APPENDIX 3

2005 PACIFIC MACKEREL STOCK ASSESSMENT
AND
STOCK ASSESSMENT REVIEW PANEL REPORT

The 2005 Pacific mackerel stock assessment and harvest guideline for 2005-2006 fishery management were approved at the June 2005 Council meeting and can be found at the Council web page at the link below.

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ASSESSMENT OF THE PACIFIC MACKEREL (*Scomber japonicus*) STOCK FOR U.S. MANAGEMENT IN THE 2005-2006 SEASON

by

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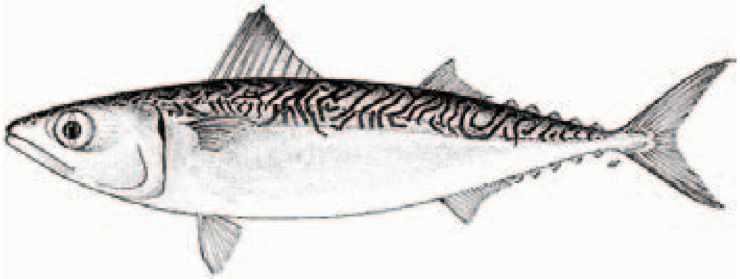

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LIST OF ACRONYMS AND ABBREVIATIONS

ADAPT	adaptive framework (age-structured, ‘tunable’ VPA)
ADEPT	ADAPT model modified for Pacific mackerel
ADMB	automatic differentiation model builder
ASAP	age structured assessment program
CA	California
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CDFG	California Department of Fish and Game
CICIMAR-IPN	Centro Interdisciplinario de Ciencias Marinas – Instituto Politécnico Nacional (La Paz, Baja California, México)
CPFV	commercial passenger fishing vessel (or ‘partyboat’)
CPS	Coastal Pelagic Species
CPSMT	Coastal Pelagic Species Management Team
CPSAS	Coastal Pelagic Species Advisory Subpanel
CPUE	catch per unit of effort
CV	coefficient of variation
FMP	fishery management plan
GLM	general linear model
GUI	graphical user interface
HG	harvest guideline
IMECOCAL	Investigaciones Mexicanas de la Corriente de California
INP-CRIP	Instituto Nacional de la Pesca – Centro Regional de Investigación Pesquera
MSY	maximum sustainable yield
MX	Mexico
NMFS	National Marine Fisheries Service
NOAA Fisheries	National Oceanic and Atmospheric Administration, National Marine Fisheries Service
PFMC	Pacific Fishery Management Council
RecFIN	Recreational Fishery Information Network
SAFE	Stock Assessment and Fishery Evaluation document
SSB	spawning stock biomass
SSC	Scientific and Statistical Committee
STAR	Stock Assessment Review (Panel)
SWFSC	Southwest Fisheries Science Center (NMFS)
VPA	virtual population analysis

PREFACE

A Pacific mackerel stock assessment is conducted annually in support of the Pacific Fishery Management Council (PFMC) process, which ultimately establishes a harvest guideline (‘HG’ or quota) for the Pacific mackerel fishery that operates off the U.S. Pacific coast. The HG for mackerel applies to a fishing/management season that spans from July 1st and ends on June 30th of the subsequent year (i.e., a ‘fishing year’ basis). The primary purpose of the assessment is to provide an estimate of current abundance (in biomass), which is used in a harvest control rule for calculation of annual-based HGs. For details regarding this species’ harvest control rule, see Amendment 8 of the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP), section 4.0 (PFMC 1998).

The last assessment and quota-setting process was completed in June 2004—setting a 2004-05 ‘fishing year’ (July 1, 2004 – June 30, 2005) quota of 13,268 mt. In June 2004, the PFMC, in conjunction with NOAA Fisheries (Southwest Fisheries Science Center), organized a Stock Assessment Review (STAR) in La Jolla, California, to provide external peer review of the methods used for assessment of Pacific mackerel, as well as Pacific sardine. The following assessment report was initially prepared in draft form for the STAR Panel’s consideration, and is updated here for the PFMC’s current ‘management cycle.’ The STAR Panel Report for Pacific mackerel (PFMC 2004) included recommendations for improving the input data and model configuration. Many of these recommendations were incorporated into this updated assessment which, ultimately, is to be reviewed by the Science and Statistical Committee (SSC) of the PFMC in June 2005. For example, additional data that were not available at the time of the STAR Meeting in 2004 have been incorporated into this update, including: (1) an additional year of data associated with assessment updates (e.g., from ongoing fishery-dependent and fishery-independent sampling programs), as well as considerable enhancements to the historical catch-at-age time series; and (2) model-related considerations and sensitivity analysis. Electronic versions of model programs, input data, and displays (tables and figures) can be obtained from the authors directly. Finally, in May 2005, the assessment presented here was reviewed by the PFMC’s CPS Management Team (CPSMT).

EXECUTIVE SUMMARY

Stock assessment modeling of Pacific mackerel was conducted using a forward-simulation, maximum likelihood-based Age-structured Assessment Program (ASAP). The ASAP model is based on the 'Automatic Differentiation Model Builder' (ADMB) software environment, which is essentially a C++ library of automatic differentiation code for nonlinear statistical optimization.

The final (baseline) ASAP model was based on fishery-dependent data from a single fishery, i.e., combined landings from California's commercial and recreational fisheries, and the fishery off Baja California, Mexico. Fishery-independent data used in the model consisted of relative abundance time series (indices) developed from three research surveys: an index ('proportion positive') of spawning abundance based on ichthyoplankton data collected through the ongoing CalCOFI survey; a standardized, catch-per-unit-effort (CPUE) index from California-based commercial passenger fishing vessel (CPFV) logbooks; and an index of total abundance from aerial spotter plane survey data. Parameterization of the baseline model was similar to the final STAR-based model recommended in the most recent review of this ongoing assessment.

Based on the Pacific mackerel stock biomass estimate from the assessment presented here, the PFMC-stipulated harvest control rule for U.S. fisheries results in a HG of 17,419 mt for the 2005-06 fishing season (July 1, 2005 – June 30, 2006). This HG recommendation is 32% greater than the HG adopted by the PFMC for the 2004-05 fishing year (13,268 mt).

INTRODUCTION

Distribution

Pacific mackerel (*Scomber japonicus*; a.k.a. ‘chub’ or ‘blue’ mackerel) in the northeastern Pacific range from Banderas Bay (Puerto Vallarta), Mexico, to southeastern Alaska, including the Gulf of California (Hart 1973). They are common from Monterey Bay, California, to Cabo San Lucas, Baja California, but are most abundant south of Point Conception, California. Pacific mackerel usually occur within 30 km of shore, but have been taken as far offshore as 400 km (Fitch 1969; Frey 1971; Allen et al. 1990; MBC 1987).

Migration

Pacific mackerel adults are found in water ranging from 10.0 - 22.2°C (MBC 1987), and larvae may be found in water around 14°C (Allen et al. 1990). As adults, Pacific mackerel move north in summer and south in winter between Washington and Baja California (Fry and Roedel 1949, Roedel 1949): northerly movement in the summer is accentuated during El Niño events (MBC 1987). There is an inshore-offshore migration off California, with increased inshore abundance from July to November and increased offshore abundance from March to May (Cannon 1967; MBC 1987). Adult Pacific mackerel are commonly found near shallow banks. Juveniles are found off sandy beaches, around kelp beds, and in open bays. Adults are found from the surface to depths of 300 meters (Allen et al. 1990). Pacific mackerel often school with other CPS, particularly jack mackerel and Pacific sardine.

During the last two decades, the stock has more fully occupied the northernmost portions of its range in response to a warm oceanographic regime in the northeast Pacific Ocean, and Pacific mackerel have been found as far north as British Columbia, Canada (Ware and Hargreaves 1993; Hargreaves and Hungar 1995). During summer months, Pacific mackerel have become common incidental catch in commercial whiting and salmon fisheries off the Pacific northwest. In addition, they are taken by recreational anglers on CPFVs. Pacific mackerel sampled from Pacific northwest incidental fisheries are generally older and larger-at-age than those captured in the southern California fishery (Hill 1999).

Life History

Pacific mackerel found off the Pacific coast of the U.S. is the same species found elsewhere in the Pacific, Atlantic, and Indian oceans (Collette and Nauen 1983). Synopses of the biology of Pacific mackerel are available in Kramer (1969) and Schaefer (1980).

There are possibly three spawning stocks in the northeastern Pacific: one in the Gulf of California, one near Cabo San Lucas, and one along the Pacific coast north of Punta Abreojos, Baja California. Spawning occurs from Point Conception, California to Cabo San Lucas, from three to 320 km offshore (Moser et al. 1993). Off California, spawning occurs from late April to September at depths to 300 feet. Off central Baja California, spawning occurs year round, peaking from June through October. Around Cabo San

Lucas, spawning occurs primarily from late fall to early spring. Pacific mackerel seldom spawn north of Point Conception (Fritzsche 1978; MBC 1987), although young-of-year mackerel have been recently reported as far north as Oregon and Washington.

Like most small pelagic species, Pacific mackerel have indeterminate fecundity and seem to spawn whenever sufficient food is available and appropriate environmental conditions prevail. Individual fish may spawn eight times or more per year and release batches of 68,000 eggs per spawning. Actively spawning fish appear capable of spawning every day or every other day (Dickerson et al. 1992).

Pacific mackerel larvae eat copepods and other zooplankton including fish larvae (Collette and Nauen 1983; MBC 1987). Juvenile and adult mackerel feed on small fish, fish larvae, squid, and pelagic crustaceans such as euphausids (Clemmens and Wilby 1961; Turner and Sexsmith 1967; Fitch 1969; Fitch and Lavenberg 1971; Frey 1971; Hart 1973; Collette and Nauen 1983). Pacific mackerel larvae are subject to predation from a number of invertebrate and vertebrate planktivores. Juvenile and adults are eaten by larger fishes, marine mammals, and seabirds. Principal predators include porpoises, California sea lions, pelicans, and large piscivorous fishes such as sharks and tuna. Pacific mackerel school as a defense against predation, often with other pelagic species, including jack mackerel and Pacific sardine.

Dynamics of the Pacific mackerel population have been thoroughly described by Parrish and MacCall (1978). Pacific mackerel experience cyclical periods of abundance (‘boom-bust’) typical of other small pelagic species (e.g. sardine, anchovy) with short life spans and high intrinsic rates of increase. Analyses of mackerel scale-deposition data (Soutar and Issacs 1974) indicate that the prolonged periods of high biomass levels during the 1930s and late 1970s to 1980s are unusual events that might be expected to occur, on average, about once every 60 years MacCall et al. 1985). Recruitment of Pacific mackerel is variable and loosely linked to spawning biomass. Reproductive success, measured as spawning biomass divided by number of recruits, is highly variable and somewhat cyclic, with periods of roughly three to seven years.

Stock Structure and Management Units

There are possibly three spawning stocks along the Pacific coasts of the U.S. and Mexico: one in the Gulf of California, one in the vicinity of Cabo San Lucas, and one extending along the Pacific coast north of Punta Abreojos, Baja California (Collette and Nauen 1983; Allen et al. 1990; MBC 1987). The latter “northeastern Pacific” stock is harvested by fishers in the U.S. and Baja California, Mexico, and is considered in this assessment.

The PFMC manages the northeastern Pacific stock as a single unit, with no area- or sector-specific allocations. The PFMC’s harvest control rule does, however, prorate the seasonal HG by a 70% portion assumed to reside in U.S. waters (PFMC 1998).

Fishery Description

Pacific mackerel are currently harvested by three directed fisheries: the California commercial fishery, a sport fishery based primarily in southern California, and the

Mexican commercial fishery based in Ensenada and Magdalena Bay, Baja California. In the commercial fisheries, Pacific mackerel are landed by the same boats that catch Pacific sardine, anchovy, jack mackerel, and market squid. There is no directed fishery for mackerel in Oregon or Washington, however, small amounts (100-300 $\mathrm{mt \cdot yr^{-1}}$) are taken incidentally by whiting trawlers and salmon trollers. Pacific northwest landings of Pacific mackerel peaked in 1997 at 1,800 mt following a major El Niño event.

The history of California's Pacific mackerel fishery has been reviewed by Croker (1933, 1938), Roedel (1952), and Klingbeil (1983). Pacific mackerel supported one of California's major fisheries during the 1930s and 1940s and again in the 1980s and 1990s. During the early fishery, Pacific mackerel were taken by lampara and pole and line boats, which were replaced in the 1930s by the same purse seine fleet that fished for sardine. Before 1929, Pacific mackerel were taken incidentally, in relatively small volumes, with sardine and sold as fresh fish (Frey 1971). Canning of Pacific mackerel began in the late 1920s and increased as greater processing capacities and more marketable packs were developed. Landings decreased in the early 1930s due to the economic depression and a decline in demand, and then rose to a peak of 66,400 mt in 1935-36. During this period, Pacific mackerel was second only to Pacific sardine in annual landings. Harvests subsequently underwent a long-term decline and, for many years, demand for canned mackerel was steady and exceeded supply. Supply reached record low levels in the early 1970s, at which time the State of California implemented a moratorium on the directed fishery.

Following the mackerel population recovery in the late 1970s, the moratorium was lifted and the fishery subsequently ranked third in volume of California finfish landings through the 1990s. The market for canned mackerel fluctuated due to availability and economic conditions. Domestic demand for canned Pacific mackerel eventually waned and the last mackerel cannery in California closed in 1992. At present, most Pacific mackerel is used for human consumption or pet food, with a small but increasing amount sold as fresh fish.

Pacific mackerel are often taken by recreational anglers in considerable numbers, though seldom as a target species (Young 1969). During 1980 through 1989, California's recreational catch averaged 1,500 mt per year and Pacific mackerel was numerically the most important species taken in the California CPFV fleet during the period of 1978 through 1989. Pacific mackerel is also harvested in California's recreational fishery as bait for directed fishing on larger pelagic species. Pacific mackerel is also caught by anglers in central California but in very modest amounts. The statewide sport harvest constitutes a small fraction (two to four percent by weight) of the total landings.

The Mexican fishery for Pacific mackerel is primarily based in Ensenada and Magdalena Bay, Baja California. The Mexican purse seine fleet has slightly larger vessels, but is similar to southern California's with respect to gear (mesh size) and fishing practice. The fleet operates in the vicinity of port and also targets other small pelagic species. Demand for Pacific mackerel in Baja California increased after World War II. Mexican landings remained stable for several years, rose to 10,725 mt in 1956-57, then declined to a low of

107 tons in 1968-69. Catches were then negligible until the early-1980s. Landings of Pacific mackerel in Ensenada peaked twice, first in 1991-92 at 34,557 mt, and again in 1998-99 at 42,815 mt. The Ensenada fishery for Pacific mackerel has been comparable in volume to California's fishery since 1990. In Mexico, Pacific mackerel are either canned for human consumption or reduced to fish meal.

Management History

The state of California first applied management measures to Pacific mackerel in 1970, after the stock had collapsed in the mid-1960s. A moratorium was placed on the fishery in 1970, with a small allowance for incidental catch in mixed loads. In 1972, legislation was enacted which imposed a landing quota based on the age one-plus biomass. A series of successful year classes in the late 1970s initiated a recovery, and the fishery was reopened under a quota system in 1977. During the recovery period from 1977 to 1985, various adjustments were made to quotas for directed take of Pacific mackerel and to incidental catch limits.

State regulations enacted in 1985 imposed a moratorium on directed fishing when the total biomass was less than 18,200 mt, and limited the incidental catch of Pacific mackerel to 18 percent during moratoriums. The fishing season was set to extend from July 1 to June 30 of the following year. Seasonal quotas, equal to 30 percent of the total biomass in excess of 18,200 mt had been allowed when the biomass was between 18,200 and 136,000 mt, and there was no quota when the total biomass was 136,000 mt or greater.

A federal fishery management plan (FMP) for CPS, including Pacific mackerel, was implemented by the PFMC in January 2000 (PFMC 1998). The FMP's harvest policy for Pacific mackerel, originally implemented by the State of California, is based on MacCall et al.'s (1985) simulation analyses, with the addition of a proration to nominally account for stock assumed in U.S. waters. The current maximum sustainable yield (MSY) control rule for Pacific mackerel is:

HARVEST = (BIOMASS-CUTOFF) x FRACTION x STOCK DISTRIBUTION,

where HARVEST is the HG, CUTOFF (18,200 mt) is the lowest level of estimated biomass at which harvest is allowed, FRACTION (30%) is the fraction of biomass above CUTOFF that can be taken by fisheries, and STOCK DISTRIBUTION (70%) is the average fraction of total BIOMASS (Ages 1+) assumed in U.S. waters (PFMC 1998). Harvest guidelines under the federal FMP are applied to the same July-June fishing season established by California.

California's recreational catch of Pacific mackerel is included within the U.S. HG, but there are no other restrictions (e.g. size or bag limits) on this fishery. Total annual harvest of Pacific mackerel by the Mexican fishery is not regulated by quotas, but there is a minimum legal size limit of 255 mm. To date, no international management agreements between the U.S. and Mexico have been developed.

Management Performance

From 1985 to 1991, the biomass exceeded 136,000 mt and no state quota restrictions were in effect. State quotas for 1992-93 through 1999-00 fishing seasons averaged roughly 24,000 tons. More recently, HGs have been lower, generally below 15,000 mt. The 2006 fishing year HG based on the most recent assessment presented here is 17,419 mt. Finally, from a management context, the fishery has failed to fully utilize recommended HG levels since the 2001-02 fishing year (Table 1 and Figure 1).

ASSESSMENT DATA

Biological Parameters

Length-weight Relationship

The length-weight relationship for Pacific mackerel was modeled using fish measured from CDFG port samples collected from 1981 to 2002. The following power function was used to determine the relationship between weight (g) and fork length (mm) for both sexes combined:

$$W_L = a\,(L^b),$$

where W_L is weight-at-length L, and a and b are the estimated regression coefficients. The estimated coefficients were a = 0.0000012 and b = 3.409 (n = 58,022 fish) (Table 2).

Length-at-age Relationship

The von Bertalanffy growth equation was used to derive the relationship between fork length (mm) and age (yr) for Pacific mackerel:

$$L_A = L_\infty\,(1 - e^{-K(A-to)}),$$

where L_A is the length-at-age A, L_∞ ('L infinity') is the theoretical maximum length of the fish, K is the growth coefficient, and t_o ('t zero') is the theoretical age at which the fish would have been zero length. The best estimate of von Bertalanffy parameters for Pacific mackerel was: L_∞ = 400 mm, K = 0.3124, and t_o = -2.14 (n = 58,022 fish). Mean lengths-at-age based on this model are presented in Table 2. The reader is referred to Mallicoate and Parrish (1981) for a detailed analysis of seasonal growth patterns in Pacific mackerel.

Maximum Age and Size

The largest recorded Pacific mackerel was 630 mm long and weighed 2,900 g (Hart 1973; Roedel 1938), but the largest Pacific mackerel taken by commercial fishing (CA) was 478 mm and 1,719 g (Table 2). The oldest recorded age for a Pacific mackerel was 14 years (Table 2), but most commercially caught Pacific mackerel are less than four years old.

Maturity Schedule

Estimates of net fecundity at age for Pacific mackerel (fraction mature x spawning frequency x batch fecundity; Table 3) were used to interpret CalCOFI ichthyoplankton data and calculate spawning stock biomass (SSB) in the assessment. Fraction mature was estimated by fitting as logistic regression model to age and fraction mature data in Dickerson et al. (1992). Spawning frequency was estimated by fitting a straight line to age and spawning frequency data from the same study. Following Dickerson et al. (1992), batch fecundity per gram of female body weight was assumed constant.

Natural Mortality

Natural mortality rate (M) was assumed to be 0.5 yr^{-1}, all ages and both sexes, for all ASAP model runs. Parrish and MacCall (1978) estimated natural mortality for Pacific mackerel using early catch curves (M = 0.3-0.5), regression of Z on f (M = 0.5), and comparative studies of maximum age (M = 0.3-0.7; Beverton 1963) and growth rate (M = 0.4-0.6; Beverton and Holt 1959). They considered the regression of Z on f to be the most reliable method, and the estimate (M = 0.5) falls within the mid-range of other estimates. For purposes of this assessment, the annual rate of natural mortality (M) is therefore assumed to be 0.5 yr^{-1}, which means that 39% of the stock would die of natural causes each year in the absence of fishing (Parrish and MacCall 1978)(Table 2).

Fishery Data

Overview

Fishery data for assessing Pacific mackerel include landings (California commercial and recreational, and Mexico commercial), and port sample (biological) data from California's commercial fishery. CDFG has collected biological data on Pacific mackerel landed in San Pedro (southern California) fishery since 1929. Biological data includes individual weight (g), fork length (mm), sex, maturity, and otoliths for age determination. CDFG currently collects 12 random port samples (25 fish per sample) per month to determine age composition and weights-at-age for the directed fishery. Mexican port sampling data have been collected by INP-Ensenada since 1989, but were not available to the authors, so California commercial catch-at-age and weight-at-age are assumed to be representative of the entire fishery. Lack of Baja California port sampling data is not a serious problem for years when Mexican catches are low, however, Baja California and California catches have been roughly equal in volume so lack of Mexican data may affect results. A listing of CDFG sample sizes relative to total landings from 1939-40 to present is provided in Table 4.

Pacific mackerel were aged by CDFG biologists using annuli in whole sagittal otoliths. Historically, a birth date of May 1 was assumed when assigning year classes (Fitch 1951). For reasons unknown, the protocol changed to a July 1 birthdate in 1976-77 (when the resource rebounded and sampling of the directed fishery resumed). This change coincided with a change in the management season from opening a May 1 to June 1.

Following recommendations of the CPS STAR Panel (PFMC 2004), all fishery inputs were recompiled based on a 'biological year' as opposed to a calendar year time step, with the biological year being based on the birthdates used to assigned age. Therefore, data prior to 1976-77 were aggregated in a 'biological year' of May 1 ($year_x$) through April 30 ($year_{x+1}$), and data from 1976-77 forward were aggregated from July 1 ($year_x$) through June 30 ($year_{x+1}$). The 'biological year' used in this assessment is also synonymous with the 'fishing year' or 'fishing season' referred to in this document and as reported in the historical literature. That is, the change in birthdate assignment from May 1 to July 1 coincided with a change in the management season in the mid-1970s, and historical sources of landings and biological data reflect this change. ASAP model inputs and outputs (Appendices III & IV) label each biological year with the first year of the increment (e.g., 2004-05 is labeled '2004').

Landings

The ASAP model uses commercial and recreational landings in California and commercial landings in Baja California from 1929-30 through 2005-06, with data from all three sectors pooled and modeled as a single fishery. Landings were aggregated by biological year and are presented in Table 5 and Figure 2. Landings for 2005-06 were assumed identical to 2004-05, and were included to project a July 1, 2005 population biomass for the Council's 2005-06 HG.

