# Status and Future Prospects for the Pacific Ocean Perch Resource in Waters off Washington and Oregon as Assessed in 2007

by

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*June 13, 2007*

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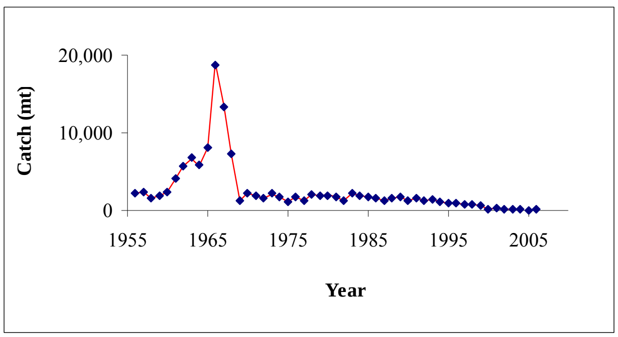
This assessment update applies to the Pacific ocean perch (*Sebastes alutus*) (POP) species of rockfish for the combined US Vancouver and Columbia INPFC areas. Catches are characterized by large removals of between 5,000 and 20,000 mt during the mid-1960's, primarily by foreign vessels. The fishery proceeded 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 60 and 150 metric tons per year from 2002 through 2006.

*Catch history from 1956-2006*




*Catch estimates for past 10 years including discard*

| *Year* | *Catch* |
|---|---|
| *1997* | *751* |
| *1998* | *739* |
| *1999* | *593* |
| *2000* | *171* |
| *2001* | *307* |
| *2002* | *179* |
| *2003* | *151* |
| *2004* | *146* |
| *2005* | *75* |
| *2006* | *83* |

This assessment is an update and uses the same model as in the 2003 and 2005 assessments, a forward projection age-structured model (Hamel 2005, Hamel et al. 2003).

New data and changes to the data used in the previous assessment are as follows. Catch data for 2003 and 2004 were updated, and new catch data were added for 2005 and 2006. Fishery age compositions from 1999-2004 were updated, with new 2005 and 2006 age compositions added. The 1999-2004 NWFSC slope survey biomass indices and age compositions were recalculated based upon changes in stratum area estimates and any updates in the database, with the 2005 and 2006 NWFSC slope survey biomass indices and age compositions added.

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 in the 2003 and 2005 assessments suggest that the overall uncertainty may be greater than that predicted by a single model specification. There are also other sources of uncertainty that are not included in the current model. These include the degree of connection between the stocks of Pacific ocean perch off British Columbia and those in PFMC waters; the effect of the PDO, ENSO and other climatic variables on recruitment, growth and survival of Pacific ocean perch; gender differences in growth and survival; a possible non-linear relationship between individual spawner biomass and effective spawning output and a 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***

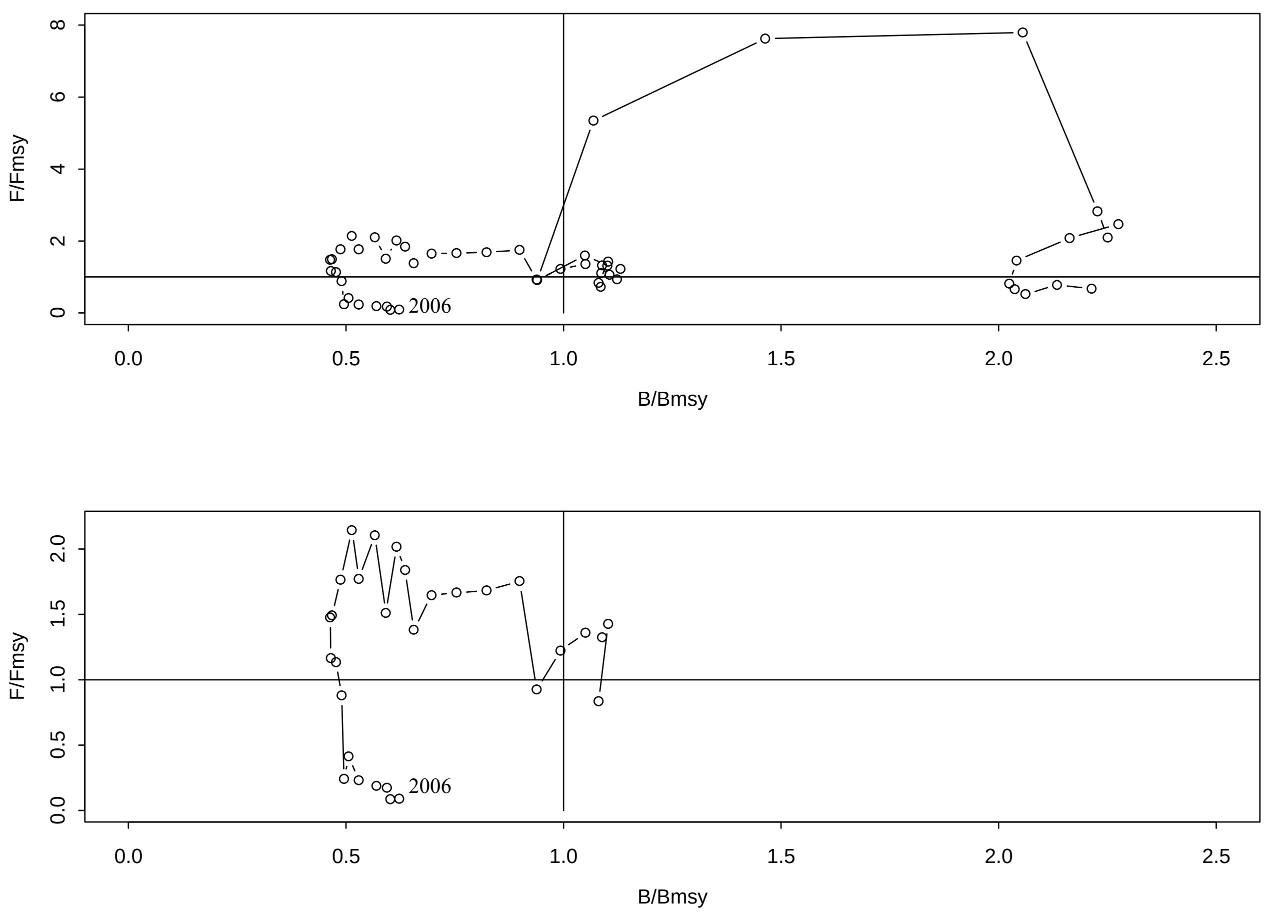
| *Year* | *1997* | *1998* | *1999* | *2000* | *2001* | *2002* | *2003* | *2004* | *2005* | *2006* | *2007* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Total Catch* | 751 | 739 | 593 | 171 | 307 | 179 | 151 | 146 | 75 | 83 | |
| *Discards* | 120 | 118 | 95 | 27 | 49 | 29 | 24 | 24 | 12 | 13 | |
| *Landings* | 631 | 621 | 498 | 144 | 258 | 150 | 127 | 122 | 63 | 70 | |
| *ABC* | | | 695 | 713 | 1541 | 640 | 689 | 980 | 966 | 934 | 900 |
| *OY (HG)* | (750) | (750) | 595 | 270 | 303 | 350 | 377 | 444 | 447 | 447 | 150 |
| *F* | 0.0445 | 0.0434 | 0.0336 | 0.0093 | 0.0158 | 0.0089 | 0.0072 | 0.0067 | 0.0033 | 0.0035 | |
| *Expl. Rate* | 0.0420 | 0.0407 | 0.0327 | 0.0094 | 0.0163 | 0.0087 | 0.0068 | 0.0062 | 0.0030 | 0.0032 | |
| *3+ Biomass* | 17809 | 18214 | 18178 | 18231 | 18760 | 20582 | 22142 | 23508 | 24618 | 25658 | 26544 |
| *Biom. sd* | 2326 | 2452 | 2519 | 2583 | 2663 | 3008 | 3314 | 3599 | 3847 | 4080 | 4310 |
| *Biom. cv* | 0.13 | 0.13 | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 |
| *Sp Biomass* | 6882 | 7055 | 7249 | 7331 | 7489 | 7826 | 8428 | 8791 | 8910 | 9210 | 10168 |
| *Sp Bio. sd* | 907 | 954 | 1006 | 1038 | 1055 | 1107 | 1194 | 1251 | 1273 | 1325 | 1506 |
| *Sp Bio. cv* | 0.13 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.15 |
| *Recruitment* | 5.07 | 3.69 | 0.53 | 0.82 | 1.69 | 10.47 | 5.35 | 3.13 | 1.61 | 1.48 | |
| *Rec. sd* | 1.15 | 0.96 | 0.32 | 0.39 | 0.67 | 2.75 | 2.05 | 1.53 | 1.27 | 1.33 | |
| *Rec. cv* | 0.23 | 0.26 | 0.61 | 0.47 | 0.39 | 0.26 | 0.38 | 0.49 | 0.79 | 0.90 | |
| *Depletion* | 0.186 | 0.191 | 0.196 | 0.198 | 0.202 | 0.212 | 0.228 | 0.238 | 0.241 | 0.249 | 0.275 |
| *Depl. sd* | 0.031 | 0.032 | 0.034 | 0.035 | 0.035 | 0.037 | 0.040 | 0.042 | 0.043 | 0.045 | 0.051 |
| *Depl. cv* | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.19 |

The point estimate (maximum of the posterior density function, MPD) for the depletion of the spawning biomass at the start of 2007 is 27.5%. The ABC for 2007 based on the MPD point estimate is 1009 mt. The OY for 2007 based upon the 40-10 rule is 588 mt (The ABC and OY for 2007 in the above table are based on current management and the 2005 assessment). 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 = 0.0382 according to the current assessment base model. Based on this assessment, POP on the West Coast are recovering, and overfishing is not occurring.

POP are essentially managed on a regional basis, as they occur almost exclusively off of Oregon and Washington for the West Coast. Management and assessment of stock status might be improved through greater cooperation with British Columbia, as the stock extends northward into Canadian waters.

***Major quantities from assessment***

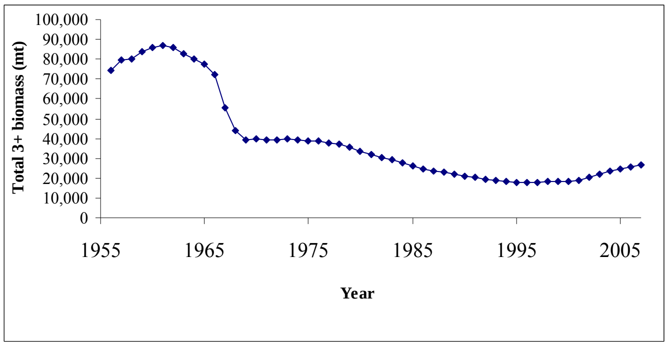
| | *Value* | *sd* | *cv* |
|---|---|---|---|
| $SB_0$ | 36,983 | 4,863 | 0.13 |
| $B_0$ | 82,052 | 11,001 | 0.13 |
| $R_0$ | 4.97 | 0.97 | 0.20 |
| *SBmsy* | 14,793 | 2,462 | 0.17 |
| *Fmsy* | 0.0382 | 0.0123 | 0.32 |
| *Basis for above* | F at equilibrium 40% biomass with S-R curve | | |
| *Exploitation rate at MSY* | 0.0388 | 0.0107 | 0.28 |
| *MSY* | 1411 | 348 | 0.25 |




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

The point estimates of summary (age 3+) biomass show an upward trend over the past ten years, increasing by nearly 50% in that time.

***3+ Biomass Levels from 1956 to 2007***



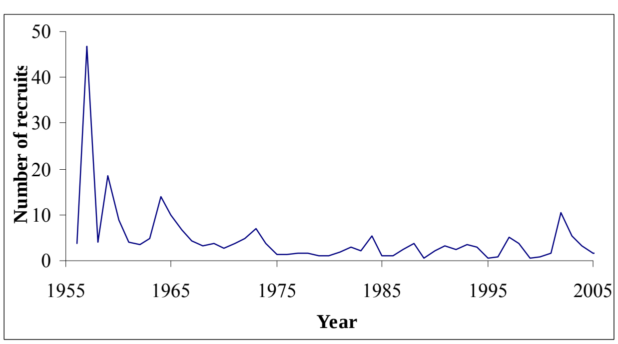

***Biomass estimates for the past 10 years***

| *Year* | *Total 3+ biomass(mt)* |
|---|---|
| *1998* | *18,214* |
| *1999* | *18,178* |
| *2000* | *18,231* |
| *2001* | *18,760* |
| *2002* | *20,582* |
| *2003* | *22,142* |
| *2004* | *23,508* |
| *2005* | *24,618* |
| *2006* | *25,658* |
| *2007* | *26,544* |

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 year class (the 2002 recruitment year ) appears to be larger than has occurred since the 1960's, and the 2000 year class appears to be relatively large as well.

The first year for which there are age-composition data to support an 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 (1997-2006 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 2006 is based on very limited information.

***Recruitment estimates (1935-2006)***

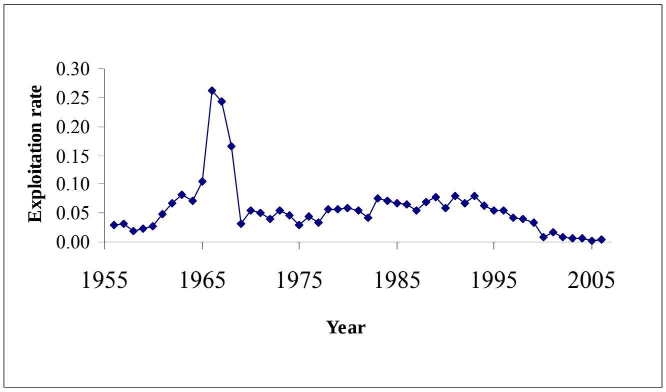



***Recruitment estimates for the past 10 years (millions of age-3 recruits)***

| *Year* | *Recruitment* |
|---|---|
| *1997* | *5.07* |
| *1998* | *3.69* |
| *1999* | *0.53* |
| *2000* | *0.82* |
| *2001* | *1.69* |
| *2002* | *10.47* |
| *2003* | *5.35* |
| *2004* | *3.13* |
| *2005* | *1.61* |
| *2006* | *1.48* |

The exploitation rate (percent of biomass taken) on fully-selected animals peaked near 25% in the mid-1960's when foreign fishing was intensive. The exploitation rate dropped by the late 1960's, but increased slowly and steadily from 1975 to the early 1990's, due to decreasing exploitable biomass. Over the past 10 years the exploitation rate has fallen from over 4% to under 0.5%.

***Exploitation rate estimates (1956-2007)***




***Exploitation estimates for the past 10 years***

| *Year* | *Exploitation rate* |
|---|---|
| *1997* | 0.0420 |
| *1998* | 0.0407 |
| *1999* | 0.0327 |
| *2000* | 0.0094 |
| *2001* | 0.0163 |
| *2002* | 0.0087 |
| *2003* | 0.0068 |
| *2004* | 0.0062 |
| *2005* | 0.0030 |
| *2006* | 0.0032 |

Near term projections show a slow monotonic increase in exploitable biomass. These were calculated with a new module within the assessment model using fishing morality rates of 0.01 and 0.02. This module projects recruitment from the estimated spawner recruit curve.

***Catch, Spawning Biomass and Depletion MPD projections with F = 0.01 and 0.02***

| | F=0.01 | | | F=0.02 | | |
|---|---|---|---|---|---|---|
| Year | Catch | Sp. Bio. | Depletion | Catch | Sp. Bio. | Depletion |
| 2007 | 257 | 10168 | 0.275 | 510 | 10168 | 0.275 |
| 2008 | 272 | 11399 | 0.308 | 535 | 11273 | 0.305 |
| 2009 | 295 | 12218 | 0.330 | 573 | 11961 | 0.323 |
| 2010 | 320 | 12612 | 0.341 | 615 | 12217 | 0.330 |
| 2011 | 334 | 12781 | 0.346 | 635 | 12244 | 0.331 |
| 2012 | 340 | 13007 | 0.352 | 640 | 12329 | 0.333 |
| 2013 | 342 | 13367 | 0.361 | 638 | 12554 | 0.339 |
| 2014 | 349 | 13765 | 0.372 | 644 | 12824 | 0.347 |
| 2015 | 359 | 14175 | 0.383 | 658 | 13110 | 0.354 |
| 2016 | 371 | 14595 | 0.395 | 675 | 13408 | 0.363 |
| 2017 | 382 | 15023 | 0.406 | 691 | 13715 | 0.371 |
| 2018 | 393 | 15455 | 0.418 | 707 | 14025 | 0.379 |

To create three different possible states of nature for the two fishing morality 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. These projections are based upon the estimated spawner recruit curve and current spawning biomass and age composition estimates. A more thorough analysis will be done for the rebuilding analysis, upon which management actions will be based, which will likely result in different projections than those seen here.

***Catch, Spawning Biomass and Depletion MCMC 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 | 225 | 271 | 328 | 8936 | 10778 | 13133 | 0.245 | 0.312 | 0.395 |
| 2008 | 239 | 288 | 352 | 9999 | 12166 | 15022 | 0.275 | 0.353 | 0.450 |
| 2009 | 256 | 312 | 384 | 10686 | 13107 | 16334 | 0.294 | 0.380 | 0.488 |
| 2010 | 274 | 337 | 420 | 10986 | 13556 | 16966 | 0.303 | 0.393 | 0.507 |
| 2011 | 286 | 354 | 445 | 11102 | 13771 | 17281 | 0.306 | 0.400 | 0.516 |
| 2012 | 293 | 364 | 458 | 11269 | 14024 | 17613 | 0.311 | 0.407 | 0.525 |
| 2013 | 296 | 369 | 463 | 11555 | 14382 | 18031 | 0.319 | 0.418 | 0.537 |
| 2014 | 301 | 375 | 470 | 11872 | 14763 | 18462 | 0.328 | 0.429 | 0.549 |
| 2015 | 309 | 384 | 480 | 12191 | 15147 | 18891 | 0.336 | 0.441 | 0.560 |
| 2016 | 317 | 395 | 492 | 12513 | 15538 | 19318 | 0.345 | 0.453 | 0.571 |
| 2017 | 326 | 405 | 503 | 12841 | 15932 | 19741 | 0.354 | 0.465 | 0.582 |
| 2018 | 334 | 415 | 513 | 13168 | 16326 | 20160 | 0.364 | 0.476 | 0.593 |

***Catch, Spawning Biomass and Depletion MCMC 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 | 447 | 538 | 653 | 8936 | 10778 | 13133 | 0.245 | 0.312 | 0.395 |
| 2008 | 469 | 566 | 691 | 9889 | 12033 | 14863 | 0.272 | 0.349 | 0.445 |
| 2009 | 497 | 606 | 748 | 10460 | 12836 | 16006 | 0.288 | 0.373 | 0.478 |
| 2010 | 527 | 647 | 808 | 10640 | 13139 | 16462 | 0.293 | 0.381 | 0.492 |
| 2011 | 544 | 673 | 847 | 10634 | 13206 | 16592 | 0.293 | 0.383 | 0.495 |
| 2012 | 551 | 686 | 863 | 10680 | 13311 | 16740 | 0.295 | 0.386 | 0.499 |
| 2013 | 551 | 688 | 865 | 10852 | 13524 | 16977 | 0.300 | 0.393 | 0.505 |
| 2014 | 556 | 694 | 870 | 11059 | 13769 | 17237 | 0.305 | 0.400 | 0.512 |
| 2015 | 566 | 705 | 881 | 11273 | 14023 | 17504 | 0.311 | 0.408 | 0.519 |
| 2016 | 577 | 718 | 895 | 11493 | 14286 | 17774 | 0.317 | 0.416 | 0.525 |
| 2017 | 589 | 732 | 909 | 11717 | 14556 | 18045 | 0.324 | 0.425 | 0.532 |
| 2018 | 600 | 745 | 922 | 11938 | 14827 | 18318 | 0.330 | 0.433 | 0.538 |

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 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 population in these areas as a single stock. Size-composition data for these areas indicate that years of good recruitment coincide.

