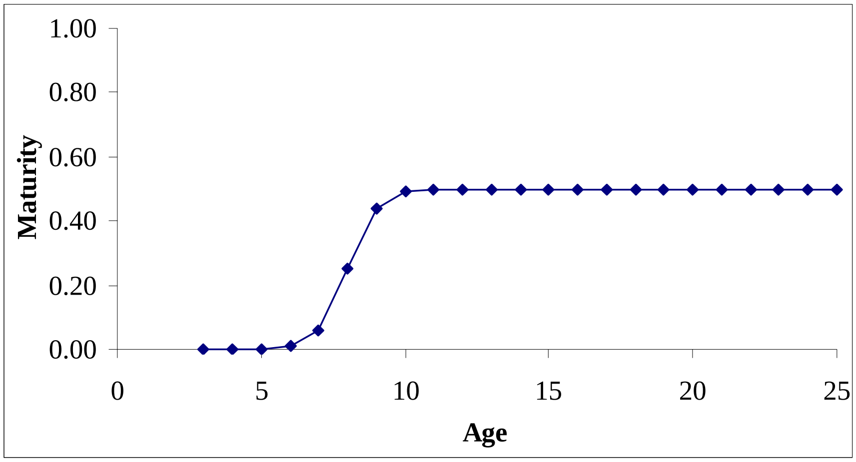


Figure 3. Modeled proportion of Pacific ocean perch that are mature females by age.

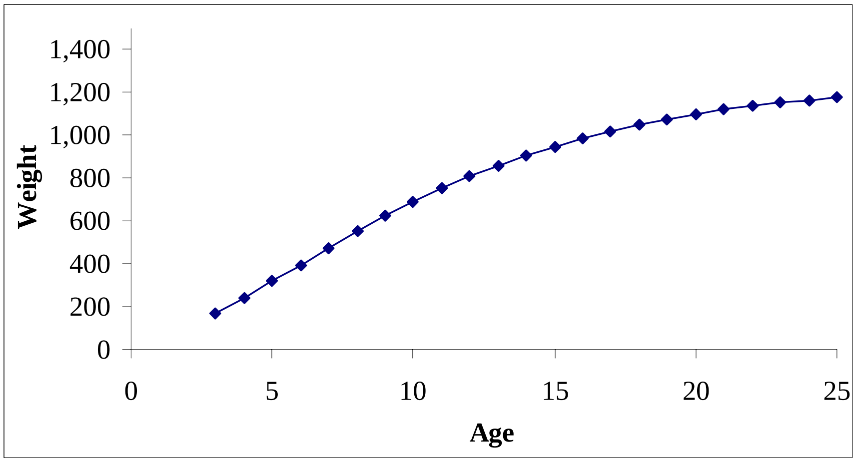


Figure 4. Weight at age (grams) for Pacific ocean perch used in the assessment model.

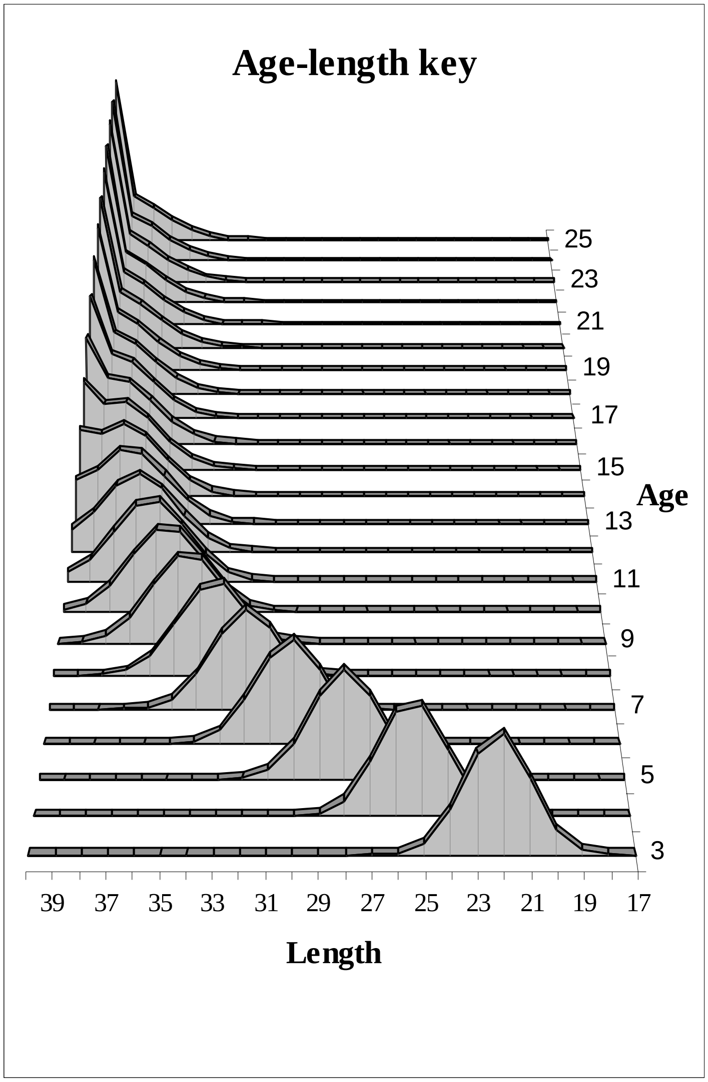


Figure 5. Length distributions by age used in the age-length transition matrix.

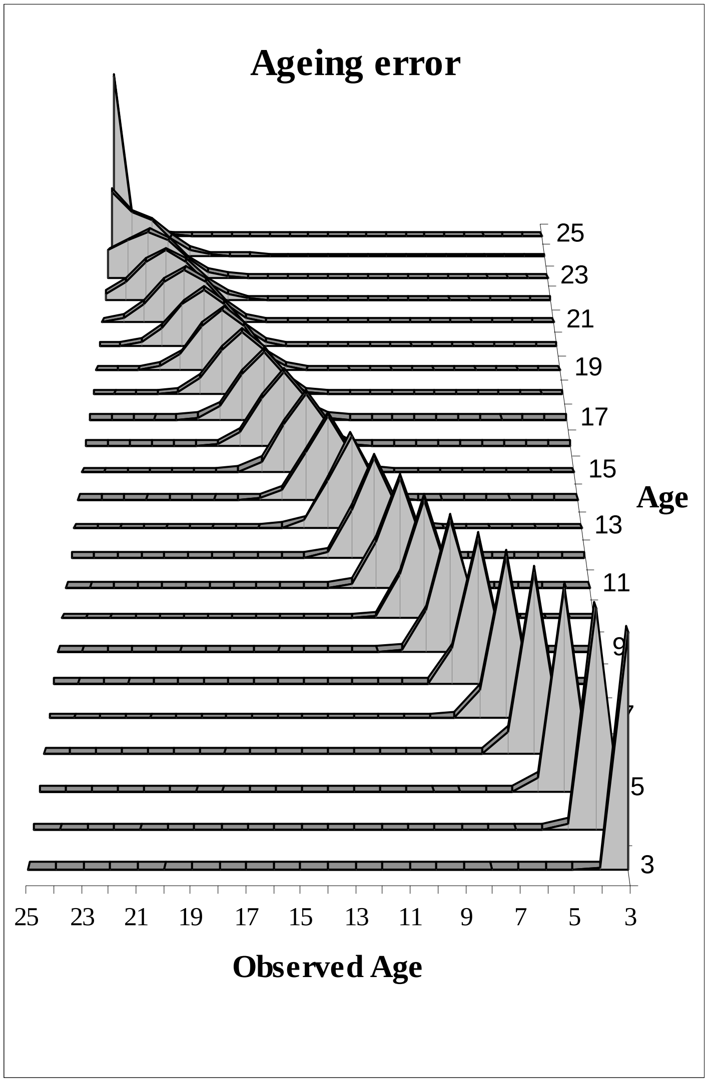


Figure 6. Assumed relationship between observed age and true age used as an ageing error matrix.

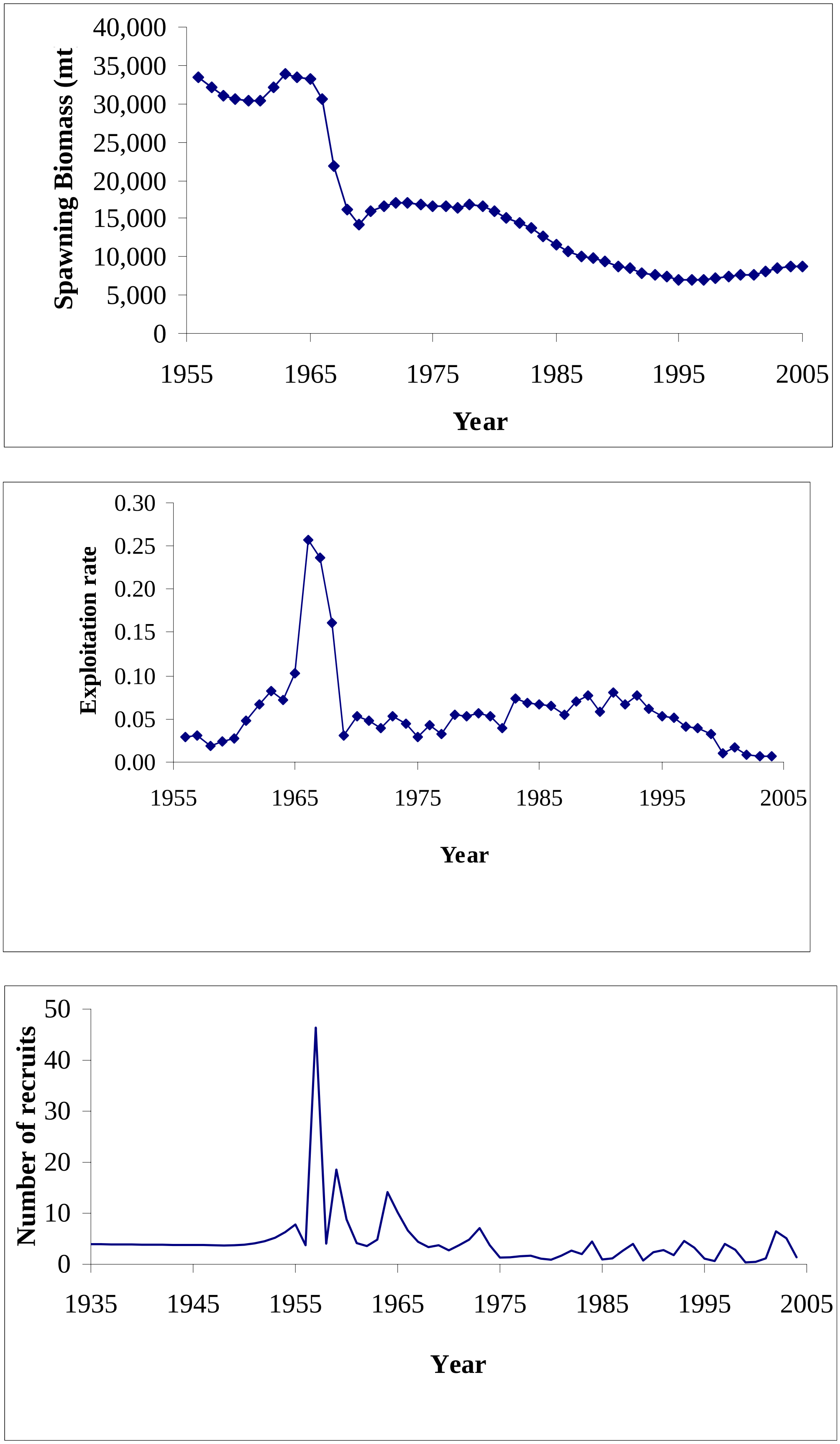


Figure 7. Time series of spawning biomass, exploitation rate and recruitment.