California commercial landings of Pacific mackerel were obtained from a variety of sources based dealer landing receipts (CDFG), in some cases augmented with port sampling for mixed load portions. Data from 1929-30 to 1961-62 were obtained from Parrish and MacCall (1978). Monthly landings for the period May 1962 to Sept. 1976 were obtained from CDFG fish bulletins recovered to an electronic database format (PFEL 2005). Raw landing receipt data for Pacific mackerel from 1976 to 1991 are of marginal quality, owing to the large quantities of Pacific mackerel landed as mixed loads with jack mackerel. During this period, many processors reported either species as 'unspecified' mackerel on landing receipts. For these years, mackerel landings data were augmented with shore side 'bucket' sampling of mixed loads to estimate portions for each species. CDFG reported these data in two forms: 1) annual stock status reports to the California legislature, and 2) single page 'CDFG Wetfish Tables'. Both sources are considered more accurate than PacFIN or other landing receipt-based statistics for this period. Data sources from late 1976 to present are as follows: Oct – Dec 1976 are from Klingbeil and Wolf (1986); Jan - Dec 1977 are from Wolf and Worcester (1987); Jan 1978 – Dec 1981 are from Jacobson et al. (1994a); Jan 1982-Feb 2005 are from CDFG Wetfish Tables. Landings for March 2005-June 2005 were substituted with corresponding months from 2004. Pacific mackerel landings from 1976-1981 were only reported by quarterly increments so, for purposes of weighting catch-at-age estimates for this period (following section), we apportioned quarters to months using monthly 'unspecified mackerel' landings from the PFEL LAS database (PFEL 2005).

Estimates of CA recreational landings (mt) from 1980 to present (2-month 'wave' resolution) were obtained directly from the Pacific RecFIN database. Historical estimates (pre-1980) of total recreational catch were derived from CPFV logbook data collected since 1936 (Hill & Schneider 1999). CPFV catch (number) was converted to metric tons using and assumed average weight of 0.453 kg (1 lb.) per individual, based on RecFIN samples and consistent with Parrish and MacCall (1978). CPFV tonnage was expanded to total recreational tonnage using wave-specific ratios from RecFIN. Nominal amounts of recreational removals were assumed for 1929-35 and 1941-46 when no recreational statistics were available.

Baja California data include landings from commercial purse seine fisheries in Ensenada, Cedros Island, and Magdalena Bay. Ensenada landings were compiled as follows: 1946-47 through 1969-70 (May-Apr) data are from Parrish and MacCall (1978); 1970-71 through 1975-76 (May-Apr) data are from Schaefer (1980); quarterly data from Jul 1976 through Dec 1986 are from Jacobson et al. (1994); monthly data from Jan 1987 through Nov 2003 were provided by INP-Ensenada (Garcia and Sánchez, 2003; Celia Eva-Cotero, INP-Ensenada, pers. comm.); monthly landings from Dec 2003 through Jun 2005 were not available, were substituted with corresponding months from the previous year. Monthly landings data for the Cedros Island (Jan 1981 - Dec 1994) and Magdalena Bay (Jan 1981 – May 2003) fisheries were provided by Roberto Felix-Uraga (CICIMAR-IPN, La Paz, pers. comm.). The fishery off Cedros Island ceased in 1994. Magdalena Bay landings for June 2003 through June 2005 were substituted with corresponding months from the previous year. Monthly-resolution catch statistics for Mexico were not available for all seasons so, for purposes of weighting catch-at-age estimates (following section), aggregate catch data (season or quarter) were apportioned to months by inflating the corresponding California data.

Small volumes (100 to 300 $mt \cdot yr^{-1}$) of Pacific mackerel are taken incidentally in other fisheries (e.g. whiting, salmon troll, sardine) off Oregon and Washington. Biological samples collected from these fisheries (Hill 1999) indicate age and size structures that are much older and larger than the directed fishery off California, so this catch is not included in the assessment.

Catch-at-age

Various sources were used to reconstruct a catch-at-age time series for Pacific mackerel. Age data for 1929 to 1932 and 1935 to 38 were derived from CDFG length composition data using Tomlinson's unpublished NORMSEP program (Parrish and MacCall 1978). Ages for all other biological years in this assessment were based on otolith data available from the literature or contemporary fishery databases. Individuals six years of age and older were pooled into a 'plus' group. See 'Fishery Data / Overview' section (above) for details regarding birthdate assumptions. Sample sizes for developing catch-at-age estimates (1939-40 to present) are provided in Table 4.

Age compositions for 1929-30 to 1938-39 (May-April) were taken from Parrish and MacCall (1978) and adjusted according to our total landing estimates for this period, using weight-at-age data from Prager and MacCall (1988) (see also 'Weight-at-age' section).

Age compositions for the period 1939-40 to 1961-62 (May-April) were based on year class, age, and length data recovered from the historical literature (Fitch 1951, Fitch 1953a, Fitch 1953b, Fitch 1955, Fitch 1956, Fitch 1958, Hyatt 1960, Parrish and Knaggs

1971, Parrish and Knaggs 1972) and now available in a database individual-level resolution by biological year. Lengths were converted to weights using the length-weight relationship published by Fitch (1951). Age compositions were estimated by using the proportions-at-age and average weights-at-age to calculate tonnage per age group. Tons per age was converted to numbers at age using average fish weights for each biological year.

Age compositions from 1962-63 to 2004-05 were developed using CDFG port sample databases, coupled with pooled monthly landings for the three respective fisheries (see ‘Landings’ section). While no directed sampling for Pacific mackerel took place during the fishing moratorium (1970-1976), Pacific mackerel samples were collected from the jack mackerel fishery during this period. From 1962-63 onward, estimates of catch-at-age were weighted to take into account variation in sample size relative to total landings. Sample percent-by-weight for each age class was calculated by dividing the total weight of fish-at-age by the total weight of fish sampled in each month. Landed weight of fish in each age class was estimated as the product of metric tons landed and the percent-by-weight in the fishery sample. Numbers-at-age in the monthly landings were then calculated by dividing the landed weight-at-age by the average individual weight-at-age for the month. For months with landings but no fishery sample taken, data were substituted by summing sample information (i.e., fish numbers, weights, and sample weights) from the two adjacent (previous and following) months. Finally, numbers-at-age were summed across months to provide the catch-at-age for each biological year (May-April prior to 1976-77; July-June for 1976-77 to present).

Catch-at-age data compiled for ASAP input are provided in Table 6, and proportions-at-age are displayed in Figure 3. For years where age sampling was carried out (i.e. 1929-30 to 2004-05), an effective sample size (λ) of 15 was used. Effective sample size was set to zero for cases with landings but no samples (2005-06).

Weight-at-age

A year-specific weight-at-age matrix based on fishery samples was developed for use in the ASAP model. This matrix was used to calculate SSB and age 1+ biomass from modeled population estimates. Weight-at-age data are presented in Table 7 and Figure 4. While it is possible that the population weight-at-age of Pacific mackerel differs from that derived from fishery samples, fishery-independent data do not exist to explore this question.

Weights-at-age from 1929-30 to 1938-89 were obtained from Prager and MacCall (1988). Prager and MacCall (1988) did not include weights for age-0 or age-6+ fish, so we regressed weight-at-age by year class to estimate values for this period. Weights-at-age from 1939-40 to 1961-62 were calculated from the historical database based on various sources (see ‘Catch-at-age’ section above), again, noting that weights were converted from lengths in the original source using the length-weight relationship published by Fitch (1951). Weights-at-age from 1962-63 to 2004-05 were obtained directly from CDFG port sample databases.

Fishery-independent Indices of Abundance

Overview

Fishery-independent survey data used in the ASAP model include 1) aerial sightings by spotter pilots, 2) larval abundance from the CalCOFI program, 3) CPUE indices from CPFV logbooks. Survey data for Pacific mackerel vary in quality with respect to over space and time, but no single index is proposed to be superior with respect to comprehensiveness or sampling design. Strengths and weaknesses of each survey will be briefly addressed in the following sections.

Aerial Spotter Survey (Index 1)

Pilots employed by the fishing fleet to locate Pacific mackerel (and other pelagic fish) schools report data for each flight on standardized logbooks and provide them under contract to NOAA Fisheries. 'Spotter' data for Pacific mackerel were calculated for year effects estimated using delta log-normal linear models (Lo et al. 1992). Coefficients of variation for Spotter data were calculated as described in Lo et al. (1992). Spotter data were aggregated using April to March annual periods, for example, the estimate for 1993 was based on data collected from April 1992 to March 1993. The spotter index covers the period 1963 through 2000 (Figure 5). After the year 2000, there was rapid decline in both the number of active pilots and total logbooks returned, as well as a southward shift in effort to offshore areas off of Baja California.

The selectivity pattern applied for this index is such that all age groups (ages 0-6+) were fully selected (Table 8, Figure 6). This is based on the assumption that spotter pilots will record all fish schools sighted (including age-0 fish), not only those schools reported to the wetfish fleet.

Commercial Passenger Fishing Vessel Logbook CPUE (Index 2)

California Fish and Game Code has required CPFV skippers to provide records of catch and effort data to CDFG since 1936. In the past, Pacific mackerel has been among the top five species reported on CPFV logs both in southern California and statewide. We utilized an historical logbook database (Hill and Barnes 1998, Hill and Schneider 1999) which summarizes CPFV catch and effort by month and Fish and Game statistical blocks (10 nautical mile squares). For the current assessment, a single statewide index of relative abundance was developed and standardized using a Generalized Linear Model (GLM; described below)(Figure 5). Length data from the Recreational Fisheries Information Network (RecFIN) database were used outside the model to estimate a fixed selectivity pattern for use in the ASAP baseline model (Table 8, Figure 6).

To account for potential changes in catchability associated with the CPFV fleet over time, a straightforward general linear model (GLM; Table 9) was used to 'standardize' the data and separate effects from critical factors (e.g., spatial-temporal). That is, by incorporating year as a factor, the GLM generates estimates of annual standardized catch rate and its variance that can be generally interpreted as a relative index of abundance of the population. Technical issues concerning the GLM analysis follow:

(1) data were combined within year/quarter/fleet strata (i.e., the overall, statewide fishery was partitioned into a northern and southern ‘fleet’ based on latitude/longitude spatial fishing ‘blocks’);

(2) CPUE was calculated as a log-transformed statistic, where CPUE (number of fish/1,000 angler-hours fishing) was calculated for each spatial/temporal stratum;

(3) years 1936-04 were used in the analysis, with the exception of a few years that were omitted due to missing data (e.g., 1941-46 and 1979);

(4) latitude/longitude blocks were combined into broader spatial areas based on the fishing practices of the northern and southern CPFV fleets, i.e., historically, the southern fleet has exerted the vast amount of fishing pressure associated with this overall fishery (Pt. Conception was used as the ‘north/south’ delimiter to partition the two regional fleets);

(5) the basic model included the response variable (i.e., catch rate, $\log_e$(CPUE) as a function of three main effects (year *i*, quarter *j*, and fleet *k*),

$$\log_e(CPUE_{ijk}) = \log_e(U_R) + \log_e(Y_i) + \log_e(Q_j) + \log_e(F_k) + \varepsilon_{ijk},$$

where $CPUE_{ijk}$ is the mean catch rate (number/100 hr) in year *i*, quarter *j*, and fleet *k*. The year effect is denoted by Y_i (i=1, 2, ..., I; I=62 years). The quarter of the year effect is denoted by Q_j (j=1, 2, ..., J; J=4 quarters). The fleet effect is denoted as F_k (k=1, ..., K; K=2 fleets). The error term is denoted ε_{ijk}, where for each combination of indices, ε_{ijk} is an *iid* normal random variable with zero mean and constant variance σ^2. Finally, the reference cell is denoted as *UR* (*R*=1 reference cell, i.e., year=2004, quarter=4, and fleet=south);

(6) no correction for log-transformation bias was made, i.e., no adjustments (based on the residual variance σ^2 from the basic model) were applied to the predicted catch rates generated from the analysis;

(7) no temporal/spatial interactions (e.g., year and fleet or quarter and fleet) were included in the final GLM model, given such interactions had little effect on increasing the amount of variability in mean catch rate as a function of the suite of explanatory variables (i.e., minor improvement of R^2 statistic).

CalCOFI Larval Survey (Index 3)

CalCOFI ichthyoplankton data from 1951 to 2004 were compiled and an annual index of proportion positive bongo net tows for the Southern California Bight was calculated (Figure 5). Proportion positive indices are believed to better represent abundance than density when eggs are rare or patchy in distribution (Mangel and Smith, 1990). Data from all available years were used, but data were filtered to include only cruises from March through September, months of the normal Pacific mackerel spawning season. The filtered data grid included standard CalCOFI lines greater than 76 and less than 94 and standard stations out to 115 (roughly 200 nm offshore). The modeled selectivity pattern used the normalized net fecundity ogive described below in ‘Maturity Schedule’ and provided in Tables 3 and 8, and in Figure 6.

ASSESSMENT MODEL

History of Modeling Approaches

Historically, the ADEPT model ('ADAPT' VPA modified for Pacific mackerel; see Jacobson 1993 and Jacobson et al 1994b) has been used to evaluate the status of the population in accordance with this stock's Fishery Management Plan (FMP). The assessment conducted last year (2004-05 fishing year) represented the final VPA-based analysis for this fish stock (see Hill and Crone 2004a) and further, this year's (2005-06 fishing year) assessment represents the first analysis based on a forward-simulation, age-structured model. Details regarding the overall modeling transition for this population are presented in (Hill and Crone 2004b) and PFMC (2004).

ASAP Model

Overview

The ASAP model (Legault and Restrepo 1998; Appendix I) is based on the AD Model Builder software environment, which is essentially a C++ library of automatic differentiation code for nonlinear statistical optimization (Otter Research 2001). Further, ASAP model development is maintained through the NOAA Fisheries Toolbox (NFT 2005), which includes various fishery-related models that have been customized with additional 'front end' (GUIs) software to enable users to conduct modeling exercises and evaluate results more easily. The general estimation approach used in the ASAP is a forward-computing algorithm, whereby a fully-integrated model allows for the calculation of large numbers of parameters.

The following is a brief description of estimation methods employed in the ASAP model and readers interested in further details and explicit equations should refer to Legault and Restrepo (1998)(Appendices I and II). Also, the population dynamics theory that serves as the underpinnings of forward-estimation, age-structured models such as ASAP is presented generally in Fournier and Archibald (1982), Deriso et al. (1985), Megrey (1989), and Methot (1990, 1998).

- Model estimation begins in the first year of available data with an estimate of the population abundance-at-age.
- The spawning stock for that year is calculated and the associated recruitment for the next year is determined via the stock-recruitment relationship (in this case, based on a Beverton-Holt model). Recruitment variability is accommodated by accounting for divergence from the estimated central tendency (expected value).
- Each cohort estimated in the initial population abundance at age is then reduced by the total mortality rate and subsequently, forecasted into the next year/age combination. This process of estimating recruitment and projecting the population 'forward' continues until the final year of data is reached.
- Total mortality rates (Z) used to decrease cohort abundances over time represent the sum of natural mortality (M) and the fishing mortalities (F) from all fisheries (in this case, a single fishery).

- The Fs for each fishery are assumed to be ‘separable’ into age (commonly referred to as selectivity) and year (commonly referred to as F-multipliers). This method of selectivity estimation and further, the flexible treatment of the separable assumption is unique to ASAP (vs. VPA), e.g., patterns in selectivity over time can be formally evaluated.
- The product of year-specific selectivity-at-age and the F-multiplier equals the F for each fishery/year/age combination.
- Catches are estimated following the traditional ‘catch equation,’ using the estimated F, the hypothesized M, and the estimate of population abundance described above. When estimated catches from all fisheries, years, and ages are calculated, they are compared to the observed catch information. Iterative modeling routines entail changing parameter estimates to better fit the model to the data sources (e.g., increasing recruitment from its estimated mean in a given year or modifying the selectivity-at-age for a fishery in a specific year, in efforts to most closely fit the observed and predicted catch-at-age estimates). The matching of predicted and observed catch-at-age estimates necessarily involves integrated numerical estimation, given fits to other important sources of data (in this case, maximum likelihood components) are used to tune catch-at-age estimation, i.e., a balance must be found by examining the degree of fit between predicted and observed values of the indices of abundance.
- The method of maximum likelihood serves as the foundation of the overall numerical estimation relied upon in the ASAP model, whereby sources of data are compartmentalized into various likelihood components, depending on the level of structure of the overall, fully-integrated population model. Generally speaking, the ASAP model includes nine likelihood components and a few penalties, given a baseline population model (e.g., see Table 10).
- The tuning indices are assumed to represent changes in the population over time for specific age ranges and can be measured in numbers or weight. The expected values for the indices are generated from the estimated population abundance and compared to the observed values. This particular statistical procedure involves fitting the indices more (or less) closely than the catch-at-age component, depending upon the values of the relative weights assigned to each component by the analyst. Given the large number of unknown parameters, it is possible to fit both the catch-at-age and the abundance indices relatively well, but often at the expense of producing somewhat unrealistic trends in other stock parameters of interest (e.g., recruitment, selectivity, and catchability). In this context, penalties (or weights) are placed on parameters, which constrains the amount of error that is accounted for when estimating across years or ages.
- The constraints are often based on analyst decisions regarding the relative variability associated with the different parameters. Ideally, a summarized measure of dispersion (e.g., a coefficient of variation of the mean, CV) that is associated with the different parameters can be used to determine the magnitude of these constraints on each parameter. For example, the fits to components such as the catch, catch-at-age, and abundance index time series are often emphasized (i.e., increased weights) over assumptions concerning how much recruitment is allowed to deviate from the stock-recruitment relationship.
- Following the assignment of weights, the statistical optimization involves ‘searching’ (i.e., non-linear, multi-dimensional spaces) for the set of parameter values

that produces the closest fit between predicted and observed values, given the constraints placed on how much parameters are allowed to vary. The best set of parameter values are those that minimize the total objective function, which measures the degree of agreement between all predicted and observed values associated with the various likelihood components (and penalties). The minimization processes proceed in phases, whereby groups of parameters are estimated simultaneously, while the remaining parameters are maintained at their initially assigned (‘starting’) values. Once the objective function is minimized for a particular phase, more parameters are evaluated in a step-wise fashion. Estimation within phases continues until all parameters to be estimated contribute to the objective function, with the ultimate set of parameters being the summation of the individual likelihoods that minimizes the objective function. Keep in mind that the complete model is ‘refitted’ whenever fixed parameter values are changed (vs. keeping previous estimates from phase to phase). This process of refitting is done to ensure the model maintains an internally consistent (fully-integrated) characterization of the status of the population.

Assessment Program with Last Revision Date

ASAP Version 1.4, compiled 14 Sept., 2004, was used for all modeling runs in this report. ASAP 1.4 is implemented through NFT’s GUI Version 2.6 (NFT 2005). A listing of the ADMB code (template file) is provided in Appendix II. The reader is referred to Legault and Restrepo (1998) for a complete description of ASAP’s population dynamics model (see Appendix I).

Likelihood Components and Model Parameters

A summary of likelihood function components is provided in Table 10. See Table 11 for a parameterization summary of the baseline ASAP model. A complete ‘report’ file associated with baseline model is provided in Appendix IV.

Convergence Criteria

The iterative process for determining numerical solutions in the model was continued until the difference between successive likelihood estimates was <0.0001. The maximum number of function evaluations (recalculations of the Hessian matrix) ranged from 800 to 10,000, depending on the likelihood component of interest; however, the convergence criterion was generally realized with far fewer than the maximum number of evaluations currently used in the underlying modeling environment. Fidelity of model convergence was briefly explored by changing particular ‘starting’ values (stock size at the beginning of the time series, catchability coefficients associated with indices of abundance, etc.) and evaluating the converged ‘minimum’ values, i.e., evaluating ‘global’ vs. ‘local’ convergence properties of the multi-dimensional numerical estimation method.

Model Selection and Evaluation

As presented in the Preface above, following the STAR conducted in 2004, a refined ASAP model was developed this year for purposes of assessing the status of the Pacific mackerel stock and ultimately, determination of the HG for the upcoming 2005-06 fishing year. In May 2005, the refined model (henceforth referred to as the ‘baseline’) received review from the PFMC’s CPSMT. Finally, the following recommendations from the STAR Panel were addressed in this assessment and/or noted for further work in the future (see PFMC 2004)—in this context, we present the list in order of descending order of priority (i.e., in terms of improving the quality of the overall assessment):

- Begin efforts to establish an annually-conducted, coast wide (Baja Mexico to B.C. Canada) research survey concerning CPS.
  - *SWFSC-based strategic planning has identified such a survey as critically important and a high priority in long-term research efforts.*

- Maintain the general configuration of the final STAR-based model scenario, recognizing additional data and revised time series may warrant some parameterization changes.
  - *The baseline model presented here represents a similarly parameterized model as that recommended in the STAR conducted in 2004.*

- Critically review catch-at-age time series, including: updating all landing data (1929-05) and documenting methods more fully; re-examining assignment of age distributions to the appropriate year of the catch-at-age matrix; extending the distribution by one age class; and formally identifying an age-0 age group within the model.
  - *Entire catch-at-age time series was updated, including landings, age/year distributions, and establishing the 'plus' age group at age 6 (vs. age 5). The current structure of the ASAP model does not allow for a 'age-0 group'; however, the naming convention used to define age groups within the model is not expected to influence model dynamics and ultimately, overall convergence/fits/etc., i.e., age groups 0-6+ are simply defined as 1-7+ within the model (also, see the final point in this list below).*

- Obtain survey and biological data from Mexico to bolster population-wide assessment.
  - *Informal discussion and tentative plans to exchange these data have been made; however, formal commitments for this collaborative work are not yet in place.*

- Examine spatial/temporal interactions in the GLM associated with the CPFV relative index of abundance.
  - *Both year (time) and fleet (space), and quarter (time) and fleet (space) interactions had little effect on increasing (explaining) the amount of variability in mean catch rate as a function of the suite of explanatory variables (i.e., minor improvement of* R^2 *statistic) and thus, no interaction terms were incorporated in the 'standardization' of this index.*

- Explore estimating (vs. fixing) selectivity pattern for the CPFV fleet by using available length data and defining the index as an 'artificial fishery' within the model
  - *In sensitivity analysis, we developed a model scenario whereby parameterization of selectivity for the CPFV fleet was estimated within the model based on limited biological data (length information) collected from this component of the recreational fishery and nominal landing statistics. The estimated selectivity schedule was much different than the pattern developed outside of the model, increasing*

exponentially to a maximum of 1 at the oldest age group (6+). Given the implausible nature of the model-estimated selectivity, we maintained the earlier selectivity for this index, given: model parsimony; and caution associated with the manner in which selectivity for indices of abundance can be estimated within the current configuration of the ASAP model.