Prior to 1965, the Pacific ocean perch resource in the US Vancouver and Columbia areas of the INPFC was harvested almost entirely by Canadian and United States vessels. 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. 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 since 1994.

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 (out to three miles) 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 of various forms 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) and was repeated every three years through 2004. 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 was repeated in 1985. Two slope surveys have been conducted on the west coast in recent years, one using the research vessel Miller Freeman, which ended in 2001, and another a cooperative survey using commercial fishing vessels which began in 1998 and is ongoing.

## 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. At that time, 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 2001-2005 indicate average discard rates of 14-17%.

***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 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 is biased for Pacific ocean perch; the ages of animals older than 15 tend to be under-estimated. Therefore, 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 1999-2006 from the PacFIN database (Table 3). 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 a particular 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 excluding those years for which age data were used. This includes 1981-1991 and 1995-1998. The model is fit to the size-composition data (17-40cm, where 40cm is a plus-group) from the commercial fishery for these years. Neither size nor age data were available for 1992-1993. 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***

Data on catch-per-unit-of-effort (CPUE) in mt/hr from the domestic fishery were combined for the INPFC Vancouver and Columbia areas (Figure 9; 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.

### 1.2.2. Surveys

***NMFS Cruises***

The results from four fishery-independent surveys are used in this assessment (Figure 9; Tables 4-5).

1. The triennial shelf survey that was conducted every third year from 1977-2004 (Although for many species assessed in 2005 and to be assessed in 2007, the 1977 triennial survey biomass value is not used, it was used in the 2005 Pacific ocean perch assessment, and therefore is used in this update; the primary reasons for the omission of the 1977 data point are less relevant for Pacific ocean perch.).
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 1999-2006.

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 6. Tables of data that has not changed from last assessment can be found in that assessment (Hamel, 2005).

### 1.2.3. Biology and life history

***Natural mortality, longevity, and age at recruitment***

Pacific ocean perch ages, determined using scales and surface readings from otoliths, gave estimates of natural mortality of about $0.15 yr^{-1}$ and longevity of about 30 years (Gunderson 1977). Based on the now-accepted break-and-burn method of age determination using otoliths, Chilton and Beamish (1982) determined the maximum age of *S. alutus* to be 90 years. Using similar information, Archibald et al. (1981) concluded that natural mortality for Pacific ocean perch should be on the order of 0.05yr$^{-1}$. 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 0.05 yr$^{-1}$ and $\sigma$ 0.1). Essentially, this acknowledges that there is some uncertainty regarding the value for *M*, while nevertheless constraining the estimate of *M* to the general range of past estimates. The age at recruitment is set at 3 years.

***Sex ratio, maturation and fecundity***
Survey data indicate that sex ratios are within 5% of 1:1, so a sex ratio of 1:1 is assumed. Age 8 is used 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.

***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 2005 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 2005 assessment

The 2005 and 2006 catch data and fishery age compositions are included in this assessment, along with updated 2003 and 2004 catch data (Table 2). Fishery age composition data from 1999-2004 were updated with an increased number of ages available from PacFIN (Table 3). These data were extracted on April 26, 2007.

The 1999-2004 NWFSC slope survey biomass indices and age compositions were recalculated based upon changes in stratum area estimates and any updates in the database, with the 2005 and 2006 NWFSC slope survey biomass indices and age compositions added (Tables 4 and 5). These data were obtained on April 9, 2007.

## 1.3. Assessment model

### 1.3.1. Changes between the 2005 assessment model and the current model

No changes to the estimating model have been made since the last assessment.

### 1.3.2. Model features unchanged from the 2005 assessment model

The population dynamics model used in the present assessment is the same as that used in the 2003 and 2005 assessments, 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 7.

Following the 2003 and 2005 assessments, natural mortality was estimated using a prior probability distribution 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 and the recruitment residuals remain unchanged from the 2005 assessment.

The same parameterization of the Beverton-Holt stock-recruitment relationship was used in this assessment as was the case for the 2005 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*,

$\xi_i$ is the correlated recruitment anomaly for year *i*, and

$\alpha$, $\beta$ are parameters of the stock-recruitment relationship.

The values for the stock-recruitment relationship parameters $\alpha$ and $\beta$ 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:

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

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

[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.

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.

### 1.3.3. Likelihood contributions

The objective function which is 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 6) 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 7.

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).

### 1.3.4. Bayesian analysis

The joint posterior density function is proportional to the product of the likelihood function (see Table 7) 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 7. 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$^{th}$ 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 the determination of 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.

## 1.4. Results

### 1.4.1. Model selection and evaluation

The initial *a priori* model (Model 1) is identical to the model used in the 2005 assessment, which included the following features:

1. The standard deviation of the fluctuations about the stock-recruitment relationship, $\sigma_R$, 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 time trajectories of spawning biomass and depletion from this assessment and the previous two assessments are compared in Figure 8. The fits of model 1 (base model) to the various indices are summarized in Figure 9 (survey biomass indices and fishery CPUE data), Figures 10 and 11 (fishery age-composition data), Figures 12 and 13 (survey age-composition data), Figure 14 (fishery size-composition data) and Figure 15 (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 16). 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 and the slope survey exhibit domed shapes, but selectivity is forced to be flat beyond age 12 (Figure 17). Selectivity for younger ages is notably lower for the slope surveys than for the triennial survey.
Table 8 lists the numbers-at-age matrix for Model 1, while Table 9 lists the point estimates of catch-at-age for this Model. Model 1 estimates that the spawning stock biomass was depleted to 27.5% of its unfished equilibrium level of 36,983 mt in 2007 (Table 10). The estimate of $M$ is 0.053 $yr^{-1}$ while steepness is estimated at 0.652. The estimate of $MSY$ is 1,411 mt, which is smaller than all but seven of the annual catches (including discard) from 1956-93. The fishing mortality throughout the period 1999-2006 was less than $F_{MSY}$.

### 1.4.3. Retrospective analysis

Retrospective analysis (Table 10) going back two years were used for comparison to the 2005 assessment:

1) Retro 2006: Retrospective analysis – ignores the assessment data for 2006 (as if assessment were conducted in 2006)

2) Retro 2005: Retrospective analysis – ignores the assessment data for 2005 and 2006 (as if assessment were conducted in 2005)

Ignoring the data for 2005 and 2006 (Retrospective for comparison to the 2005 assessment) has a moderate impact on current spawning biomass and depletion. Note that the depletion level of 0.227 for the Retrospective 2005 model should be compared to the estimated depletion of 0.241 in 2005 in the current base model, of 0.232 in 2005 in the retrospective 2006 model, and of 0.234 in the 2005 assessment. Perhaps more interesting is the progressive increase in the estimated steepness value, from 0.551 for the 2005 assessment, to 0.569 in the 2005 retrospective, to 0.579 in the 2006 retrospective and finally to 0.652 for the current assessment. The estimate of natural mortality is consistent between the current assessment and the two retrospective cases at 0.053, while it was 0.051 for the 2005 assessment.

### 1.4.4. Markov-Chain Monte Carlo results

*Evaluation of convergence*

Convergence was demonstrated in the 2005 assessment and similar results of the tests of convergence were satisfied for the 2007 MCMC run.

*The posteriors*

The posterior probability that the 2007 spawning biomass is less than $0.25B_0$ is 0.120 (One can interpret this as indicating a 12% probability that Pacific ocean perch is currently below the overfished threshold). The posterior probability that the 2007 spawning biomass is less than half of $B_{40}$ is ~0.012 (1.2%), while the posterior probability that it is below $B_{40}$ is 0.912 (91.2%), or, equivalently, the posterior probability that Pacific ocean perch is recovered is 0.088 (8.8%).

The posterior distribution for steepness is relatively wide (Figure 18) although low values (below 0.3) are effectively ruled out. This indicates that the data are relatively uninformative about the shape of stock-recruitment relationship. This 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 19). The posterior distributions for 2007 spawning biomass, depletion, and virgin spawning biomass are shown in Figures 20-22. The difference in depletion between the Bayesian and MPD estimates (median MCMC value = 31.2% vs. MPD value of 27.5%) is largely due to the uncertainty about virgin spawning biomass and steepness. Uncertainty in both these quantities increased in the current assessment update.

### 1.4.5. Future research

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

1) Inclusion of age 1 and 2 Pacific ocean perch catches and discards.
2) Estimation of effective sample sizes for size- and age-composition data.
3) Use of simulation models to evaluate how well one can estimate recruitment using size-composition data or biased or unbiased age-composition data, or a mix of the three.
4) Estimation of climatic effects on recruitment, growth and survival.
5) Selection of an appropriate prior distribution for the survey catchability coefficients.

6) Research on the relationship of individual female age and biomass to maturity, fecundity and survival of offspring.
7) Further research on the accuracy of Pacific ocean perch ageing, as well as the magnitude of bias in surface ageing compared to break-and-burn ageing.
8) Research on the relative density of Pacific ocean perch in trawlable and untrawlable areas and difference in age and/or length compositions between those areas.
9) Research on the relative status of the British Columbia stock of Pacific ocean perch.

**Acknowledgements**

The author would like to thank Ian Stewart for help in obtaining PacFIN age and length data and Beth Horness for providing NWFSC Survey data.

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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.<br>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.<br>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. 100 pounds per month open access limit. In effect in 2007. |

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 | | 127 | 151 | 151 |
| 2004 | | 122 | 146 | 146 |
| 2005 | | 63 | 75 | 75 |
| 2006 | | 70 | 83 | 83 |

Table 3. 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, 1999-2006).

| Year | 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 | 3 | 4 | 14 | 50 | 77 | 133 | 106 | 70 | 39 | 41 | 30 | 25 | 35 | 30 | 22 | 20 | 18 | 19 | 10 | 7 | 162 |
| **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 | 45 | 64 | 43 | 45 | 99 | 124 | 146 | 118 | 57 | 54 | 53 | 38 | 48 | 20 | 27 | 24 | 10 | 22 | 15 | 287 |
| **2002** | 0 | 1 | 1 | 20 | 108 | 109 | 68 | 79 | 134 | 134 | 137 | 108 | 59 | 50 | 31 | 30 | 30 | 23 | 29 | 17 | 21 | 15 | 213 |
| **2003** | 32 | 7 | 3 | 1 | 21 | 64 | 68 | 52 | 85 | 121 | 130 | 111 | 101 | 62 | 61 | 66 | 39 | 46 | 40 | 34 | 21 | 19 | 250 |
| **2004** | 0 | 0 | 3 | 4 | 6 | 13 | 33 | 57 | 39 | 31 | 54 | 57 | 50 | 35 | 36 | 31 | 32 | 26 | 19 | 17 | 16 | 9 | 136 |
| **2005** | 0 | 0 | 5 | 17 | 15 | 10 | 33 | 53 | 65 | 49 | 48 | 43 | 56 | 55 | 28 | 33 | 31 | 28 | 26 | 14 | 24 | 22 | 213 |
| **2006** | 0 | 0 | 3 | 16 | 41 | 26 | 26 | 37 | 50 | 38 | 35 | 35 | 27 | 23 | 21 | 24 | 29 | 19 | 18 | 21 | 10 | 8 | 126 |

Table 4. Survey age-composition data for the NWFSC Slope Survey: 2001-2006.

| Age | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|
| **3** | 0.0000 | 0.0342 | 0.0257 | 0.0331 | 0.0013 | 0.0053 |
| **4** | 0.0000 | 0.0117 | 0.0813 | 0.1382 | 0.0010 | 0.0214 |
| **5** | 0.0000 | 0.0086 | 0.0090 | 0.1104 | 0.0692 | 0.0589 |
| **6** | 0.0000 | 0.0156 | 0.0022 | 0.0148 | 0.1650 | 0.0782 |
| **7** | 0.0016 | 0.0524 | 0.0136 | 0.0350 | 0.0328 | 0.1017 |
| **8** | 0.0048 | 0.0630 | 0.1494 | 0.0050 | 0.0177 | 0.0517 |
| **9** | 0.0000 | 0.0305 | 0.0866 | 0.0297 | 0.1859 | 0.0463 |
| **10** | 0.0496 | 0.0560 | 0.0830 | 0.0436 | 0.1036 | 0.0738 |
| **11** | 0.0019 | 0.0686 | 0.0616 | 0.0065 | 0.1308 | 0.0426 |
| **12** | 0.0932 | 0.1164 | 0.0950 | 0.0357 | 0.0358 | 0.0986 |
| **13** | 0.1162 | 0.0833 | 0.0970 | 0.0426 | 0.0348 | 0.0479 |
| **14** | 0.0184 | 0.0584 | 0.0721 | 0.0957 | 0.0030 | 0.0004 |
| **15** | 0.0649 | 0.0859 | 0.0622 | 0.0324 | 0.1490 | 0.0637 |
| **16** | 0.1217 | 0.0760 | 0.0819 | 0.1744 | 0.0048 | 0.0908 |
| **17** | 0.1025 | 0.0478 | 0.0169 | 0.0464 | 0.0354 | 0.1408 |
| **18** | 0.0961 | 0.0592 | 0.0301 | 0.0318 | 0.0028 | 0.0052 |
| **19** | 0.0683 | 0.0298 | 0.0013 | 0.0171 | 0.0101 | 0.0110 |
| **20** | 0.0664 | 0.0021 | 0.0066 | 0.0442 | 0.0148 | 0.0069 |
| **21** | 0.0891 | 0.0216 | 0.0098 | 0.0234 | 0.0000 | 0.0102 |
| **22** | 0.0061 | 0.0152 | 0.0034 | 0.0287 | 0.0003 | 0.0000 |
| **23** | 0.0502 | 0.0280 | 0.0038 | 0.0061 | 0.0008 | 0.0076 |
| **24** | 0.0052 | 0.0136 | 0.0007 | 0.0021 | 0.0000 | 0.0144 |
| **25** | 0.0439 | 0.0222 | 0.0067 | 0.0030 | 0.0013 | 0.0225 |

Table 5. Biomass indices (and associated coefficients of variance, expressed as percentages) from the 1999-2006 NWFSC Slope Survey.

| Year | Biomass Indices | Sampling CV |
|---|---|---|
| 1999 | 3,059 | 46.9% |
| 2000 | 3,602 | 51.1% |
| 2000 | 3,960 | 41.2% |
| 2002 | 2,949 | 47.2% |
| 2003 | 26,691 | 43.1% |
| 2004 | 6,626 | 70.5% |
| 2005 | 10,040 | 74.8% |
| 2006 | 15,738 | 57.3% |

Table 6. List of the data sources and associated time periods used in present assessment.

| Data Source | Years |
|---|---|
| Fishery Catch | 1956-2006 |
| Fishery age-composition data | 1966-80 (biased); 1994, 1999-2006 (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 | 1999-2006 |
| Survey age-composition data | |
| Triennial survey | 1989, 1992, 1995, 1998, 2001, 2004 |
| POP / NWFSC slope surveys | 1985, 2001-2006 |
| 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 7. 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(0.05,0.1) | 6 |
| Stock-recruitment steepness | $h$ | | Uniform(0.21,0.99) | 7 |
| Average fishing mortality | $\overline{F}$ | | Log-Uniform(-∞,∞) | 1 |
| Recruitment deviation | $\varepsilon_i^R$ | 72 | Log-Uniform(-10,10) | 3 |
| Fishing mortality deviation | $\varepsilon_i^F$ | 51 | 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) | $\varsigma_{k_i,j}^F$ | 104 (12*9) | Log-Uniform(-5,5) | 3 |

(Table 7 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 | $\mu$ | 8* |
| Extent of auto-correlation in recruitment | $\rho$ | 0* |
| Extent of variability in recruitment | $\sigma_R$ | 1.0* |
| Number of years in a grouping for time-varying fishery selectivity | $g$ | 6* |
| | | |
| *Weighting factors* | | |
| CPUE cv | $\tau$ | 0.2 |
| Catch biomass weight | $\lambda_1$ | 100 |
| Age/size data weight | $\lambda_3$ | 1 |
| Fishing mortality regularity weight | $\lambda_5$ | 0.0 |
| Selectivity prior overall weight | $\lambda_6$ | 1 |
| Fishery selectivity dome-shapedness penalty | $\lambda_8$ | 20 |
| Fishery selectivity temporal penalty | $\lambda_9$ | 20 |
| Selectivity curvature penalty | $\lambda_{10}$ | 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 7 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 | $F_{i,j} = \overline{F} \varepsilon_i^F s_{i,j}^F$ |
| Total mortality rate | $Z_{i,j} = F_{i,j} + M$ |
| Annual survival rate | $S_{i,j} = e^{-Z_{i,j}}$ |
| Number at age | $N_{i,j} = \begin{cases} \overline{R} \varepsilon_i^R & j = 3 \\ N_{i-1,j-1} S_{i-1,j-1} & 4 \leq j \leq 23 \\ N_{i-1,24} S_{i-1,24} + N_{i-1,25} S_{i-1,25} & j = 25 \end{cases}$ |
| 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 7 Continued)

(d) Model predictions

| Data Type | Symbol | Model prediction |
|---|---|---|
| Triennial survey abundance index<br>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<br>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<br>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<br>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<br>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<br>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 7 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 7 Continued)