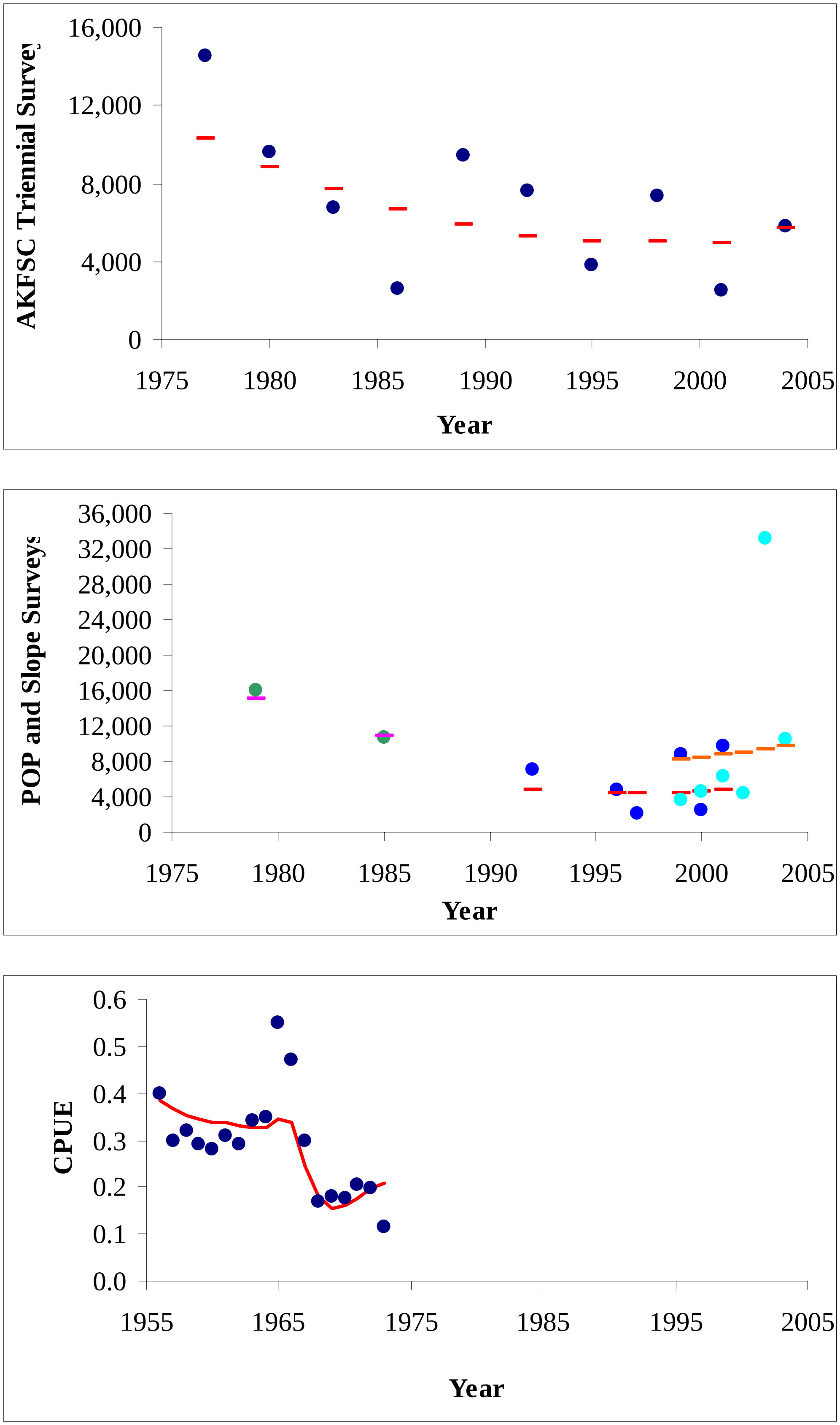


Figure 8. Fit of Model 1 to the survey biomass indices and to the fishery CPUE data. Note that each survey has a unique catchability coefficient so that there is a separate trajectory of survey-selected biomass for each survey; the curves shown are only through expected biomass indices for the years of data.

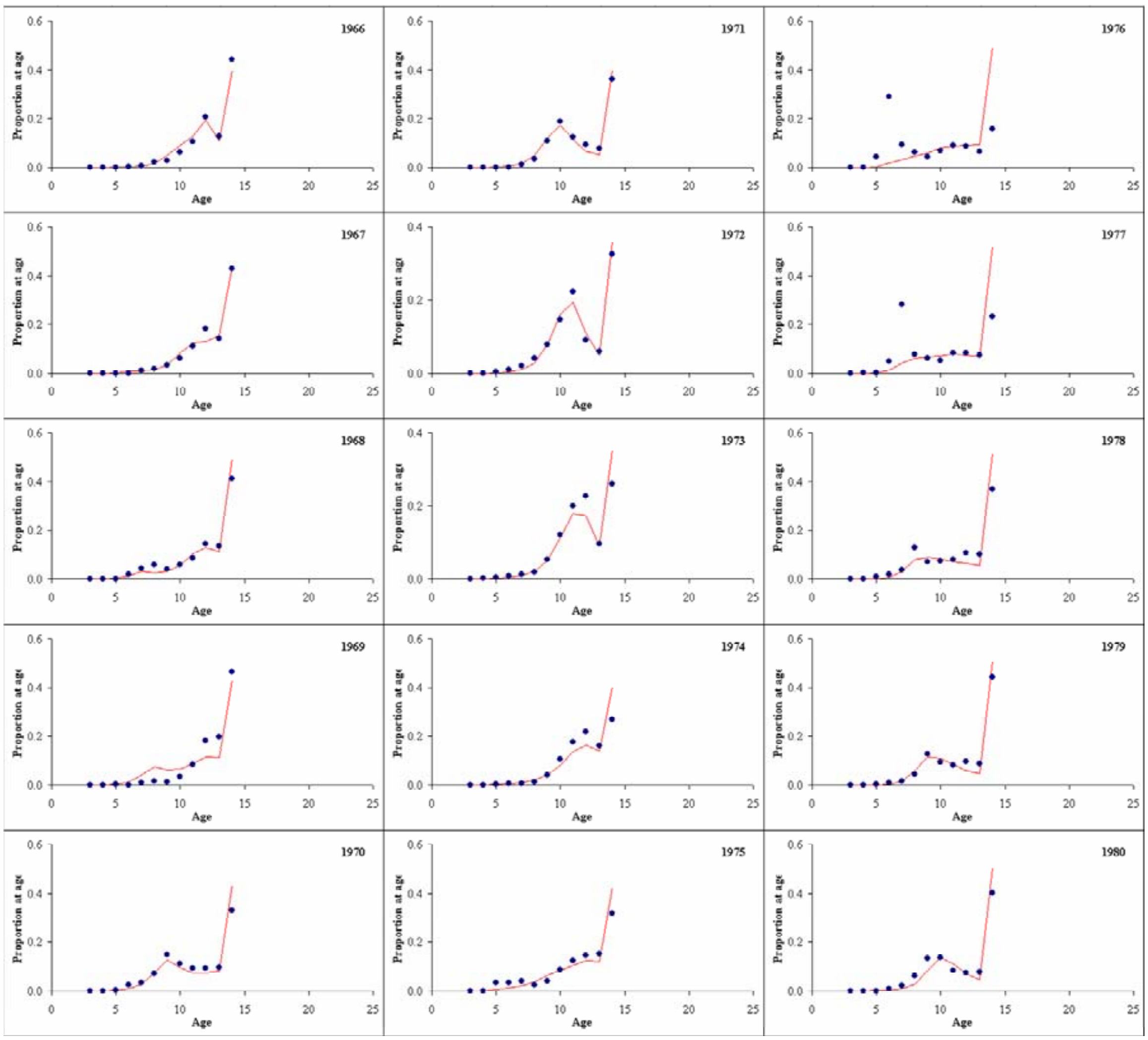


Figure 9. Fit of model 1 to the “biased” (1966-80) fishery age-composition data.

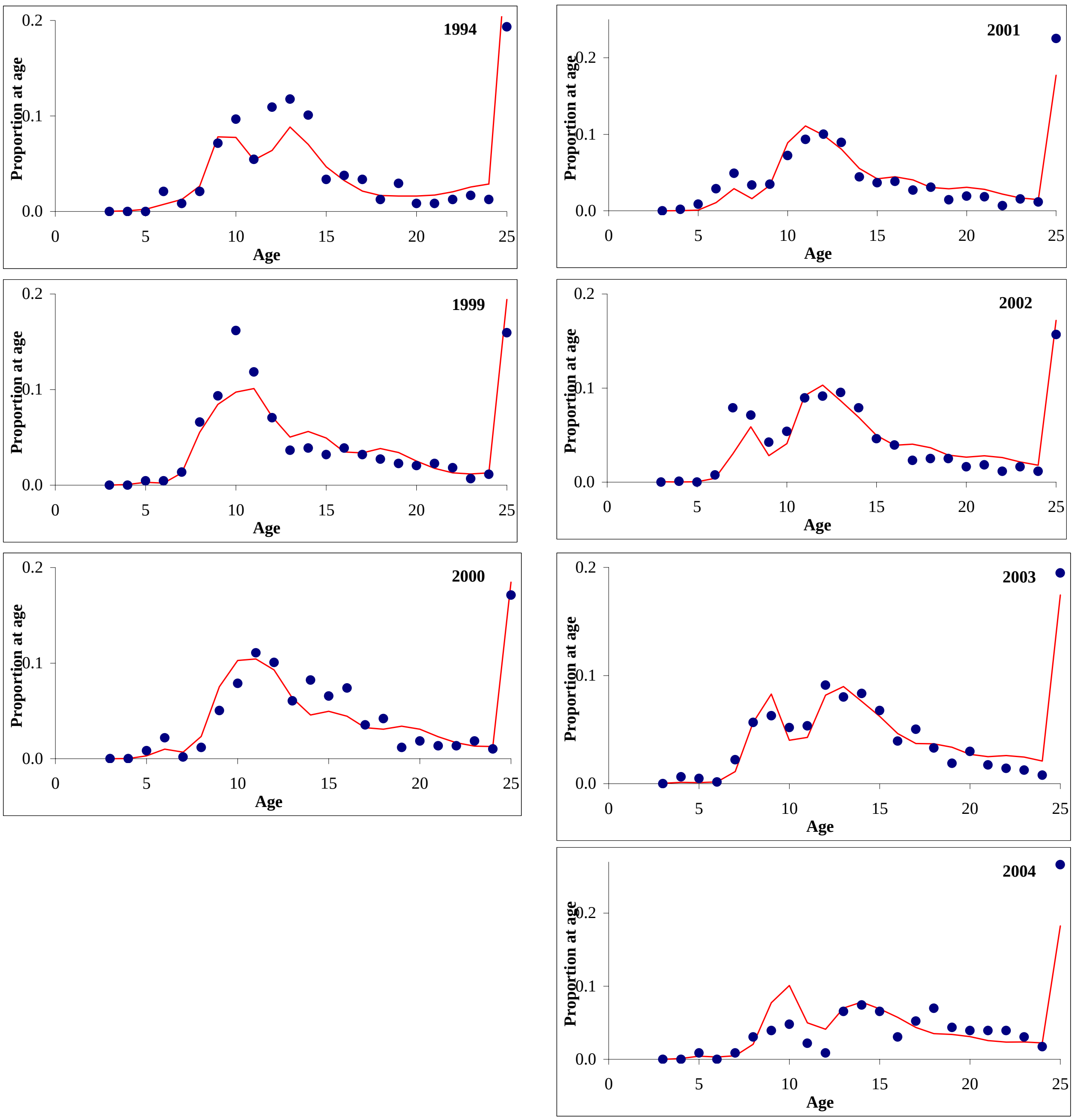


Figure 10. Fit of Model 1 to the “unbiased” (1994,1999-2004) fishery age-composition data.

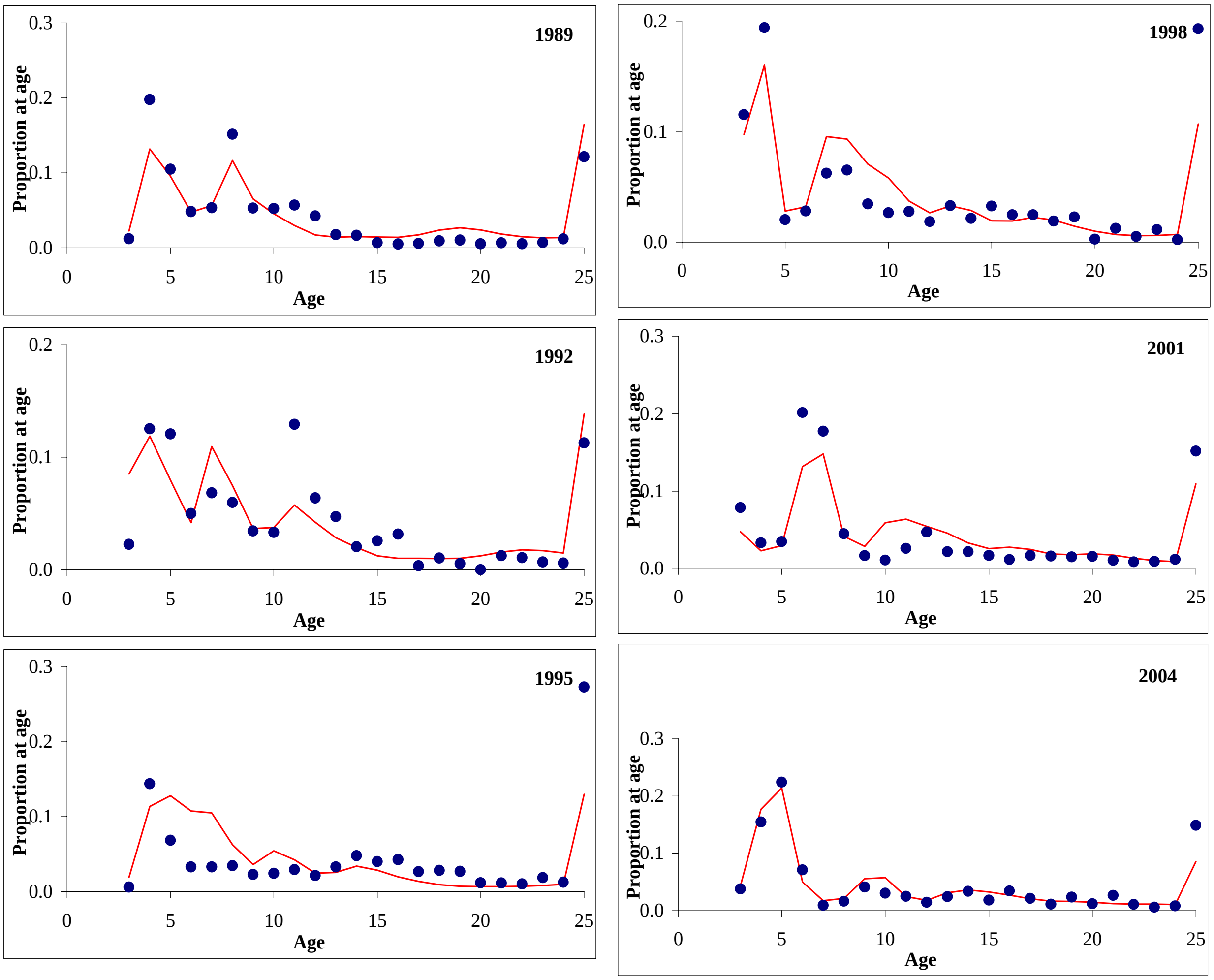


Figure 11. Fit of model 1 to triennial survey age-composition data.