- Further explore the imprecise fit to the aerial spotter index.
  - *In sensitivity analysis, we further examined other plausible selectivity assumptions regarding this index and in particular, various asymptotic and dome-shaped patterns vs. fully-selected across all age groups, i.e., no auxiliary length data are available for this index. Generally speaking, no selectivity pattern resulted in substantially better fits and thus, we maintained the current selectivity configuration, given: consistency to the final STAR-reviewed model; management-based statistics (e.g., stock biomass, SSB, etc.) were similar between alternative selectivity hypotheses; and no definitive reason to depart from initial supposition that this survey provides biomass estimates that inherently include all age classes.*

- Examine an abbreviated time series in model runs, given concerns regarding catch statistics prior to the late 1970s.
  - *Given the potential repercussions for omitting large amounts of sample information and thus, the need for thorough (and time consuming) sensitivity analysis, we felt it would be prudent to examine this recommendation when time permits in the future (also, see the final point in this list below). Moreover, the largest recruitments in the complete time series occurred during the late-1970s (e.g. 1976, 1978, 1980, 1981 year-classes), thus, beginning a truncated time series at this point in time may prove problematic.*

- Accommodate 'population-related' weight-at-age input time series in addition to the 'fishery-based' weight-at-age data within the model
  - *Given the paucity of data directly applicable to the overall population (i.e., research survey collected information), as well as time demands necessary to re-configure the current ASAP platform, we decided to examine this recommendation when time permits in the future (also, see the final point in this list below).*

- Examine model diagnostic-related issues in efforts to reduce potential statistical correlations among estimated parameters included in the various likelihood components (e.g., estimated vs. predicted catch-at-age proportions and parameterization of selectivity in the first year of the model)—the use of the MCMC module of AD Model Builder software is an effective method for evaluating such correlations in highly-parameterized models.
  - *We relied on classical examination of residual patterns that are indicative of statistical violations involved in formal tests and modeling efforts (e.g., fits to catch-at-age time series, fits to indices of abundance, etc.); however, we recognize the critical need to transition to more formal methods (such as MCMC routines) to ensure overall parameterization of the assessment model indeed leads to appropriate convergence and subsequent output (also, see the final point in this list below).*

- Re-configure the ASAP model to address various parameterization issues not possible (or straightforward) with the current configuration of this model.
  - *Over the next year, we intend to either: (1) add/re-configure particular likelihood components in ASAP; or examine/develop similarly-structured baseline models using other fully-integrated, age-structured modeling platforms available for fishery-related assessments (e.g., AMAK and Synthesis II models) that allow parameterization issues to be more readily addressed than currently possible with the more basic ASAP model.*

In summary, as presented above, the parameterization of the baseline model was similar to the final model reviewed in the most recent STAR in June 2004. That is, with the exception of emphasizing the fit to the catch and some flexibility in generating estimates of recruitment (i.e., the error associated with recruitment deviations and the divergence from an assumed Beverton-Holt stock-recruitment relationship), the baseline model was allowed to freely estimate stock parameters of interest (e.g., F, selectivity, catchability, stock abundance in numbers and biomass, SSB, recruitment, etc.). Sensitivity analysis addressed primarily selectivity associated with the indices (see points above), number of age groups included in the catch-at-age (see points above), stock-recruitment variability (steepness and variability around the stock-recruitment hypothesis), and effective sample sizes associated with the catch-at-age distributions. Collectively, the sensitivity-based model scenarios resulted in very robust findings, including overall likelihood fits, diagnostic-related results, and bottom-line management statistics (biomass, SSB, and recruitment). Results from the baseline model (least constrained of the scenarios) are presented here, given this configuration best illustrated the overall analysis of the available sample data for this fish population.

MODEL RESULTS

Catch

The estimated time series of catch (C) from the baseline ASAP model is presented in Figure 7. Note that the observed and predicted time series are nearly identical, i.e., likelihood emphasis results in a precise fit to the catch data.

Catch-at-Age

Estimates of effective sample sizes (assumed vs. predicted) associated with the age distribution time series are presented in Figure 8. Model fits to the catch-at-age (in proportion) distributions are presented in Figure 9.

Fishery-independent Indices of Abundance

Statistics (ANOVA table) from the GLM analysis regarding the CPFV index are presented in Table 9. The model resulted in statistically significant findings, i.e., the overall model and factors within the model were highly significant ($P<0.001$). The observed estimates for the suite of relative (‘tuning’) indices of abundance are presented in Figure 5. Model fits to the individual indices included in the final (ASAP) model (i.e., aerial ‘spotter’ survey, CPFV, and CalCOFI) are presented in Figures 10-12. Observed values for the three surveys are compared in Figure 13.

Selectivity Estimates

The estimated selectivity time series for the baseline ASAP model is presented in Figure 14.

Fishing Mortality Rate

The estimated fishing mortality (F-at-age) time series for the baseline ASAP model is presented in Table 12 and Figure 15.

Population Numbers

The estimated time series of population abundance for the baseline model is presented in Table 13.

Recruitment

The estimated time series of recruitment (‘R’; abundance of age-0 fish) for the baseline model is presented in Tables 13-14 and displayed in Figure 16.

Spawning Stock Biomass

The estimated time series of SSB for the baseline model is presented in Table 14 and Figure 17.

Stock-recruitment Relationship

In general, estimated recruitment was loosely (i.e., very low ‘weight,’ see ASAP Model Overview above) constrained to a stock-recruitment relationship (Beverton-Holt model, SSB/R) in the baseline model, i.e., given the overall general configuration of these models, convergence problems and/or unrealistic estimated recruitment precluded strictly unconstrained estimation of this stock parameter; however, the compensatory productivity of the population at low adult stock sizes (i.e., the ‘steepness’ parameter) was freely estimated.

The stock-recruitment relationship for the baseline model is presented in Figure 18. The baseline model configuration resulted in a relatively low estimated steepness (0.32), i.e., relatively minor compensatory processes acting on the spawning stock at low absolute levels of abundance. A plot of R/SSB relative to SSB further illustrates the slightly negative correlation between relative spawning success and spawning stock size (Figure 19).

Relative spawning success (R/SSB) since 1929-30 is displayed in Figure 20. Spawning success in Pacific mackerel appears cyclical in nature, with a periodicity of 6-12 years. The largest positive anomalies were observed in the mid-1970s to early-1980s, concurrent with an onset of a warm oceanic regime in the California Current System.

Biomass of Age 1+ Stock for PFMC Management

The estimated time series of population biomass (‘B’, age 1+ fish) for the baseline model is presented in Table 14 and Figure 21. Population biomass for PFMC management in 2005-06 is estimated to be 101,147 mt.

Comparison of Baseline Results to Previous Assessments

Biomass estimates from the 2004 STAR final model and 2004 ADEPT model are compared to the baseline model in Figure 21.

Pacific mackerel quotas and HGs calculated from annual ADEPT assessments (Hill et al. 1999a; Hill et al. 1999b; Hill 2000; Hill et al. 2001; Hill et al. 2002; Hill et al. 2003; Hill and Crone 2004a) are presented in Figure 22. Retrospective HGs based biomasses from the current ASAP baseline are included for comparison. With the exception of 1999-00, prior ADEPT forecasts were reasonably similar (average difference = 13%) to our current estimate of appropriate harvest levels based on ASAP (Figure 22). The assessment for 1999-00 management (Hill et al. 1999a) was poorly forecast biomass at the time due to lack of complete catch information from the Mexican fishery. The Ensenada fishery ultimately landed 50,726 mt in calendar year 1998.

HARVEST GUIDELINE RECOMMENDATION FOR 2005-2006

In Amendment 8 to the CPS FMP (PFMC 1998), the recommended maximum sustainable yield (MSY) control rule for Pacific mackerel was:

HARVEST = (BIOMASS-CUTOFF) x FRACTION x DISTRIBUTION,

where HARVEST is the U.S. HG, CUTOFF (18,200 mt) is the lowest level of estimated biomass at which harvest is allowed, FRACTION (30%) is the fraction of biomass above CUTOFF that can be taken by fisheries, and DISTRIBUTION (70%) is the average fraction of total BIOMASS in U.S. waters. CUTOFF and FRACTION values applied in the Council’s harvest policy for mackerel are based on analyses published by MacCall et al. (1985). BIOMASS (101,147 mt) is the estimated biomass of fish age 1 and older for the whole stock as of July 1, 2005. Based on this formula, the 2005-06 HG would be 17,419 mt. The recommended HG is 32% higher than the 2004-05 HG, and higher than the average yield (~11,600 mt) realized by the fishery since 1992-93 (Tables 1 & 15; Figure 1).

RESEARCH AND DATA NEEDS

California's Pacific mackerel fishery has been sampled by CDFG for age composition and size-at-age since the late-1920s. The current stock assessment model incorporates a complete time series of landings and age composition data from 1929 onward. Ensenada (Baja California) landings have rivaled California's over the past decade, however, no biological data are readily available from Mexico's fishery. Landings are accounted for in the assessment, but size and age composition are assumed to be similar to the San

Pedro, California fishery. There is a need to establish a program of port sample data exchange with Mexican scientists (INP, Ensenada) to fill this major gap in the mackerel stock assessment. Samples (size, sex, otoliths) of Pacific mackerel have been collected by INP-Ensenada since the mid-1980s, but the otoliths have not been aged.

Fishery-independent survey data for measuring changes in mackerel recruitment and spawning biomass are generally lacking. The current CalCOFI sampling pattern provides information on mackerel egg distributions in the Southern California Bight, the extreme northern end of the spawning area. Mexican scientists have conducted a number of egg and larval surveys off of Baja California in recent years (e.g., IMECOCAL program). Access to this data would enable us to continue the historical CalCOFI time series, which begins in 1951. This information could be directly incorporated into the assessment model. Night-light surveys for newly recruited Pacific mackerel should be re-instituted in the Southern California Bight. Surveys following protocols employed during CDFG Sea Survey cruises (1950-1988) could allow splining the new recruitment data set to the historical time series. The new time series would represent the only recruitment index in the mackerel stock assessment and would strengthen the ability to accurately forecast age zero and total stock abundance for each coming fishing season.

Pacific mackerel biomass has been declining since the early 1980s, but recent El Niño events have concurrently extended their northern range to British Columbia. Pacific mackerel are caught incidentally in the Pacific whiting and salmon troll fisheries. Pacific mackerel are regularly caught in triennial survey trawls off the Pacific Northwest. A simple reporting system is needed to document incidental take of mackerel in fisheries to the north. Presence-absence information may allow us to detect southward movement or further decreases in biomass.

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Table 1. Commercial landings (California directed fishery) and quotas or HGs for Pacific mackerel. Units are metric tons. Incidental landings from Pacific northwest fisheries are not included, but typically range 100 to 300 mt per year. See also Table 15 and Figure 1.

Season	**Quota or HG[/a]**	**Landings**
1992-93	34,010	18,307
1993-94	23,147	10,793
1994-95	14,706	9,372
1995-96	9,798	7,615
1996-97	8,709	9,788
1997-98	22,045	23,413
1998-99	30,572	19,578
1999-00	42,819	7,170
2000-01	20,740	20,936
2001-02	13,837	8,436
2002-03	12,535	3,541
2003-04	10,652	5,972
2004-05[/b]	13,268	5,399
2005-06[/c]	**17,419**	---

[/a] California Quotas 1992-03 through 1998-99. PFMC HGs 1999-00 onward.

[/b] 2004/05 landings as of May 19, 2005 (CDFG wetfish tables).

[/c] Proposed HG for 2005-06.

Table 2. Biological parameters (age-specific) for Pacific mackerel. Units are as follows: age is in yr; length is fork length in mm; weight is in g; natural mortality is unitless; maturity is in proportion.

	Age						
Biological Parameter	0	1	2	3	4	5	6+
Modeled Length-at-age[a]							
Jul-Dec	195	250	290	319	341	357	368+
Jan-Jun	224	271	306	331	349	363	373+
Von Bertalanffy Parameters (Length)							
$L_\infty = 400$; $K = 0.312$; $t_0 = -2.14$							
Maximum recorded length							
Fishery 478							
Literature 630							
Modeled Weight-at-age[a]							
Jul-Dec	80	183	301	414	514	598	664+
Jan-Jun	129	242	359	466	558	633	692+
Von Bertalanffy Parameters (Weight)							
$W_\infty = 871$; $K = 0.312$; $t_0 = -2.14$; $b = 3.41$							
Maximum recorded weight							
Fishery 1,719							
Literature 2,900							
Natural Mortality-at-age	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Maturity-at-age[b]	0.000	0.074	0.246	0.474	0.733	1.000	1.000
Maximum observed age: 14							

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[a] July 1 birthdate is assumed when assigning age. Length- and Weight-at-age estimates are presented for 'Jul-Jun' (ages 0, 1, 2, ...) and 'Jan-Jun' (ages 0.5, 1.5, 2.5....).

[b] Maturity-at-age is reported as normalized net fecundity, as described in 'Maturity Schedule' and as calculated in Table 2.

Table 3. Normalized net fecundity [a] calculations for Pacific mackerel.

Age (yrs)	**Observed Fraction Mature**	**Predicted Fraction Mature**	**Observed Spawning Frequency (% spawning day^{-1})**	**Predicted Spawning Frequency (% spawning day^{-1})**	**Net Fecundity (eggs g^{-1})**	**Normalized Net Fecundity (eggs g^{-1})**
0	0.000	0.000	0.0	0.00	0.000	0.000
1	0.214	0.487	0.0	1.38	0.672	0.074
2	0.867	0.636	3.9	3.52	2.240	0.246
3	0.815	0.763	6.8	5.66	4.320	0.474
4	0.851	0.855	9.9	7.80	6.670	0.733
5	0.882	0.916	7.7	9.94	9.110	1.000
6+	0.882	0.916	7.7	9.94	9.110	1.000

[a] Observed fraction mature and observed spawning frequency from Dickerson et al. (1992). Predicted fraction mature from logistic regression. Predicted spawning frequency from linear regression. Normalized net fecundity is adjusted to a maximum value of 1.0. Batch fecundity assumed constant.

Table 4. Sample sizes for Pacific mackerel sampled from southern California's commercial fishery by the CDFG. Sample sizes relative to total tonnage (all sectors) are provided as fish per 1,000 mt. Details on raw sample sizes prior to 1939-40 were not available from the historical literature.

Biological Year	Landings (mt)	# Fish Sampled	Fish per 1,000 mt	Biological Year	Landings (mt)	# Fish Sampled	Fish per 1,000 mt
1939-40	45,454	1,524	34	1972-73	532	223	419
1940-41	48,868	2,258	46	1973-74	401	239	596
1941-42	32,597	2,445	75	1974-75	634	179	282
1942-43	21,922	1,287	59	1975-76	2,149	1,326	617
1943-44	35,341	2,250	64	1976-77	4,092	2,202	538
1944-45	36,694	1,520	41	1977-78	13,751	1,943	141
1945-46	23,638	2,088	88	1978-79	27,173	3,810	140
1946-47	27,616	2,637	95	1979-80	35,612	3,491	98
1947-48	19,437	1,397	72	1980-81	34,252	6,711	196
1948-49	18,125	631	35	1981-82	46,778	5,067	108
1949-50	24,189	1,835	76	1982-83	36,124	4,764	132
1950-51	17,493	1,019	58	1983-84	41,422	2,694	65
1951-52	15,857	911	57	1984-85	45,819	2,394	52
1952-53	10,326	397	38	1985-86	46,567	2,607	56
1953-54	5,266	447	85	1986-87	54,024	3,000	56
1954-55	18,465	811	44	1987-88	47,632	4,150	87
1955-56	22,201	572	26	1988-89	49,080	4,479	91
1956-57	36,835	1,011	27	1989-90	49,309	3,583	73
1957-58	27,753	931	34	1990-91	71,551	2,121	30
1958-59	11,875	903	76	1991-92	65,505	1,689	26
1959-60	19,332	755	39	1992-93	32,168	2,015	63
1960-61	20,823	488	23	1993-94	20,807	2,740	132
1961-62	26,199	422	16	1994-95	23,128	4,357	188
1962-63	23,901	205	9	1995-96	11,371	2,718	239
1963-64	23,703	205	9	1996-97	24,316	2,222	91
1964-65	19,988	268	13	1997-98	50,477	2,722	54
1965-66	11,279	111	10	1998-99	62,568	2,261	36
1966-67	7,405	1,944	263	1999-00	15,863	1,674	106
1967-68	1,713	720	420	2000-01	27,647	1,919	69
1968-69	1,695	2,145	1,265	2001-02	12,561	2,114	168
1969-70	1,168	498	426	2002-03	13,948	2,150	154
1970-71	835	150	180	2003-04	11,756	1,599	136
1971-72	911	344	378	2004-05	9,850	1,297	132

Table 5. Commercial and recreational landings (metric tons) of Pacific mackerel in California (CA) and Baja California (MX), for 1929-30 to 2004-05. Data from 1929-30 through 1975-76 are based on a May-April 'biological year', and data from 1976-77 through 2005-06 are based on a July-June 'biological year'. See also Figure 2.

Season	CA Com.	CA Rec.	MX Com.	Total
1929-30	25,716	25	0	25,741
1930-31	5,809	25	0	5,834
1931-32	6,873	50	0	6,923
1932-33	4,922	50	0	4,972
1933-34	33,055	50	0	33,105
1934-35	51,467	50	0	51,517
1935-36	66,400	50	0	66,450
1936-37	45,697	17	0	45,714
1937-38	31,954	34	0	31,988
1938-39	34,502	59	0	34,562
1939-40	45,341	113	0	45,454
1940-41	48,786	82	0	48,868
1941-42	32,547	50	0	32,597
1942-43	21,872	50	0	21,922
1943-44	35,291	50	0	35,341
1944-45	36,644	50	0	36,694
1945-46	23,588	50	0	23,638
1946-47	26,715	50	851	27,616
1947-48	17,975	200	1,262	19,437
1948-49	17,329	281	515	18,125
1949-50	22,708	130	1,352	24,189
1950-51	15,372	92	2,029	17,493
1951-52	14,472	65	1,320	15,857
1952-53	9,171	103	1,052	10,326
1953-54	4,005	84	1,177	5,266
1954-55	12,342	442	5,681	18,465
1955-56	12,200	203	9,798	22,201
1956-57	25,938	172	10,725	36,835
1957-58	25,509	210	2,034	27,753
1958-59	11,238	188	449	11,875
1959-60	18,725	112	495	19,332
1960-61	17,724	117	2,981	20,823
1961-62	20,094	141	5,964	26,199
1962-63	20,527	143	3,231	23,901
1963-64	15,517	220	7,966	23,703
1964-65	11,283	87	8,618	19,988
1965-66	3,442	222	7,615	11,279
1966-67	1,848	267	5,290	7,405
1967-68	619	146	948	1,713
1968-69	1,492	96	107	1,695
1969-70	809	158	201	1,168
1970-71	277	158	400	835
1971-72	90	321	500	911
1972-73	28	304	200	532
1973-74	52	249	100	401
1974-75	43	120	471	634
1975-76	141	199	1,809	2,149
1976-77	2,654	167	1,271	4,092
1977-78	7,748	837	5,165	13,751
1978-79	18,446	1,355	7,372	27,173
1979-80	28,755	1,707	5,150	35,612
1980-81	27,972	1,734	4,546	34,252
1981-82	38,407	1,216	7,155	46,778
1982-83	30,626	1,169	4,329	36,124
1983-84	36,309	849	4,264	41,422
1984-85	39,240	818	5,761	45,819
1985-86	37,615	756	8,197	46,567
1986-87	44,298	760	8,965	54,024
1987-88	44,838	674	2,120	47,632
1988-89	41,968	504	6,608	49,080
1989-90	25,063	521	23,724	49,309
1990-91	39,974	616	30,961	71,551
1991-92	30,268	680	34,557	65,505
1992-93	25,584	414	6,170	32,168
1993-94	10,787	496	9,524	20,807
1994-95	9,372	453	13,302	23,128
1995-96	7,615	389	3,368	11,371
1996-97	9,788	439	14,089	24,316
1997-98	23,413	205	26,860	50,477
1998-99	19,578	175	42,815	62,568
1999-00	7,170	106	8,587	15,863
2000-01	20,936	180	6,530	27,647
2001-02	8,436	122	4,003	12,561
2002-03	3,541	79	10,328	13,948
2003-04	5,972	56	5,728	11,756
2004-05	4,067	56	5,728	9,850

Table 6. Pacific mackerel catch-at-age (1,000s of individuals) matrix and associated landings used in the ASAP model. See also Figure 3.

	-------------------- Catch-at-Age (thousands) -------------------							
Season	**0**	**1**	**2**	**3**	**4**	**5**	**6+**	**Landings (mt)**
1929-30	9.3	12,437.2	22,473.6	20,825.3	5,209.6	3,875.7	4,979.7	25,741.2
1930-31	0.0	1,394.6	7,173.8	4,844.8	1,918.8	671.1	68.4	5,833.6
1931-32	0.0	961.7	10,038.2	6,219.6	1,313.3	756.5	580.7	6,922.9
1932-33	0.0	145.4	3,243.3	5,883.7	1,403.0	946.5	766.4	4,971.7
1933-34	0.0	4,624.7	19,035.8	31,918.5	23,386.4	8,285.2	4,254.3	33,104.9
1934-35	0.0	4,897.4	53,387.7	35,620.9	40,833.7	15,518.0	8,829.6	51,516.5
1935-36	0.0	10,876.9	12,743.7	61,734.5	63,851.1	33,649.6	9,663.7	66,450.2
1936-37	0.0	2,247.8	20,403.8	17,399.3	33,062.4	35,158.5	8,175.0	45,714.2
1937-38	128.5	1,475.8	2,592.2	8,035.2	15,910.4	26,039.3	12,242.3	31,987.6
1938-39	771.6	11,577.2	31,967.4	16,527.6	4,309.5	10,883.8	10,285.8	34,561.8
1939-40	1,793.5	23,108.8	23,591.7	33,525.1	11,037.1	6,277.3	5,794.5	45,454.0
1940-41	3,188.8	18,392.4	59,220.2	27,503.2	16,968.9	2,505.5	797.2	48,867.8
1941-42	636.7	18,357.8	31,162.2	28,757.0	6,508.3	919.7	141.5	32,597.4
1942-43	0.0	28,409.7	10,326.5	15,085.2	6,138.8	1,094.5	190.3	21,922.3
1943-44	425.1	14,113.8	61,939.1	10,500.3	7,397.0	1,020.3	255.1	35,341.3
1944-45	0.0	20,750.0	20,635.0	35,234.7	8,851.8	1,609.4	287.4	36,693.7
1945-46	2,027.7	15,285.7	12,036.2	8,890.6	8,292.7	4,809.3	2,937.5	23,638.0
1946-47	3,281.9	16,633.3	20,213.6	11,014.3	6,688.1	4,276.4	3,455.9	27,616.3
1947-48	7,398.3	4,627.8	10,420.5	9,192.7	6,044.5	3,494.5	2,801.9	19,437.0
1948-49	2,714.0	37,154.4	9,078.0	3,649.9	4,024.3	1,403.8	1,029.5	18,124.7
1949-50	563.0	21,876.8	36,153.1	9,128.8	3,056.3	1,970.5	1,045.6	24,188.9
1950-51	44.1	6,565.9	17,009.7	17,097.8	3,172.8	528.8	484.7	17,493.0
1951-52	1,024.5	3,979.7	6,816.6	11,742.0	11,229.7	669.8	433.4	15,857.1
1952-53	504.9	321.3	1,973.7	1,973.7	8,629.4	4,636.0	183.6	10,325.8
1953-54	10,780.2	2,013.9	1,303.1	1,342.6	552.8	789.8	868.7	5,265.9
1954-55	691.9	47,664.4	10,147.9	2,152.6	1,230.1	0.0	461.3	18,464.7
1955-56	15,380.1	17,471.8	24,731.2	10,581.5	1,107.4	123.0	984.3	22,200.9
1956-57	418.3	54,695.7	22,484.8	19,033.7	8,784.8	313.7	0.0	36,835.0
1957-58	1,989.0	7,887.6	29,972.9	10,836.9	8,504.9	3,017.9	1,646.1	27,753.4
1958-59	11,463.8	2,656.3	4,578.5	7,374.6	3,145.6	1,433.0	908.7	11,874.8
1959-60	1,677.4	46,548.3	7,716.1	3,606.4	2,432.3	1,006.4	335.5	19,332.5
1960-61	1,623.3	12,681.8	16,942.9	10,145.5	5,072.7	1,724.7	1,318.9	20,822.5
1961-62	7,321.3	28,587.9	15,514.1	14,642.6	5,752.4	1,220.2	522.9	26,199.2
1962-63	760.9	23,880.0	12,455.6	10,283.9	6,755.4	1,448.6	205.7	23,901.0
1963-64	177.3	6,312.4	18,516.7	9,856.8	9,313.9	2,930.2	449.1	23,703.0
1964-65	351.4	7,789.7	6,637.1	9,667.1	11,614.9	3,822.4	752.3	19,987.9
1965-66	13,074.1	1,264.8	766.7	1,700.6	5,524.5	8,676.7	1,563.0	11,279.4
1966-67	2,769.3	6,376.8	1,496.8	1,168.0	948.1	2,649.0	1,697.7	7,405.2

Continued….