(f) Components of the objective function (priors)

| Component | Parameter |
|---|---|
| $P_1 = \frac{n}{2}\ln(2\pi\sigma_R^2) + \sum_{i\ge 1935} \frac{(\xi_i - \rho\xi_{i-1})^2}{2(1-\rho^2)\sigma_R^2}$ | 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 |
| | |
| $P_4 = \frac{\ln(2\pi)}{2} + \ln(0.1) + \frac{\left(\ln(M/0.05)\right)^2}{0.02}$ | Natural mortality |
| | |

Table 8. Point estimates of the numbers at age (millions of fish) for the US west coast population of Pacific ocean perch (1956-2007) 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 | 3.82 | 8.26 | 6.05 | 4.63 | 3.76 | 3.20 | 2.84 | 2.61 | 2.45 | 2.34 | 2.24 | 2.13 | 2.03 | 1.93 | 1.84 | 1.75 | 1.67 | 1.59 | 1.52 | 1.45 | 1.39 | 1.33 | 30.45 |
| 1957 | 46.80 | 3.62 | 7.83 | 5.73 | 4.39 | 3.56 | 3.02 | 2.66 | 2.42 | 2.26 | 2.14 | 2.04 | 1.94 | 1.85 | 1.76 | 1.68 | 1.60 | 1.52 | 1.45 | 1.39 | 1.33 | 1.27 | 29.04 |
| 1958 | 4.09 | 44.40 | 3.44 | 7.43 | 5.43 | 4.15 | 3.35 | 2.82 | 2.46 | 2.21 | 2.05 | 1.95 | 1.86 | 1.77 | 1.68 | 1.60 | 1.53 | 1.46 | 1.39 | 1.32 | 1.26 | 1.21 | 27.57 |
| 1959 | 18.63 | 3.88 | 42.12 | 3.26 | 7.04 | 5.14 | 3.92 | 3.14 | 2.63 | 2.28 | 2.04 | 1.89 | 1.79 | 1.71 | 1.63 | 1.55 | 1.48 | 1.41 | 1.34 | 1.28 | 1.22 | 1.16 | 26.54 |
| 1960 | 8.80 | 17.68 | 3.68 | 39.94 | 3.09 | 6.66 | 4.85 | 3.67 | 2.92 | 2.42 | 2.08 | 1.86 | 1.73 | 1.64 | 1.57 | 1.49 | 1.42 | 1.35 | 1.29 | 1.23 | 1.17 | 1.12 | 25.36 |
| 1961 | 4.15 | 8.35 | 16.77 | 3.49 | 37.85 | 2.92 | 6.27 | 4.53 | 3.39 | 2.66 | 2.19 | 1.89 | 1.69 | 1.57 | 1.49 | 1.42 | 1.36 | 1.29 | 1.23 | 1.17 | 1.12 | 1.06 | 24.04 |
| 1962 | 3.54 | 3.94 | 7.92 | 15.90 | 3.30 | 35.69 | 2.73 | 5.78 | 4.09 | 3.00 | 2.33 | 1.92 | 1.66 | 1.48 | 1.37 | 1.31 | 1.25 | 1.19 | 1.13 | 1.08 | 1.03 | 0.98 | 22.01 |
| 1963 | 4.87 | 3.36 | 3.74 | 7.51 | 15.03 | 3.11 | 33.17 | 2.49 | 5.12 | 3.52 | 2.53 | 1.97 | 1.62 | 1.40 | 1.26 | 1.17 | 1.11 | 1.06 | 1.01 | 0.96 | 0.91 | 0.87 | 19.48 |
| 1964 | 14.06 | 4.62 | 3.18 | 3.54 | 7.10 | 14.11 | 2.87 | 30.00 | 2.19 | 4.31 | 2.88 | 2.08 | 1.63 | 1.35 | 1.17 | 1.05 | 0.97 | 0.92 | 0.88 | 0.84 | 0.80 | 0.76 | 16.91 |
| 1965 | 10.01 | 13.34 | 4.38 | 3.02 | 3.35 | 6.67 | 13.10 | 2.62 | 26.66 | 1.87 | 3.61 | 2.42 | 1.76 | 1.38 | 1.14 | 0.99 | 0.89 | 0.82 | 0.78 | 0.75 | 0.71 | 0.68 | 14.98 |
| 1966 | 6.66 | 9.50 | 12.65 | 4.15 | 2.85 | 3.14 | 6.15 | 11.76 | 2.27 | 22.02 | 1.50 | 2.91 | 1.98 | 1.44 | 1.13 | 0.93 | 0.81 | 0.72 | 0.67 | 0.64 | 0.61 | 0.58 | 12.76 |
| 1967 | 4.29 | 6.31 | 9.00 | 11.95 | 3.89 | 2.61 | 2.75 | 5.01 | 8.75 | 1.47 | 13.16 | 0.91 | 1.81 | 1.23 | 0.90 | 0.70 | 0.58 | 0.50 | 0.45 | 0.42 | 0.40 | 0.38 | 8.33 |
| 1968 | 3.32 | 4.07 | 5.98 | 8.50 | 11.20 | 3.57 | 2.29 | 2.25 | 3.75 | 5.71 | 0.89 | 8.03 | 0.57 | 1.14 | 0.78 | 0.57 | 0.44 | 0.37 | 0.32 | 0.28 | 0.26 | 0.25 | 5.48 |
| 1969 | 3.64 | 3.15 | 3.86 | 5.66 | 8.00 | 10.38 | 3.20 | 1.96 | 1.80 | 2.73 | 3.94 | 0.62 | 5.72 | 0.41 | 0.81 | 0.55 | 0.40 | 0.32 | 0.26 | 0.23 | 0.20 | 0.19 | 4.08 |
| 1970 | 2.70 | 3.45 | 2.99 | 3.66 | 5.36 | 7.55 | 9.73 | 2.96 | 1.78 | 1.60 | 2.42 | 3.53 | 0.56 | 5.20 | 0.37 | 0.74 | 0.50 | 0.37 | 0.29 | 0.24 | 0.21 | 0.18 | 3.88 |
| 1971 | 3.84 | 2.56 | 3.27 | 2.83 | 3.46 | 5.03 | 7.01 | 8.82 | 2.59 | 1.50 | 1.35 | 2.08 | 3.11 | 0.49 | 4.57 | 0.33 | 0.65 | 0.44 | 0.32 | 0.25 | 0.21 | 0.18 | 3.58 |
| 1972 | 4.78 | 3.65 | 2.43 | 3.10 | 2.68 | 3.26 | 4.69 | 6.41 | 7.84 | 2.23 | 1.29 | 1.18 | 1.86 | 2.77 | 0.44 | 4.08 | 0.29 | 0.58 | 0.39 | 0.29 | 0.23 | 0.19 | 3.35 |
| 1973 | 6.99 | 4.53 | 3.46 | 2.31 | 2.94 | 2.53 | 3.05 | 4.34 | 5.80 | 6.94 | 1.97 | 1.15 | 1.07 | 1.69 | 2.52 | 0.40 | 3.70 | 0.26 | 0.53 | 0.36 | 0.26 | 0.20 | 3.21 |
| 1974 | 3.72 | 6.63 | 4.30 | 3.28 | 2.18 | 2.77 | 2.36 | 2.80 | 3.87 | 5.02 | 6.01 | 1.73 | 1.03 | 0.96 | 1.51 | 2.25 | 0.36 | 3.31 | 0.24 | 0.47 | 0.32 | 0.23 | 3.06 |
| 1975 | 1.47 | 3.53 | 6.29 | 4.08 | 3.10 | 2.06 | 2.59 | 2.17 | 2.52 | 3.39 | 4.40 | 5.33 | 1.56 | 0.93 | 0.86 | 1.36 | 2.03 | 0.32 | 2.99 | 0.21 | 0.43 | 0.29 | 2.97 |
| 1976 | 1.48 | 1.39 | 3.34 | 5.96 | 3.86 | 2.92 | 1.91 | 2.37 | 1.96 | 2.25 | 3.05 | 4.00 | 4.91 | 1.44 | 0.86 | 0.80 | 1.25 | 1.87 | 0.30 | 2.75 | 0.20 | 0.39 | 3.00 |
| 1977 | 1.62 | 1.40 | 1.32 | 3.17 | 5.63 | 3.61 | 2.69 | 1.72 | 2.08 | 1.70 | 1.97 | 2.71 | 3.63 | 4.45 | 1.30 | 0.78 | 0.72 | 1.14 | 1.70 | 0.27 | 2.49 | 0.18 | 3.07 |
| 1978 | 1.55 | 1.53 | 1.33 | 1.25 | 3.00 | 5.29 | 3.35 | 2.44 | 1.54 | 1.85 | 1.52 | 1.78 | 2.48 | 3.32 | 4.07 | 1.20 | 0.71 | 0.66 | 1.04 | 1.55 | 0.25 | 2.28 | 2.98 |
| 1979 | 1.08 | 1.47 | 1.45 | 1.26 | 1.18 | 2.80 | 4.83 | 2.96 | 2.10 | 1.30 | 1.57 | 1.32 | 1.59 | 2.22 | 2.97 | 3.64 | 1.07 | 0.64 | 0.59 | 0.93 | 1.39 | 0.22 | 4.70 |
| 1980 | 0.97 | 1.02 | 1.40 | 1.38 | 1.19 | 1.10 | 2.56 | 4.29 | 2.56 | 1.79 | 1.12 | 1.38 | 1.19 | 1.42 | 1.99 | 2.67 | 3.27 | 0.96 | 0.57 | 0.53 | 0.84 | 1.25 | 4.42 |
| 1981 | 1.82 | 0.92 | 0.97 | 1.32 | 1.30 | 1.11 | 1.01 | 2.27 | 3.70 | 2.18 | 1.53 | 0.98 | 1.24 | 1.06 | 1.28 | 1.78 | 2.39 | 2.93 | 0.86 | 0.51 | 0.47 | 0.75 | 5.08 |
| 1982 | 2.91 | 1.73 | 0.88 | 0.92 | 1.25 | 1.23 | 1.04 | 0.92 | 2.04 | 3.30 | 1.95 | 1.37 | 0.87 | 1.10 | 0.95 | 1.14 | 1.59 | 2.13 | 2.61 | 0.77 | 0.46 | 0.42 | 5.19 |
| 1983 | 2.24 | 2.76 | 1.64 | 0.83 | 0.87 | 1.18 | 1.15 | 0.95 | 0.84 | 1.84 | 2.99 | 1.76 | 1.24 | 0.79 | 0.99 | 0.86 | 1.03 | 1.44 | 1.92 | 2.36 | 0.69 | 0.41 | 5.07 |
| 1984 | 5.39 | 2.12 | 2.62 | 1.56 | 0.79 | 0.82 | 1.09 | 1.03 | 0.84 | 0.73 | 1.60 | 2.60 | 1.53 | 1.07 | 0.68 | 0.86 | 0.74 | 0.89 | 1.24 | 1.66 | 2.04 | 0.60 | 4.75 |
| 1985 | 1.10 | 5.11 | 2.02 | 2.48 | 1.47 | 0.74 | 0.76 | 0.98 | 0.90 | 0.73 | 0.63 | 1.40 | 2.26 | 1.33 | 0.93 | 0.59 | 0.75 | 0.64 | 0.77 | 1.08 | 1.45 | 1.77 | 4.65 |
| 1986 | 1.16 | 1.04 | 4.85 | 1.91 | 2.35 | 1.38 | 0.68 | 0.68 | 0.86 | 0.79 | 0.63 | 0.55 | 1.22 | 1.96 | 1.15 | 0.81 | 0.51 | 0.65 | 0.56 | 0.67 | 0.94 | 1.26 | 5.58 |
| 1987 | 2.36 | 1.10 | 0.99 | 4.59 | 1.81 | 2.21 | 1.28 | 0.62 | 0.60 | 0.75 | 0.69 | 0.56 | 0.48 | 1.06 | 1.71 | 1.00 | 0.71 | 0.45 | 0.57 | 0.49 | 0.59 | 0.82 | 5.96 |
| 1988 | 3.66 | 2.24 | 1.04 | 0.94 | 4.35 | 1.70 | 2.06 | 1.17 | 0.55 | 0.53 | 0.67 | 0.61 | 0.49 | 0.42 | 0.93 | 1.51 | 0.88 | 0.62 | 0.39 | 0.50 | 0.43 | 0.52 | 5.97 |
| 1989 | 0.66 | 3.48 | 2.12 | 0.99 | 0.89 | 4.09 | 1.58 | 1.87 | 1.03 | 0.48 | 0.46 | 0.57 | 0.52 | 0.42 | 0.37 | 0.80 | 1.30 | 0.76 | 0.53 | 0.34 | 0.43 | 0.37 | 5.58 |
| 1990 | 2.14 | 0.63 | 3.30 | 2.01 | 0.94 | 0.83 | 3.78 | 1.42 | 1.63 | 0.88 | 0.41 | 0.39 | 0.49 | 0.45 | 0.36 | 0.31 | 0.68 | 1.10 | 0.65 | 0.46 | 0.29 | 0.37 | 5.07 |
| 1991 | 3.13 | 2.03 | 0.59 | 3.13 | 1.91 | 0.88 | 0.77 | 3.46 | 1.27 | 1.43 | 0.78 | 0.36 | 0.34 | 0.43 | 0.39 | 0.31 | 0.27 | 0.60 | 0.97 | 0.57 | 0.40 | 0.25 | 4.76 |
| 1992 | 2.29 | 2.97 | 1.93 | 0.56 | 2.96 | 1.79 | 0.81 | 0.70 | 3.01 | 1.08 | 1.22 | 0.66 | 0.30 | 0.29 | 0.36 | 0.33 | 0.27 | 0.23 | 0.51 | 0.82 | 0.48 | 0.34 | 4.25 |
| 1993 | 3.45 | 2.17 | 2.82 | 1.83 | 0.53 | 2.78 | 1.66 | 0.74 | 0.62 | 2.61 | 0.94 | 1.06 | 0.57 | 0.26 | 0.25 | 0.31 | 0.29 | 0.23 | 0.20 | 0.44 | 0.71 | 0.42 | 3.96 |
| 1994 | 3.05 | 3.28 | 2.06 | 2.67 | 1.73 | 0.50 | 2.56 | 1.49 | 0.64 | 0.52 | 2.20 | 0.79 | 0.90 | 0.48 | 0.22 | 0.21 | 0.27 | 0.24 | 0.19 | 0.17 | 0.37 | 0.60 | 3.71 |
| 1995 | 0.65 | 2.89 | 3.11 | 1.95 | 2.52 | 1.62 | 0.46 | 2.32 | 1.31 | 0.56 | 0.45 | 1.90 | 0.69 | 0.78 | 0.42 | 0.19 | 0.18 | 0.23 | 0.21 | 0.17 | 0.15 | 0.32 | 3.73 |
| 1996 | 0.73 | 0.62 | 2.74 | 2.95 | 1.85 | 2.38 | 1.51 | 0.42 | 2.07 | 1.15 | 0.49 | 0.39 | 1.67 | 0.60 | 0.68 | 0.37 | 0.17 | 0.16 | 0.20 | 0.18 | 0.15 | 0.13 | 3.55 |
| 1997 | 5.07 | 0.69 | 0.59 | 2.60 | 2.79 | 1.74 | 2.21 | 1.38 | 0.38 | 1.82 | 1.01 | 0.43 | 0.35 | 1.46 | 0.53 | 0.60 | 0.32 | 0.15 | 0.14 | 0.18 | 0.16 | 0.13 | 3.23 |
| 1998 | 3.69 | 4.81 | 0.66 | 0.55 | 2.46 | 2.63 | 1.62 | 2.03 | 1.24 | 0.34 | 1.62 | 0.90 | 0.38 | 0.31 | 1.31 | 0.47 | 0.53 | 0.29 | 0.13 | 0.13 | 0.16 | 0.14 | 3.00 |
| 1999 | 0.53 | 3.50 | 4.56 | 0.62 | 0.53 | 2.32 | 2.45 | 1.49 | 1.84 | 1.11 | 0.30 | 1.44 | 0.80 | 0.34 | 0.28 | 1.17 | 0.42 | 0.48 | 0.26 | 0.12 | 0.11 | 0.14 | 2.81 |
| 2000 | 0.82 | 0.51 | 3.32 | 4.33 | 0.59 | 0.50 | 2.17 | 2.27 | 1.37 | 1.66 | 1.01 | 0.27 | 1.31 | 0.73 | 0.31 | 0.25 | 1.06 | 0.38 | 0.43 | 0.23 | 0.11 | 0.10 | 2.68 |
| 2001 | 1.69 | 0.78 | 0.48 | 3.15 | 4.10 | 0.56 | 0.47 | 2.04 | 2.13 | 1.28 | 1.56 | 0.94 | 0.25 | 1.22 | 0.68 | 0.29 | 0.23 | 0.99 | 0.36 | 0.41 | 0.22 | 0.10 | 2.61 |
| 2002 | 10.47 | 1.60 | 0.74 | 0.46 | 2.98 | 3.88 | 0.53 | 0.44 | 1.91 | 1.98 | 1.19 | 1.44 | 0.87 | 0.24 | 1.14 | 0.63 | 0.27 | 0.22 | 0.92 | 0.33 | 0.38 | 0.20 | 2.51 |
| 2003 | 5.35 | 9.93 | 1.52 | 0.70 | 0.43 | 2.83 | 3.67 | 0.50 | 0.41 | 1.79 | 1.86 | 1.11 | 1.35 | 0.82 | 0.22 | 1.07 | 0.59 | 0.25 | 0.20 | 0.86 | 0.31 | 0.35 | 2.55 |
| 2004 | 3.13 | 5.08 | 9.42 | 1.44 | 0.67 | 0.41 | 2.67 | 3.46 | 0.47 | 0.39 | 1.68 | 1.74 | 1.05 | 1.27 | 0.77 | 0.21 | 1.00 | 0.56 | 0.24 | 0.19 | 0.81 | 0.29 | 2.73 |
| 2005 | 1.61 | 2.97 | 4.82 | 8.94 | 1.37 | 0.63 | 0.39 | 2.52 | 3.26 | 0.44 | 0.36 | 1.58 | 1.64 | 0.98 | 1.20 | 0.72 | 0.20 | 0.94 | 0.52 | 0.22 | 0.18 | 0.76 | 2.84 |
| 2006 | 1.48 | 1.53 | 2.81 | 4.57 | 8.48 | 1.30 | 0.60 | 0.37 | 2.39 | 3.08 | 0.42 | 0.34 | 1.49 | 1.55 | 0.93 | 1.13 | 0.68 | 0.18 | 0.89 | 0.50 | 0.21 | 0.17 | 3.40 |
| 2007 | 1.48 | 1.41 | 1.45 | 2.67 | 4.34 | 8.04 | 1.23 | 0.56 | 0.35 | 2.26 | 2.91 | 0.39 | 0.32 | 1.40 | 1.46 | 0.88 | 1.07 | 0.65 | 0.17 | 0.84 | 0.47 | 0.20 | 3.37 |