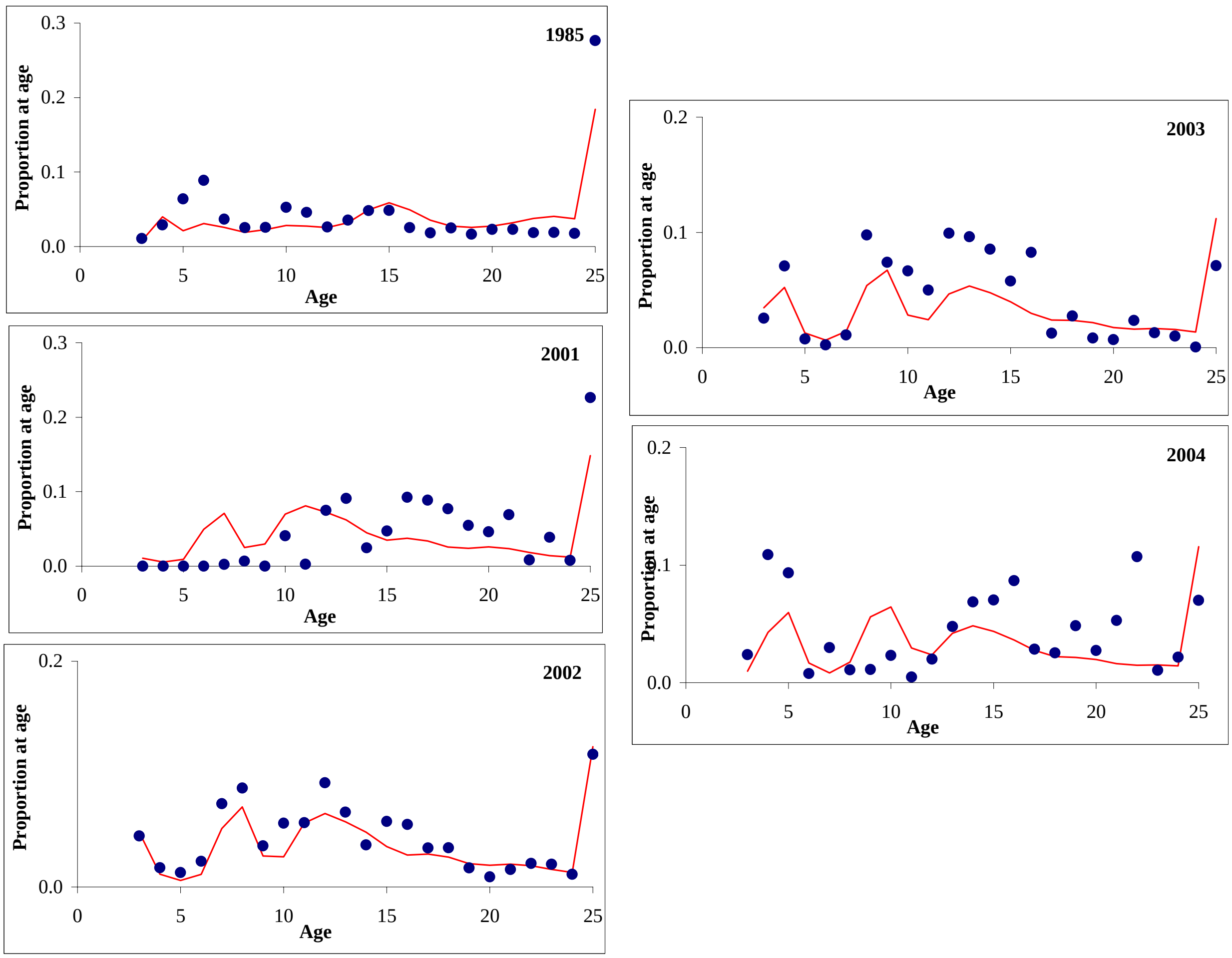


Figure 12. Fit of Model 1 to POP and slope survey age-composition data.

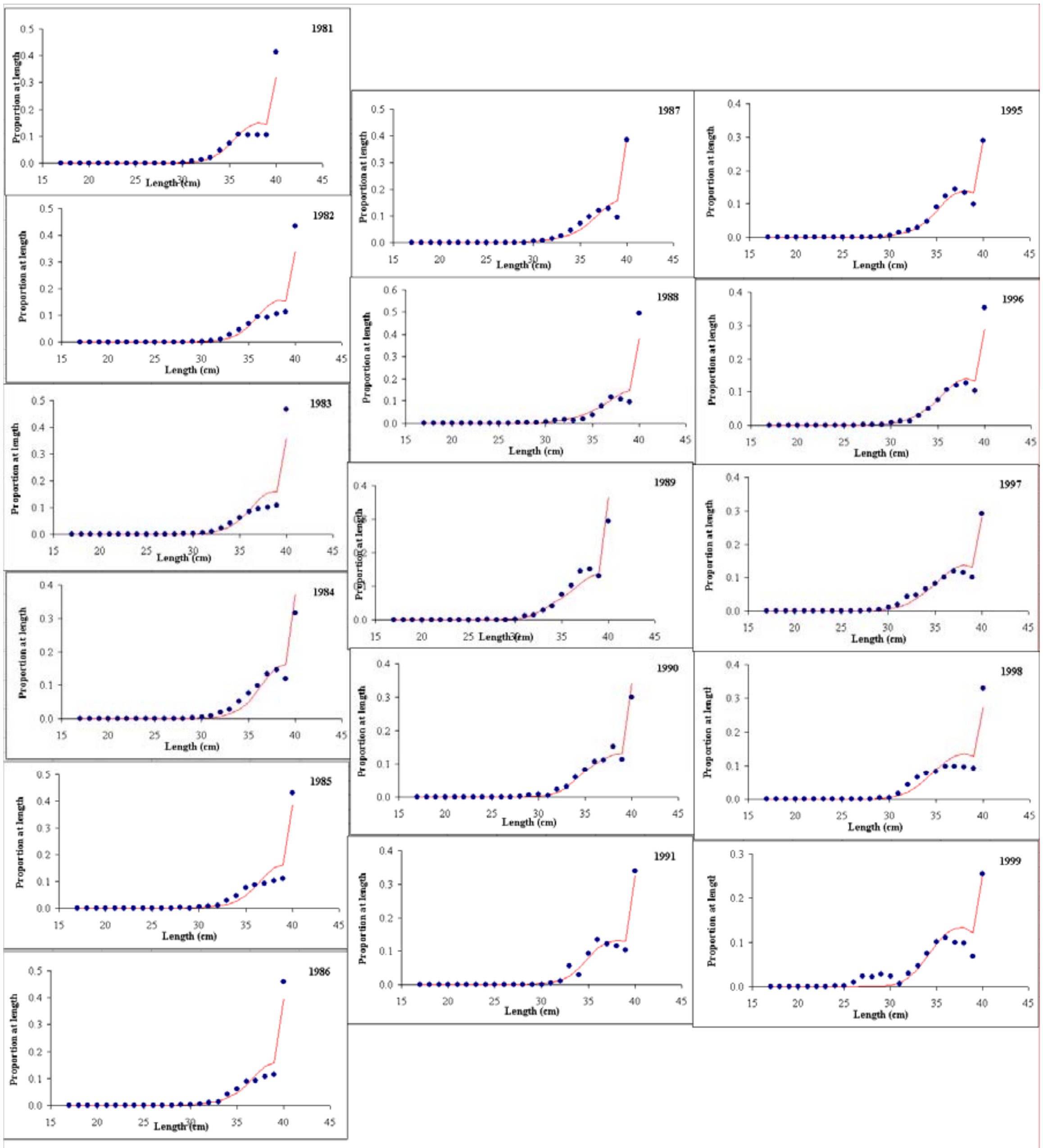


Figure 13. Fit of Model 1 to fishery size-composition data (1981-1991,1995-1998).

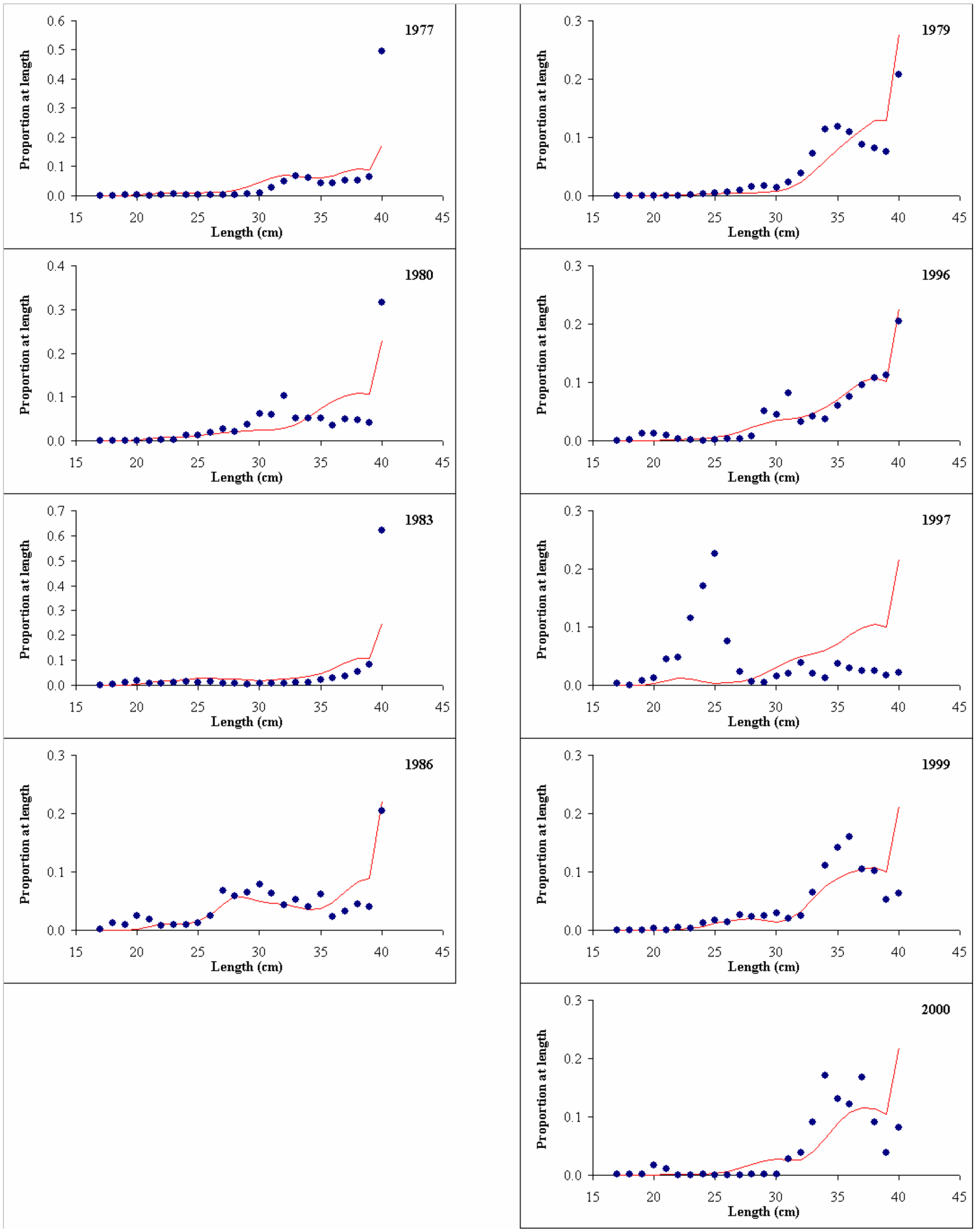


Figure 14. Fit of Model 1 to triennial and slope survey size-composition data.