Table 6 (cont'd). Pacific mackerel catch-at-age (1,000s of individuals) matrix and associated landings used in the ASAP model. See also Figure 3.

	Catch-at-Age (thousands)							
Season	**0**	**1**	**2**	**3**	**4**	**5**	**6+**	**Landings (mt)**
1967-68	5,697.5	731.7	62.3	455.9	159.8	135.1	279.5	1,713.3
1968-69	7,572.9	475.1	202.9	346.4	90.6	85.4	145.8	1,695.0
1969-70	44.3	2,371.3	595.7	212.3	74.8	65.8	10.2	1,168.2
1970-71	683.9	3,325.7	0.0	0.0	0.0	0.0	0.0	835.5
1971-72	0.0	2,804.4	229.8	10.5	14.1	9.4	0.0	911.3
1972-73	1,097.8	202.0	321.4	350.9	9.6	7.3	0.0	532.0
1973-74	46.8	560.3	163.4	30.9	72.3	85.2	51.5	400.9
1974-75	2,182.4	844.3	236.3	37.4	12.5	0.0	0.0	633.8
1975-76	15.2	6,041.7	375.5	31.1	3.9	6.5	3.3	2,149.3
1976-77	13,973.7	164.2	1,763.3	0.7	23.0	0.0	26.9	4,091.7
1977-78	11,070.9	36,733.9	78.0	286.8	0.0	0.0	0.0	13,751.3
1978-79	73,773.1	18,836.9	28,597.9	1,165.5	1,006.0	257.3	0.0	27,172.6
1979-80	27.2	102,035.3	14,823.6	15,124.5	221.1	673.5	0.0	35,612.1
1980-81	61,969.2	3,317.6	75,641.6	7,985.2	7,150.1	397.2	123.4	34,252.2
1981-82	18,495.0	45,248.5	10,883.9	69,199.4	4,793.5	3,063.7	199.9	46,778.0
1982-83	16,017.9	36,157.5	33,124.7	9,886.7	30,776.3	2,299.6	767.3	36,123.9
1983-84	2,780.0	2,765.8	43,686.2	39,482.5	6,213.8	17,433.8	247.2	41,422.2
1984-85	2,819.6	526.1	9,506.2	48,395.4	24,817.5	6,161.1	8,031.4	45,819.0
1985-86	3,227.3	17,399.0	5,160.6	16,156.1	49,841.2	10,646.3	2,425.0	46,567.4
1986-87	18,776.7	44,338.3	23,015.8	5,275.1	8,989.9	25,594.9	9,538.5	54,023.6
1987-88	18,002.5	70,986.5	32,303.0	5,260.2	2,823.9	3,468.7	7,494.2	47,632.2
1988-89	104,388.7	15,084.5	36,010.4	13,089.6	2,841.4	1,940.5	9,882.5	49,079.9
1989-90	21,861.6	160,807.0	8,372.4	6,711.3	4,510.9	2,716.5	5,082.8	49,308.8
1990-91	29,559.3	19,434.1	43,284.4	11,973.6	16,877.9	19,587.7	22,962.0	71,550.6
1991-92	27,181.0	91,781.7	21,911.7	21,684.3	10,412.4	9,327.5	14,180.2	65,504.9
1992-93	10,893.2	30,081.7	12,326.8	9,837.5	10,631.1	8,098.9	9,247.3	32,167.9
1993-94	51,114.0	9,311.3	10,616.0	3,438.5	3,357.6	5,040.9	7,410.5	20,807.4
1994-95	24,847.8	37,276.6	9,743.1	4,407.2	5,595.6	2,928.8	3,867.6	23,127.9
1995-96	43,904.2	20,162.5	5,046.4	944.9	519.1	1,329.4	1,535.6	11,371.0
1996-97	28,544.8	43,355.8	12,446.9	5,961.1	3,718.3	2,548.3	3,165.9	24,316.1
1997-98	24,253.0	49,396.5	32,477.6	12,788.8	8,270.7	7,516.0	15,758.6	50,477.3
1998-99	13,537.2	19,800.4	38,611.0	23,602.7	15,463.2	13,291.9	25,018.0	62,567.6
1999-00	11,915.4	2,943.1	2,672.7	6,103.3	5,818.4	4,436.5	4,233.4	15,863.0
2000-01	28,945.4	15,226.0	5,152.5	8,738.5	10,277.1	6,622.0	4,606.3	27,646.8
2001-02	13,732.9	19,688.0	3,404.9	1,883.0	2,329.9	2,051.2	1,762.4	12,561.4
2002-03	7,026.5	50,787.7	5,123.5	1,177.8	225.7	361.8	250.2	13,947.8
2003-04	25,649.8	14,666.9	5,067.1	1,861.6	654.1	642.2	485.1	11,755.8
2004-05	44,230.7	6,045.2	2,094.3	1,520.5	665.5	142.1	222.6	9,850.4
2005-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9,850.4

Table 7. Pacific mackerel weight-at-age (mean weight, kg) matrix used in ASAP. See also Figure 4.

	----------------------------- **Weight-at-Age (kg)** -------------------------------						
Season	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
1929-30	0.074	0.167	0.297	0.402	0.523	0.615	0.704
1930-31	0.060	0.139	0.301	0.422	0.511	0.603	0.698
1931-32	0.077	0.114	0.276	0.399	0.527	0.606	0.701
1932-33	0.058	0.081	0.277	0.379	0.508	0.604	0.711
1933-34	0.059	0.083	0.200	0.299	0.493	0.585	0.700
1934-35	0.065	0.142	0.198	0.233	0.431	0.538	0.683
1935-36	0.079	0.186	0.217	0.251	0.379	0.472	0.629
1936-37	0.086	0.193	0.284	0.338	0.393	0.453	0.574
1937-38	0.119	0.176	0.318	0.429	0.461	0.502	0.575
1938-39	0.124	0.174	0.310	0.448	0.532	0.582	0.633
1939-40	0.191	0.247	0.364	0.461	0.585	0.683	0.795
1940-41	0.181	0.261	0.340	0.444	0.529	0.643	0.748
1941-42	0.115	0.260	0.344	0.441	0.561	0.653	0.810
1942-43	0.180	0.237	0.374	0.473	0.548	0.629	0.744
1943-44	0.165	0.293	0.340	0.476	0.576	0.653	0.716
1944-45	0.144	0.272	0.380	0.474	0.589	0.663	0.797
1945-46	0.122	0.235	0.385	0.495	0.613	0.707	0.779
1946-47	0.125	0.261	0.385	0.488	0.619	0.682	0.765
1947-48	0.119	0.292	0.401	0.501	0.625	0.712	0.770
1948-49	0.107	0.227	0.355	0.507	0.618	0.709	0.813
1949-50	0.109	0.193	0.320	0.458	0.610	0.728	0.833
1950-51	0.084	0.250	0.324	0.457	0.567	0.667	0.797
1951-52	0.163	0.255	0.347	0.430	0.571	0.697	0.860
1952-53	0.173	0.298	0.387	0.473	0.570	0.723	0.951
1953-54	0.162	0.296	0.412	0.514	0.605	0.767	0.866
1954-55	0.084	0.258	0.388	0.507	0.588	0.744	0.764
1955-56	0.140	0.253	0.358	0.486	0.585	0.748	0.883
1956-57	0.111	0.249	0.374	0.487	0.600	0.756	0.874
1957-58	0.179	0.311	0.375	0.510	0.604	0.652	0.651
1958-59	0.176	0.293	0.397	0.490	0.620	0.688	0.779
1959-60	0.133	0.252	0.399	0.512	0.605	0.705	0.820
1960-61	0.102	0.276	0.393	0.509	0.613	0.703	0.771
1961-62	0.145	0.252	0.390	0.497	0.586	0.650	0.821
1962-63	0.276	0.320	0.420	0.540	0.622	0.712	0.782
1963-64	0.197	0.298	0.434	0.538	0.627	0.730	0.743
1964-65	0.181	0.300	0.400	0.503	0.612	0.748	0.812
1965-66	0.109	0.195	0.384	0.501	0.596	0.723	0.735
1966-67	0.149	0.273	0.419	0.525	0.658	0.790	0.834

Continued….

Table 7 (cont'd). Pacific mackerel weight-at-age (mean weight, kg) matrix used in ASAP. See also Figure 4.

	Weight-at-Age (kg)						
Season	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
1967-68	0.166	0.235	0.488	0.510	0.599	0.723	0.879
1968-69	0.138	0.266	0.391	0.562	0.593	0.709	0.955
1969-70	0.103	0.322	0.428	0.505	0.662	0.746	0.907
1970-71	0.099	0.232	0.402	0.584	0.730	0.837	0.852
1971-72	0.266	0.282	0.457	0.481	0.740	0.955	0.977
1972-73	0.147	0.266	0.449	0.508	0.552	0.746	0.975
1973-74	0.119	0.329	0.433	0.609	0.606	0.686	0.763
1974-75	0.107	0.303	0.604	0.740	0.837	0.800	0.781
1975-76	0.127	0.361	0.517	0.973	1.053	1.029	1.350
1976-77	0.170	0.297	0.672	0.864	1.291	1.223	1.531
1977-78	0.122	0.322	0.600	0.847	1.063	1.548	1.457
1978-79	0.062	0.334	0.473	0.705	0.908	1.308	1.841
1979-80	0.082	0.189	0.440	0.598	0.810	0.969	1.553
1980-81	0.072	0.176	0.270	0.437	0.598	0.874	1.066
1981-82	0.083	0.190	0.239	0.391	0.597	0.757	0.939
1982-83	0.032	0.151	0.237	0.345	0.516	0.773	0.916
1983-84	0.049	0.191	0.302	0.390	0.458	0.511	0.688
1984-85	0.120	0.235	0.351	0.396	0.505	0.614	0.643
1985-86	0.157	0.285	0.418	0.461	0.484	0.560	0.650
1986-87	0.148	0.290	0.408	0.508	0.561	0.595	0.658
1987-88	0.133	0.272	0.414	0.523	0.600	0.691	0.743
1988-89	0.101	0.301	0.415	0.576	0.666	0.734	0.841
1989-90	0.104	0.193	0.381	0.542	0.647	0.749	0.779
1990-91	0.094	0.267	0.377	0.554	0.649	0.680	0.775
1991-92	0.071	0.217	0.397	0.514	0.591	0.664	0.754
1992-93	0.087	0.175	0.330	0.459	0.544	0.661	0.715
1993-94	0.073	0.228	0.294	0.408	0.583	0.607	0.761
1994-95	0.100	0.156	0.248	0.361	0.493	0.597	0.690
1995-96	0.081	0.179	0.275	0.431	0.586	0.689	0.783
1996-97	0.105	0.182	0.318	0.471	0.589	0.649	0.702
1997-98	0.149	0.239	0.333	0.446	0.572	0.637	0.734
1998-99	0.139	0.267	0.325	0.419	0.530	0.615	0.660
1999-00	0.148	0.228	0.399	0.509	0.575	0.633	0.727
2000-01	0.114	0.266	0.370	0.550	0.590	0.608	0.675
2001-02	0.103	0.253	0.347	0.534	0.567	0.619	0.623
2002-03	0.133	0.218	0.303	0.412	0.552	0.529	0.656
2003-04	0.125	0.284	0.414	0.603	0.679	0.745	0.808
2004-05	0.131	0.267	0.397	0.594	0.688	0.782	0.812
2005-06	0.131	0.267	0.397	0.594	0.688	0.782	0.812

Table 8. Selectivity ogives applied to survey data in the ASAP model. See respective survey data sections for details. See also Figure 6.

	Age						
Survey	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
Spotter Index	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.000
CPFV-GLM							
1936-89	0.0003	0.5001	1.0000	1.0000	1.0000	1.0000	1.000
1990-04	0.0003	0.3329	0.6663	1.0000	1.0000	1.0000	1.000
CalCOFI Larval Index	0.0000	0.0738	0.2459	0.4742	0.7329	1.0000	1.000

Table 9. General linear model (GLM) results from recreational fishery catch/effort ‘standardization’ analysis based on CPFV logbook data (1936-04). ‘Reference cell’ used in the analysis is highlighted in bold. See also section ‘Assessment Data, Commercial Passenger Fishing Vessel Logbook CPUE (Index 2)’ and Figure 5.

```
Class    Levels    Values

Year      62       1936 1937 1938 1939 1940 1947 1948 1949 1950 1951
                   1952 1953 1954 1955 1956 1957 1958 1959 1960 1961
                   1962 1963 1964 1965 1966 1967 1968 1969 1970 1971
                   1972 1973 1974 1975 1976 1977 1978 1980 1981 1982
                   1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
                   1993 1994 1995 1996 1997 1998 1999 2000 2001 2002
                   2003 2004

Quarter    4       1 2 3 4

Fleet      2       North South

Dependent Variable: Ln(CPUE)
                                Sum of          Mean
Source                  DF      Squares         Square    F Value   Pr >F

Model                   65     25086.26         380.09     117.93  0.0001

Error               22,689    73,130.58           3.22

Corrected Total     22,755    98,216.85

                       R^2           CV        Root MSE       Ln(CPUE)- Mean

                     0.26          116.27        1.80              1.54

Source                  DF    Type I SS   Mean Square  F Value    Pr >F

Year                    61     16,625.39      272.54    84.56    0.0001
Quarter                  3      2,084.36      694.78   215.56    0.0001
Fleet                    1      6,376.50     3188.25   989.16    0.0001

Source                  DF   Type III SS   Mean Square  F Value    Pr >F

Year                    61     18988.30       311.28      96.58    0.0001
Quarter                  3     2,635.34       878.44     272.54    0.0001
Fleet                    1     6,376.50     3,188.25     989.16    0.0001
```

Table 10. Likelihood function components for the ASAP baseline model in which 179 parameters were estimated. RSS=residual sum of squared deviations, nobs=number of observations in that component, Lambda=weight given that component.

Component	**RSS**	**nobs**	**Lambda**	**Likelihood**	**% of Total**
Catch_Fleet_1	0.0179	77	101	1.8037	
Catch_Fleet_Total	**0.0179**	**77**	**101**	**1.8037**	**0.1%**
Discard_Fleet_1	0.0000	77	0	0.0000	
Discard_Fleet_Total	0.0000	77	0	0.0000	
CAA_proportions	**N/A**	**539**	**see_below**	**394.5510**	**29.2%**
Discard_proportions	N/A	539	see_below	0.0000	
Index_Fit_1 (Spotter)	**93.4513**	**37**	**1**	**519.5260**	**38.5%**
Index_Fit_2 (CPFV)	**15.1296**	**62**	**1**	**49.7857**	**3.7%**
Index_Fit_3 (CalCOFI)	**53.2396**	**48**	**1**	**279.4780**	**20.7%**
Index_Fit_Total	161.8210	147	3	848.7900	
Selectivity_devs_fleet_1	0.0000	1	0	0.0000	
Selectivity_devs_Total	**0.0000**	**1**	**0**	**0.0000**	**0.0%**
Catchability_devs_index_1	0.0000	37	1	0.0000	
Catchability_devs_index_2	0.0000	62	1	0.0000	
Catchability_devs_index_3	0.0000	48	1	0.0000	
Catchability_devs_Total	**0.0000**	**147**	**3**	**0.0000**	**0.0%**
Fmult_fleet_1	22.6760	76	0	0.0000	
Fmult_fleet_Total	**22.6760**	**76**	**0**	**0.0000**	**0.0%**
N_year_1	1.6383	6	0	0.0000	
Stock-Recruit_Fit	**17.1809**	**77**	**1**	**87.7400**	**6.5%**
Recruit_devs	**17.1809**	**77**	**1**	**17.1809**	**1.3%**
SRR_steepness	1.0945	1	0	0.0000	
SRR_virgin_stock	6.0798	1	0	0.0000	
Curvature_over_age	1.0718	5	0	0.0000	
Curvature_over_time	0.0000	525	0	0.0000	
F_penalty	**0.6844**	**539**	**0.001**	**0.0007**	**0.0%**
Mean_Sel_year1_pen	0.0000	7	1000	0.0000	
Max_Sel_penalty	0.1558	1	100	0.0000	
Fmult_Max_penalty	0.0000	?	100	0.0000	
Total	**219.5606**	**1680**		**1350.0660**	**100.0%**

Table 11. ASAP parameter estimates and standard deviations for the baseline model. The first 179 parameters are formal model parameters. The remaining are state variables derived from the formal model parameters. Coded ages are actual age +1; e.g., coded age 1 = age 0 fish.

Coded Age	Year	Index	Parameter	Estimate	Std Deviation
1	1929	1	log_sel_year1	-3.89E+00	2.35E+02
2	1929	2	log_sel_year1	-2.87E+00	2.35E+02
3	1929	3	log_sel_year1	-2.64E+00	2.35E+02
4	1929	4	log_sel_year1	-2.32E+00	2.35E+02
5	1929	5	log_sel_year1	-2.08E+00	2.35E+02
6	1929	6	log_sel_year1	-1.86E+00	2.35E+02
7	1929	7	log_sel_year1	-2.30E+00	2.35E+02
1	1929	8	log_sel_devs_vector	0.00E+00	5.81E+03
2	1929	9	log_sel_devs_vector	0.00E+00	5.81E+03
3	1929	10	log_sel_devs_vector	0.00E+00	5.81E+03
4	1929	11	log_sel_devs_vector	0.00E+00	5.81E+03
5	1929	12	log_sel_devs_vector	0.00E+00	5.81E+03
6	1929	13	log_sel_devs_vector	0.00E+00	5.81E+03
7	1929	14	log_sel_devs_vector	0.00E+00	5.81E+03
	1929	15	log_Fmult_year1	-3.21E-01	2.35E+02
	1930	16	log_Fmult_devs	-1.55E+00	1.18E-01
	1931	17	log_Fmult_devs	1.34E-01	1.10E-01
	1932	18	log_Fmult_devs	-2.88E-01	1.08E-01
	1933	19	log_Fmult_devs	2.06E+00	1.08E-01
	1934	20	log_Fmult_devs	6.56E-01	1.08E-01
	1935	21	log_Fmult_devs	5.50E-01	1.07E-01
	1936	22	log_Fmult_devs	-1.45E-01	1.04E-01
	1937	23	log_Fmult_devs	-2.56E-01	1.03E-01
	1938	24	log_Fmult_devs	1.59E-01	1.04E-01
	1939	25	log_Fmult_devs	1.90E-01	1.07E-01
	1940	26	log_Fmult_devs	2.89E-01	1.07E-01
	1941	27	log_Fmult_devs	-2.73E-01	1.03E-01
	1942	28	log_Fmult_devs	-4.56E-01	1.06E-01
	1943	29	log_Fmult_devs	5.21E-01	1.07E-01
	1944	30	log_Fmult_devs	1.58E-01	1.05E-01
	1945	31	log_Fmult_devs	-3.07E-01	1.02E-01
	1946	32	log_Fmult_devs	3.22E-01	1.08E-01
	1947	33	log_Fmult_devs	-2.70E-01	1.06E-01
	1948	34	log_Fmult_devs	-1.22E-01	1.10E-01
	1949	35	log_Fmult_devs	3.85E-01	1.07E-01
	1950	36	log_Fmult_devs	-2.23E-01	1.03E-01
	1951	37	log_Fmult_devs	-1.46E-02	1.05E-01
	1952	38	log_Fmult_devs	-3.92E-01	1.05E-01
	1953	39	log_Fmult_devs	-9.38E-01	1.10E-01
	1954	40	log_Fmult_devs	1.06E+00	1.15E-01
	1955	41	log_Fmult_devs	1.64E-01	1.08E-01
	1956	42	log_Fmult_devs	5.12E-01	1.10E-01
	1957	43	log_Fmult_devs	-1.68E-01	1.08E-01
	1958	44	log_Fmult_devs	-8.46E-01	1.04E-01

Table 11 (cont'd).

Coded Age	Year	Index	Parameter	Estimate	Std Deviation
	1959	45	log_Fmult_devs	4.93E-01	1.08E-01
	1960	46	log_Fmult_devs	9.97E-02	1.05E-01
	1961	47	log_Fmult_devs	3.10E-01	1.07E-01
	1962	48	log_Fmult_devs	-7.68E-02	1.05E-01
	1963	49	log_Fmult_devs	2.89E-01	1.05E-01
	1964	50	log_Fmult_devs	2.12E-01	1.05E-01
	1965	51	log_Fmult_devs	-1.03E-01	1.03E-01
	1966	52	log_Fmult_devs	-3.12E-01	1.06E-01
	1967	53	log_Fmult_devs	-1.41E+00	9.96E-02
	1968	54	log_Fmult_devs	-6.18E-02	1.04E-01
	1969	55	log_Fmult_devs	-5.26E-01	1.05E-01
	1970	56	log_Fmult_devs	-4.18E-01	1.04E-01
	1971	57	log_Fmult_devs	-1.30E-01	1.05E-01
	1972	58	log_Fmult_devs	-5.25E-01	1.02E-01
	1973	59	log_Fmult_devs	-4.51E-01	1.05E-01
	1974	60	log_Fmult_devs	1.92E-01	1.04E-01
	1975	61	log_Fmult_devs	8.58E-01	1.08E-01
	1976	62	log_Fmult_devs	8.93E-02	1.20E-01
	1977	63	log_Fmult_devs	6.38E-01	1.17E-01
	1978	64	log_Fmult_devs	4.69E-01	1.16E-01
	1979	65	log_Fmult_devs	8.67E-02	1.14E-01
	1980	66	log_Fmult_devs	6.93E-02	1.09E-01
	1981	67	log_Fmult_devs	1.16E-01	1.12E-01
	1982	68	log_Fmult_devs	-2.02E-01	1.08E-01
	1983	69	log_Fmult_devs	4.62E-02	1.09E-01
	1984	70	log_Fmult_devs	3.29E-02	1.06E-01
	1985	71	log_Fmult_devs	-4.86E-02	1.06E-01
	1986	72	log_Fmult_devs	1.78E-01	1.05E-01
	1987	73	log_Fmult_devs	-4.39E-02	1.04E-01
	1988	74	log_Fmult_devs	5.47E-02	1.04E-01
	1989	75	log_Fmult_devs	1.64E-01	1.04E-01
	1990	76	log_Fmult_devs	4.57E-01	1.07E-01
	1991	77	log_Fmult_devs	1.14E-01	1.05E-01
	1992	78	log_Fmult_devs	-4.62E-01	1.02E-01
	1993	79	log_Fmult_devs	-3.89E-01	1.03E-01
	1994	80	log_Fmult_devs	2.74E-01	1.05E-01
	1995	81	log_Fmult_devs	-8.50E-01	1.01E-01
	1996	82	log_Fmult_devs	7.07E-01	1.06E-01
	1997	83	log_Fmult_devs	8.37E-01	1.07E-01
	1998	84	log_Fmult_devs	7.59E-01	1.12E-01
	1999	85	log_Fmult_devs	-1.14E+00	9.92E-02
	2000	86	log_Fmult_devs	6.71E-01	1.10E-01
	2001	87	log_Fmult_devs	-6.79E-01	1.08E-01
	2002	88	log_Fmult_devs	2.34E-01	1.10E-01

Table 11 (cont'd).