Table 9. Point estimates of the catch-at-age (millions of fish) for the US west coast population of Pacific ocean perch (1956-2006) based on Model 1.

| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1956 | 0.000 | 0.001 | 0.002 | 0.005 | 0.010 | 0.020 | 0.035 | 0.053 | 0.071 | 0.080 | 0.080 | 0.076 | 0.072 | 0.069 | 0.065 | 0.062 | 0.059 | 0.057 | 0.054 | 0.052 | 0.049 | 0.047 | 1.084 |
| 1957 | 0.002 | 0.000 | 0.003 | 0.007 | 0.014 | 0.026 | 0.044 | 0.065 | 0.086 | 0.094 | 0.089 | 0.082 | 0.078 | 0.075 | 0.071 | 0.068 | 0.064 | 0.061 | 0.059 | 0.056 | 0.053 | 0.051 | 1.169 |
| 1958 | 0.000 | 0.004 | 0.001 | 0.006 | 0.012 | 0.021 | 0.033 | 0.047 | 0.059 | 0.063 | 0.058 | 0.053 | 0.051 | 0.048 | 0.046 | 0.044 | 0.042 | 0.040 | 0.038 | 0.036 | 0.034 | 0.033 | 0.750 |
| 1959 | 0.001 | 0.000 | 0.014 | 0.003 | 0.019 | 0.032 | 0.049 | 0.066 | 0.079 | 0.081 | 0.072 | 0.065 | 0.061 | 0.059 | 0.056 | 0.053 | 0.051 | 0.048 | 0.046 | 0.044 | 0.042 | 0.040 | 0.909 |
| 1960 | 0.000 | 0.002 | 0.001 | 0.049 | 0.010 | 0.052 | 0.074 | 0.094 | 0.108 | 0.105 | 0.090 | 0.078 | 0.072 | 0.069 | 0.066 | 0.063 | 0.060 | 0.057 | 0.054 | 0.052 | 0.049 | 0.047 | 1.064 |
| 1961 | 0.000 | 0.002 | 0.012 | 0.008 | 0.226 | 0.041 | 0.171 | 0.206 | 0.221 | 0.204 | 0.168 | 0.140 | 0.125 | 0.116 | 0.110 | 0.105 | 0.100 | 0.095 | 0.091 | 0.087 | 0.082 | 0.079 | 1.777 |
| 1962 | 0.000 | 0.001 | 0.008 | 0.050 | 0.028 | 0.705 | 0.106 | 0.372 | 0.376 | 0.323 | 0.250 | 0.199 | 0.172 | 0.154 | 0.143 | 0.136 | 0.130 | 0.123 | 0.118 | 0.112 | 0.107 | 0.102 | 2.286 |
| 1963 | 0.001 | 0.001 | 0.005 | 0.029 | 0.160 | 0.076 | 1.511 | 0.180 | 0.571 | 0.468 | 0.328 | 0.238 | 0.197 | 0.170 | 0.152 | 0.141 | 0.134 | 0.128 | 0.122 | 0.116 | 0.111 | 0.105 | 2.360 |
| 1964 | 0.001 | 0.001 | 0.003 | 0.011 | 0.064 | 0.295 | 0.111 | 1.853 | 0.209 | 0.491 | 0.321 | 0.216 | 0.170 | 0.140 | 0.121 | 0.109 | 0.101 | 0.096 | 0.091 | 0.087 | 0.083 | 0.079 | 1.756 |
| 1965 | 0.001 | 0.006 | 0.006 | 0.013 | 0.041 | 0.187 | 0.680 | 0.215 | 3.366 | 0.281 | 0.530 | 0.332 | 0.242 | 0.190 | 0.157 | 0.136 | 0.122 | 0.113 | 0.107 | 0.102 | 0.097 | 0.093 | 2.055 |
| 1966 | 0.002 | 0.011 | 0.049 | 0.050 | 0.095 | 0.237 | 0.840 | 2.478 | 0.705 | 7.954 | 0.532 | 0.970 | 0.659 | 0.480 | 0.377 | 0.311 | 0.269 | 0.241 | 0.223 | 0.212 | 0.203 | 0.193 | 4.259 |
| 1967 | 0.001 | 0.007 | 0.034 | 0.140 | 0.126 | 0.193 | 0.368 | 1.036 | 2.668 | 0.522 | 4.579 | 0.298 | 0.595 | 0.405 | 0.295 | 0.231 | 0.191 | 0.165 | 0.148 | 0.137 | 0.130 | 0.124 | 2.731 |
| 1968 | 0.001 | 0.003 | 0.016 | 0.070 | 0.256 | 0.187 | 0.220 | 0.337 | 0.844 | 1.513 | 0.230 | 1.955 | 0.139 | 0.278 | 0.189 | 0.138 | 0.108 | 0.089 | 0.077 | 0.069 | 0.064 | 0.061 | 1.335 |
| 1969 | 0.000 | 0.001 | 0.002 | 0.011 | 0.042 | 0.123 | 0.078 | 0.085 | 0.115 | 0.174 | 0.212 | 0.025 | 0.234 | 0.017 | 0.033 | 0.023 | 0.016 | 0.013 | 0.011 | 0.009 | 0.008 | 0.008 | 0.167 |
| 1970 | 0.000 | 0.001 | 0.003 | 0.013 | 0.050 | 0.156 | 0.415 | 0.223 | 0.194 | 0.175 | 0.225 | 0.250 | 0.040 | 0.368 | 0.026 | 0.052 | 0.036 | 0.026 | 0.020 | 0.017 | 0.015 | 0.013 | 0.275 |
| 1971 | 0.000 | 0.001 | 0.003 | 0.008 | 0.026 | 0.086 | 0.246 | 0.550 | 0.235 | 0.136 | 0.103 | 0.122 | 0.182 | 0.029 | 0.268 | 0.019 | 0.038 | 0.026 | 0.019 | 0.015 | 0.012 | 0.011 | 0.209 |
| 1972 | 0.000 | 0.001 | 0.002 | 0.006 | 0.015 | 0.040 | 0.118 | 0.287 | 0.513 | 0.146 | 0.071 | 0.050 | 0.078 | 0.117 | 0.019 | 0.172 | 0.012 | 0.024 | 0.017 | 0.012 | 0.009 | 0.008 | 0.141 |
| 1973 | 0.000 | 0.001 | 0.003 | 0.006 | 0.021 | 0.040 | 0.100 | 0.253 | 0.494 | 0.590 | 0.142 | 0.063 | 0.059 | 0.092 | 0.138 | 0.022 | 0.203 | 0.014 | 0.029 | 0.020 | 0.014 | 0.011 | 0.176 |
| 1974 | 0.000 | 0.001 | 0.003 | 0.007 | 0.013 | 0.038 | 0.067 | 0.142 | 0.287 | 0.372 | 0.376 | 0.083 | 0.049 | 0.046 | 0.072 | 0.107 | 0.017 | 0.158 | 0.011 | 0.022 | 0.015 | 0.011 | 0.146 |
| 1975 | 0.000 | 0.001 | 0.004 | 0.010 | 0.025 | 0.040 | 0.089 | 0.104 | 0.138 | 0.176 | 0.182 | 0.155 | 0.045 | 0.027 | 0.025 | 0.040 | 0.059 | 0.009 | 0.087 | 0.006 | 0.012 | 0.008 | 0.086 |
| 1976 | 0.000 | 0.000 | 0.004 | 0.023 | 0.047 | 0.086 | 0.099 | 0.171 | 0.161 | 0.175 | 0.190 | 0.175 | 0.215 | 0.063 | 0.038 | 0.035 | 0.055 | 0.082 | 0.013 | 0.121 | 0.009 | 0.017 | 0.131 |
| 1977 | 0.000 | 0.000 | 0.001 | 0.009 | 0.052 | 0.081 | 0.106 | 0.095 | 0.131 | 0.101 | 0.093 | 0.090 | 0.121 | 0.148 | 0.044 | 0.026 | 0.024 | 0.038 | 0.057 | 0.009 | 0.083 | 0.006 | 0.102 |
| 1978 | 0.000 | 0.001 | 0.002 | 0.006 | 0.047 | 0.201 | 0.223 | 0.226 | 0.162 | 0.184 | 0.121 | 0.100 | 0.140 | 0.187 | 0.229 | 0.067 | 0.040 | 0.037 | 0.059 | 0.087 | 0.014 | 0.129 | 0.168 |
| 1979 | 0.000 | 0.001 | 0.002 | 0.006 | 0.017 | 0.099 | 0.299 | 0.254 | 0.205 | 0.120 | 0.117 | 0.069 | 0.083 | 0.116 | 0.155 | 0.191 | 0.056 | 0.033 | 0.031 | 0.049 | 0.073 | 0.012 | 0.246 |
| 1980 | 0.000 | 0.000 | 0.002 | 0.006 | 0.018 | 0.040 | 0.163 | 0.378 | 0.257 | 0.170 | 0.085 | 0.074 | 0.064 | 0.076 | 0.107 | 0.143 | 0.176 | 0.052 | 0.031 | 0.028 | 0.045 | 0.067 | 0.237 |
| 1981 | 0.000 | 0.000 | 0.001 | 0.003 | 0.009 | 0.020 | 0.037 | 0.121 | 0.218 | 0.126 | 0.087 | 0.059 | 0.074 | 0.064 | 0.077 | 0.107 | 0.144 | 0.177 | 0.052 | 0.031 | 0.029 | 0.045 | 0.306 |
| 1982 | 0.000 | 0.000 | 0.000 | 0.002 | 0.007 | 0.017 | 0.029 | 0.037 | 0.091 | 0.145 | 0.085 | 0.063 | 0.040 | 0.051 | 0.043 | 0.052 | 0.073 | 0.098 | 0.120 | 0.035 | 0.021 | 0.019 | 0.238 |
| 1983 | 0.000 | 0.001 | 0.002 | 0.003 | 0.009 | 0.031 | 0.059 | 0.072 | 0.070 | 0.151 | 0.241 | 0.150 | 0.106 | 0.067 | 0.085 | 0.073 | 0.088 | 0.122 | 0.164 | 0.201 | 0.059 | 0.035 | 0.433 |
| 1984 | 0.000 | 0.001 | 0.002 | 0.005 | 0.008 | 0.020 | 0.054 | 0.075 | 0.067 | 0.057 | 0.124 | 0.213 | 0.125 | 0.088 | 0.056 | 0.071 | 0.061 | 0.073 | 0.102 | 0.137 | 0.167 | 0.049 | 0.389 |
| 1985 | 0.000 | 0.001 | 0.002 | 0.008 | 0.014 | 0.018 | 0.037 | 0.071 | 0.072 | 0.057 | 0.049 | 0.113 | 0.183 | 0.108 | 0.076 | 0.048 | 0.061 | 0.052 | 0.063 | 0.088 | 0.117 | 0.144 | 0.377 |
| 1986 | 0.000 | 0.000 | 0.004 | 0.006 | 0.022 | 0.034 | 0.033 | 0.048 | 0.068 | 0.061 | 0.048 | 0.044 | 0.098 | 0.158 | 0.093 | 0.065 | 0.041 | 0.052 | 0.045 | 0.054 | 0.075 | 0.101 | 0.448 |
| 1987 | 0.000 | 0.000 | 0.001 | 0.010 | 0.012 | 0.036 | 0.043 | 0.033 | 0.039 | 0.050 | 0.046 | 0.038 | 0.033 | 0.073 | 0.118 | 0.070 | 0.049 | 0.031 | 0.039 | 0.034 | 0.041 | 0.057 | 0.412 |
| 1988 | 0.000 | 0.001 | 0.001 | 0.003 | 0.037 | 0.037 | 0.091 | 0.082 | 0.047 | 0.047 | 0.059 | 0.055 | 0.045 | 0.039 | 0.085 | 0.137 | 0.081 | 0.057 | 0.036 | 0.045 | 0.039 | 0.047 | 0.544 |
| 1989 | 0.000 | 0.001 | 0.002 | 0.003 | 0.008 | 0.098 | 0.077 | 0.143 | 0.097 | 0.046 | 0.044 | 0.057 | 0.052 | 0.042 | 0.036 | 0.080 | 0.129 | 0.076 | 0.053 | 0.034 | 0.043 | 0.037 | 0.554 |
| 1990 | 0.000 | 0.000 | 0.002 | 0.005 | 0.007 | 0.015 | 0.138 | 0.082 | 0.116 | 0.065 | 0.030 | 0.030 | 0.037 | 0.034 | 0.027 | 0.023 | 0.052 | 0.083 | 0.049 | 0.034 | 0.022 | 0.028 | 0.382 |
| 1991 | 0.000 | 0.001 | 0.001 | 0.010 | 0.019 | 0.022 | 0.039 | 0.276 | 0.124 | 0.144 | 0.078 | 0.037 | 0.035 | 0.044 | 0.040 | 0.032 | 0.028 | 0.062 | 0.100 | 0.059 | 0.041 | 0.026 | 0.492 |
| 1992 | 0.000 | 0.001 | 0.002 | 0.002 | 0.024 | 0.038 | 0.035 | 0.047 | 0.249 | 0.092 | 0.104 | 0.058 | 0.027 | 0.026 | 0.032 | 0.029 | 0.023 | 0.020 | 0.045 | 0.072 | 0.042 | 0.030 | 0.373 |
| 1993 | 0.000 | 0.001 | 0.003 | 0.007 | 0.006 | 0.081 | 0.091 | 0.061 | 0.062 | 0.284 | 0.102 | 0.109 | 0.059 | 0.027 | 0.026 | 0.032 | 0.029 | 0.024 | 0.021 | 0.045 | 0.073 | 0.043 | 0.409 |
| 1994 | 0.000 | 0.001 | 0.002 | 0.008 | 0.017 | 0.012 | 0.116 | 0.102 | 0.054 | 0.047 | 0.198 | 0.068 | 0.077 | 0.042 | 0.019 | 0.018 | 0.023 | 0.021 | 0.017 | 0.015 | 0.032 | 0.052 | 0.319 |
| 1995 | 0.000 | 0.001 | 0.002 | 0.005 | 0.021 | 0.033 | 0.018 | 0.135 | 0.093 | 0.043 | 0.035 | 0.139 | 0.050 | 0.057 | 0.031 | 0.014 | 0.013 | 0.017 | 0.015 | 0.012 | 0.011 | 0.023 | 0.273 |
| 1996 | 0.000 | 0.000 | 0.002 | 0.008 | 0.015 | 0.048 | 0.057 | 0.024 | 0.145 | 0.088 | 0.037 | 0.028 | 0.120 | 0.043 | 0.049 | 0.027 | 0.012 | 0.012 | 0.015 | 0.013 | 0.011 | 0.009 | 0.257 |
| 1997 | 0.000 | 0.000 | 0.000 | 0.005 | 0.018 | 0.028 | 0.067 | 0.063 | 0.021 | 0.110 | 0.061 | 0.024 | 0.020 | 0.084 | 0.030 | 0.034 | 0.019 | 0.009 | 0.008 | 0.010 | 0.009 | 0.007 | 0.186 |
| 1998 | 0.000 | 0.001 | 0.000 | 0.001 | 0.015 | 0.041 | 0.048 | 0.091 | 0.068 | 0.020 | 0.095 | 0.050 | 0.021 | 0.017 | 0.073 | 0.026 | 0.030 | 0.016 | 0.007 | 0.007 | 0.009 | 0.008 | 0.169 |
| 1999 | 0.000 | 0.000 | 0.002 | 0.001 | 0.003 | 0.034 | 0.057 | 0.051 | 0.082 | 0.052 | 0.014 | 0.062 | 0.035 | 0.015 | 0.012 | 0.051 | 0.018 | 0.021 | 0.011 | 0.005 | 0.005 | 0.006 | 0.122 |
| 2000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.001 | 0.002 | 0.014 | 0.022 | 0.017 | 0.022 | 0.013 | 0.003 | 0.016 | 0.009 | 0.004 | 0.003 | 0.013 | 0.005 | 0.005 | 0.003 | 0.001 | 0.001 | 0.032 |
| 2001 | 0.000 | 0.000 | 0.000 | 0.003 | 0.012 | 0.004 | 0.005 | 0.033 | 0.045 | 0.029 | 0.034 | 0.019 | 0.005 | 0.025 | 0.014 | 0.006 | 0.005 | 0.020 | 0.007 | 0.008 | 0.005 | 0.002 | 0.054 |
| 2002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.005 | 0.015 | 0.003 | 0.004 | 0.023 | 0.025 | 0.015 | 0.017 | 0.010 | 0.003 | 0.013 | 0.007 | 0.003 | 0.003 | 0.011 | 0.004 | 0.004 | 0.002 | 0.029 |
| 2003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.009 | 0.019 | 0.004 | 0.004 | 0.018 | 0.019 | 0.011 | 0.013 | 0.008 | 0.002 | 0.010 | 0.006 | 0.002 | 0.002 | 0.008 | 0.003 | 0.003 | 0.024 |
| 2004 | 0.000 | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.012 | 0.024 | 0.004 | 0.004 | 0.015 | 0.015 | 0.009 | 0.011 | 0.007 | 0.002 | 0.009 | 0.005 | 0.002 | 0.002 | 0.007 | 0.003 | 0.024 |
| 2005 | 0.000 | 0.000 | 0.000 | 0.002 | 0.001 | 0.001 | 0.001 | 0.008 | 0.012 | 0.002 | 0.002 | 0.007 | 0.007 | 0.004 | 0.005 | 0.003 | 0.001 | 0.004 | 0.002 | 0.001 | 0.001 | 0.003 | 0.013 |
| 2006 | 0.000 | 0.000 | 0.000 | 0.001 | 0.005 | 0.002 | 0.001 | 0.001 | 0.009 | 0.013 | 0.002 | 0.002 | 0.007 | 0.007 | 0.004 | 0.005 | 0.003 | 0.001 | 0.004 | 0.002 | 0.001 | 0.001 | 0.016 |

Table 10: Estimates of model parameters, output statistics and fit diagnostics for Model 1 and for the sensitivity tests.