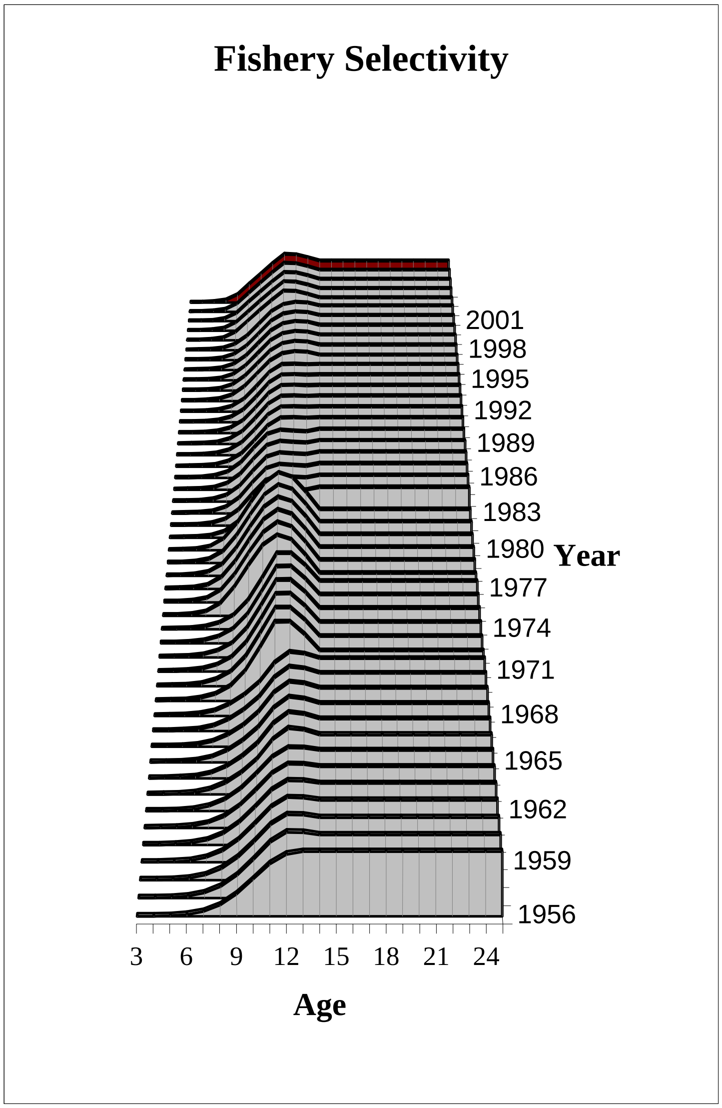
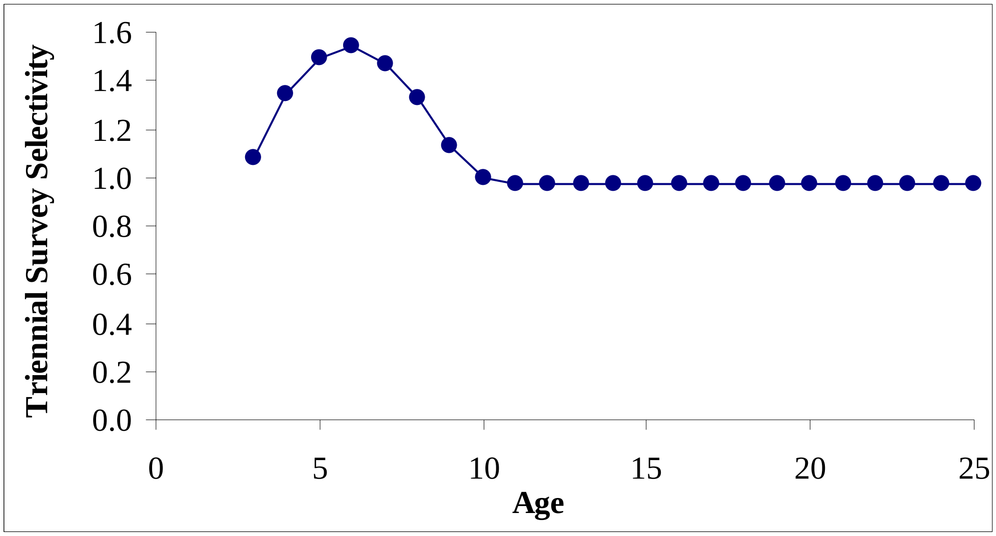


Figure 15. Fishery selectivity patterns (1956-2004).



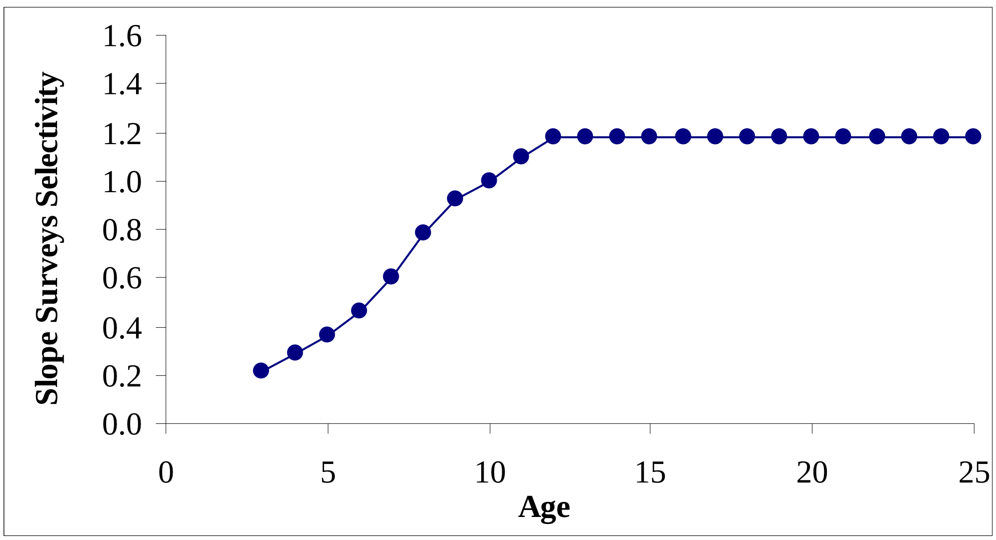


Figure 16. Selectivity patterns for the triennial and slope surveys.

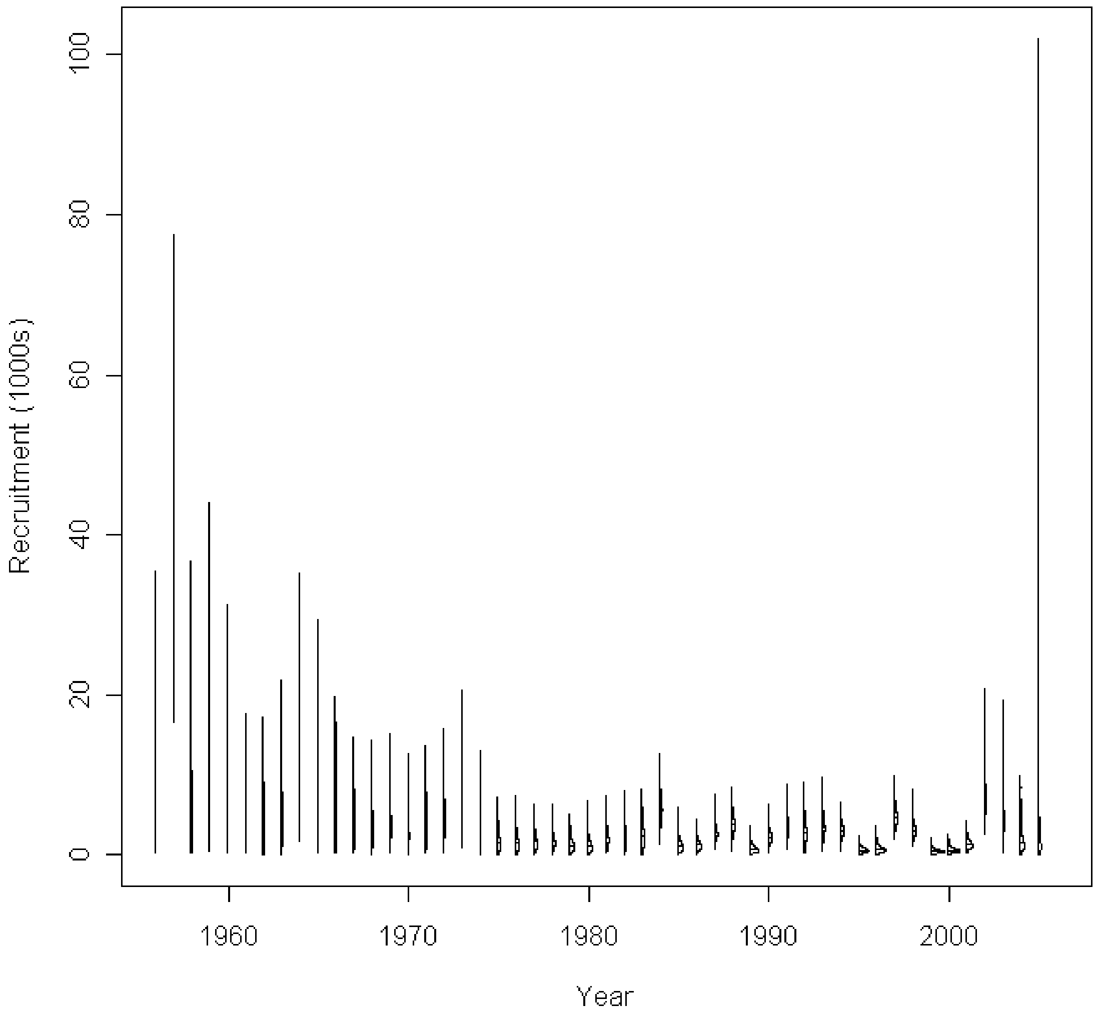


Figure 17. Smoothed posterior densities for estimated recruitment (1956-2005).

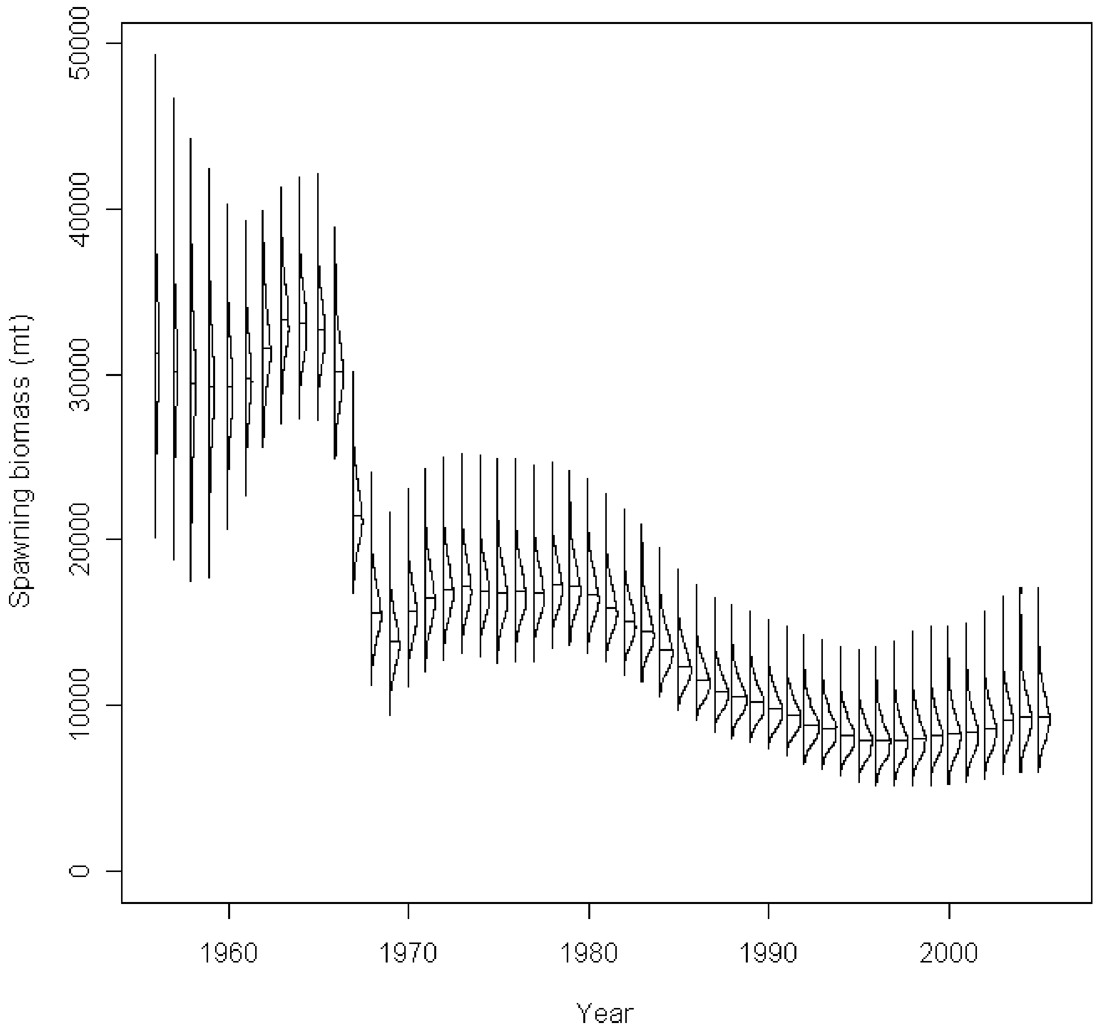


Figure 18. Smoothed posterior densities for estimated spawning biomass (1956-2005).