Coded Age	Year	Index	Parameter	Estimate	Std Deviation
	2003	89	log_Fmult_devs	-4.18E-01	1.05E-01
	2004	90	log_Fmult_devs	-2.44E-01	1.09E-01
	2005	91	log_Fmult_devs	-1.25E-01	1.14E-01
1	1929	92	log_recruit_devs	2.01E-01	1.95E-01
1	1930	93	log_recruit_devs	1.12E-01	1.85E-01
1	1931	94	log_recruit_devs	9.12E-02	1.80E-01
1	1932	95	log_recruit_devs	1.49E-01	1.72E-01
1	1933	96	log_recruit_devs	-2.79E-01	1.79E-01
1	1934	97	log_recruit_devs	-4.54E-01	1.76E-01
1	1935	98	log_recruit_devs	-5.50E-01	1.75E-01
1	1936	99	log_recruit_devs	-2.75E-01	1.70E-01
1	1937	100	log_recruit_devs	-2.04E-01	1.78E-01
1	1938	101	log_recruit_devs	9.74E-02	1.72E-01
1	1939	102	log_recruit_devs	-6.83E-02	1.77E-01
1	1940	103	log_recruit_devs	-2.13E-01	1.78E-01
1	1941	104	log_recruit_devs	3.32E-01	1.65E-01
1	1942	105	log_recruit_devs	-7.21E-02	1.84E-01
1	1943	106	log_recruit_devs	-4.17E-02	1.84E-01
1	1944	107	log_recruit_devs	-2.13E-03	1.77E-01
1	1945	108	log_recruit_devs	-3.58E-01	1.82E-01
1	1946	109	log_recruit_devs	-4.67E-01	1.86E-01
1	1947	110	log_recruit_devs	5.43E-01	1.55E-01
1	1948	111	log_recruit_devs	3.37E-01	1.69E-01
1	1949	112	log_recruit_devs	-3.26E-01	1.88E-01
1	1950	113	log_recruit_devs	-4.38E-01	1.90E-01
1	1951	114	log_recruit_devs	-3.91E-01	1.94E-01
1	1952	115	log_recruit_devs	-1.03E-01	1.92E-01
1	1953	116	log_recruit_devs	1.24E+00	1.54E-01
1	1954	117	log_recruit_devs	1.04E-01	1.96E-01
1	1955	118	log_recruit_devs	5.91E-01	1.73E-01
1	1956	119	log_recruit_devs	-7.73E-02	1.92E-01
1	1957	120	log_recruit_devs	-2.09E-01	1.85E-01
1	1958	121	log_recruit_devs	4.12E-01	1.55E-01
1	1959	122	log_recruit_devs	6.70E-02	1.73E-01
1	1960	123	log_recruit_devs	1.34E-01	1.63E-01
1	1961	124	log_recruit_devs	-1.35E-02	1.53E-01
1	1962	125	log_recruit_devs	-5.46E-01	1.68E-01
1	1963	126	log_recruit_devs	-5.94E-01	1.67E-01
1	1964	127	log_recruit_devs	-5.84E-01	1.67E-01
1	1965	128	log_recruit_devs	-5.35E-01	1.58E-01
1	1966	129	log_recruit_devs	-7.14E-01	1.68E-01
1	1967	130	log_recruit_devs	-4.86E-01	1.61E-01
1	1968	131	log_recruit_devs	3.57E-02	1.60E-01
1	1969	132	log_recruit_devs	-1.63E-02	1.67E-01

Table 11 (cont'd).

Coded Age	Year	Index	Parameter	Estimate	Std Deviation
1	1970	133	log_recruit_devs	3.58E-02	1.66E-01
1	1971	134	log_recruit_devs	-5.62E-01	1.77E-01
1	1972	135	log_recruit_devs	-1.13E-01	1.66E-01
1	1973	136	log_recruit_devs	-2.66E-01	1.88E-01
1	1974	137	log_recruit_devs	3.70E-01	1.74E-01
1	1975	138	log_recruit_devs	-3.53E-01	2.00E-01
1	1976	139	log_recruit_devs	1.83E+00	1.80E-01
1	1977	140	log_recruit_devs	7.54E-01	2.55E-01
1	1978	141	log_recruit_devs	1.57E+00	1.69E-01
1	1979	142	log_recruit_devs	7.34E-02	2.11E-01
1	1980	143	log_recruit_devs	8.52E-01	1.79E-01
1	1981	144	log_recruit_devs	9.44E-01	1.70E-01
1	1982	145	log_recruit_devs	2.36E-01	2.04E-01
1	1983	146	log_recruit_devs	7.10E-02	2.14E-01
1	1984	147	log_recruit_devs	2.17E-01	1.99E-01
1	1985	148	log_recruit_devs	1.22E-01	1.78E-01
1	1986	149	log_recruit_devs	-1.18E-02	1.68E-01
1	1987	150	log_recruit_devs	-3.70E-01	1.74E-01
1	1988	151	log_recruit_devs	1.88E-01	1.52E-01
1	1989	152	log_recruit_devs	-3.08E-01	1.73E-01
1	1990	153	log_recruit_devs	-1.23E-02	1.69E-01
1	1991	154	log_recruit_devs	-2.28E-01	1.71E-01
1	1992	155	log_recruit_devs	-4.02E-01	1.73E-01
1	1993	156	log_recruit_devs	7.45E-02	1.63E-01
1	1994	157	log_recruit_devs	1.64E-03	1.69E-01
1	1995	158	log_recruit_devs	2.51E-01	1.57E-01
1	1996	159	log_recruit_devs	-8.70E-02	1.60E-01
1	1997	160	log_recruit_devs	-5.69E-01	1.62E-01
1	1998	161	log_recruit_devs	-7.74E-01	1.61E-01
1	1999	162	log_recruit_devs	-5.88E-01	1.57E-01
1	2000	163	log_recruit_devs	1.39E-01	1.78E-01
1	2001	164	log_recruit_devs	7.40E-02	1.67E-01
1	2002	165	log_recruit_devs	-1.21E-01	1.91E-01
1	2003	166	log_recruit_devs	1.20E-01	1.99E-01
1	2004	167	log_recruit_devs	4.17E-01	2.14E-01
1	2005	168	log_recruit_devs	3.03E-03	2.31E-01
2	1929	169	log_N_year1_devs	1.54E-01	3.18E-01
3	1929	170	log_N_year1_devs	1.33E-01	3.58E-01
4	1929	171	log_N_year1_devs	9.71E-02	4.22E-01
5	1929	172	log_N_year1_devs	-6.84E-01	7.58E-01
6	1929	173	log_N_year1_devs	-8.09E-01	1.08E+00
7	1929	174	log_N_year1_devs	-6.82E-01	9.03E-01
	1929	175	log_q_year1 (Spotter)	-1.36E+01	9.63E-02
	1929	176	log_q_year1 (CPFV)	-1.25E+01	8.63E-02

Table 11 (cont'd).

Coded Age	Year	Index	Parameter	Estimate	Std Deviation
	1929	177	log_q_year1 (CalCOFI)	-1.18E+01	1.08E-01
		178	log_SRR_virgin	1.25E+01	1.41E-01
		179	SRR_steepness	3.16E-01	1.60E-02
	1929	180	SSB	2.13E+05	5.76E+04
	1930	181	SSB	2.35E+05	4.90E+04
	1931	182	SSB	2.60E+05	4.51E+04
	1932	183	SSB	2.68E+05	4.01E+04
	1933	184	SSB	2.51E+05	3.23E+04
	1934	185	SSB	2.07E+05	2.44E+04
	1935	186	SSB	1.56E+05	1.81E+04
	1936	187	SSB	1.13E+05	1.38E+04
	1937	188	SSB	9.28E+04	1.17E+04
	1938	189	SSB	8.40E+04	1.03E+04
	1939	190	SSB	8.34E+04	1.00E+04
	1940	191	SSB	6.79E+04	8.07E+03
	1941	192	SSB	5.62E+04	7.43E+03
	1942	193	SSB	5.26E+04	6.77E+03
	1943	194	SSB	5.66E+04	6.54E+03
	1944	195	SSB	5.25E+04	6.41E+03
	1945	196	SSB	4.50E+04	5.89E+03
	1946	197	SSB	4.18E+04	5.23E+03
	1947	198	SSB	3.44E+04	4.71E+03
	1948	199	SSB	3.20E+04	4.28E+03
	1949	200	SSB	3.32E+04	3.96E+03
	1950	201	SSB	3.10E+04	3.72E+03
	1951	202	SSB	2.90E+04	3.72E+03
	1952	203	SSB	2.68E+04	3.73E+03
	1953	204	SSB	2.60E+04	3.61E+03
	1954	205	SSB	3.12E+04	3.34E+03
	1955	206	SSB	3.79E+04	3.97E+03
	1956	207	SSB	4.21E+04	4.55E+03
	1957	208	SSB	3.63E+04	4.35E+03
	1958	209	SSB	3.21E+04	4.17E+03
	1959	210	SSB	3.52E+04	3.96E+03
	1960	211	SSB	3.59E+04	3.78E+03
	1961	212	SSB	3.39E+04	3.59E+03
	1962	213	SSB	3.18E+04	3.33E+03
	1963	214	SSB	2.79E+04	2.89E+03
	1964	215	SSB	1.96E+04	2.35E+03
	1965	216	SSB	1.22E+04	1.75E+03
	1966	217	SSB	9.98E+03	1.58E+03
	1967	218	SSB	8.61E+03	1.43E+03
	1968	219	SSB	9.44E+03	1.45E+03
	1969	220	SSB	1.05E+04	1.52E+03

Table 11 (cont'd).

Coded Age	Year	Index	Parameter	Estimate	Std Deviation
	1970	221	SSB	1.20E+04	1.64E+03
	1971	222	SSB	1.42E+04	1.86E+03
	1972	223	SSB	1.47E+04	1.86E+03
	1973	224	SSB	1.65E+04	1.99E+03
	1974	225	SSB	2.20E+04	2.57E+03
	1975	226	SSB	3.19E+04	3.62E+03
	1976	227	SSB	4.11E+04	4.73E+03
	1977	228	SSB	6.02E+04	6.47E+03
	1978	229	SSB	9.62E+04	1.11E+04
	1979	230	SSB	1.25E+05	1.45E+04
	1980	231	SSB	1.31E+05	1.51E+04
	1981	232	SSB	1.55E+05	1.86E+04
	1982	233	SSB	1.63E+05	2.01E+04
	1983	234	SSB	1.74E+05	2.02E+04
	1984	235	SSB	1.90E+05	2.23E+04
	1985	236	SSB	1.94E+05	2.27E+04
	1986	237	SSB	1.96E+05	2.24E+04
	1987	238	SSB	1.92E+05	2.20E+04
	1988	239	SSB	1.93E+05	2.20E+04
	1989	240	SSB	1.68E+05	1.93E+04
	1990	241	SSB	1.54E+05	1.75E+04
	1991	242	SSB	1.24E+05	1.52E+04
	1992	243	SSB	9.41E+04	1.24E+04
	1993	244	SSB	8.77E+04	1.13E+04
	1994	245	SSB	7.73E+04	9.48E+03
	1995	246	SSB	8.47E+04	1.02E+04
	1996	247	SSB	9.02E+04	9.36E+03
	1997	248	SSB	8.87E+04	8.51E+03
	1998	249	SSB	6.49E+04	6.69E+03
	1999	250	SSB	3.65E+04	5.42E+03
	2000	251	SSB	3.33E+04	4.68E+03
	2001	252	SSB	2.43E+04	3.80E+03
	2002	253	SSB	2.28E+04	3.39E+03
	2003	254	SSB	3.03E+04	4.81E+03
	2004	255	SSB	3.11E+04	5.30E+03
	2005	256	SSB	3.33E+04	6.03E+03
	1929	257	recruits	1.18E+06	2.04E+05
	1930	258	recruits	9.68E+05	1.87E+05
	1931	259	recruits	1.00E+06	1.79E+05
	1932	260	recruits	1.13E+06	1.82E+05
	1933	261	recruits	7.46E+05	1.27E+05
	1934	262	recruits	6.04E+05	1.01E+05
	1935	263	recruits	4.92E+05	8.28E+04
	1936	264	recruits	5.41E+05	8.70E+04

Table 11 (cont'd).

Coded Age	Year	Index	Parameter	Estimate	Std Deviation
	1937	265	recruits	4.63E+05	7.79E+04
	1938	266	recruits	5.42E+05	8.43E+04
	1939	267	recruits	4.25E+05	7.00E+04
	1940	268	recruits	3.65E+05	6.20E+04
	1941	269	recruits	5.34E+05	7.90E+04
	1942	270	recruits	3.05E+05	5.26E+04
	1943	271	recruits	2.97E+05	5.02E+04
	1944	272	recruits	3.29E+05	5.17E+04
	1945	273	recruits	2.16E+05	3.69E+04
	1946	274	recruits	1.70E+05	3.06E+04
	1947	275	recruits	4.37E+05	5.47E+04
	1948	276	recruits	2.99E+05	4.34E+04
	1949	277	recruits	1.45E+05	2.60E+04
	1950	278	recruits	1.33E+05	2.43E+04
	1951	279	recruits	1.31E+05	2.49E+04
	1952	280	recruits	1.65E+05	3.19E+04
	1953	281	recruits	5.88E+05	7.39E+04
	1954	282	recruits	1.84E+05	3.71E+04
	1955	283	recruits	3.53E+05	5.54E+04
	1956	284	recruits	2.16E+05	3.97E+04
	1957	285	recruits	2.07E+05	3.70E+04
	1958	286	recruits	3.38E+05	4.66E+04
	1959	287	recruits	2.14E+05	3.49E+04
	1960	288	recruits	2.49E+05	3.61E+04
	1961	289	recruits	2.19E+05	2.94E+04
	1962	290	recruits	1.22E+05	1.92E+04
	1963	291	recruits	1.10E+05	1.69E+04
	1964	292	recruits	9.84E+04	1.51E+04
	1965	293	recruits	7.46E+04	1.11E+04
	1966	294	recruits	3.97E+04	6.96E+03
	1967	295	recruits	4.11E+04	7.20E+03
	1968	296	recruits	5.99E+04	1.05E+04
	1969	297	recruits	6.22E+04	1.13E+04
	1970	298	recruits	7.26E+04	1.28E+04
	1971	299	recruits	4.54E+04	8.72E+03
	1972	300	recruits	8.38E+04	1.48E+04
	1973	301	recruits	7.43E+04	1.48E+04
	1974	302	recruits	1.56E+05	2.85E+04
	1975	303	recruits	9.96E+04	2.14E+04
	1976	304	recruits	1.24E+06	2.10E+05
	1977	305	recruits	5.32E+05	1.44E+05
	1978	306	recruits	1.67E+06	2.76E+05
	1979	307	recruits	5.44E+05	1.19E+05
	1980	308	recruits	1.44E+06	2.56E+05

Table 11 (cont'd).

Coded Age	Year	Index	Parameter	Estimate	Std Deviation
	1981	309	recruits	1.62E+06	2.74E+05
	1982	310	recruits	9.00E+05	1.87E+05
	1983	311	recruits	7.88E+05	1.71E+05
	1984	312	recruits	9.51E+05	1.84E+05
	1985	313	recruits	9.14E+05	1.59E+05
	1986	314	recruits	8.09E+05	1.34E+05
	1987	315	recruits	5.69E+05	9.95E+04
	1988	316	recruits	9.81E+05	1.41E+05
	1989	317	recruits	6.01E+05	1.01E+05
	1990	318	recruits	7.39E+05	1.18E+05
	1991	319	recruits	5.63E+05	9.39E+04
	1992	320	recruits	4.07E+05	7.08E+04
	1993	321	recruits	5.35E+05	8.54E+04
	1994	322	recruits	4.71E+05	7.69E+04
	1995	323	recruits	5.47E+05	7.87E+04
	1996	324	recruits	4.20E+05	6.18E+04
	1997	325	recruits	2.72E+05	4.21E+04
	1998	326	recruits	2.19E+05	3.47E+04
	1999	327	recruits	2.05E+05	3.21E+04
	2000	328	recruits	2.59E+05	4.32E+04
	2001	329	recruits	2.23E+05	3.82E+04
	2002	330	recruits	1.38E+05	2.88E+04
	2003	331	recruits	1.65E+05	3.67E+04
	2004	332	recruits	2.89E+05	7.22E+04
	2005	333	recruits	1.95E+05	5.31E+04
	1929	334	plus_group	7.58E+04	6.68E+04
	1930	335	plus_group	6.62E+04	4.33E+04
	1931	336	plus_group	6.60E+04	3.09E+04
	1932	337	plus_group	9.71E+04	2.90E+04
	1933	338	plus_group	1.18E+05	2.75E+04
	1934	339	plus_group	1.18E+05	2.50E+04
	1935	340	plus_group	9.50E+04	1.72E+04
	1936	341	plus_group	6.01E+04	1.32E+04
	1937	342	plus_group	4.24E+04	1.02E+04
	1938	343	plus_group	3.61E+04	8.46E+03
	1939	344	plus_group	2.60E+04	6.32E+03
	1940	345	plus_group	1.79E+04	4.64E+03
	1941	346	plus_group	1.12E+04	3.34E+03
	1942	347	plus_group	9.45E+03	2.83E+03
	1943	348	plus_group	9.26E+03	2.56E+03
	1944	349	plus_group	8.89E+03	2.46E+03
	1945	350	plus_group	6.88E+03	2.08E+03
	1946	351	plus_group	6.16E+03	1.85E+03
	1947	352	plus_group	6.47E+03	2.00E+03

Table 11 (cont'd).

Coded Age	Year	Index	Parameter	Estimate	Std Deviation
	1948	353	plus_group	5.18E+03	1.65E+03
	1949	354	plus_group	4.83E+03	1.47E+03
	1950	355	plus_group	4.42E+03	1.35E+03
	1951	356	plus_group	3.59E+03	1.13E+03
	1952	357	plus_group	2.94E+03	9.41E+02
	1953	358	plus_group	5.74E+03	1.53E+03
	1954	359	plus_group	7.36E+03	1.65E+03
	1955	360	plus_group	5.57E+03	1.30E+03
	1956	361	plus_group	4.37E+03	1.07E+03
	1957	362	plus_group	2.88E+03	8.66E+02
	1958	363	plus_group	2.46E+03	8.05E+02
	1959	364	plus_group	6.82E+03	1.81E+03
	1960	365	plus_group	4.81E+03	1.35E+03
	1961	366	plus_group	5.37E+03	1.41E+03
	1962	367	plus_group	3.78E+03	1.09E+03
	1963	368	plus_group	3.06E+03	9.05E+02
	1964	369	plus_group	2.88E+03	9.12E+02
	1965	370	plus_group	1.61E+03	6.31E+02
	1966	371	plus_group	1.19E+03	5.07E+02
	1967	372	plus_group	1.10E+03	4.73E+02
	1968	373	plus_group	1.27E+03	4.62E+02
	1969	374	plus_group	1.73E+03	5.10E+02
	1970	375	plus_group	2.57E+03	5.77E+02
	1971	376	plus_group	3.36E+03	6.18E+02
	1972	377	plus_group	3.31E+03	5.60E+02
	1973	378	plus_group	3.57E+03	5.73E+02
	1974	379	plus_group	4.67E+03	7.21E+02
	1975	380	plus_group	5.53E+03	8.15E+02
	1976	381	plus_group	6.39E+03	9.14E+02
	1977	382	plus_group	5.65E+03	7.99E+02
	1978	383	plus_group	6.47E+03	9.77E+02
	1979	384	plus_group	6.01E+03	9.93E+02
	1980	385	plus_group	7.90E+03	1.43E+03
	1981	386	plus_group	6.84E+03	1.32E+03
	1982	387	plus_group	3.37E+04	7.59E+03
	1983	388	plus_group	3.05E+04	6.25E+03
	1984	389	plus_group	5.52E+04	1.12E+04
	1985	390	plus_group	4.16E+04	8.42E+03
	1986	391	plus_group	5.57E+04	1.11E+04
	1987	392	plus_group	6.56E+04	1.29E+04
	1988	393	plus_group	5.41E+04	1.09E+04
	1989	394	plus_group	4.49E+04	9.28E+03
	1990	395	plus_group	4.17E+04	8.65E+03
	1991	396	plus_group	3.32E+04	7.67E+03

Table 11 (cont'd).

Coded Age	Year	Index	Parameter	Estimate	Std Deviation
	1992	397	plus_group	2.45E+04	6.45E+03
	1993	398	plus_group	1.93E+04	5.20E+03
	1994	399	plus_group	2.46E+04	5.85E+03
	1995	400	plus_group	2.15E+04	5.02E+03
	1996	401	plus_group	2.64E+04	5.16E+03
	1997	402	plus_group	2.54E+04	4.71E+03
	1998	403	plus_group	1.67E+04	3.73E+03
	1999	404	plus_group	7.44E+03	2.64E+03
	2000	405	plus_group	6.45E+03	2.20E+03
	2001	406	plus_group	4.88E+03	1.82E+03
	2002	407	plus_group	4.62E+03	1.61E+03
	2003	408	plus_group	3.64E+03	1.31E+03
	2004	409	plus_group	3.72E+03	1.25E+03
	2005	410	plus_group	4.38E+03	1.35E+03

Table 12. Instantaneous rates of fishing mortality at age (yr^{-1}) for biological years 1929-30 through 2005-06 estimated in the ASAP baseline model. See also Figure 15.