| **Derived Quantities of Interest** | Model 1 | Bayesian Medians | Model 1 | Retro 2006 | Retro 2005 | Model 2005 | Bayesian Medians |
|---|---|---|---|---|---|---|---|
| Depletion in 2007 (or 2005) | 0.275 | 0.311 | (0.241) | (0.232) | (0.227) | (0.234) | (0.266) |
| 2007 spawning biomass (or 2005) | 10,168 | 10,758 | (8,910) | (8,657) | (8,412) | (8,846) | (9,322) |
| Unfished spawning biomass | 36,983 | 34,573 | 36,983 | 37,304 | 37,111 | 37,838 | 35,371 |
| $B_{MSY}$ | 14,793 | 13,557 | 14,793 | 14,922 | 14,844 | 15,135 | 13,767 |
| MSY | 1,411 | 1,437 | 1,411 | 1,291 | 1,237 | 1,181 | 1,266 |
| MSYL | 0.400 | | 0.400 | 0.400 | 0.400 | 0.400 | |
| $F_{MSY}$ | 0.038 | 0.042 | 0.038 | 0.034 | 0.033 | 0.031 | 0.037 |
| Exploitation rate at MSY | 0.039 | 0.042 | 0.039 | 0.036 | 0.034 | 0.032 | 0.038 |
| $F_{2004}/F_{MSY}$ (or $F_{2002}/F_{MSY}$) | 0.091 | | 0.091 | 0.097 | 0.210 | 0.211 | |
| | | | | | | | |
| **Likelihoods** | | | | | | | |
| Objective function | 418.66 | | 418.66 | 396.35 | 369.07 | 347.39 | |
| | | | | | | | |
| Triennial survey biomass likelihood | 45.43 | | 45.43 | 44.37 | 43.53 | 43.16 | |
| POP survey biomass likelihood | 0.15 | | 0.15 | 0.16 | 0.21 | 0.48 | |
| AFSC survey biomass likelihood | 25.99 | | 25.99 | 26.02 | 26.05 | 25.99 | |
| NWFSC survey biomass likelihood | 54.43 | | 54.43 | 51.77 | 51.78 | 54.15 | |
| CPUE likelihood | 11.15 | | 11.15 | 11.21 | 11.19 | 11.56 | |
| Triennial survey age likelihood | -53.36 | | -53.36 | -53.68 | -52.66 | -54.92 | |
| POP/slope survey age likelihood | 124.30 | | 124.30 | 108.45 | 82.46 | 55.08 | |
| Fishery biased age likelihood | 52.74 | | 52.74 | 52.65 | 52.52 | 52.59 | |
| Triennial survey size likelihood | 31.81 | | 31.81 | 32.45 | 33.18 | 33.24 | |
| POP/slope survey size likelihood | 39.10 | | 39.10 | 38.96 | 39.16 | 40.82 | |
| Fishery size likelihood | 22.00 | | 22.00 | 22.20 | 22.58 | 21.65 | |
| Fishery unbiased age likelihood | 25.14 | | 25.14 | 22.10 | 20.16 | 24.13 | |
| | | | | | | | |
| **Priors** | | | | | | | |
| Catch fit prior | 0.24 | | 0.24 | 0.24 | 0.23 | 0.24 | |
| Fdevs prior | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | |
| Fishery selectivity dome prior | 6.21 | | 6.21 | 38.96 | 6.09 | 6.31 | |
| Fishery selectivity change prior | 6.84 | | 6.84 | 6.86 | 6.85 | 6.70 | |
| Fishery selectivity curvature prior | 2.07 | | 2.07 | 1.75 | 1.58 | 1.21 | |
| Survey selectivity curvature prior | 6.68 | | 6.68 | 6.44 | 6.48 | 6.76 | |
| Rho/SigmaR sp-rec prior | 18.99 | | 18.99 | 19.37 | 18.89 | 19.58 | |
| Natural mortality prior | -1.25 | | -1.25 | -1.22 | -1.24 | -1.35 | |
| Steepness prior | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | |
| Catchability prior | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | |
| | | | | | | | |
| **Parameters** | | | | | | | |
| Natural mortality | 0.053 | 0.056 | 0.053 | 0.053 | 0.053 | 0.051 | 0.054 |
| Steepness | 0.652 | 0.679 | 0.652 | 0.579 | 0.569 | 0.551 | 0.596 |
| Triennial survey catchability | 0.248 | 0.257 | 0.248 | 0.252 | 0.260 | 0.252 | 0.256 |
| POP survey catchability | 0.476 | 0.374 | 0.476 | 0.466 | 0.440 | 0.393 | 0.347 |
| NWFSC survey catchability | 0.371 | 0.287 | 0.371 | 0.348 | 0.330 | 0.465 | 0.401 |
| AFSC survey catchability | 0.294 | 0.230 | 0.294 | 0.287 | 0.274 | 0.242 | 0.212 |

Table 11. MPD and Posterior median estimates for spawning biomass and recruitment.

| | MPD estimates | | Posterior Medians | |
|---|---|---|---|---|
| Year | SpBiomass | Recruits | SpBiomass | Recruits |
| 1956 | 32748 | 3.82 | 30465 | 5.00 |
| 1957 | 31570 | 46.80 | 29432 | 42.85 |
| 1958 | 30490 | 4.09 | 28695 | 5.58 |
| 1959 | 30125 | 18.63 | 28645 | 17.47 |
| 1960 | 29944 | 8.80 | 28842 | 8.92 |
| 1961 | 30193 | 4.15 | 29481 | 4.11 |
| 1962 | 31992 | 3.54 | 31421 | 3.47 |
| 1963 | 33654 | 4.87 | 33074 | 4.67 |
| 1964 | 33291 | 14.06 | 32786 | 15.27 |
| 1965 | 32946 | 10.01 | 32395 | 10.69 |
| 1966 | 30407 | 6.66 | 29899 | 6.85 |
| 1967 | 21651 | 4.29 | 21196 | 4.60 |
| 1968 | 15806 | 3.32 | 15377 | 3.48 |
| 1969 | 13893 | 3.64 | 13541 | 3.68 |
| 1970 | 15520 | 2.70 | 15306 | 2.98 |
| 1971 | 16286 | 3.84 | 16205 | 4.04 |
| 1972 | 16609 | 4.78 | 16605 | 4.48 |
| 1973 | 16729 | 6.99 | 16799 | 7.97 |
| 1974 | 16357 | 3.72 | 16459 | 3.50 |
| 1975 | 16053 | 1.47 | 16198 | 1.50 |
| 1976 | 16073 | 1.48 | 16265 | 1.44 |
| 1977 | 15985 | 1.62 | 16169 | 1.67 |
| 1978 | 16311 | 1.55 | 16548 | 1.55 |
| 1979 | 16099 | 1.08 | 16373 | 1.07 |
| 1980 | 15540 | 0.97 | 15819 | 1.01 |
| 1981 | 14687 | 1.82 | 14971 | 1.95 |
| 1982 | 13882 | 2.91 | 14170 | 2.74 |
| 1983 | 13295 | 2.24 | 13588 | 2.39 |
| 1984 | 12173 | 5.39 | 12453 | 5.70 |
| 1985 | 11156 | 1.10 | 11435 | 1.08 |
| 1986 | 10306 | 1.16 | 10573 | 1.16 |
| 1987 | 9702 | 2.36 | 9951 | 2.60 |
| 1988 | 9403 | 3.66 | 9640 | 3.48 |
| 1989 | 9115 | 0.66 | 9350 | 0.72 |
| 1990 | 8752 | 2.14 | 8997 | 2.30 |
| 1991 | 8379 | 3.13 | 8631 | 3.40 |
| 1992 | 7829 | 2.29 | 8045 | 2.36 |
| 1993 | 7598 | 3.45 | 7801 | 3.78 |
| 1994 | 7215 | 3.05 | 7382 | 3.34 |
| 1995 | 6917 | 0.65 | 7094 | 0.68 |
| 1996 | 6856 | 0.73 | 7041 | 0.73 |
| 1997 | 6882 | 5.07 | 7084 | 5.74 |
| 1998 | 7055 | 3.69 | 7272 | 4.04 |
| 1999 | 7249 | 0.53 | 7526 | 0.55 |
| 2000 | 7331 | 0.82 | 7624 | 0.87 |
| 2001 | 7489 | 1.69 | 7798 | 1.89 |
| 2002 | 7826 | 10.47 | 8181 | 11.38 |
| 2003 | 8428 | 5.35 | 8826 | 6.37 |
| 2004 | 8791 | 3.13 | 9214 | 3.06 |
| 2005 | 8910 | 1.61 | 9343 | 1.58 |
| 2006 | 9210 | 1.48 | 9686 | 1.45 |
| 2007 | 10168 | | 10758 | |

## 1.7. Figures

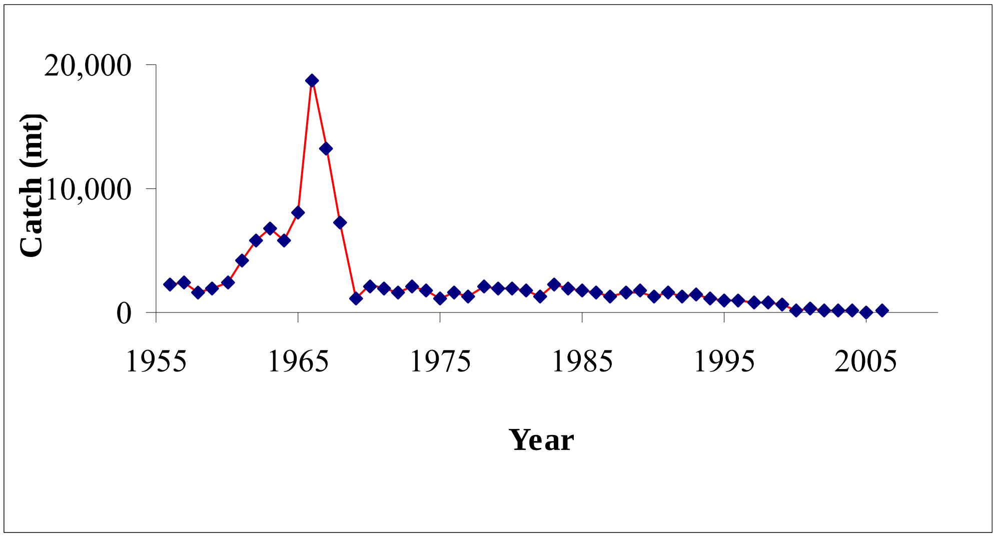



Figure 1. Catch history of Pacific ocean perch (domestic and foreign fleets combined).

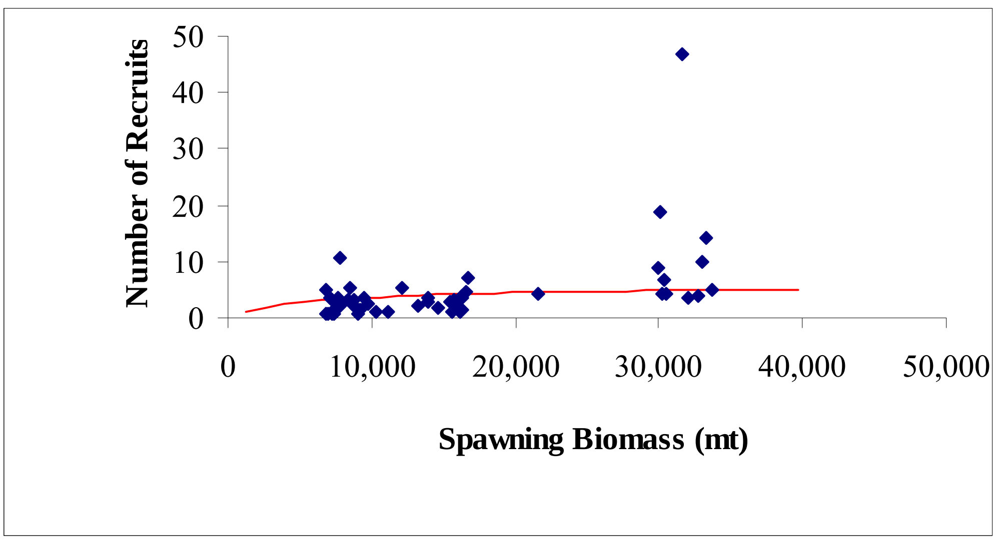



Figure 2: Fit of the deterministic stock-recruitment relationship to the spawning stock biomass and recruitment estimates.

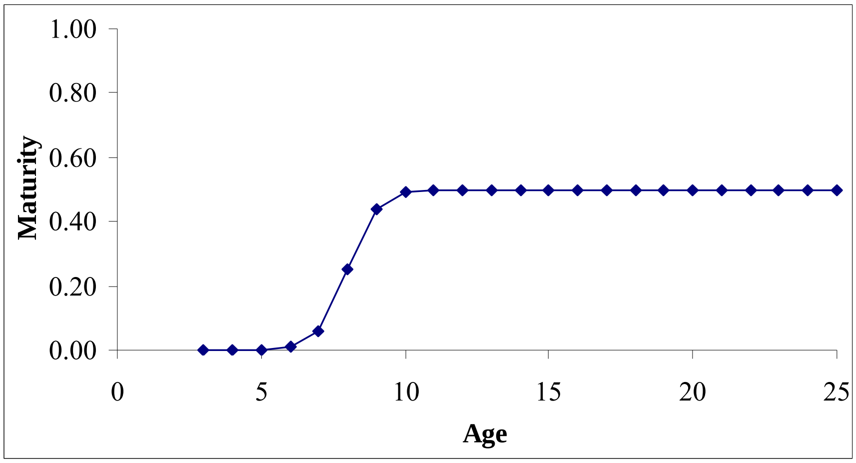



Figure 3. Modeled proportion of Pacific ocean perch that are mature females by age.

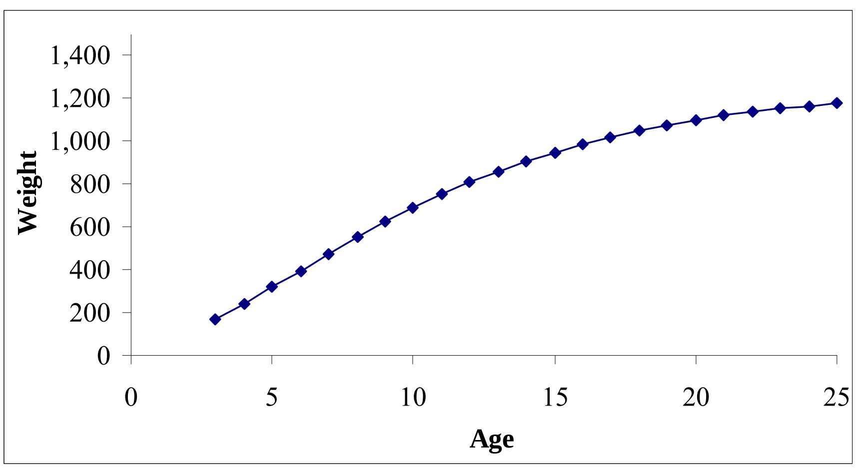



Figure 4. Weight at age (grams) for Pacific ocean perch used in the assessment model.

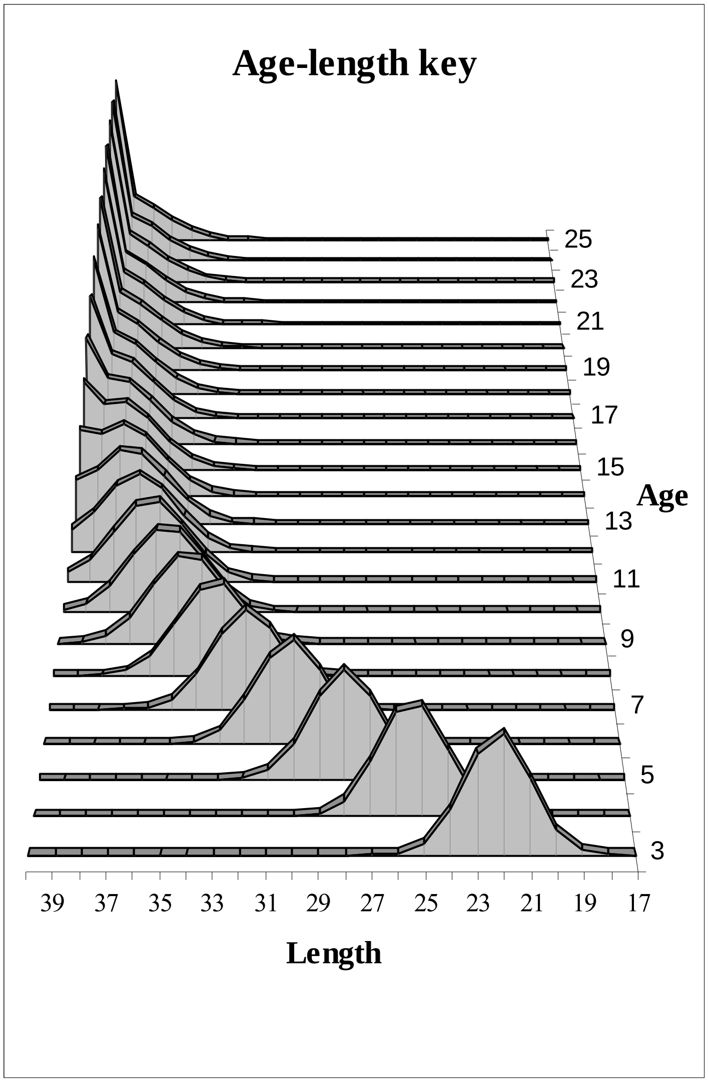



Figure 5. Length distributions by age used in the age-length transition matrix.