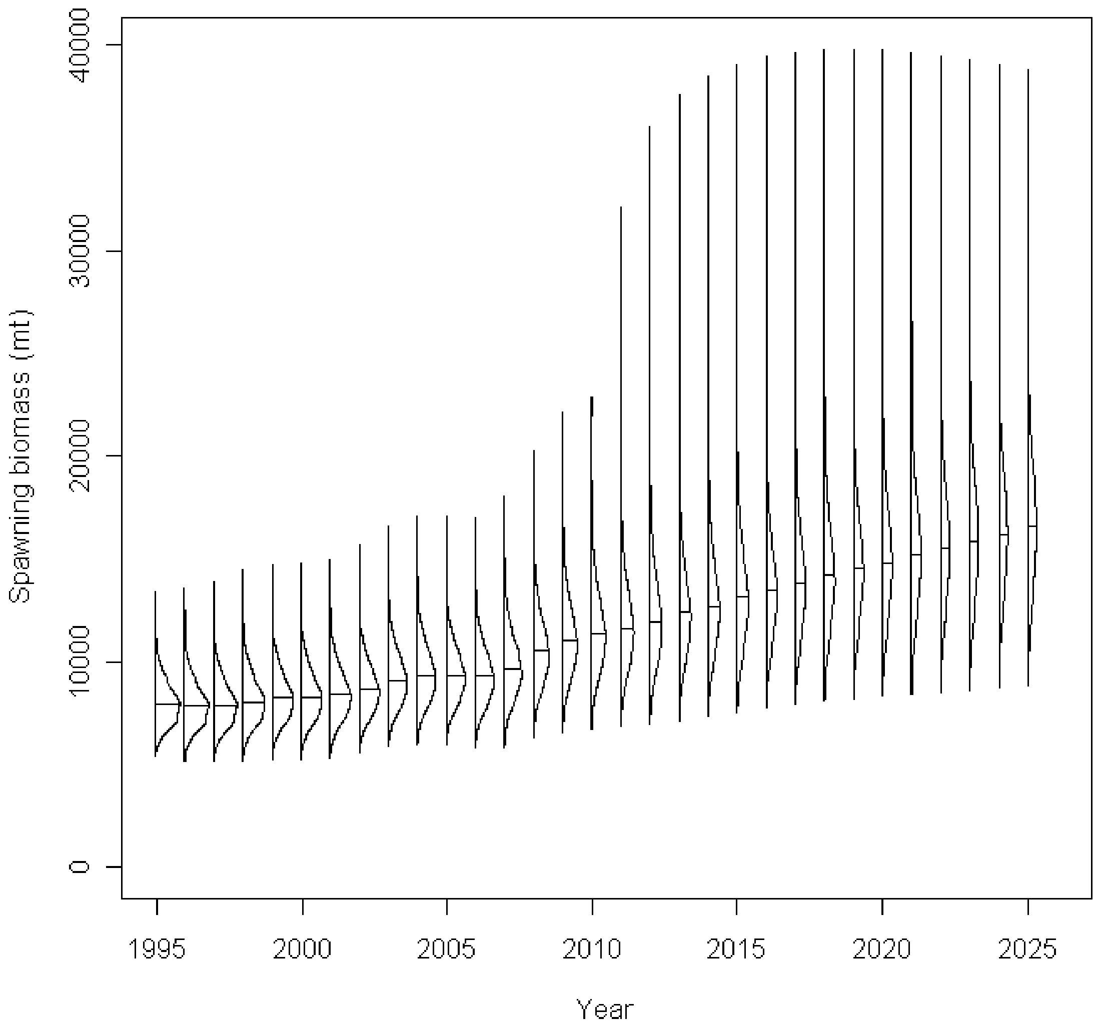


Figure 19. Smoothed posterior densities for estimated and projected spawning biomass (1995-2025) with F = 0.01.

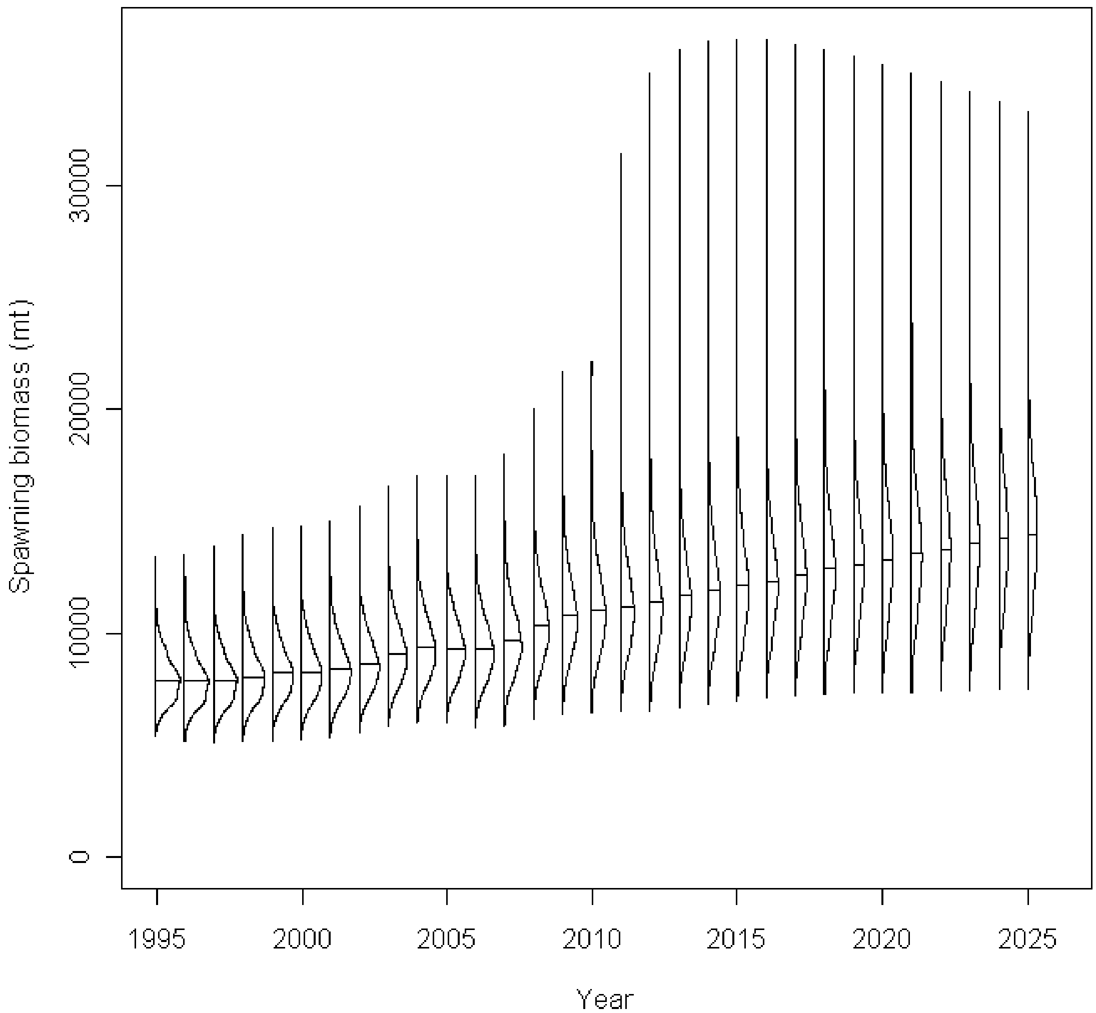


Figure 20. Smoothed posterior densities for estimated and projected spawning biomass (1995-2025) with F = 0.02.

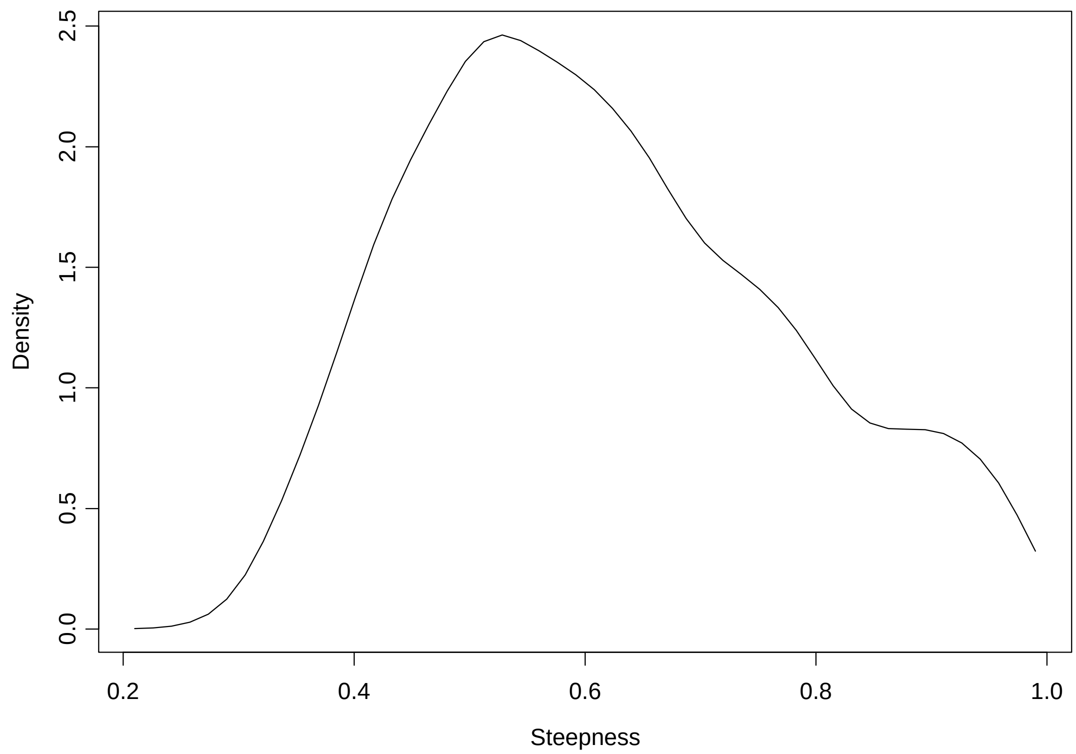


Figure 21. Posterior density for steepness.

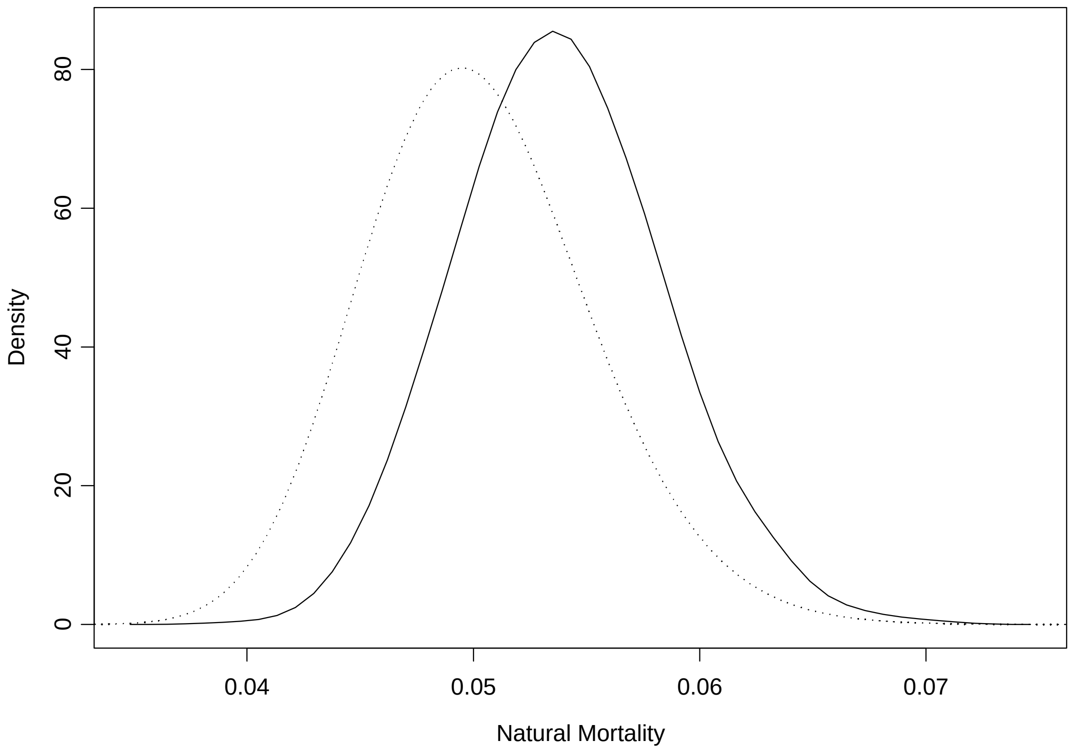


Figure 22. Posterior density for natural mortality.