Biological	---------------------- **Instantaneous Fishing Mortality Rate at Age (yr^{-1})** ----------------------						
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
1929-30	0.015	0.041	0.052	0.071	0.091	0.113	0.073
1930-31	0.003	0.009	0.011	0.015	0.019	0.024	0.015
1931-32	0.004	0.010	0.013	0.017	0.022	0.027	0.018
1932-33	0.003	0.007	0.009	0.013	0.017	0.021	0.013
1933-34	0.021	0.058	0.074	0.102	0.129	0.161	0.104
1934-35	0.041	0.112	0.142	0.196	0.249	0.310	0.200
1935-36	0.070	0.195	0.246	0.340	0.432	0.538	0.346
1936-37	0.061	0.168	0.212	0.294	0.374	0.465	0.299
1937-38	0.047	0.130	0.164	0.227	0.289	0.360	0.232
1938-39	0.055	0.153	0.193	0.267	0.339	0.422	0.272
1939-40	0.067	0.185	0.233	0.322	0.410	0.510	0.328
1940-41	0.089	0.247	0.311	0.430	0.547	0.681	0.438
1941-42	0.068	0.188	0.237	0.327	0.416	0.518	0.334
1942-43	0.043	0.119	0.150	0.207	0.264	0.328	0.211
1943-44	0.072	0.200	0.253	0.349	0.444	0.553	0.356
1944-45	0.085	0.235	0.296	0.409	0.520	0.648	0.417
1945-46	0.062	0.173	0.218	0.301	0.383	0.477	0.307
1946-47	0.086	0.238	0.300	0.415	0.528	0.658	0.423
1947-48	0.066	0.182	0.229	0.317	0.403	0.502	0.323
1948-49	0.058	0.161	0.203	0.281	0.357	0.444	0.286
1949-50	0.085	0.237	0.298	0.412	0.525	0.653	0.420
1950-51	0.068	0.189	0.239	0.330	0.420	0.522	0.336
1951-52	0.067	0.186	0.235	0.325	0.414	0.515	0.331
1952-53	0.045	0.126	0.159	0.220	0.279	0.348	0.224
1953-54	0.018	0.049	0.062	0.086	0.109	0.136	0.088
1954-55	0.051	0.142	0.179	0.247	0.315	0.392	0.252
1955-56	0.060	0.167	0.211	0.291	0.371	0.461	0.297
1956-57	0.101	0.279	0.352	0.486	0.619	0.770	0.496
1957-58	0.085	0.236	0.297	0.411	0.523	0.651	0.419
1958-59	0.036	0.101	0.128	0.176	0.224	0.279	0.180
1959-60	0.060	0.166	0.209	0.289	0.367	0.457	0.294
1960-61	0.066	0.183	0.231	0.319	0.406	0.505	0.325
1961-62	0.090	0.249	0.314	0.435	0.553	0.688	0.443
1962-63	0.083	0.231	0.291	0.403	0.512	0.638	0.411
1963-64	0.111	0.308	0.389	0.538	0.684	0.851	0.548
1964-65	0.137	0.381	0.481	0.665	0.845	1.052	0.677
1965-66	0.124	0.344	0.434	0.600	0.763	0.949	0.611
1966-67	0.091	0.252	0.317	0.439	0.558	0.695	0.447

Continued….

Table 12 (cont'd). Instantaneous rates of fishing mortality at age (yr^{-1}) for biological years 1929-30 through 2005-06 estimated in the ASAP baseline model. See also Figure 15.

Biological	---------------------- **Instantaneous Fishing Mortality Rate at Age (yr^{-1})** ----------------------						
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
1967-68	0.022	0.062	0.078	0.108	0.137	0.170	0.110
1968-69	0.021	0.058	0.073	0.101	0.129	0.160	0.103
1969-70	0.012	0.034	0.043	0.060	0.076	0.095	0.061
1970-71	0.008	0.023	0.028	0.039	0.050	0.062	0.040
1971-72	0.007	0.020	0.025	0.035	0.044	0.055	0.035
1972-73	0.004	0.012	0.015	0.020	0.026	0.032	0.021
1973-74	0.003	0.007	0.009	0.013	0.017	0.021	0.013
1974-75	0.003	0.009	0.011	0.016	0.020	0.025	0.016
1975-76	0.008	0.021	0.027	0.037	0.047	0.059	0.038
1976-77	0.008	0.023	0.029	0.041	0.052	0.064	0.041
1977-78	0.016	0.044	0.056	0.077	0.098	0.122	0.078
1978-79	0.025	0.071	0.089	0.123	0.156	0.195	0.125
1979-80	0.028	0.077	0.097	0.134	0.171	0.212	0.137
1980-81	0.030	0.082	0.104	0.144	0.183	0.228	0.147
1981-82	0.033	0.093	0.117	0.162	0.205	0.256	0.165
1982-83	0.027	0.076	0.095	0.132	0.168	0.209	0.135
1983-84	0.029	0.079	0.100	0.138	0.176	0.219	0.141
1984-85	0.030	0.082	0.103	0.143	0.182	0.226	0.146
1985-86	0.028	0.078	0.098	0.136	0.173	0.215	0.139
1986-87	0.034	0.093	0.118	0.163	0.207	0.257	0.166
1987-88	0.032	0.089	0.112	0.156	0.198	0.246	0.159
1988-89	0.034	0.094	0.119	0.164	0.209	0.260	0.167
1989-90	0.040	0.111	0.140	0.194	0.246	0.307	0.197
1990-91	0.063	0.175	0.221	0.306	0.389	0.484	0.312
1991-92	0.071	0.196	0.248	0.343	0.436	0.542	0.349
1992-93	0.045	0.124	0.156	0.216	0.275	0.342	0.220
1993-94	0.030	0.084	0.106	0.146	0.186	0.232	0.149
1994-95	0.040	0.110	0.139	0.192	0.245	0.305	0.196
1995-96	0.017	0.047	0.059	0.082	0.105	0.130	0.084
1996-97	0.034	0.096	0.121	0.167	0.212	0.264	0.170
1997-98	0.080	0.221	0.279	0.385	0.490	0.610	0.393
1998-99	0.170	0.472	0.595	0.823	1.047	1.303	0.839
1999-00	0.054	0.151	0.190	0.263	0.335	0.417	0.268
2000-01	0.107	0.295	0.372	0.515	0.655	0.815	0.525
2001-02	0.054	0.150	0.189	0.261	0.332	0.414	0.266
2002-03	0.068	0.189	0.239	0.330	0.420	0.523	0.337
2003-04	0.045	0.125	0.157	0.217	0.276	0.344	0.221
2004-05	0.035	0.098	0.123	0.170	0.216	0.269	0.173
2005-06	0.031	0.086	0.109	0.150	0.191	0.238	0.153

Table 13. Pacific mackerel population numbers at age at the beginning of each biological year, 1929-30 through 2005-06 estimated in the ASAP baseline model.

Biological	**------------- Population Numbers at Age (1,000s) at Start of Biological Year (July 1)-----------------**						
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
1929-30	1,184,040	837,532	497,398	291,143	80,847	43,275	75,764
1930-31	968,370	707,636	487,615	286,512	164,423	44,781	66,172
1931-32	1,004,340	585,507	425,485	292,527	171,162	97,822	66,036
1932-33	1,125,640	606,983	351,613	254,853	174,376	101,550	97,076
1933-34	745,767	680,899	365,417	211,267	152,579	104,029	118,442
1934-35	603,627	442,917	389,588	205,923	115,750	81,315	118,480
1935-36	491,982	351,580	240,089	205,081	102,675	54,719	95,020
1936-37	541,154	278,157	175,492	113,903	88,560	40,425	60,148
1937-38	463,112	308,881	142,553	86,072	51,501	36,968	42,444
1938-39	541,674	267,987	164,437	73,352	41,586	23,391	36,061
1939-40	425,070	310,925	139,504	82,254	34,082	17,972	25,974
1940-41	365,434	241,196	156,762	67,025	36,146	13,720	17,888
1941-42	534,288	202,782	114,310	69,664	26,441	12,685	11,211
1942-43	304,750	302,853	101,943	54,721	30,459	10,576	9,454
1943-44	297,157	177,081	163,092	53,221	26,974	14,191	9,261
1944-45	329,229	167,674	87,906	76,839	22,763	10,491	8,886
1945-46	216,156	183,486	80,427	39,662	30,956	8,205	6,881
1946-47	169,720	123,191	93,640	39,238	17,802	12,802	6,160
1947-48	436,570	94,465	58,877	42,057	15,708	6,365	6,469
1948-49	299,084	247,985	47,768	28,393	18,577	6,365	5,177
1949-50	144,554	171,176	128,051	23,652	13,008	7,885	4,835
1950-51	133,451	80,509	81,955	57,640	9,498	4,669	4,416
1951-52	131,424	75,604	40,413	39,157	25,136	3,786	3,593
1952-53	164,839	74,529	38,055	19,376	17,158	10,082	2,937
1953-54	588,022	95,540	39,854	19,692	9,434	7,870	5,743
1954-55	183,752	350,365	55,159	22,715	10,959	5,129	7,357
1955-56	353,398	105,893	184,398	27,975	10,758	4,853	5,571
1956-57	215,555	201,812	54,343	90,595	12,679	4,504	4,366
1957-58	207,312	118,233	92,615	23,189	33,789	4,143	2,879
1958-59	338,075	115,489	56,645	41,724	9,323	12,147	2,459
1959-60	214,428	197,704	63,305	30,241	21,213	4,518	6,817
1960-61	249,293	122,516	101,607	31,159	13,740	8,910	4,815
1961-62	219,017	141,547	61,881	48,928	13,735	5,553	5,370
1962-63	121,849	121,414	66,900	27,405	19,210	4,791	3,783
1963-64	109,744	67,999	58,453	30,325	11,111	6,981	3,058
1964-65	98,357	59,557	30,297	24,030	10,742	3,400	2,879
1965-66	74,649	51,996	24,674	11,364	7,498	2,798	1,607
1966-67	39,723	39,997	22,360	9,701	3,784	2,121	1,186

Continues….

Table 13 (cont'd). Pacific mackerel population numbers at age at the beginning of each biological year, 1929-30 through 2005-06 estimated in the ASAP baseline model.

Biological	**-------------- Population Numbers at Age (1,000s) at Start of Biological Year (July 1)-----------------**						
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**
1967-68	41,062	22,003	18,863	9,875	3,794	1,314	1,102
1968-69	59,913	24,358	12,548	10,585	5,379	2,007	1,271
1969-70	62,226	35,587	13,942	7,074	5,803	2,869	1,733
1970-71	72,587	37,278	20,858	8,099	4,042	3,262	2,572
1971-72	45,439	43,669	22,106	12,296	4,723	2,332	3,358
1972-73	83,808	27,364	25,967	13,077	7,205	2,741	3,305
1973-74	74,319	50,618	16,404	15,519	7,771	4,258	3,573
1974-75	156,175	44,956	30,473	9,856	9,291	4,636	4,668
1975-76	99,585	94,417	27,021	18,273	5,884	5,523	5,529
1976-77	1,238,150	59,938	56,058	15,954	10,679	3,404	6,387
1977-78	532,455	744,686	35,516	33,016	9,291	6,150	5,653
1978-79	1,670,390	317,850	432,167	20,375	18,541	5,110	6,472
1979-80	543,524	987,689	179,652	239,810	10,928	9,617	6,014
1980-81	1,438,400	320,643	554,696	98,889	127,190	5,588	7,898
1981-82	1,623,300	846,872	179,085	303,214	51,946	64,250	6,837
1982-83	900,339	952,234	468,204	96,645	156,476	25,655	33,694
1983-84	788,149	531,378	535,450	258,128	51,370	80,239	30,490
1984-85	950,719	464,564	297,732	293,873	136,349	26,134	55,165
1985-86	914,011	559,854	259,607	162,860	154,515	68,959	41,568
1986-87	809,059	538,992	314,075	142,703	86,212	78,823	55,667
1987-88	569,055	474,497	297,816	169,370	73,569	42,523	65,570
1988-89	981,320	334,222	263,232	161,415	87,928	36,611	54,101
1989-90	600,686	575,314	184,484	141,771	83,068	43,272	44,873
1990-91	739,386	350,030	312,259	97,272	70,847	39,382	41,656
1991-92	562,710	420,982	178,157	151,827	43,457	29,126	33,222
1992-93	407,257	317,960	209,797	84,350	65,380	17,049	24,484
1993-94	535,284	236,227	170,391	108,855	41,226	30,132	19,264
1994-95	471,093	314,989	131,745	92,971	57,036	20,758	24,562
1995-96	547,406	274,583	171,083	69,526	46,517	27,082	21,528
1996-97	419,737	326,419	158,870	97,776	38,840	25,412	26,428
1997-98	272,027	245,952	179,922	85,411	50,193	19,054	25,360
1998-99	218,857	152,359	119,608	82,598	35,244	18,652	16,668
1999-00	205,370	111,971	57,644	40,011	22,001	7,505	7,445
2000-01	258,792	117,962	58,396	28,902	18,651	9,547	6,453
2001-02	223,046	141,104	53,247	24,404	10,473	5,875	4,877
2002-03	137,504	128,169	73,675	26,737	11,399	4,556	4,623
2003-04	164,803	77,896	64,328	35,195	11,656	4,543	3,641
2004-05	288,667	95,566	41,710	33,343	17,178	5,363	3,723
2005-06	195,380	169,030	52,573	22,369	17,059	8,391	4,383

Table 14. Pacific mackerel population biomass (age 1+), SSB, and recruit (age 0) abundance at the beginning of each biological year (July 1), 1929-30 through 2005-05 estimated in the ASAP baseline model. Biomasses are in metric tons, and recruit abundance is 1,000s of individuals. Age 1+ biomass at the start of 2005-06 (bold typeface) is used for establishing the HG for 2005-06. See also Figures 16, 17, and 21.

Biological Year	Biomass Ages 1+	SSB	Recruits (Age 0)
1929-30	526,869	212,549	1,184,040
1930-31	523,253	234,931	968,370
1931-32	496,674	260,308	1,004,340
1932-33	462,092	268,210	1,125,640
1933-34	411,755	250,594	745,767
1934-35	362,570	207,325	603,627
1935-36	293,477	155,798	491,982
1936-37	229,665	112,557	541,154
1937-38	203,325	92,788	463,112
1938-39	189,031	84,043	541,674
1939-40	218,359	83,371	425,070
1940-41	187,333	67,879	365,434
1941-42	154,965	56,153	534,288
1942-43	166,163	52,592	304,750
1943-44	164,104	56,641	297,157
1944-45	142,878	52,487	329,229
1945-46	123,853	45,000	216,156
1946-47	111,816	41,751	169,720
1947-48	91,594	34,416	436,570
1948-49	107,848	32,048	299,084
1949-50	102,548	33,208	144,554
1950-51	85,041	30,993	133,451
1951-52	70,221	28,976	131,424
1952-53	65,964	26,765	164,839
1953-54	71,539	26,018	588,022
1954-55	139,193	31,232	183,752
1955-56	121,243	37,912	353,398
1956-57	129,524	42,110	215,555
1957-58	108,311	36,288	207,312
1958-59	92,823	32,091	338,075
1959-60	112,172	35,223	214,428
1960-61	108,005	35,929	249,293
1961-62	100,188	33,854	219,017
1962-63	100,067	31,792	121,849
1963-64	76,281	27,882	109,744
1964-65	53,528	19,642	98,357
1965-66	32,980	12,221	74,649
1966-67	30,536	9,983	39,723
1967-68	23,604	8,608	41,062
1968-69	23,161	9,442	59,913
1969-70	28,552	10,490	62,226
1970-71	29,636	12,000	72,587
1971-72	37,334	14,226	45,439
1972-73	34,826	14,718	83,808
1973-74	43,564	16,469	74,319
1974-75	54,452	22,015	156,175
1975-76	85,178	31,906	99,585
1976-77	96,986	41,149	1,238,150
1977-78	316,696	60,223	532,455
1978-79	360,376	96,176	1,670,390
1979-80	436,636	125,349	543,524
1980-81	338,779	130,530	1,438,400
1981-82	408,332	155,381	1,623,300
1982-83	419,530	163,113	900,339
1983-84	449,376	174,000	788,149
1984-85	450,423	190,246	950,719
1985-86	483,574	193,815	914,011
1986-87	488,837	195,884	809,059
1987-88	463,183	191,817	569,055
1988-89	433,748	193,171	981,320
1989-90	379,276	168,060	600,686
1990-91	370,111	153,929	739,386
1991-92	310,193	123,893	562,710
1992-93	227,934	94,139	407,257
1993-94	205,352	87,663	535,284
1994-95	172,833	77,250	471,093
1995-96	188,938	84,701	547,406
1996-97	213,903	90,178	419,737
1997-98	216,252	88,707	272,027
1998-99	155,312	64,939	218,857
1999-00	91,709	36,507	205,370
2000-01	90,045	33,263	258,792
2001-02	79,821	24,253	223,046
2002-03	73,015	22,750	137,504
2003-04	84,218	30,286	164,803
2004-05	80,916	31,079	288,667
2005-06	**101,147**	33,310	195,380

Table 15. Proposed HG for Pacific mackerel for the 2005-06 management year opening July 1, 2005. See 'Harvest Guideline' section for methods used to derive the HG. See also Table 1 and Figure 1.

Biomass (Age 1+, mt)	**Cutoff (mt)**	**Fraction**	**Distribution**	**2005-06 Harvest Guideline (mt)**
101,147	18,200	30%	70%	17,419

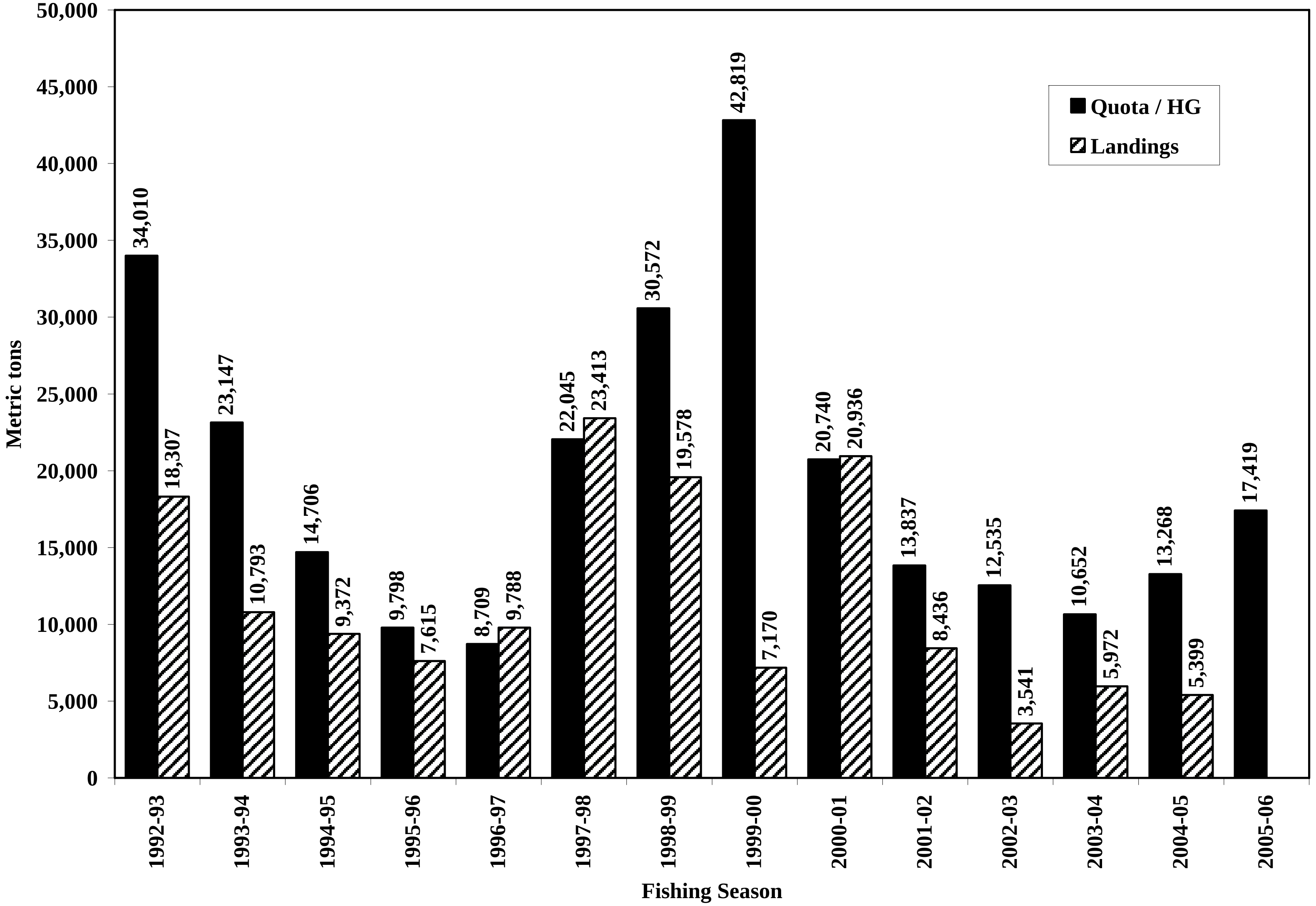

Figure 1. Commercial landings (California directed fishery) and quotas or HGs for Pacific mackerel. All units are metric tons. Incidental landings from Pacific northwest fisheries are not included, but typically range 100 to 300 mt per year.

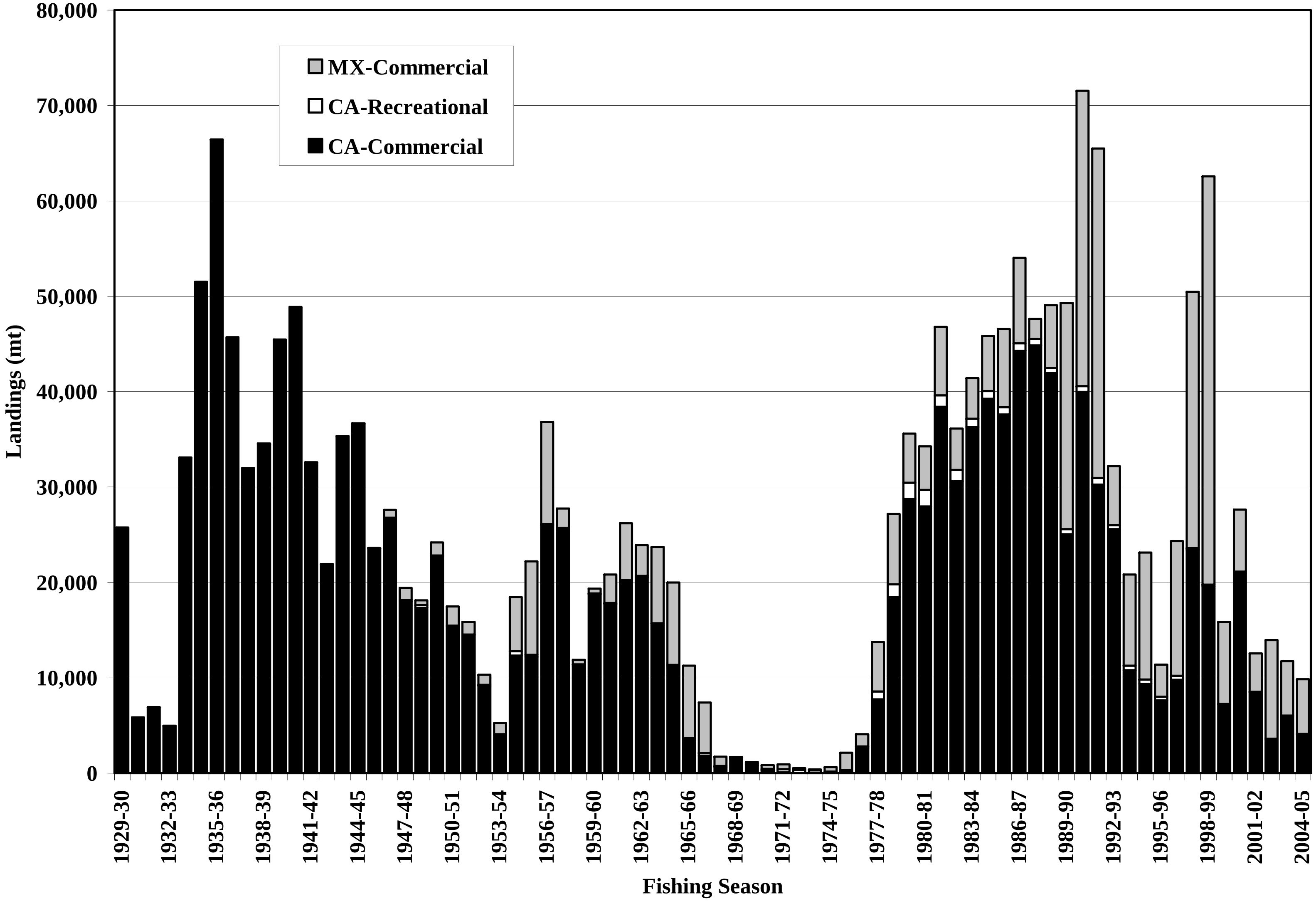

Figure 2. Commercial and recreational landings (metric tons) of Pacific mackerel in California (CA) and Baja California (MX), for 1929-30 to 2004-05. See also Table 5.