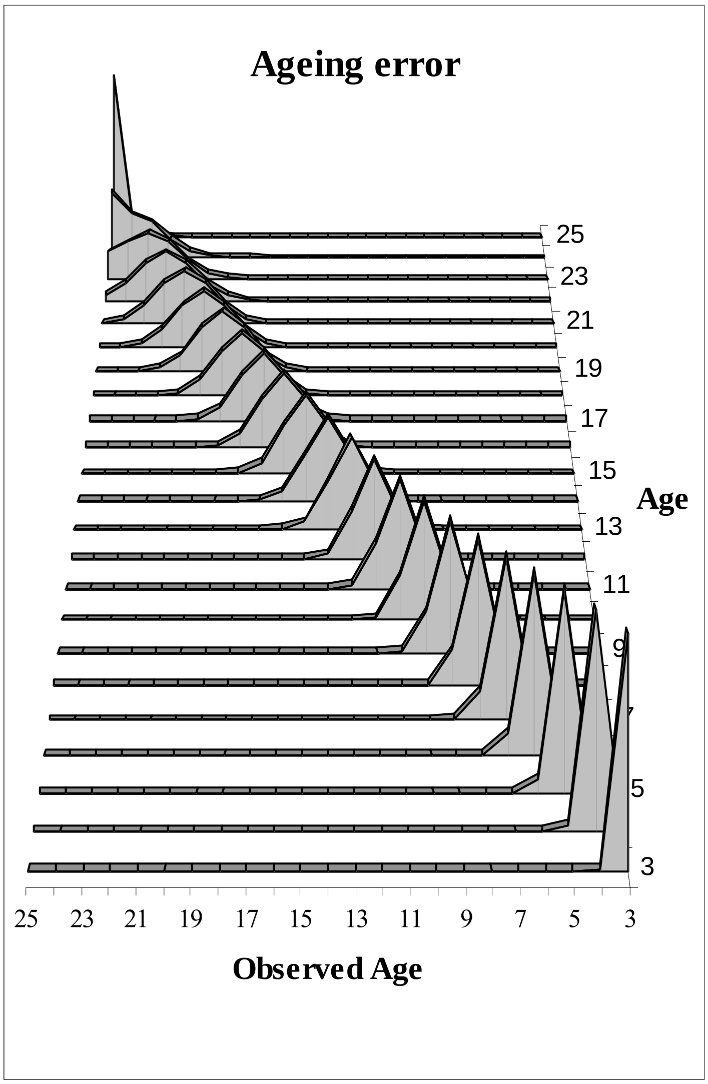



Figure 6. Assumed relationship between observed age and true age used as an ageing error matrix.

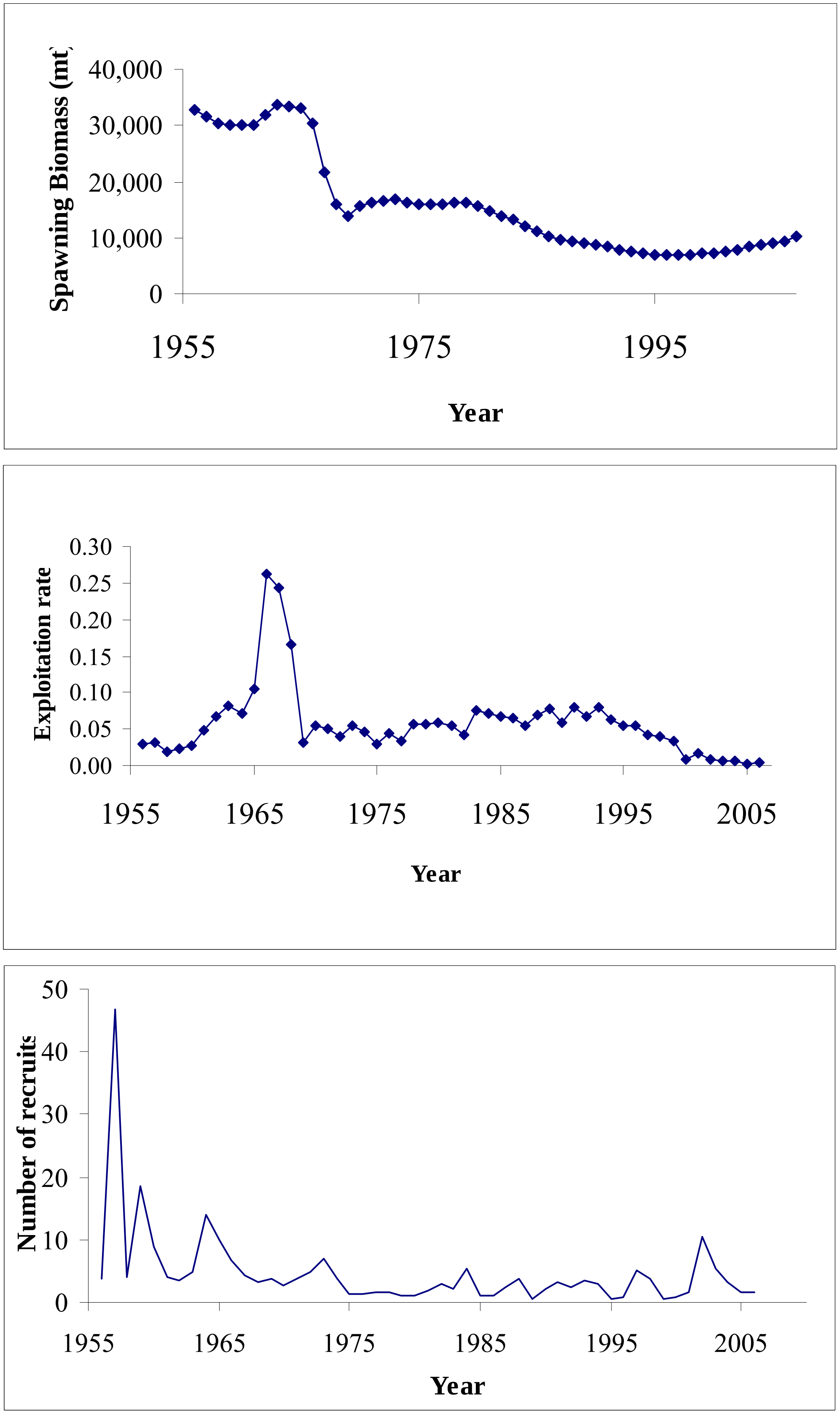
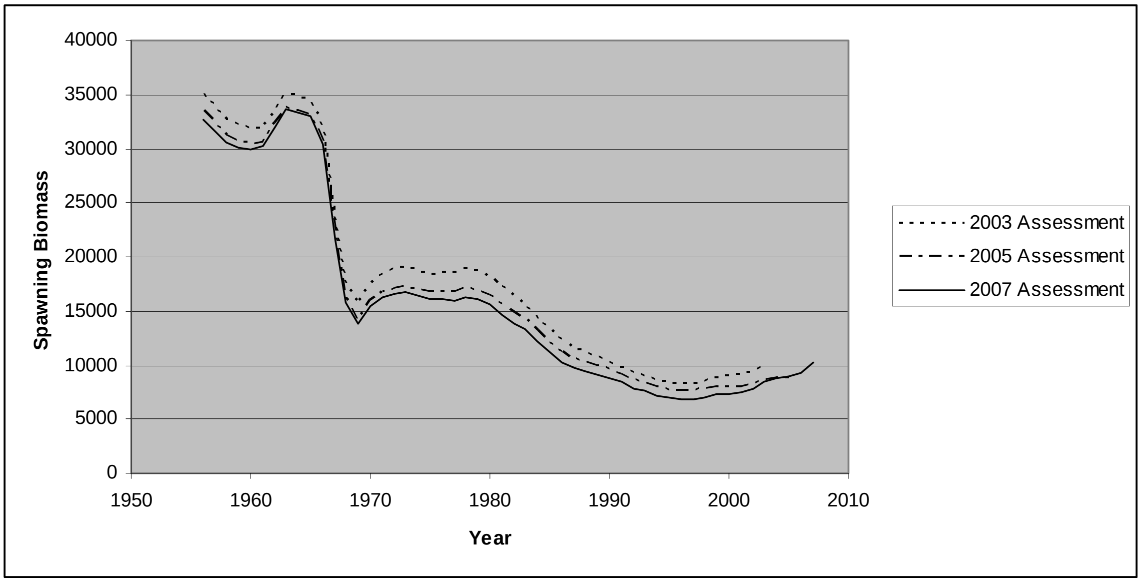



Figure 7. Time series of spawning biomass, exploitation rate and recruitment.



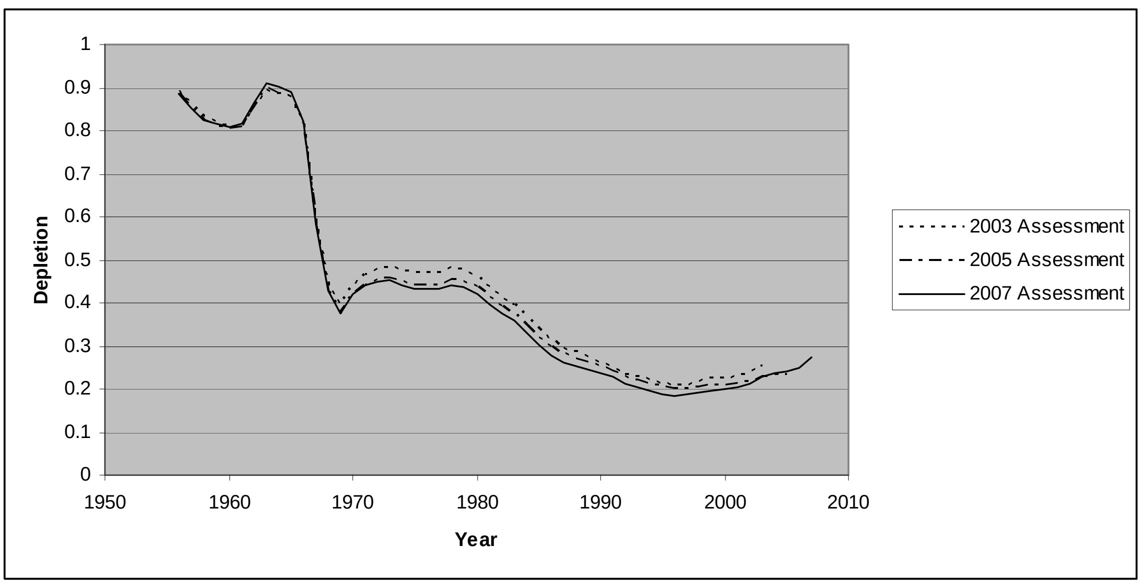




Figure 8. Time series of MPD estimates of spawning biomass and depletion from 2003, 2005 and 2007 base assessment models.

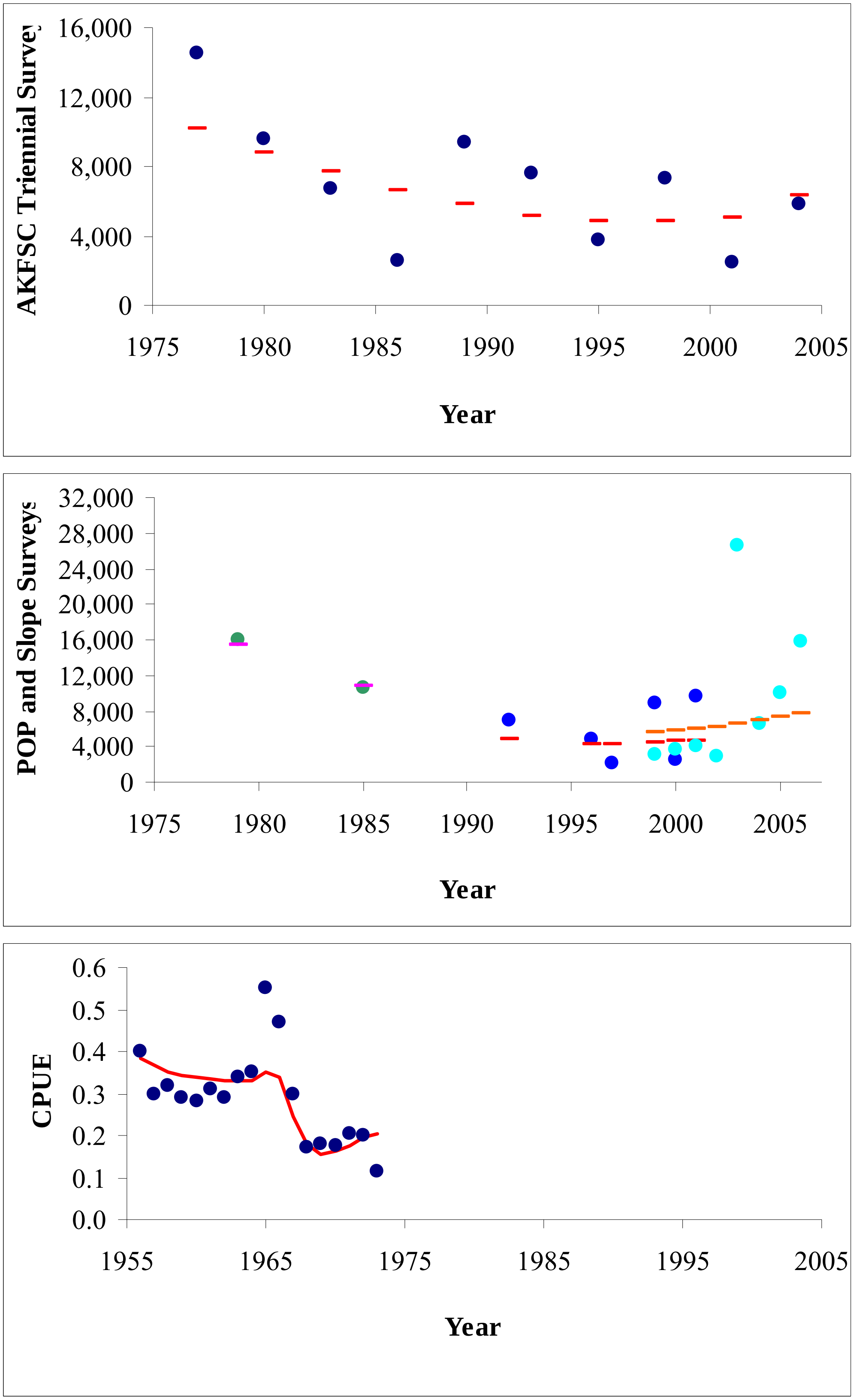



Figure 9. Fit of Model 1 to the survey biomass indices and to the fishery CPUE (mt/hr) data. Note that each survey has a unique catchability coefficient so that there is a separate trajectory of survey-selected biomass for each survey; the curves shown are only through expected biomass indices for the years of data.

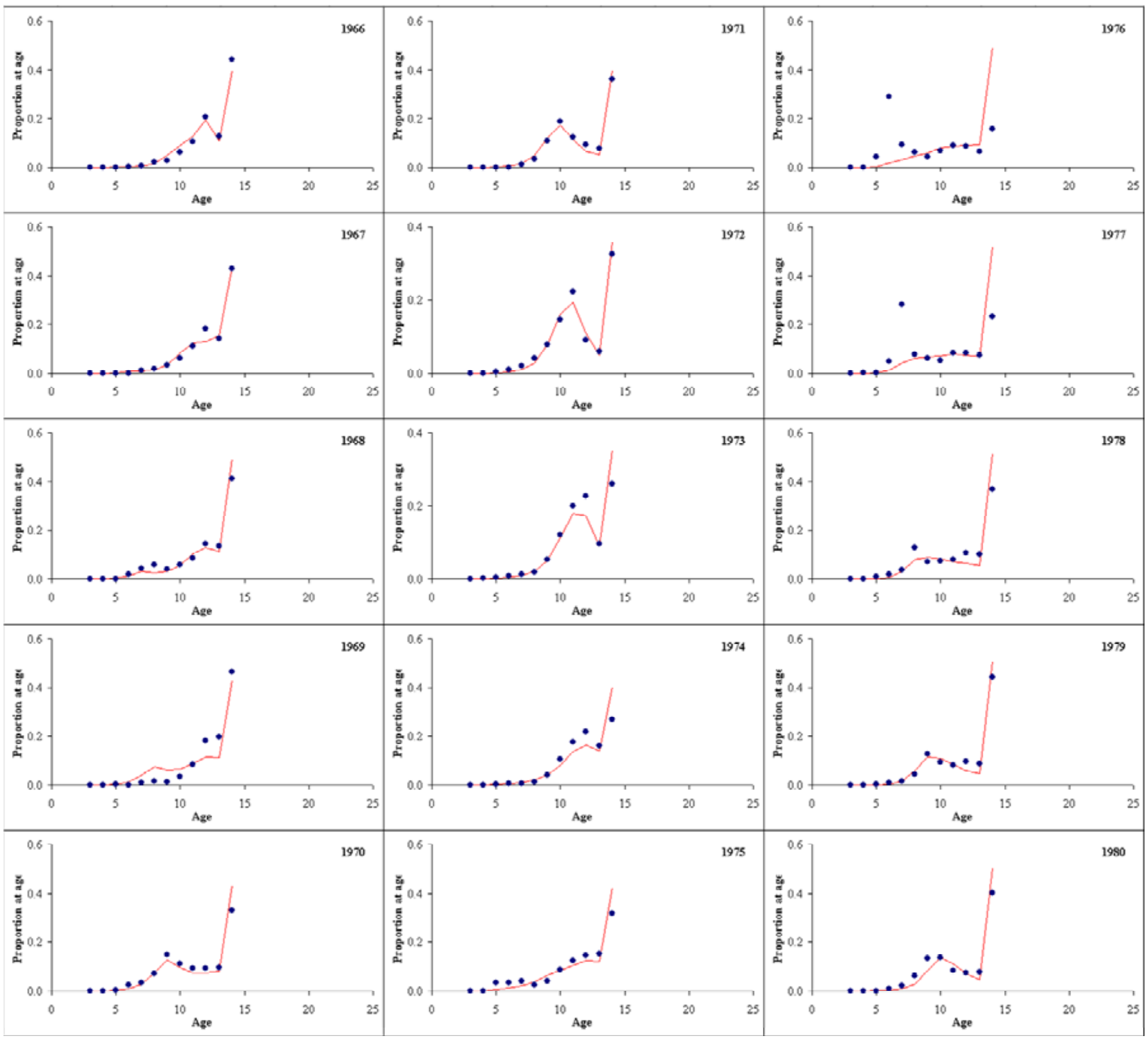



Figure 10. Fit of model 1 to the “biased” (1966-80) fishery age-composition data.