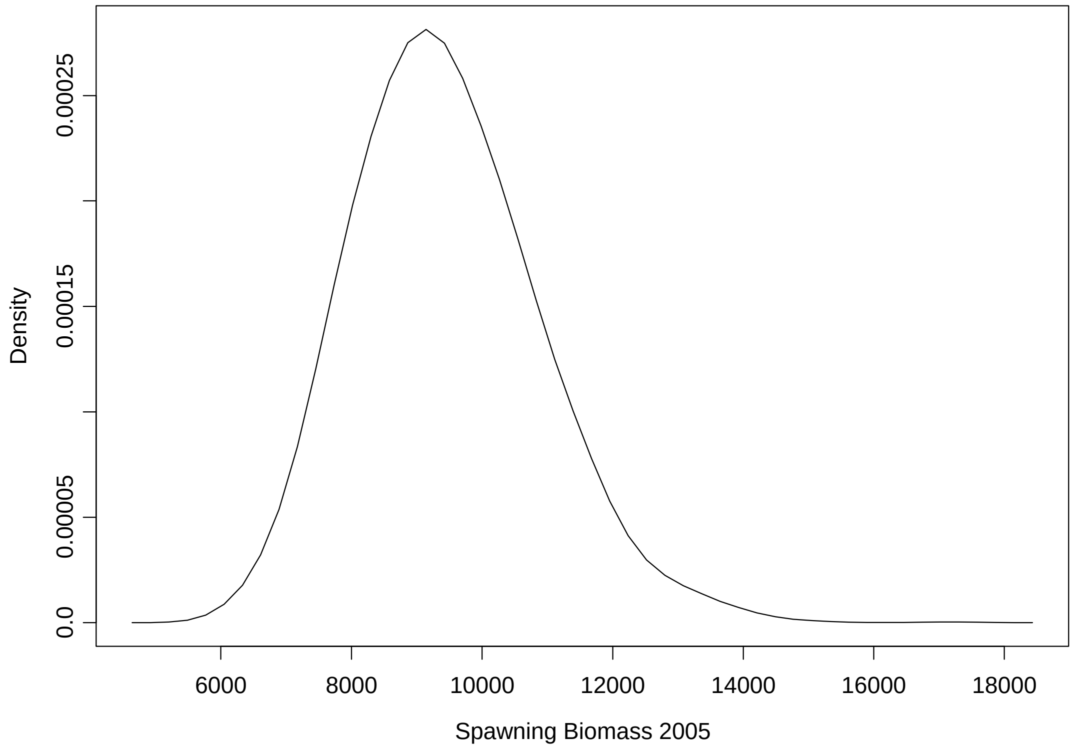


Figure 23. Posterior density for spawning biomass in 2005

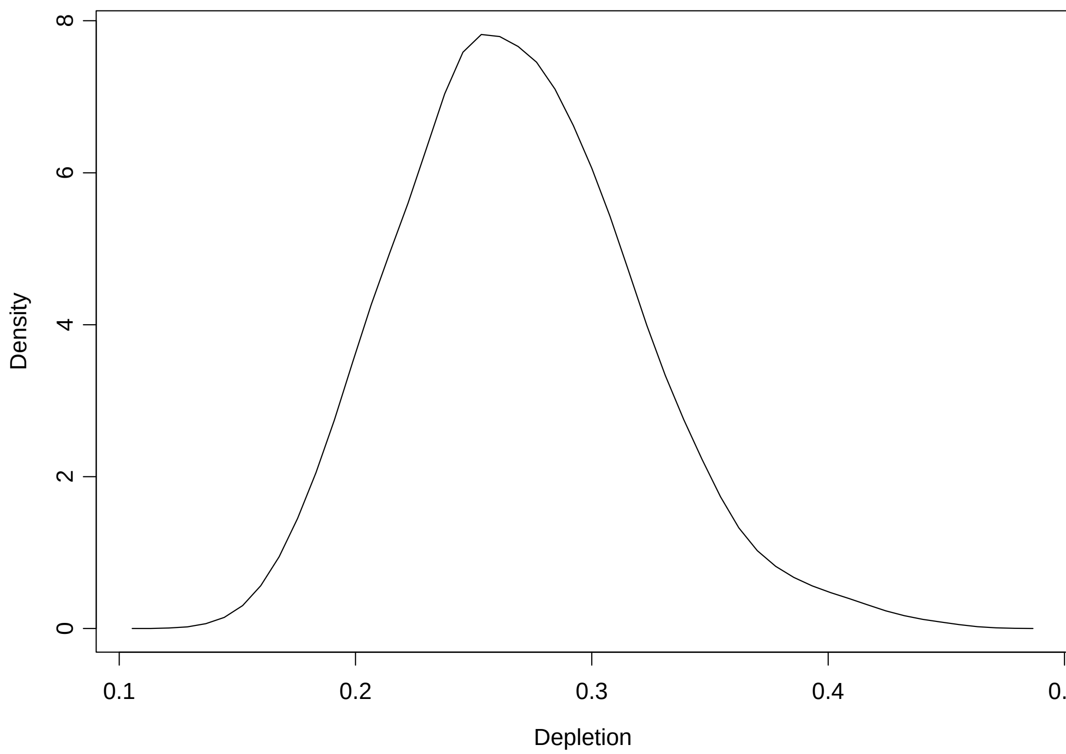


Figure 24. Posterior density for depletion in 2005.

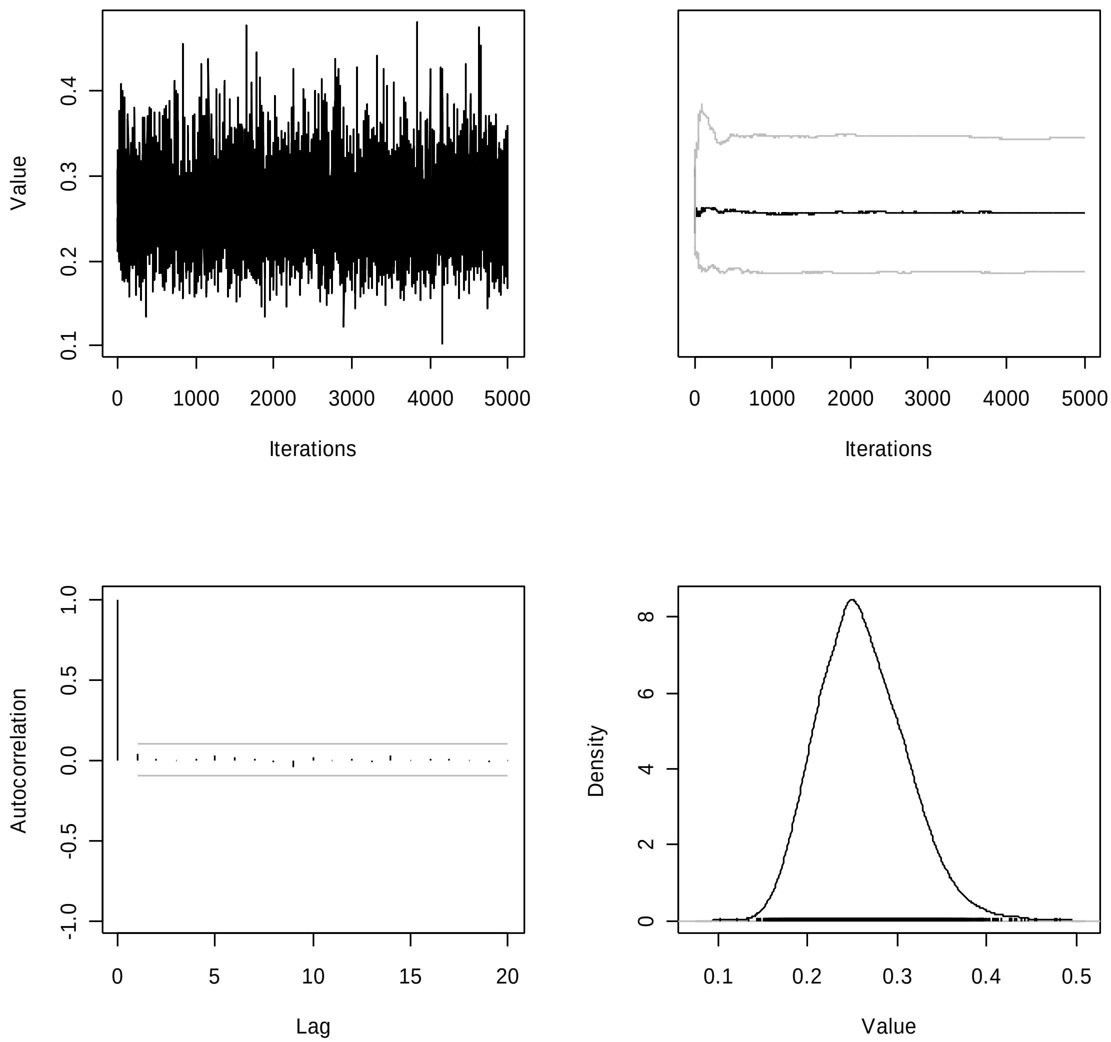


Figure 25: Trace, moving average, autocorrelation and posterior for depletion from MCMC construction of Bayesian posterior.

Summary of convergence diagnostics for 26 key parameters and derived quantities.

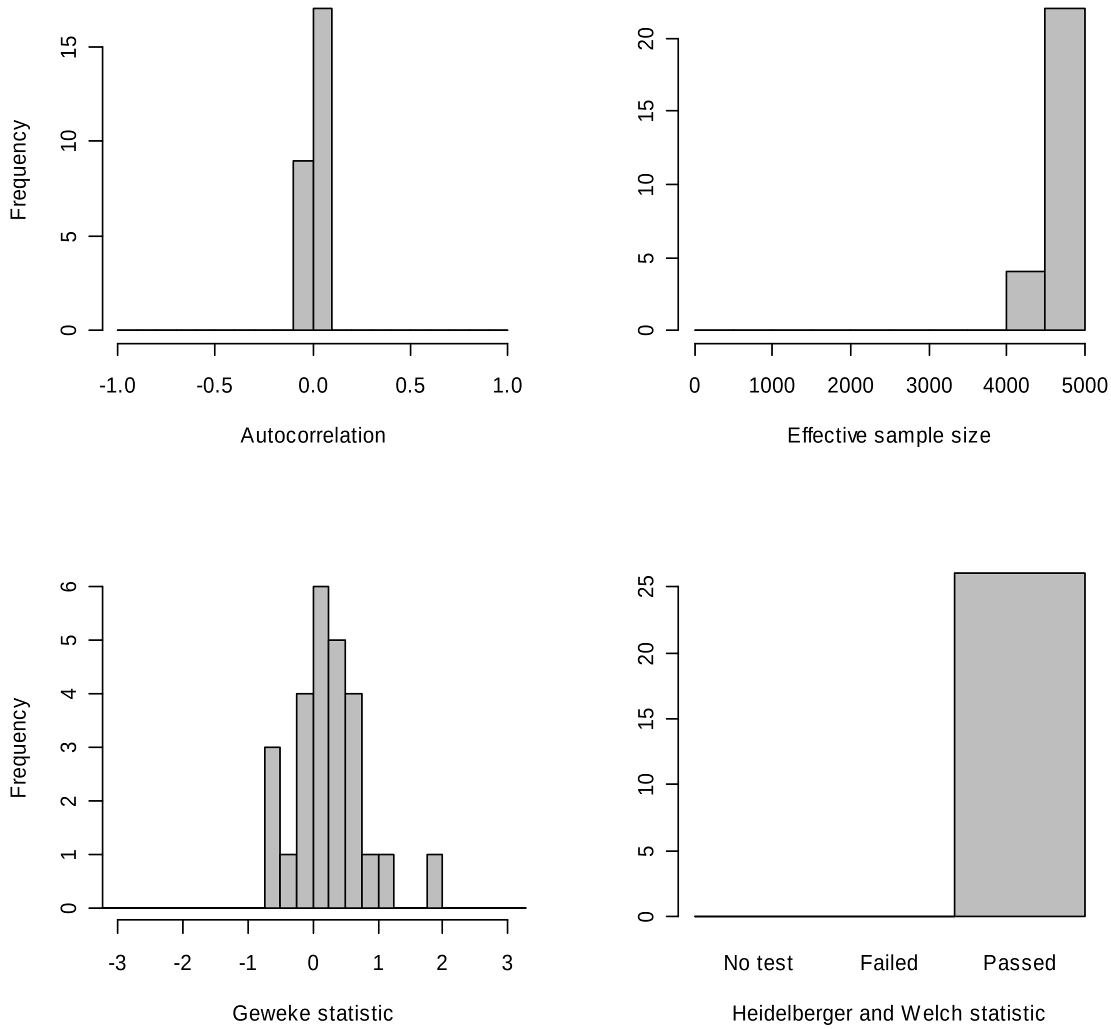


Figure 26. Summary of convergence diagnostics for 26 key parameters and derived quantities.