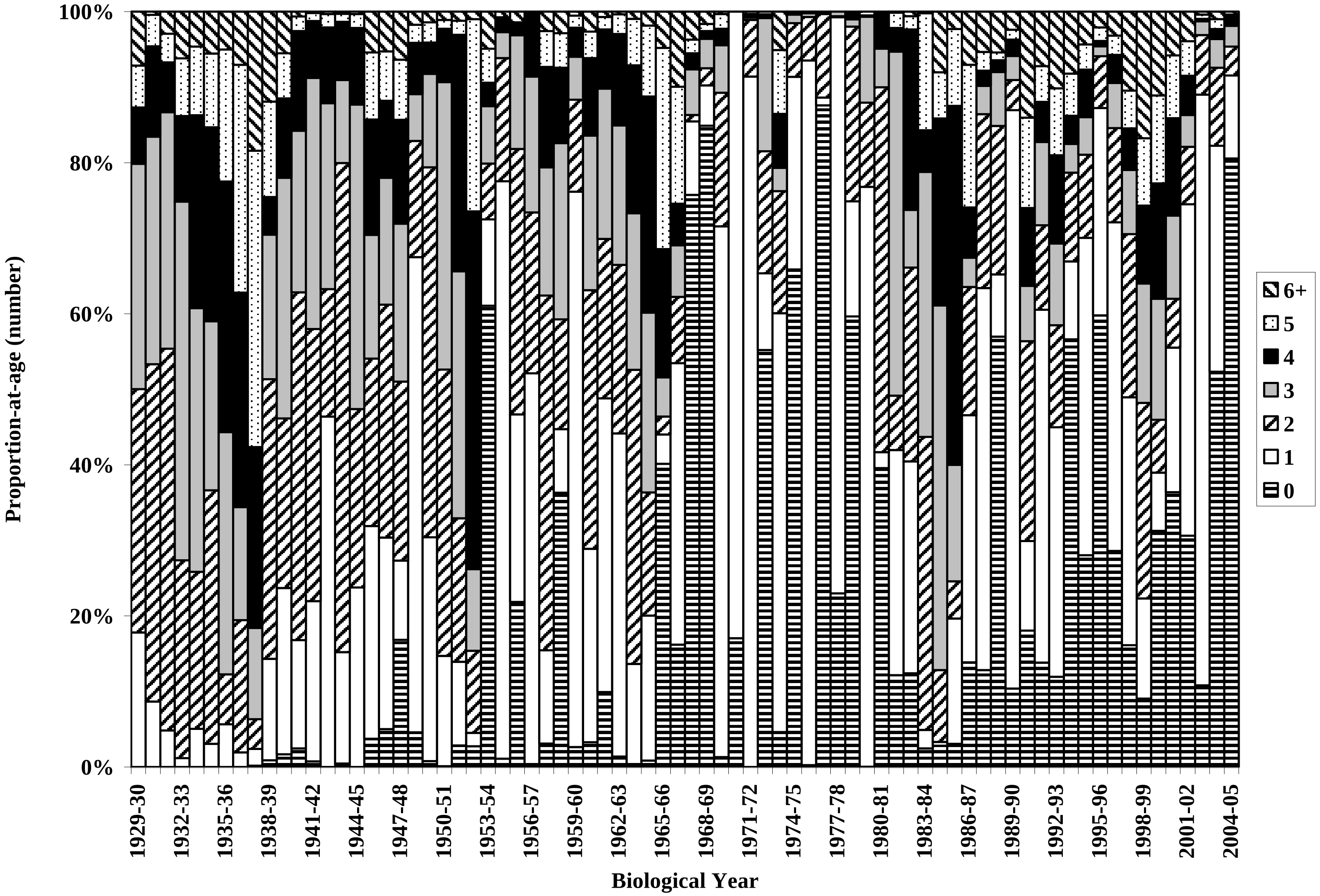

Figure 3. Catch-at-age (proportion by number) for the Pacific mackerel fishery in California for the biological years 1929-30 to 2004-05. See also Table 6.

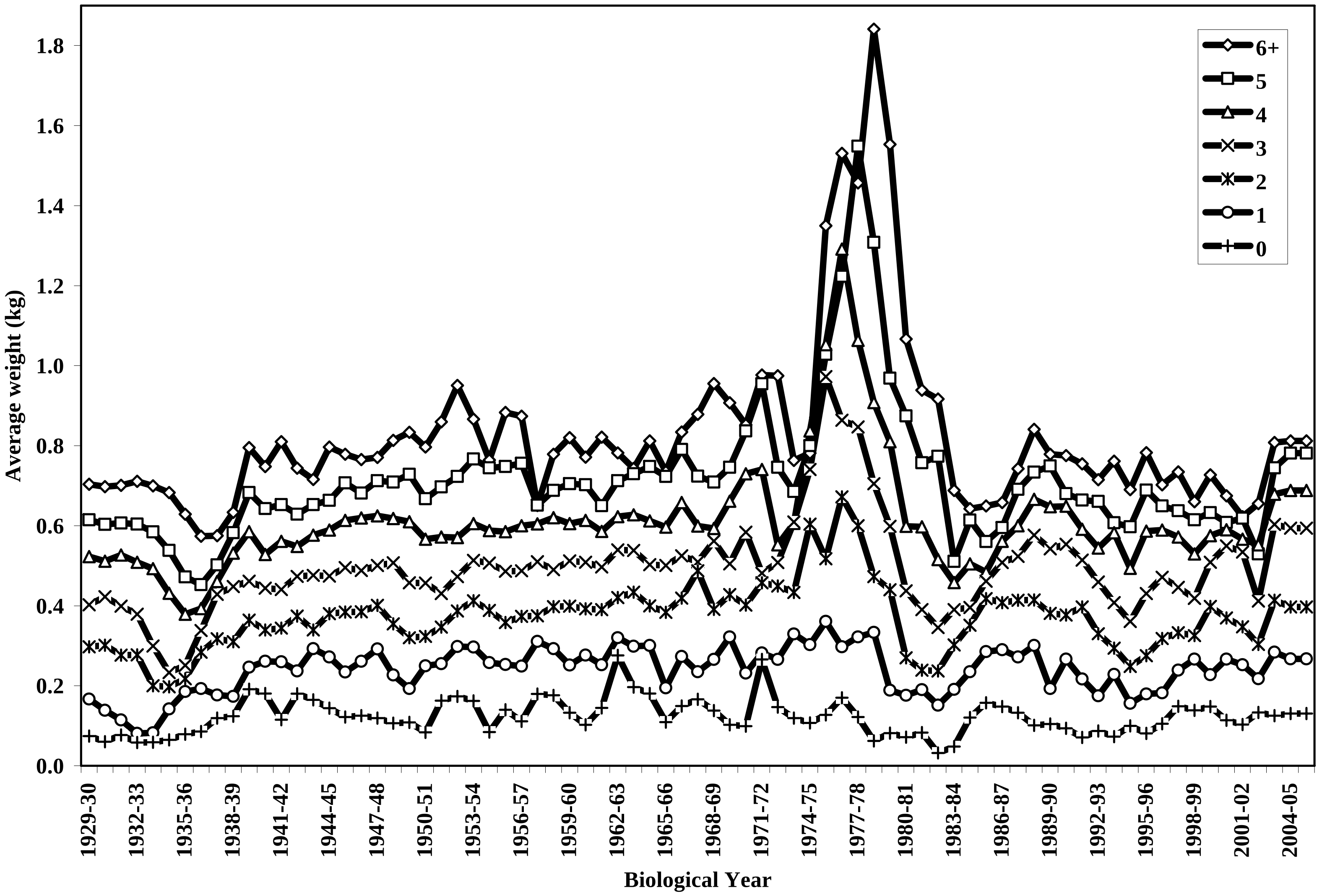

Figure 4. Pacific mackerel weight-at-age (mean weight, kg) used in ASAP. See also Table 7.

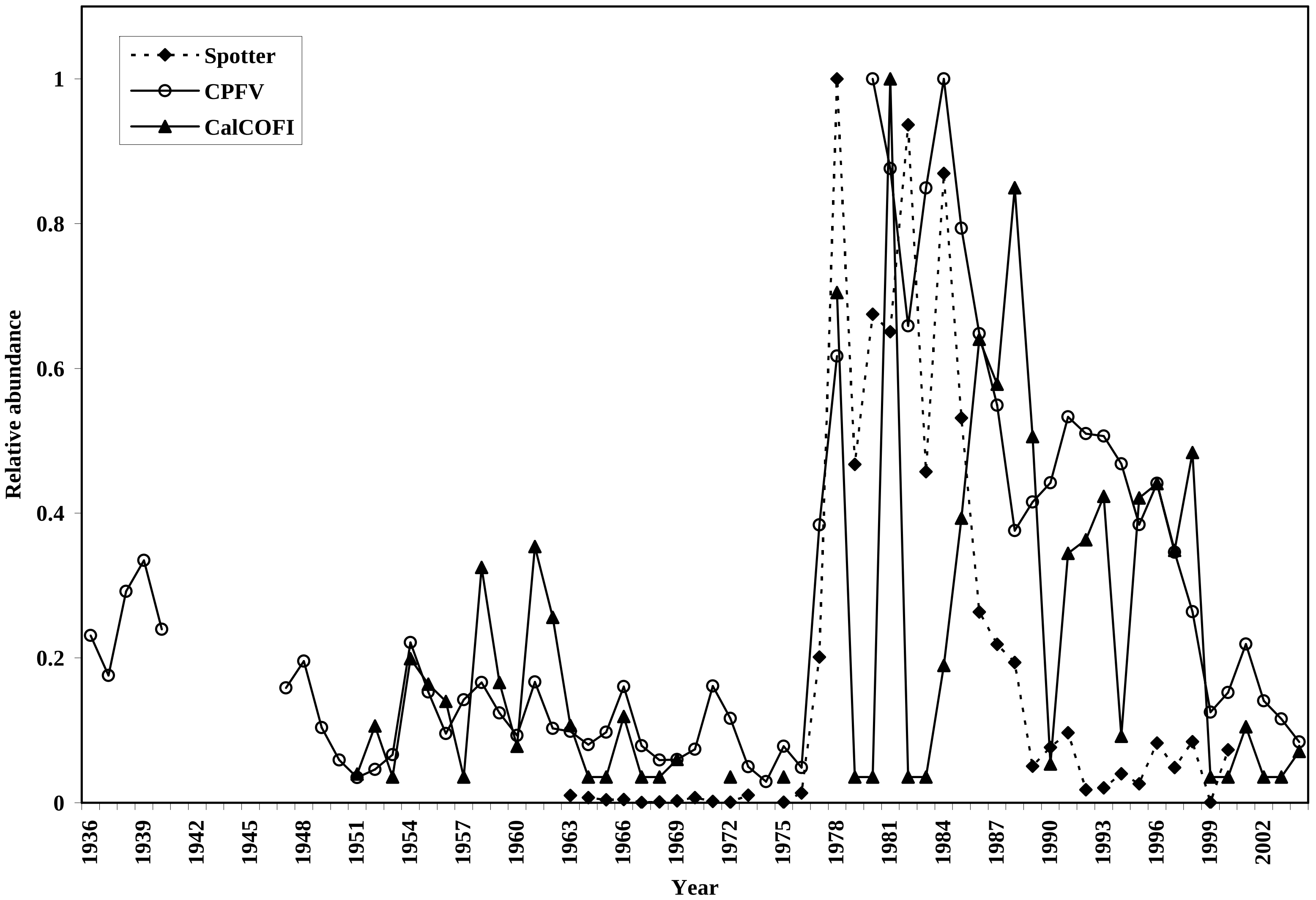

Figure 5. Indices of abundance time series for Pacific mackerel applied in the ASAP model analysis. Indices are rescaled to a maximum of 1 for comparison.

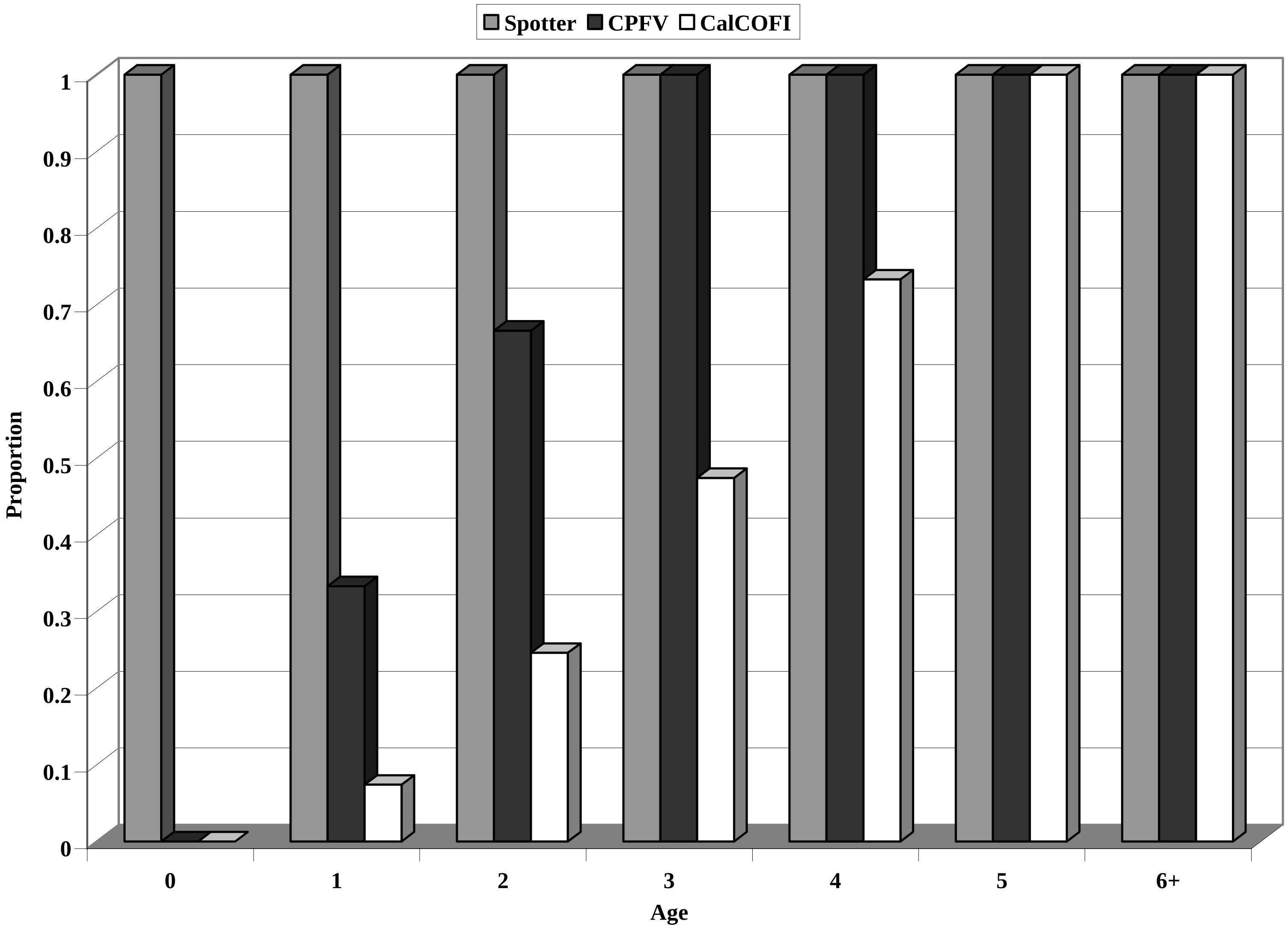

Figure 6. Selectivity ogives applied to survey data in the ASAP model. See also Table 8.

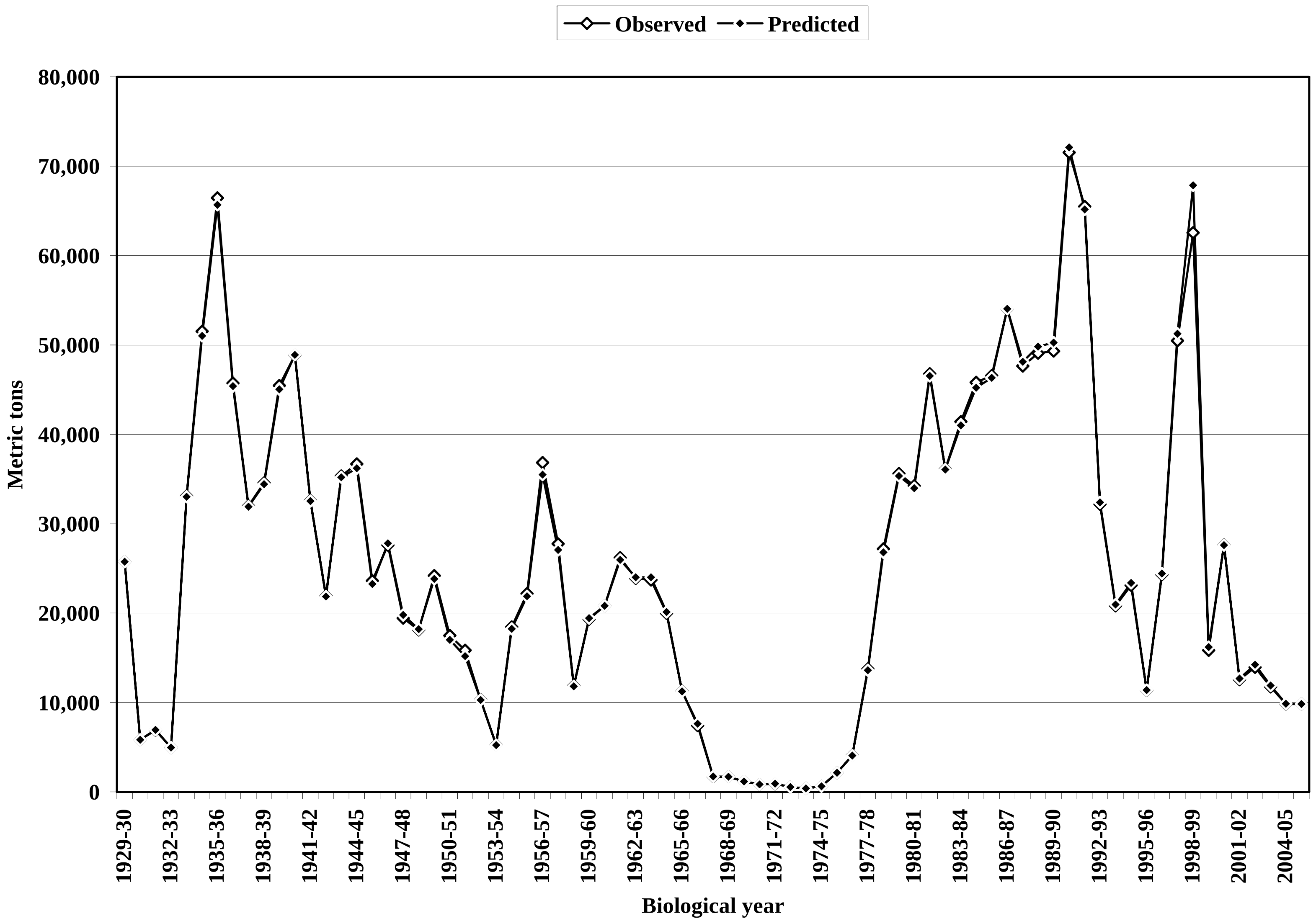

Figure 7. Observed and predicted estimates of total catch (mt) for Pacific mackerel generated from the ASAP baseline model.

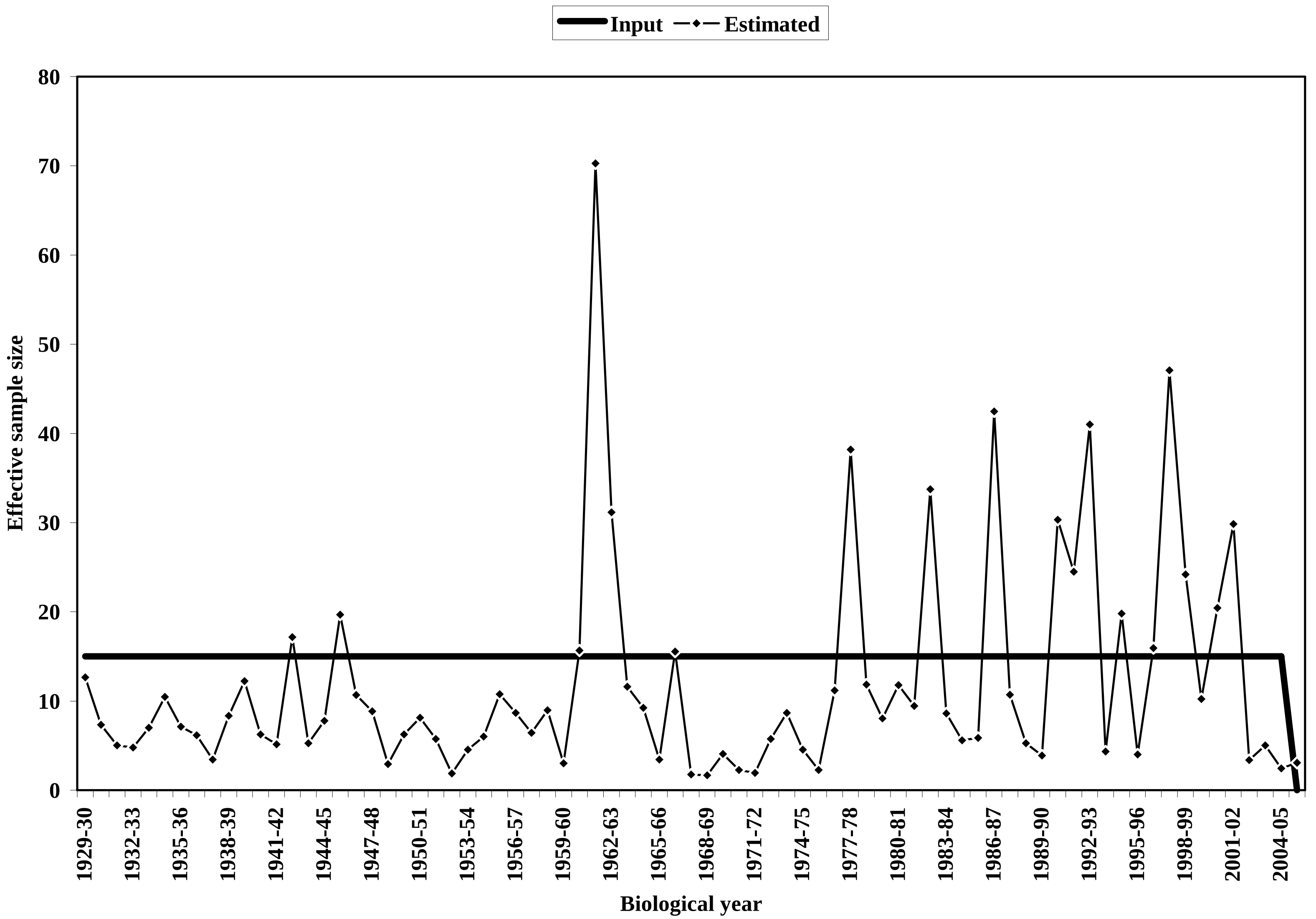

Figure 8. Effective sample sizes estimated for catch-at-age data. Catch-at-age data were given a lambda weighting of ‘15’ for all years.