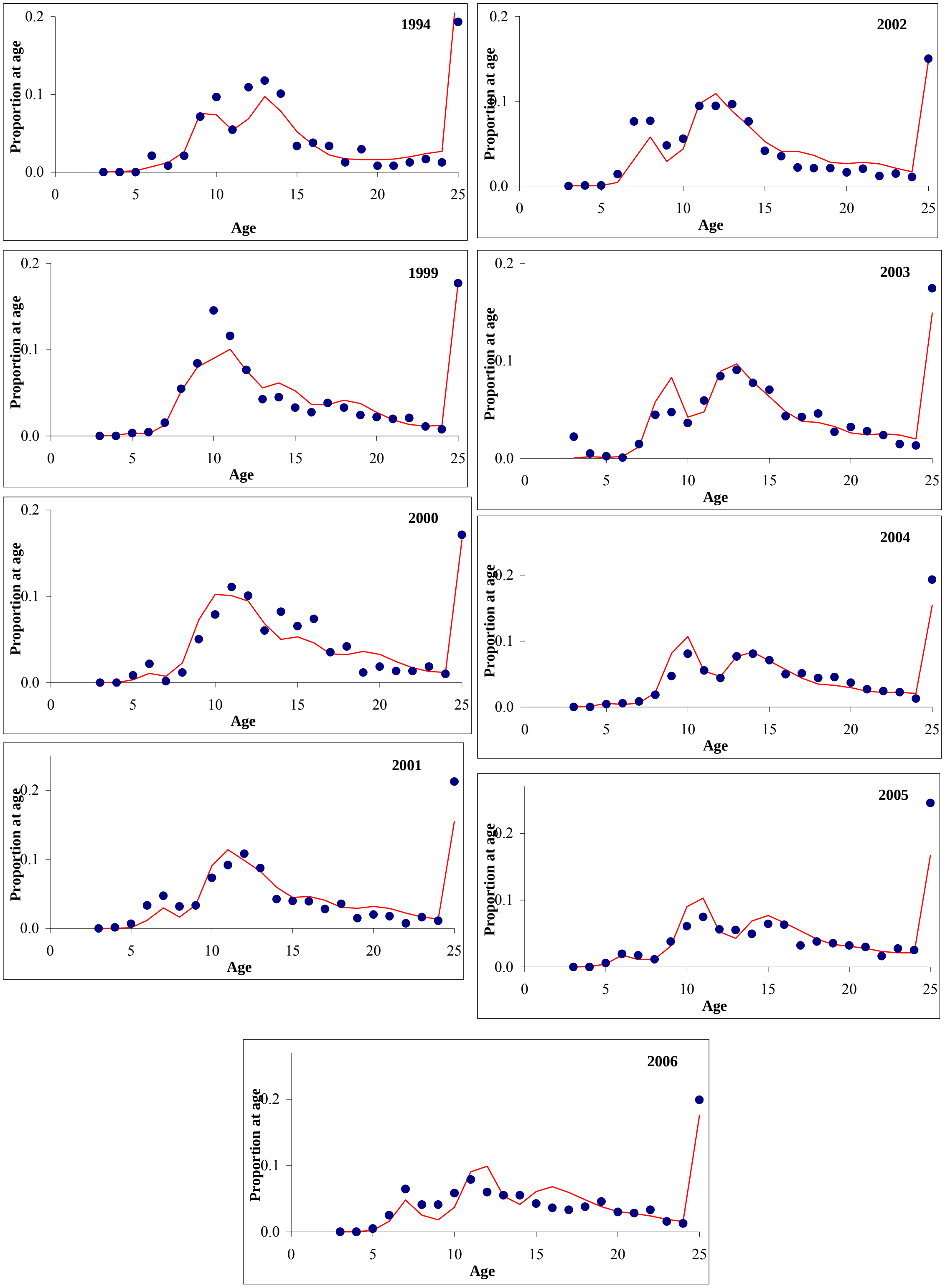



Figure 11. Fit of Model 1 to the “unbiased” (1994,1999-2004) fishery age-composition data.

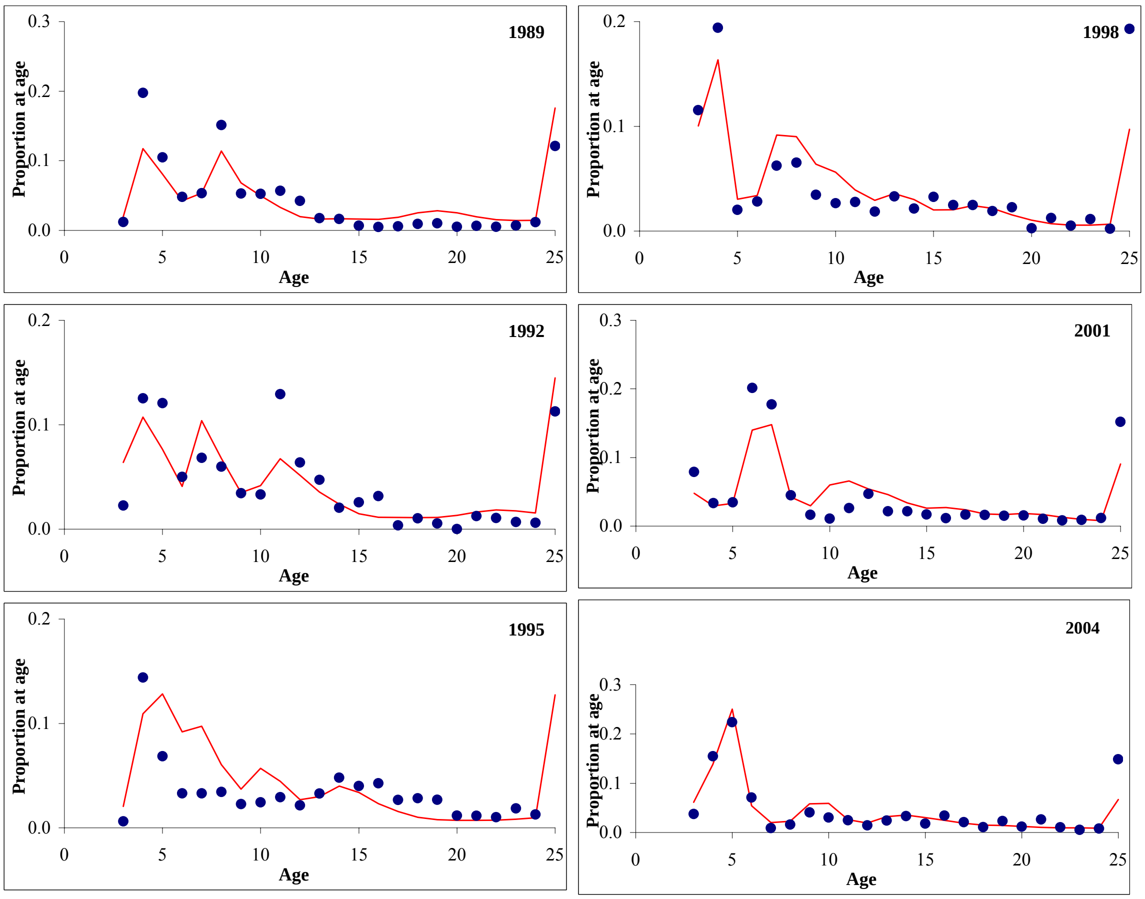



Figure 12. Fit of model 1 to triennial survey age-composition data.

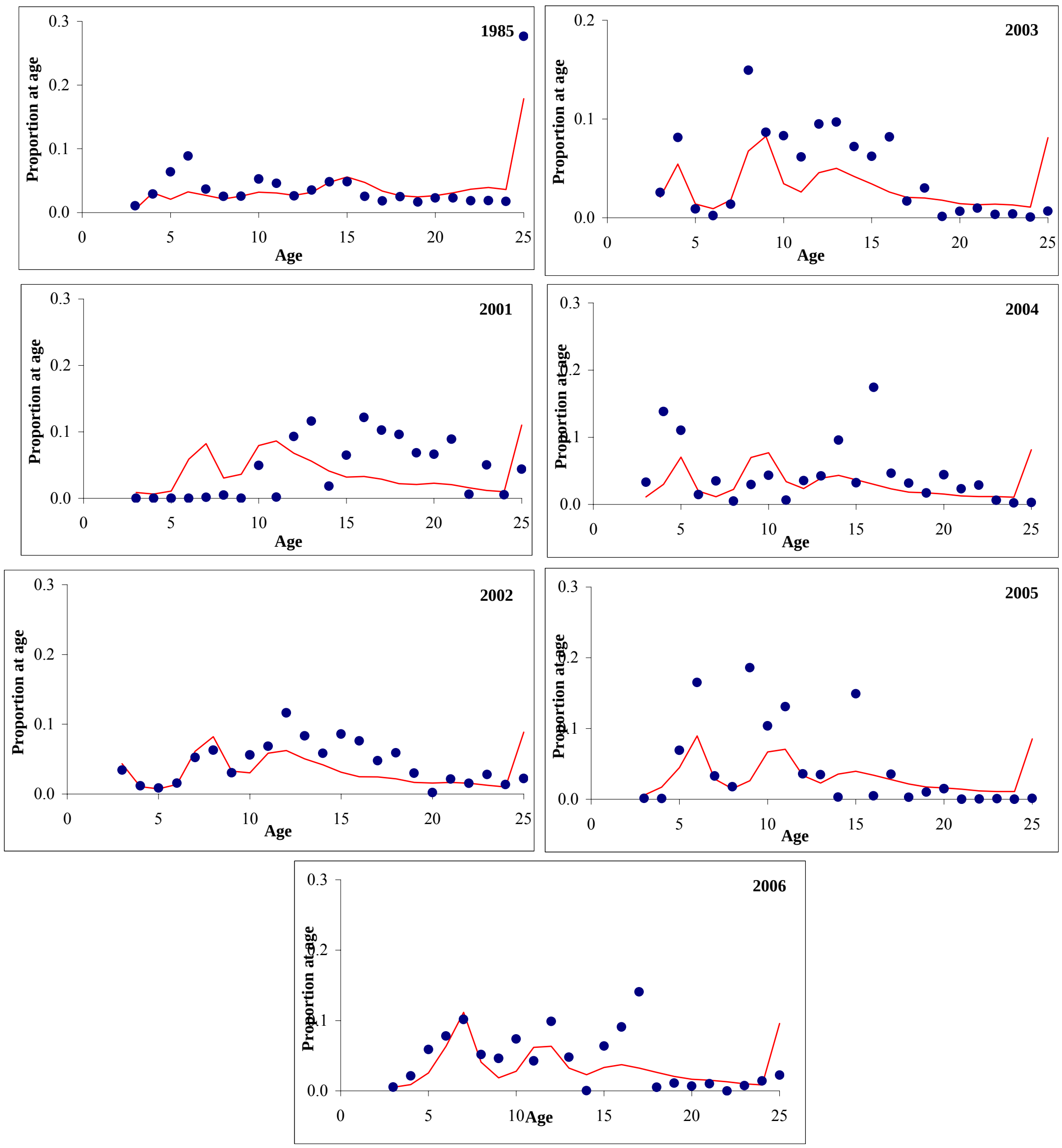



Figure 13. Fit of Model 1 to POP and slope survey age-composition data.

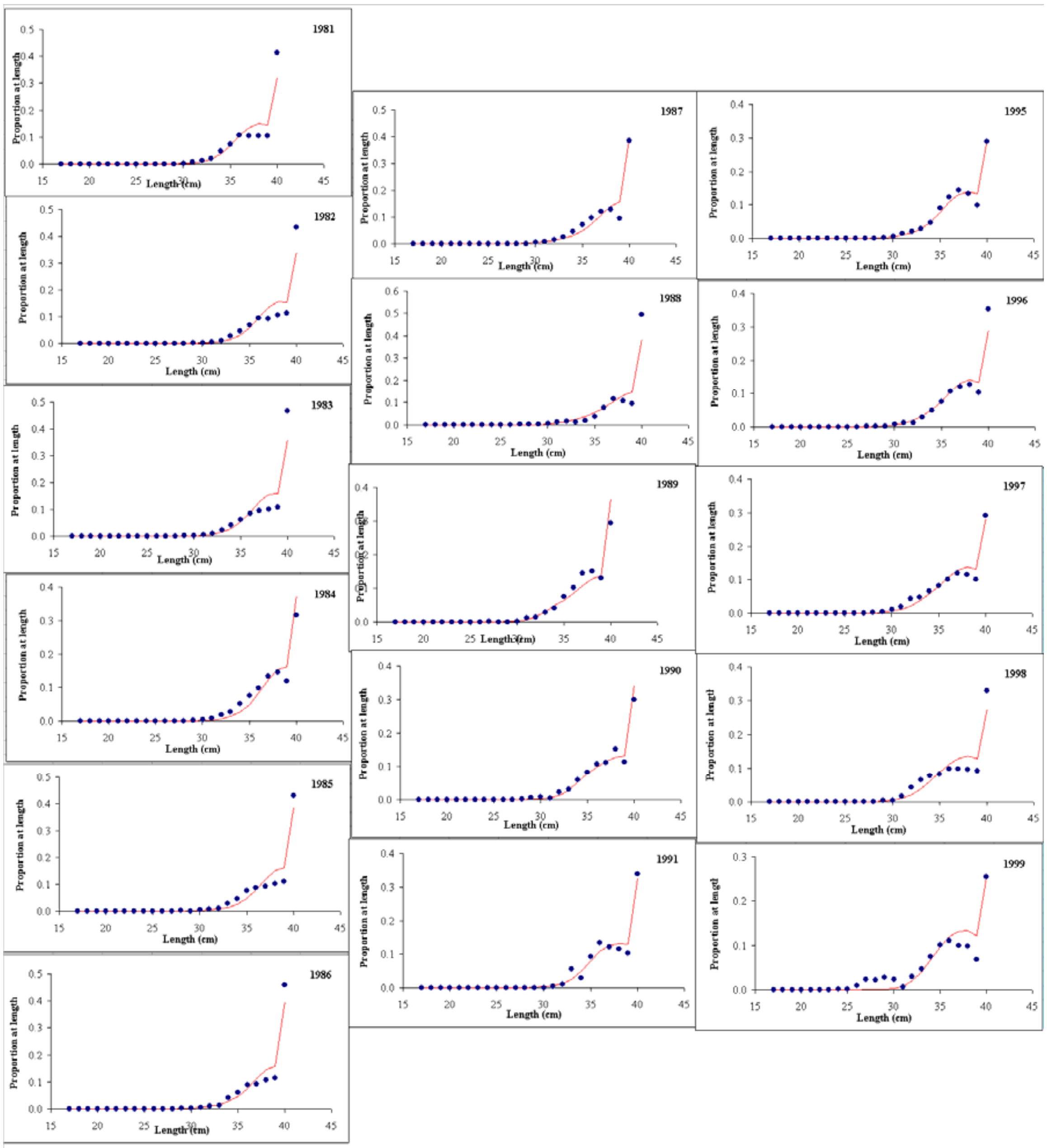


Figure 14. Fit of Model 1 to fishery size-composition data (1981-1991,1995-1998).

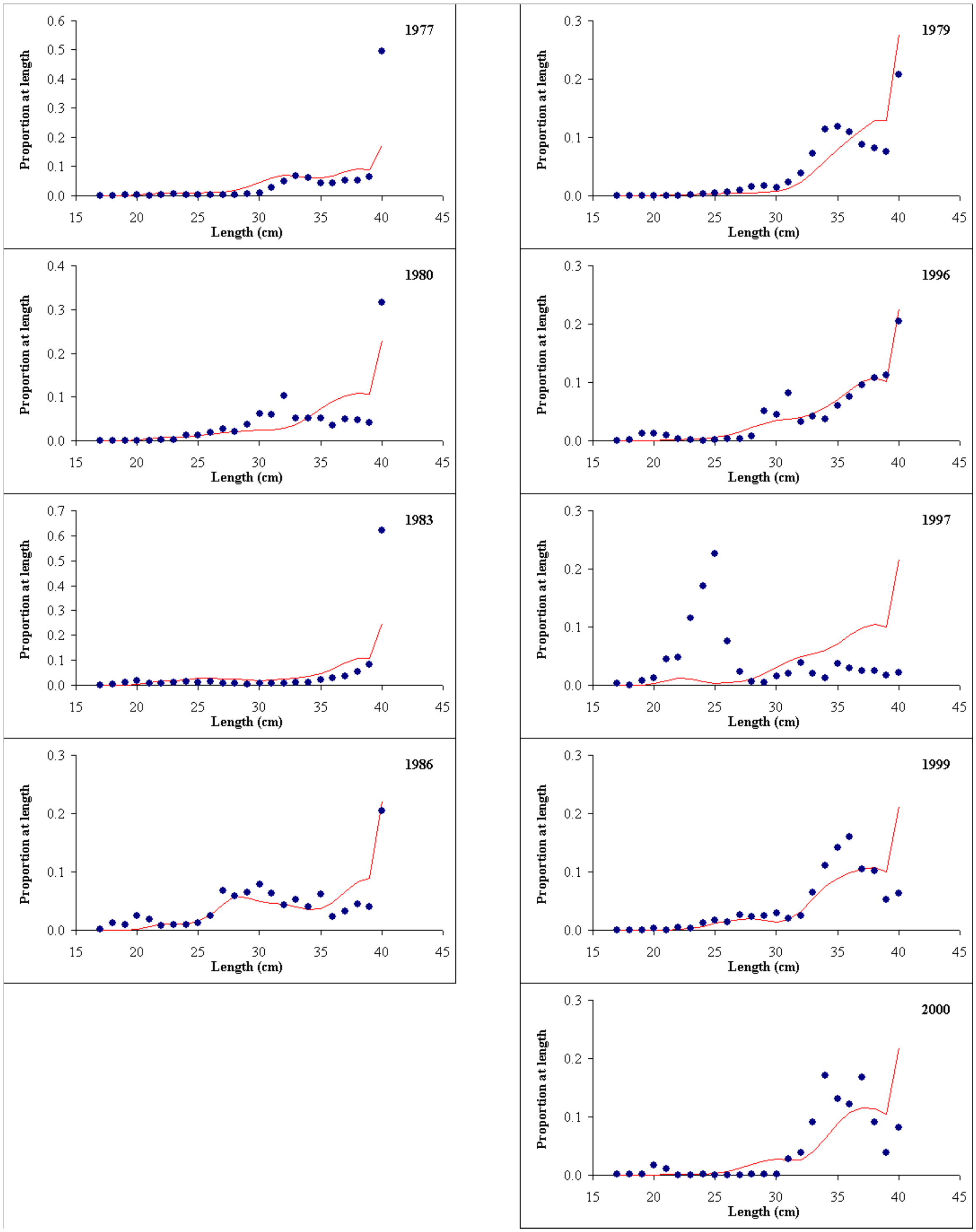



Figure 15. Fit of Model 1 to triennial and slope survey size-composition data.