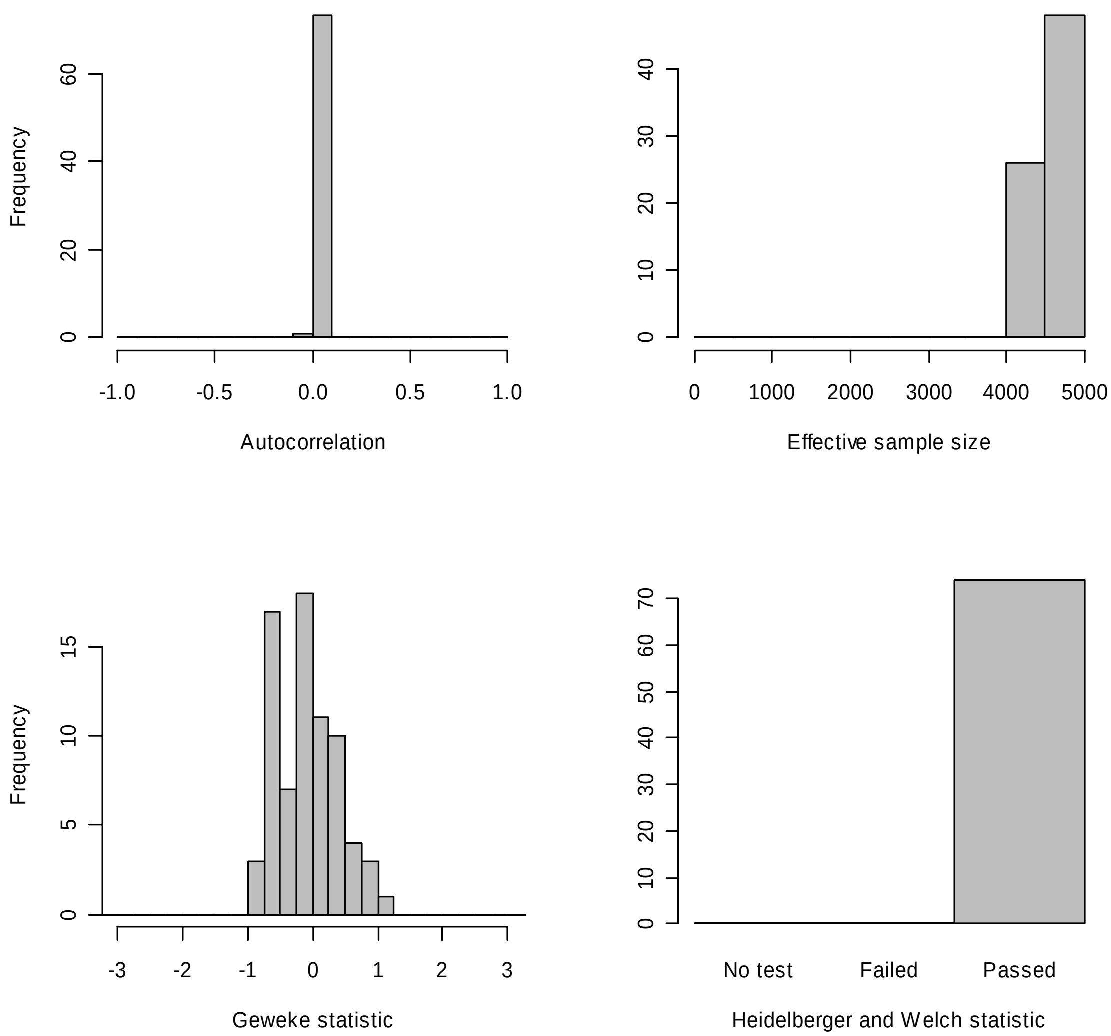


Figure 27. Summary of convergence diagnostics for the spawning biomass time series.

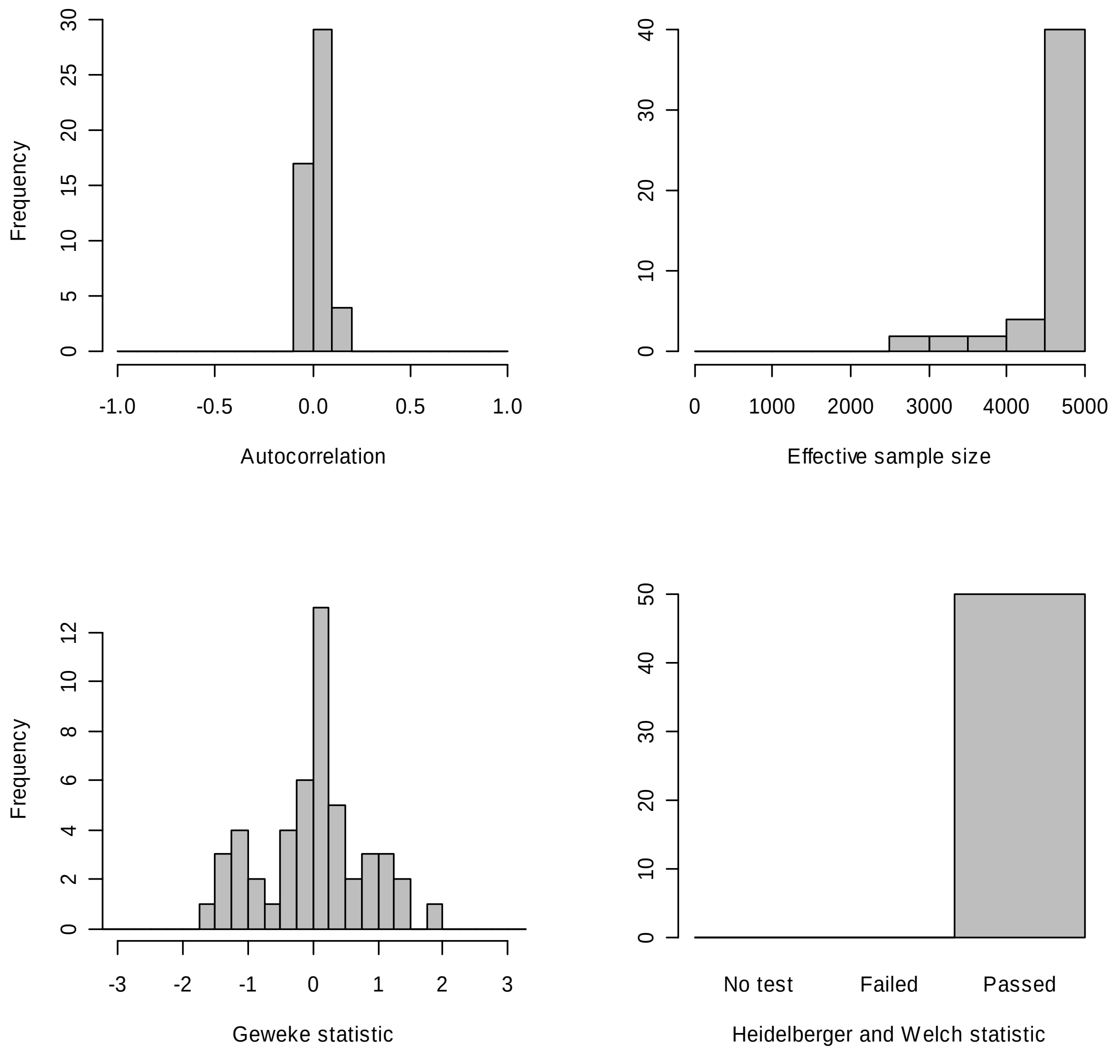


Figure 28. Summary of convergence diagnostics for the recruitment time series.

Appendix: Comparison of normal and lognormal 90% confidence intervals and Bayesian 90% intervals.

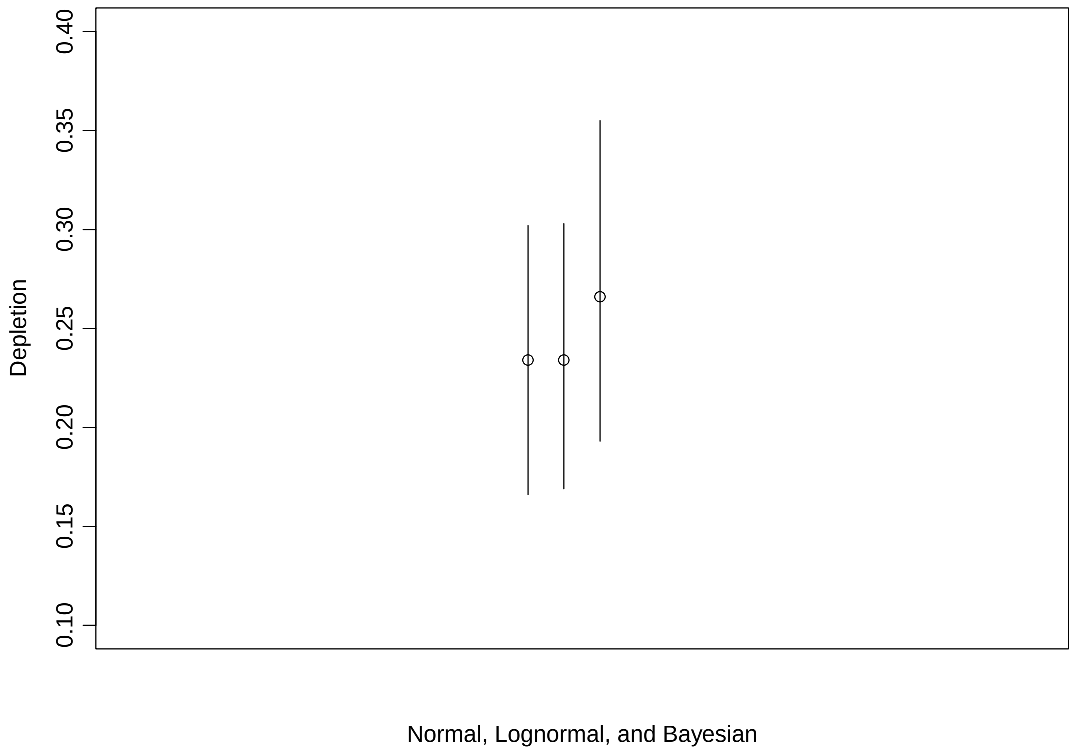


Figure A1: Normal, lognormal and Bayesian 90% intervals for depletion in 2005. Median values are represented by: °

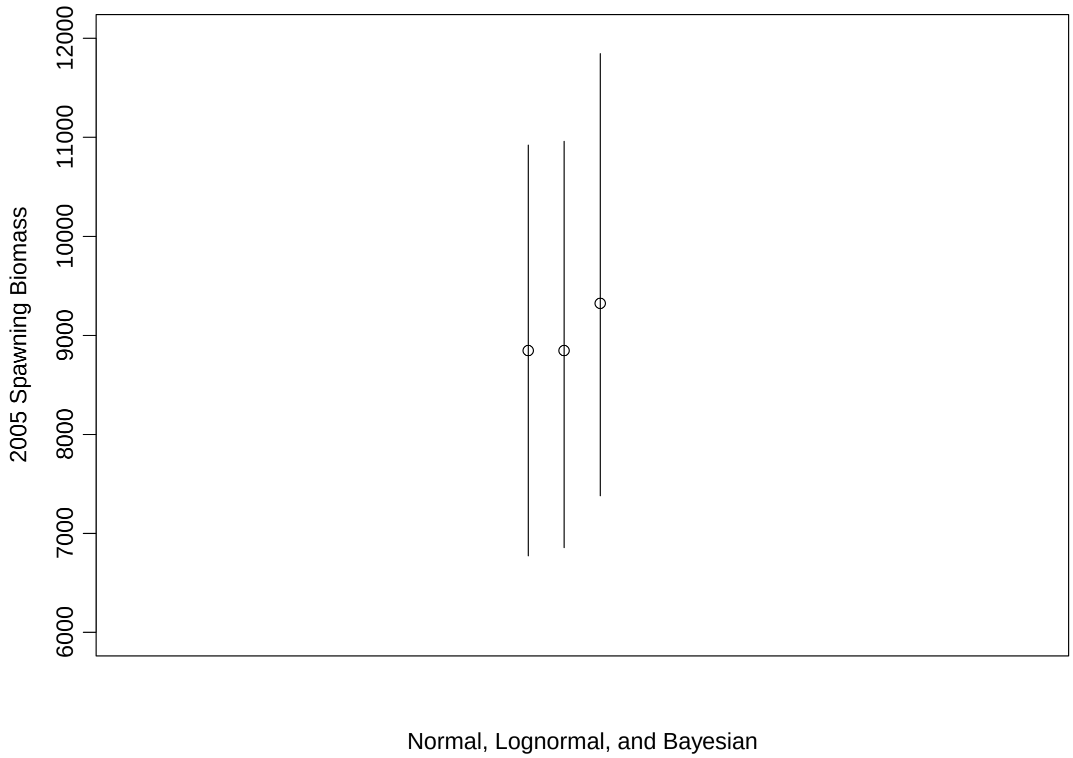


Figure A2: Normal, lognormal and Bayesian 90% intervals for 2005 spawning biomass. Median values are represented by: °