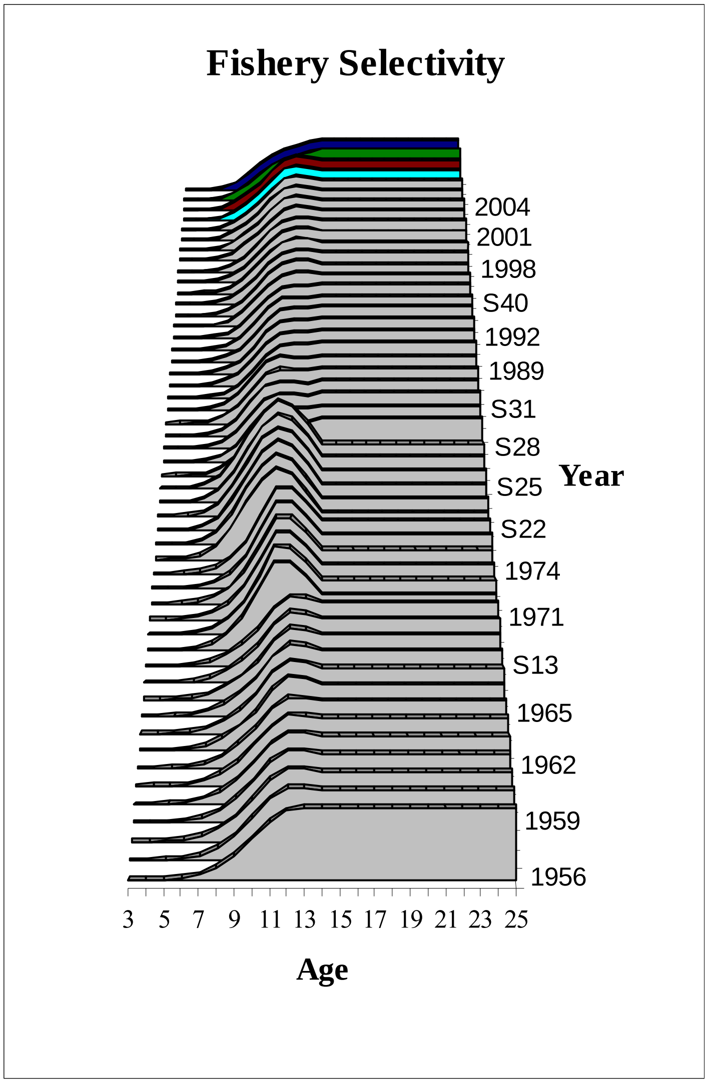
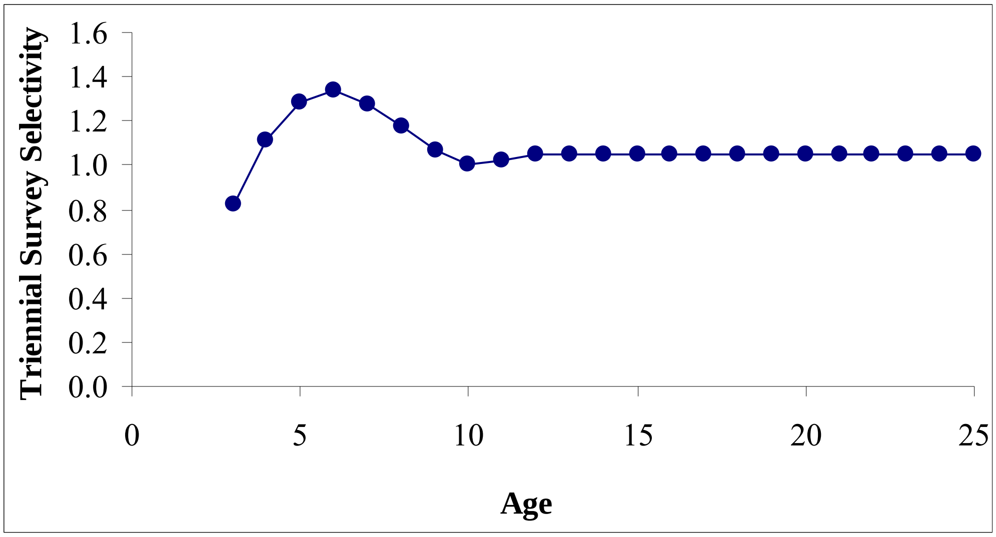



Figure 16. Fishery selectivity patterns (1956-2007).



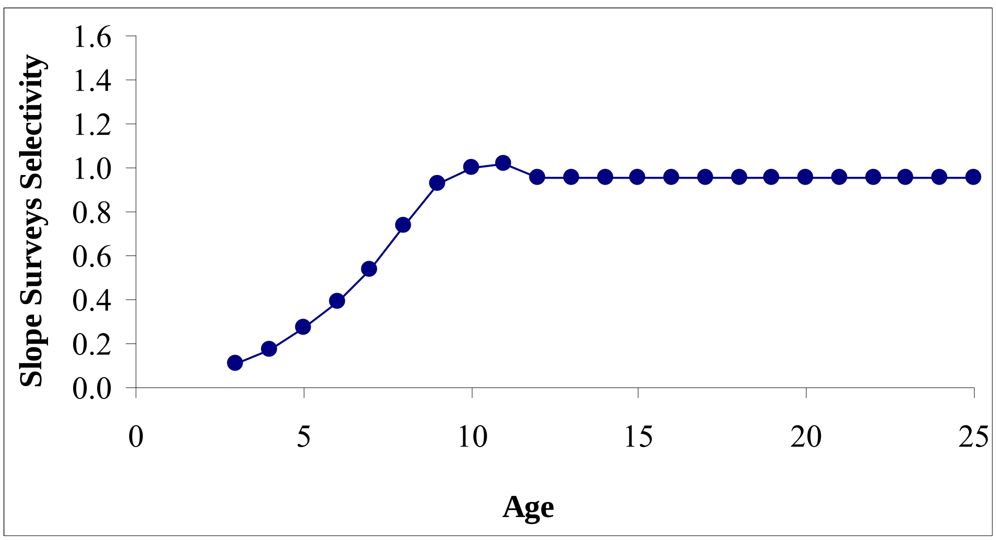




Figure 17. Selectivity patterns for the triennial and slope surveys.

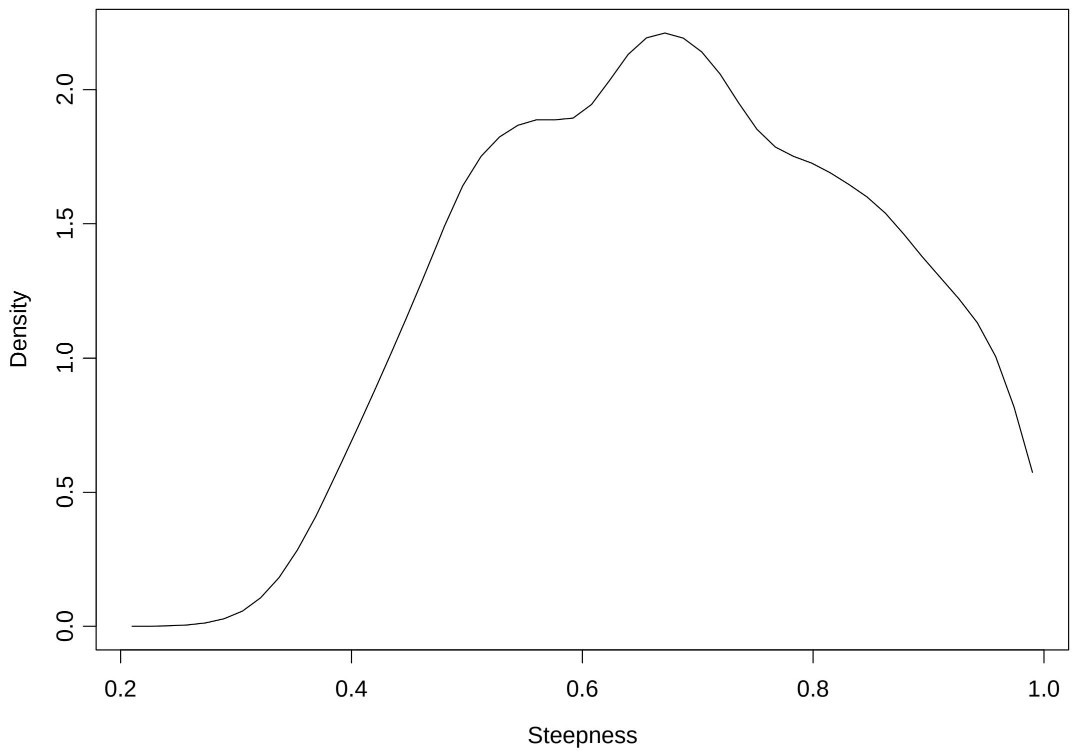



Figure 18. Posterior density for steepness.

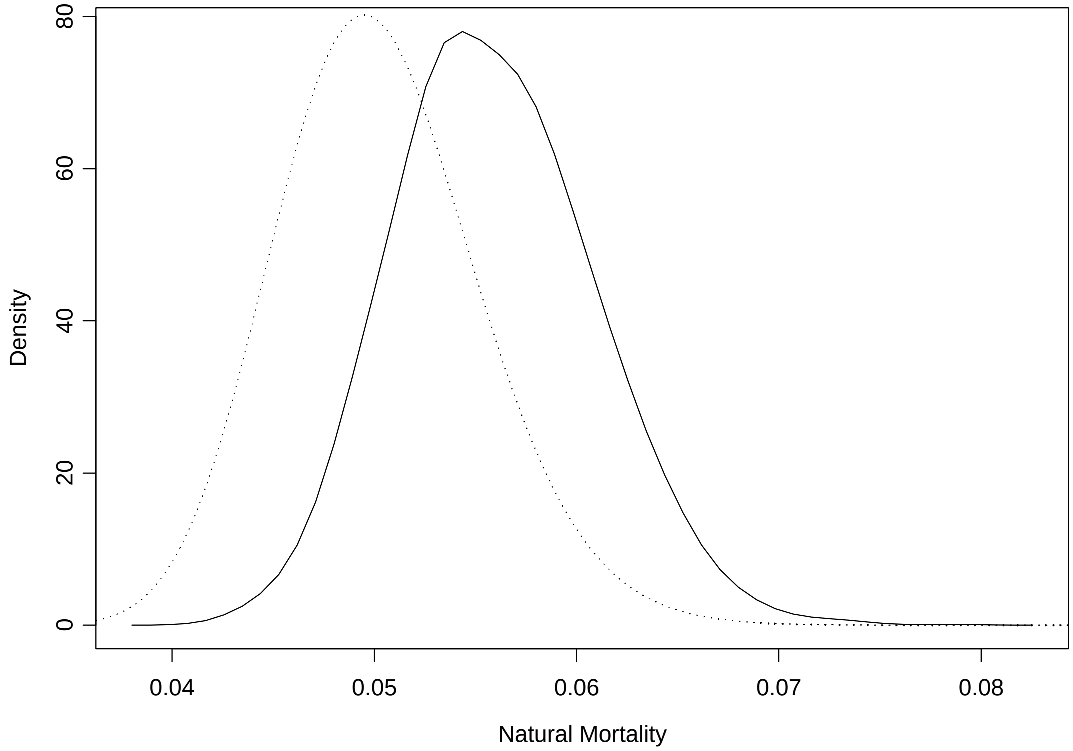



Figure 19. Prior (dotted curve) and posterior (solid curve) densities for natural mortality.

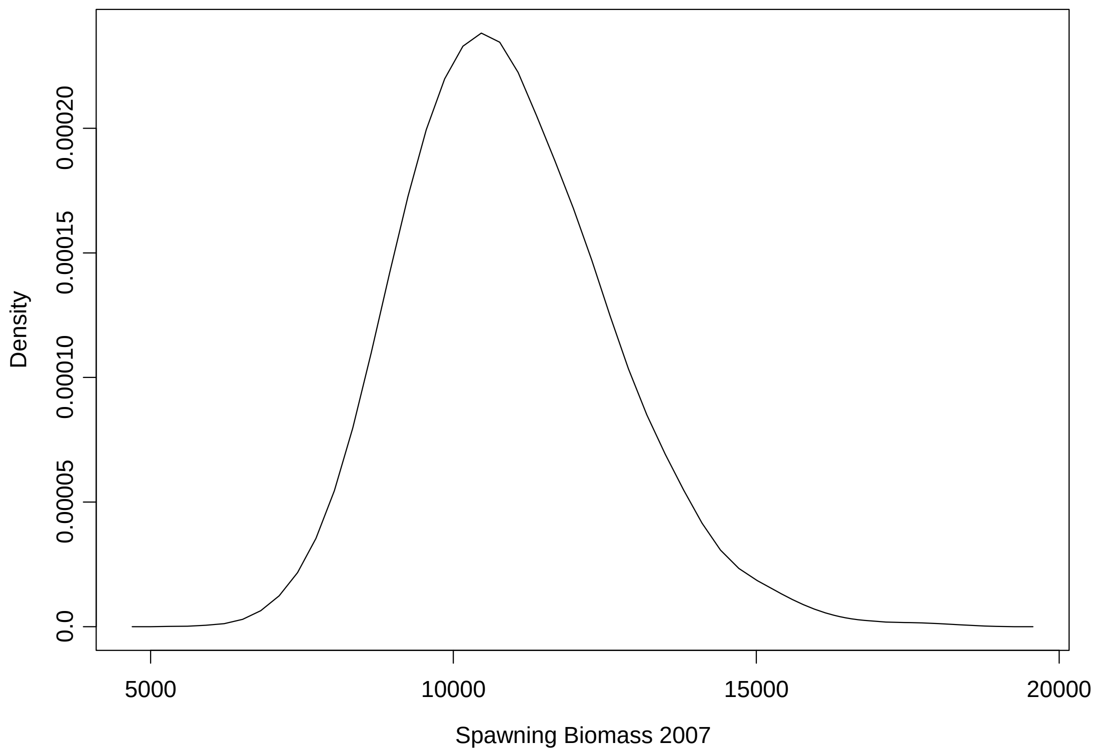



Figure 20. Posterior density for spawning biomass in 2007

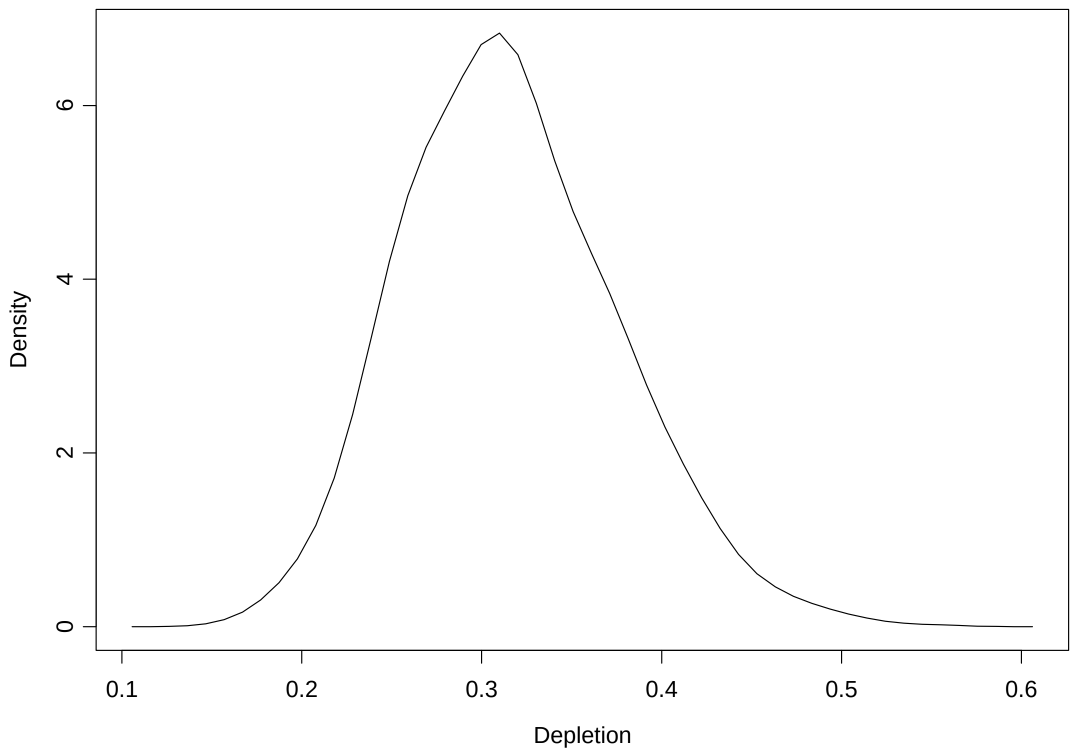



Figure 21. Posterior density for depletion in 2007.

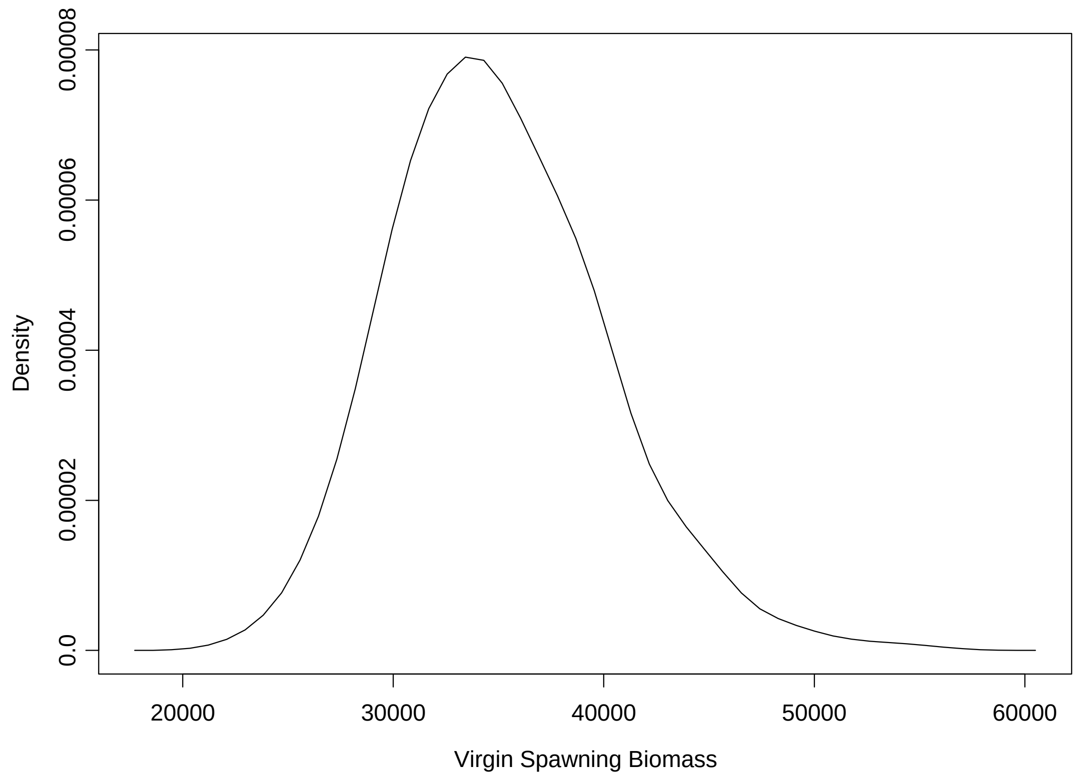



Figure 22. Posterior density for virgin spawning biomass in 2007.