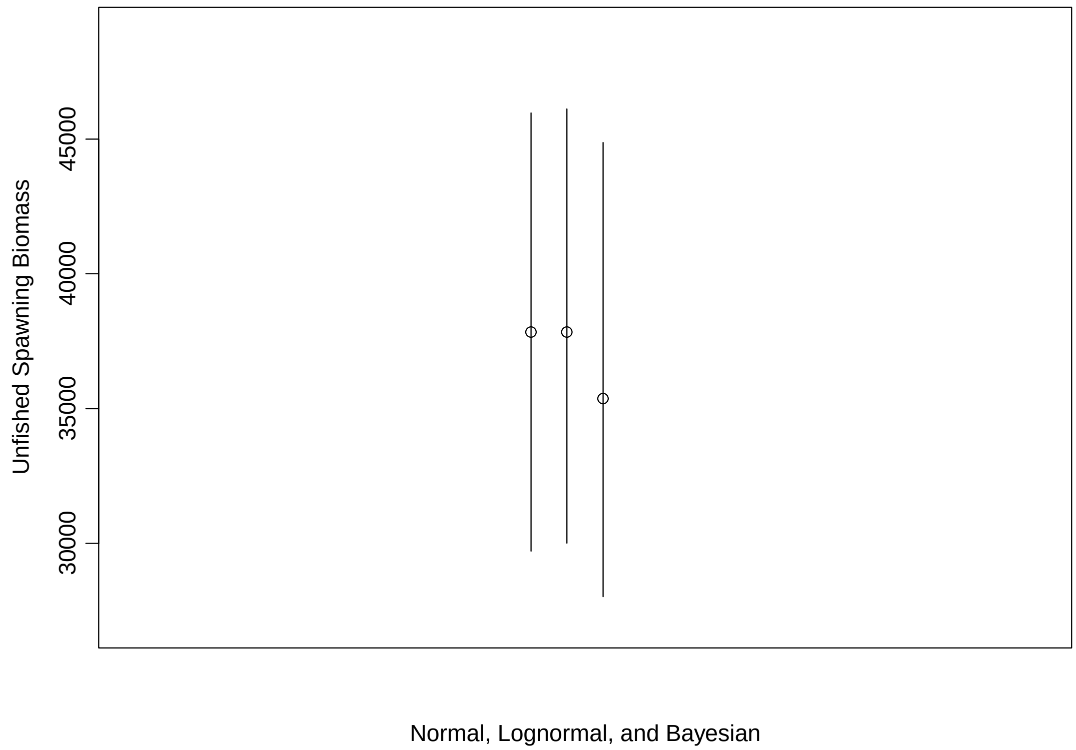


Figure A3: Normal, lognormal and Bayesian 90% intervals for unfished spawning biomass. Median values are represented by: °

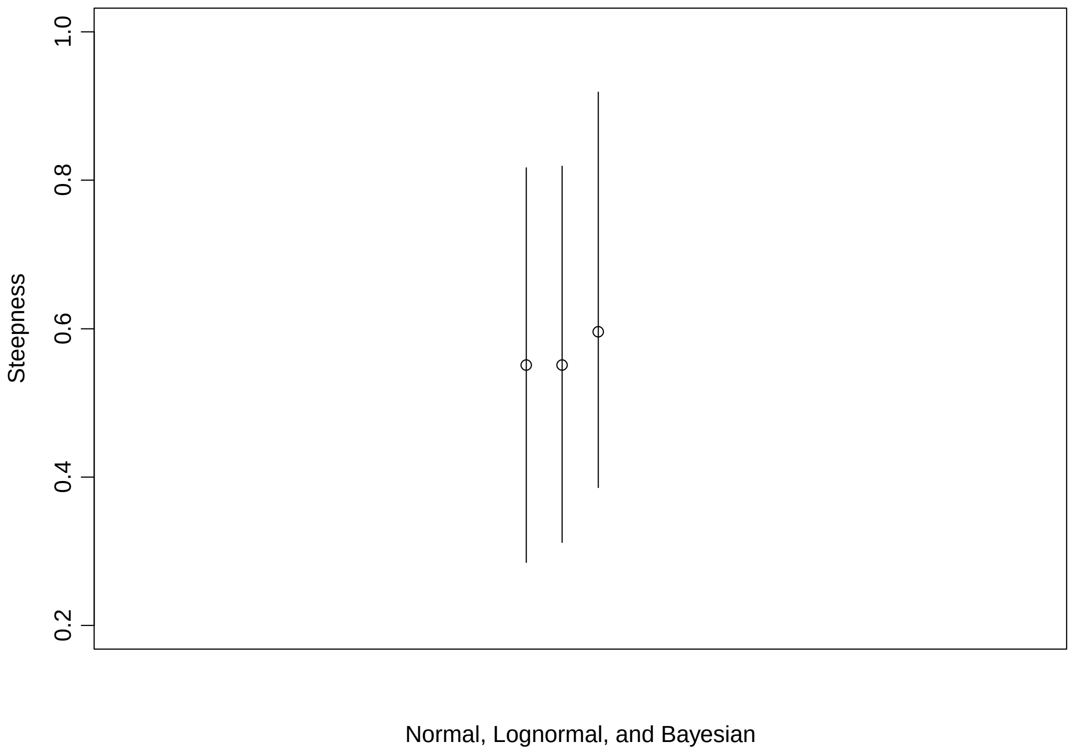


Figure A4: Normal, lognormal and Bayesian 90% intervals for steepness.

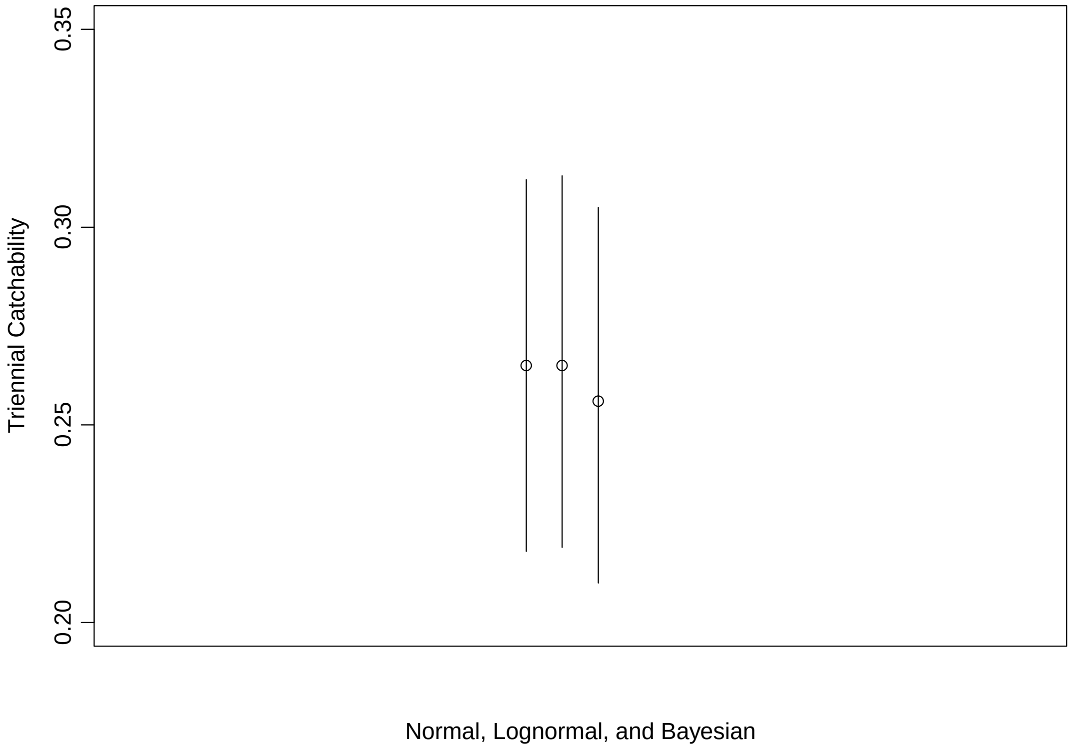


Figure A5: Normal, lognormal and Bayesian 90% intervals for triennial survey catchability. Median values are represented by: °

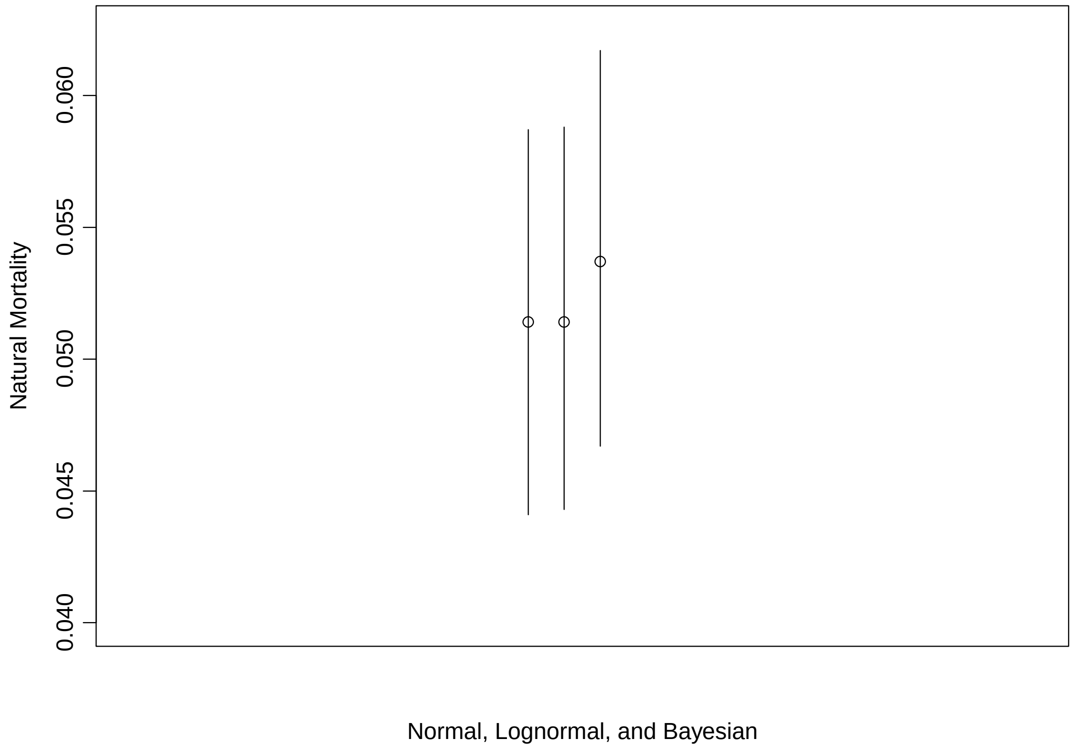


Figure A6: Normal, lognormal and Bayesian 90% intervals for natural mortality.
Median values are represented by: °

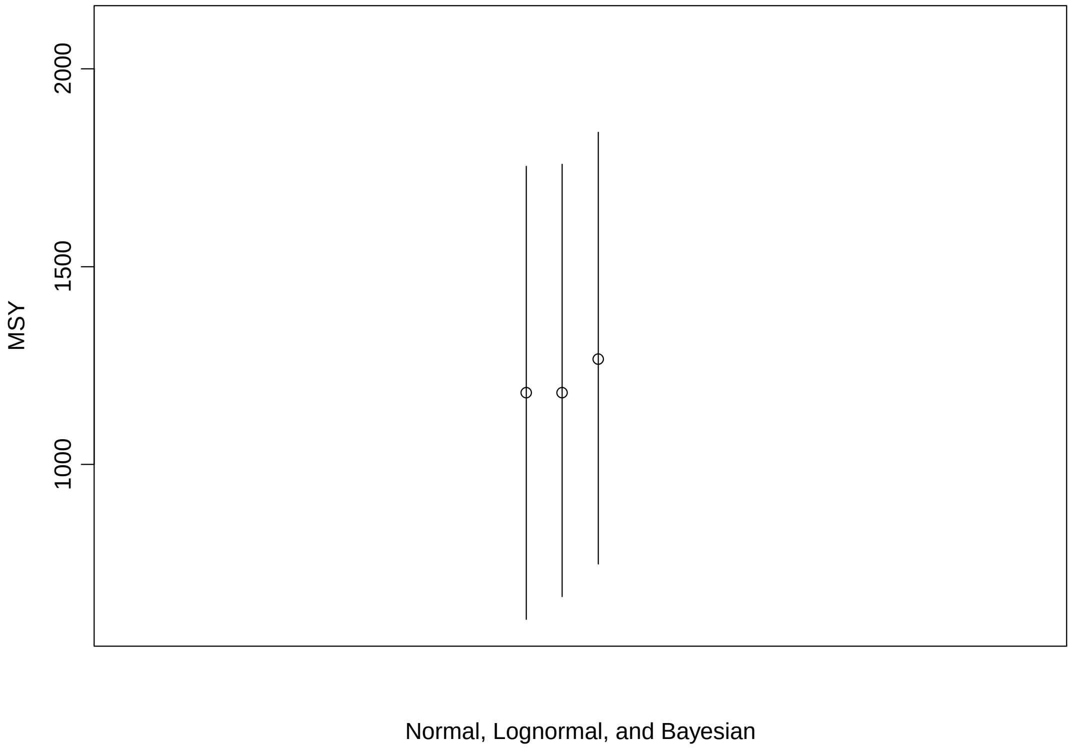


Figure A7: Normal, lognormal and Bayesian 90% intervals for MSY.
Median values are represented by: °