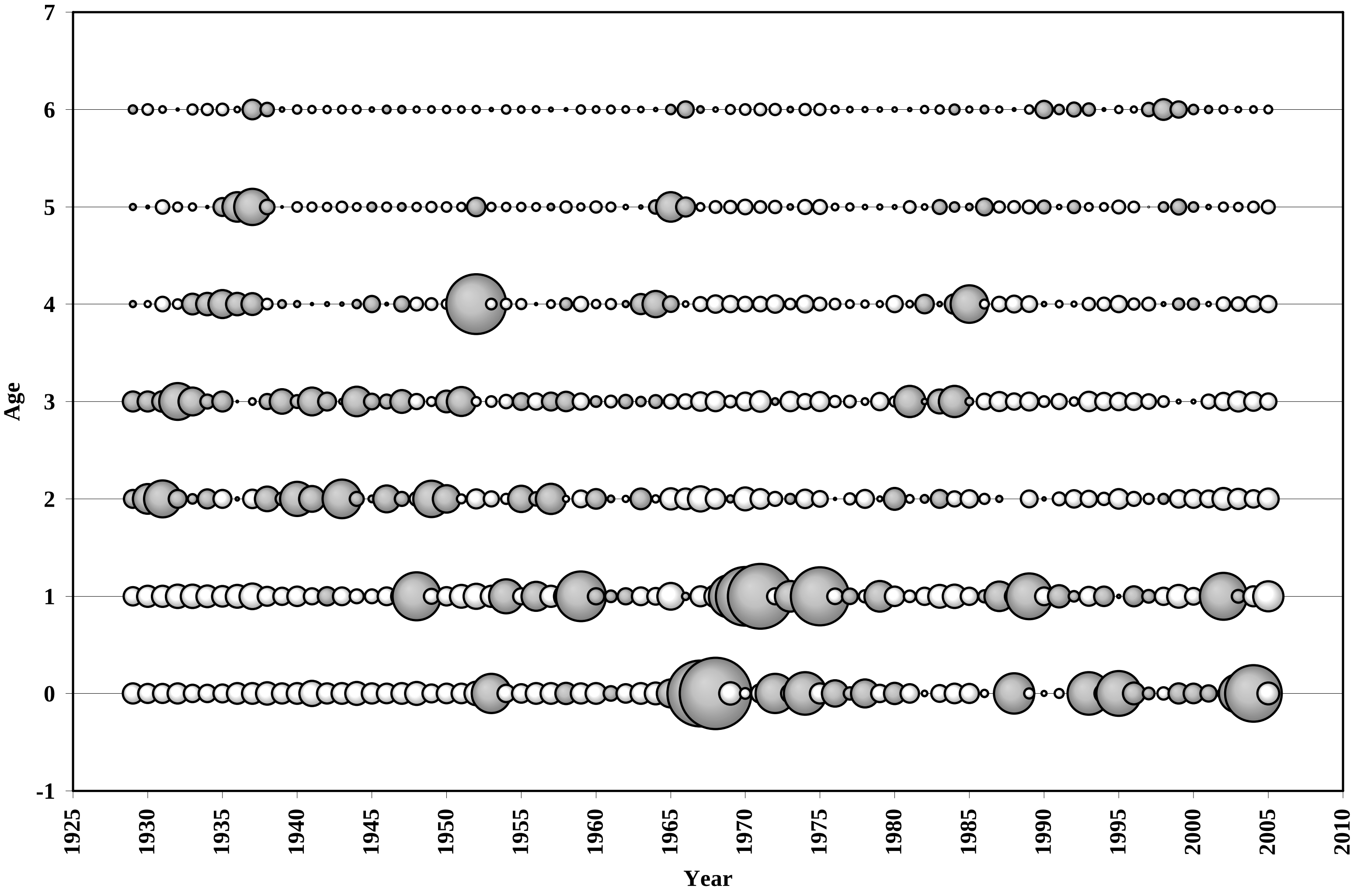

Figure 9. Standardized residuals from ASAP model fit to catch-at-age data for the Pacific mackerel fishery. Circle size is proportional to the magnitude of the residual. Gray circles are positive residuals and light circles are negative residuals.

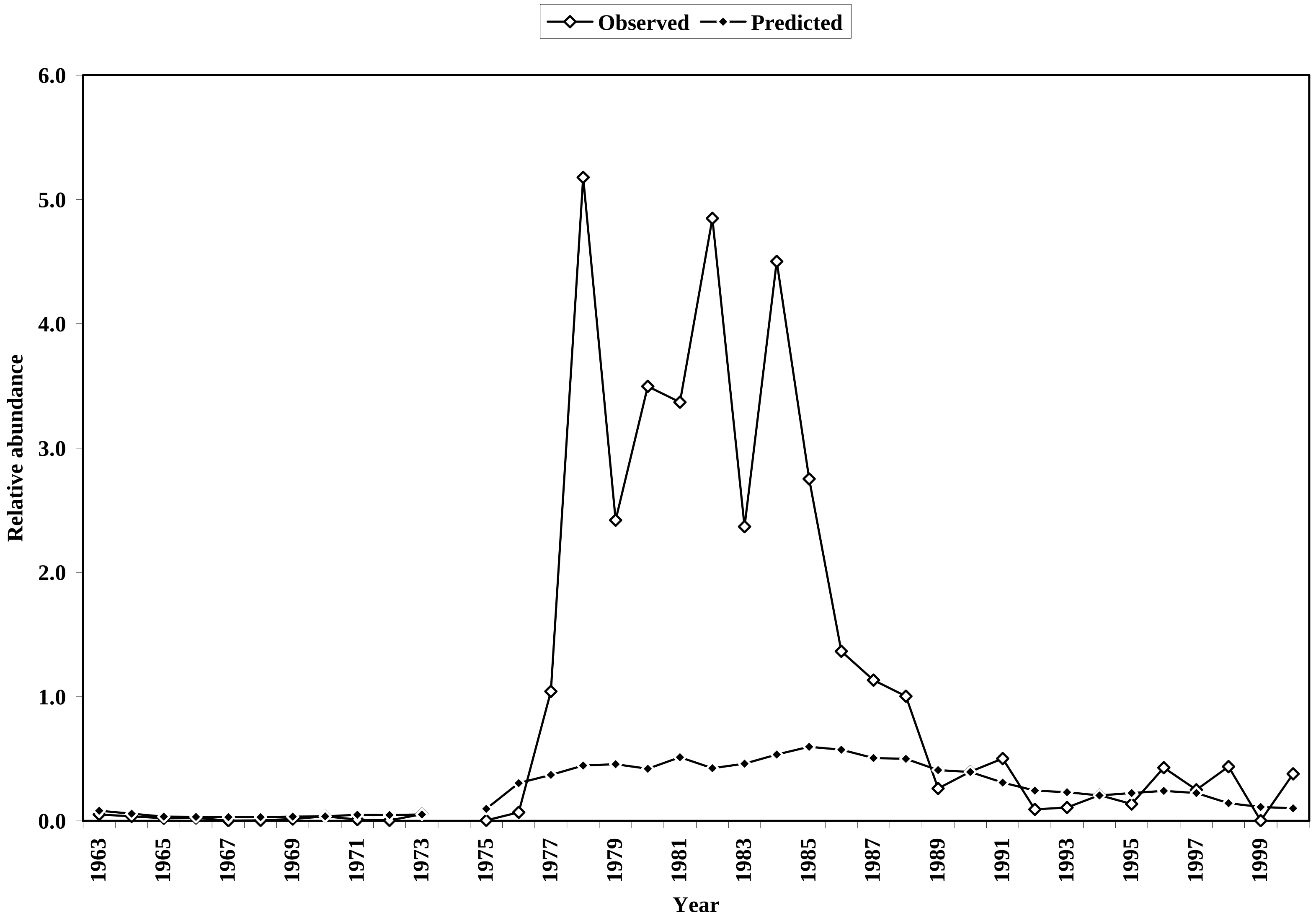

Figure 10. Observed and predicted estimates of the 'Spotter' index of relative abundance for Pacific mackerel generated from the ASAP baseline model.

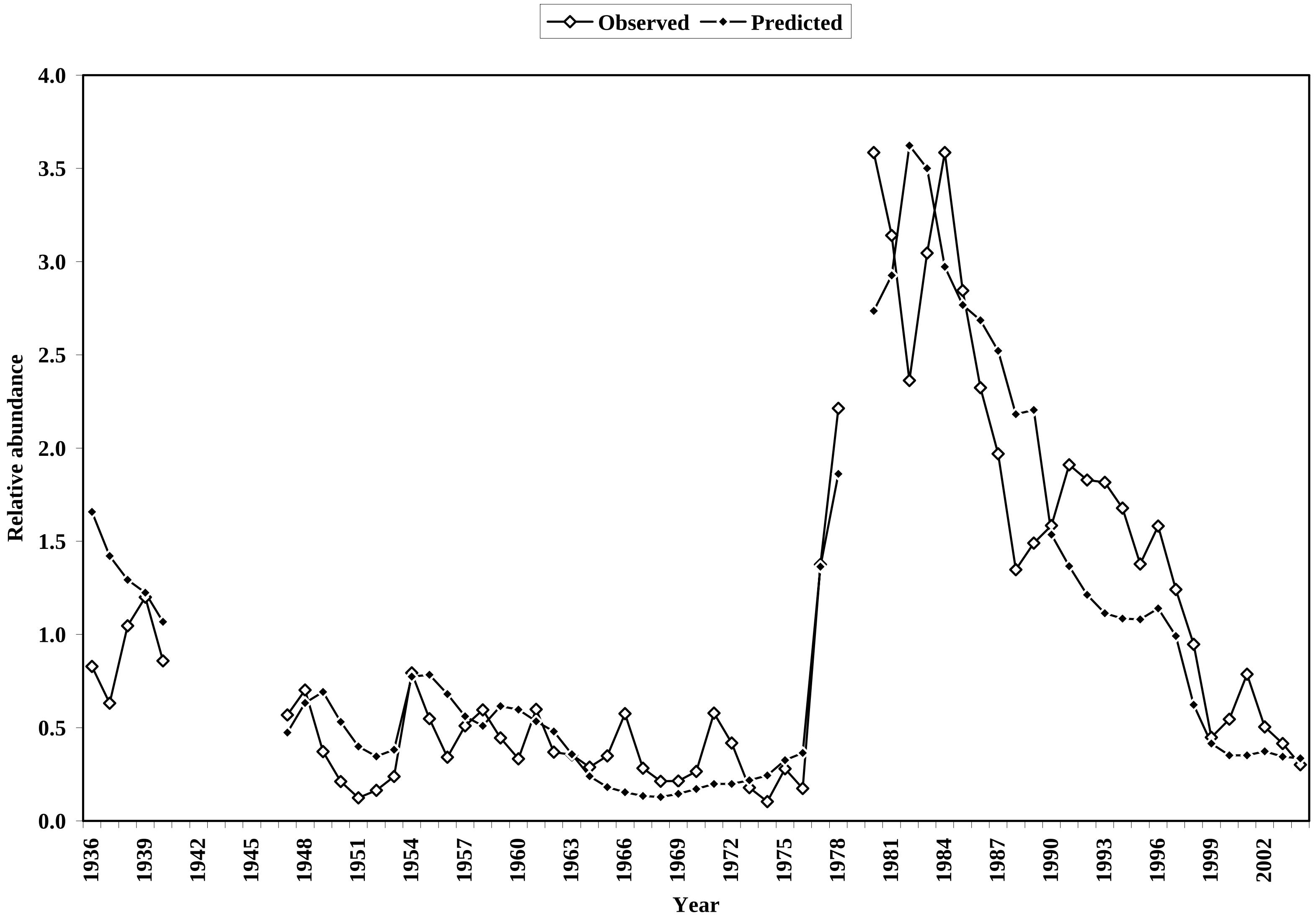

Figure 11. Observed and predicted estimates of the CPFV index of relative abundance for Pacific mackerel generated from the ASAP baseline model.

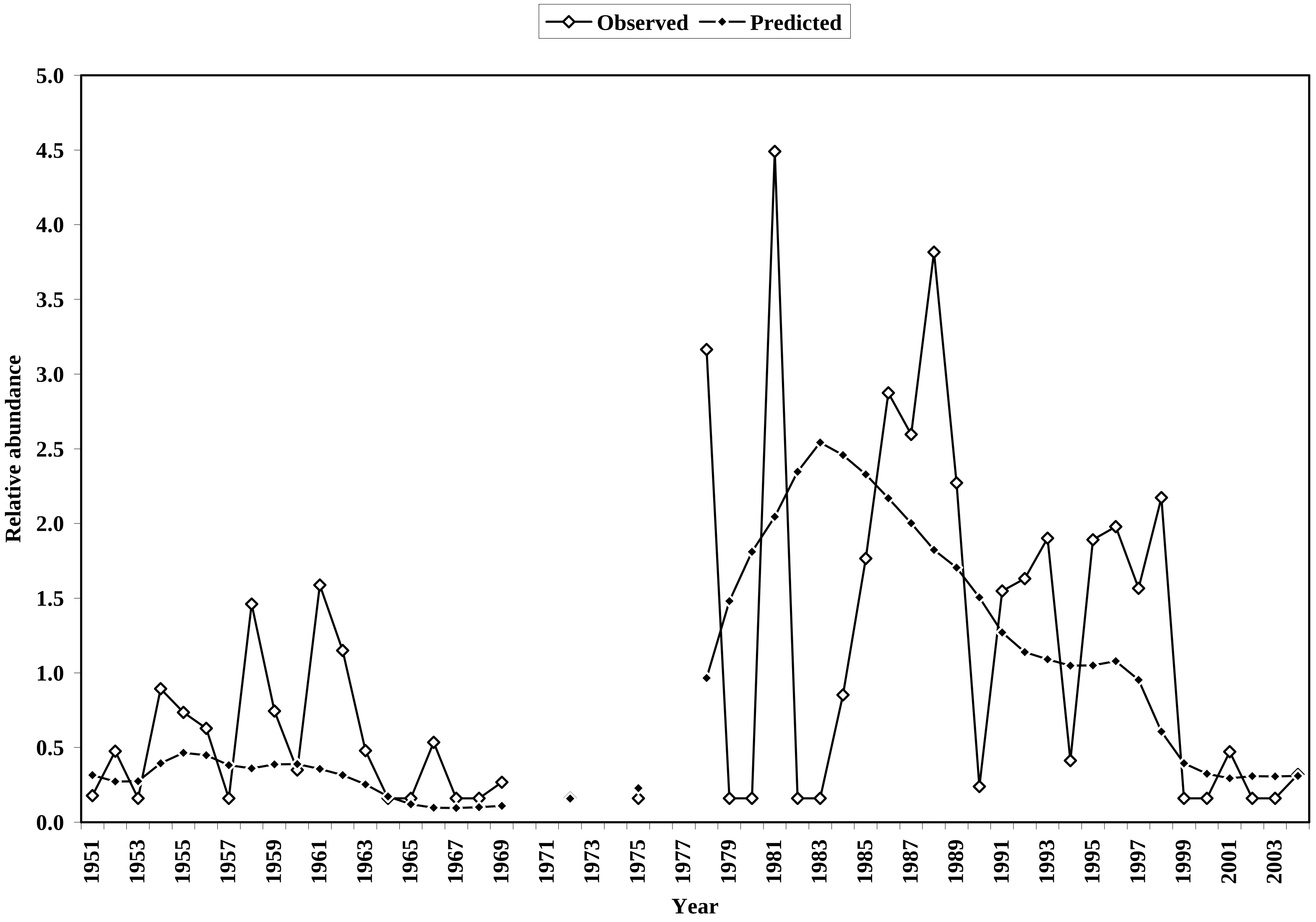

Figure 12. Observed and predicted estimates of the ‘CalCOFI’ index of relative abundance for Pacific mackerel generated from the ASAP baseline model.

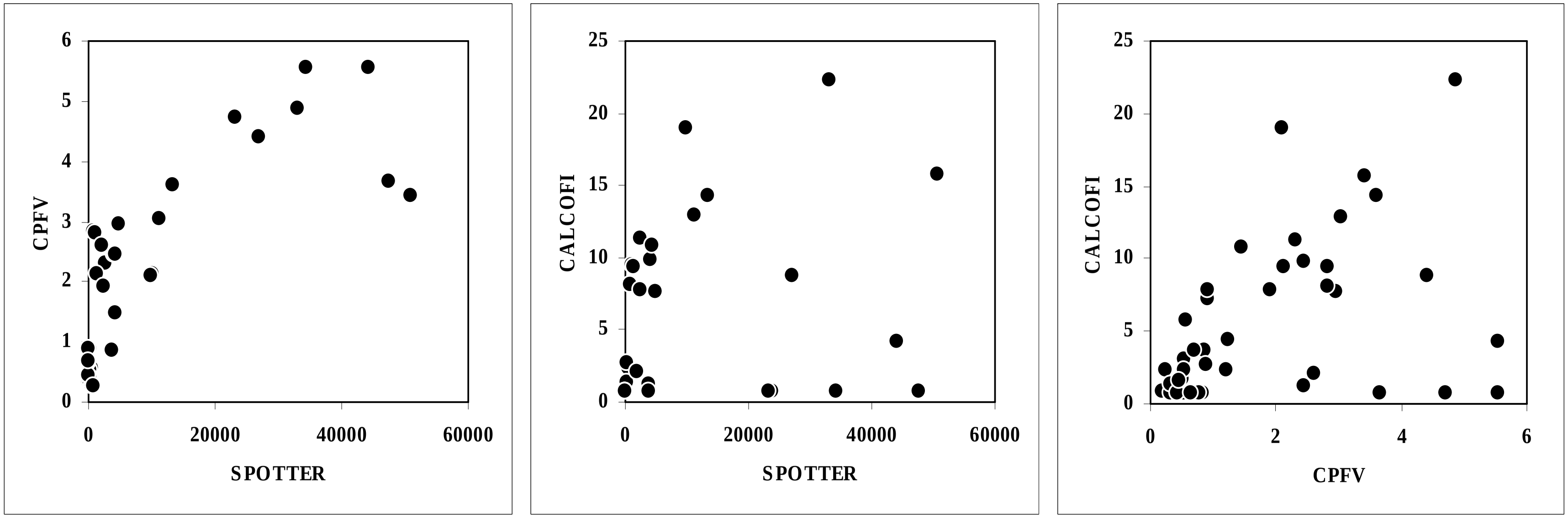

Figure 13. Comparison of observed values for the ‘Spotter’, ‘CPFV’, and ‘CalCOFI’ indices of relative abundance.

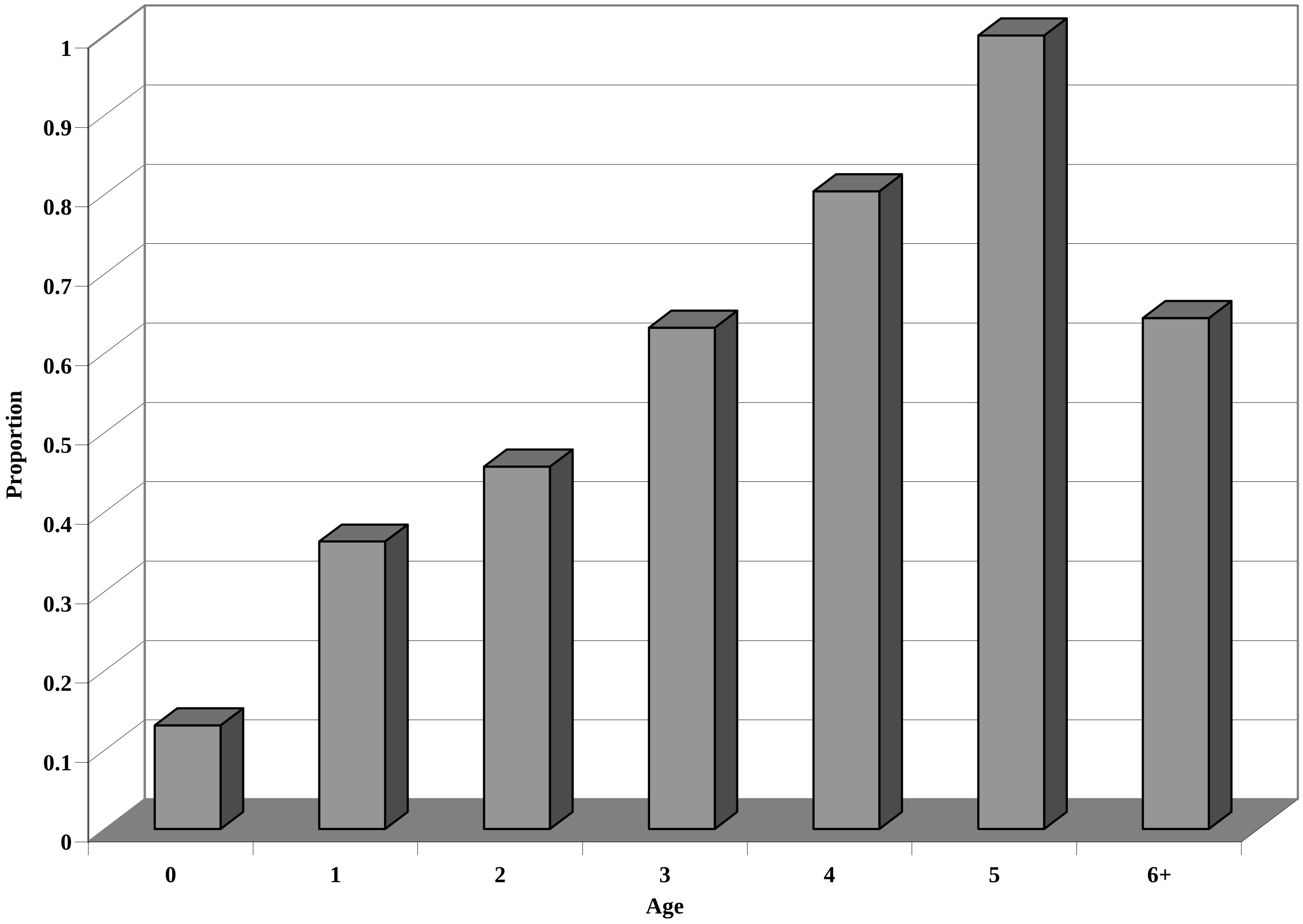

Figure 14. Estimated fishery selectivity-at-age from the ASAP baseline model.

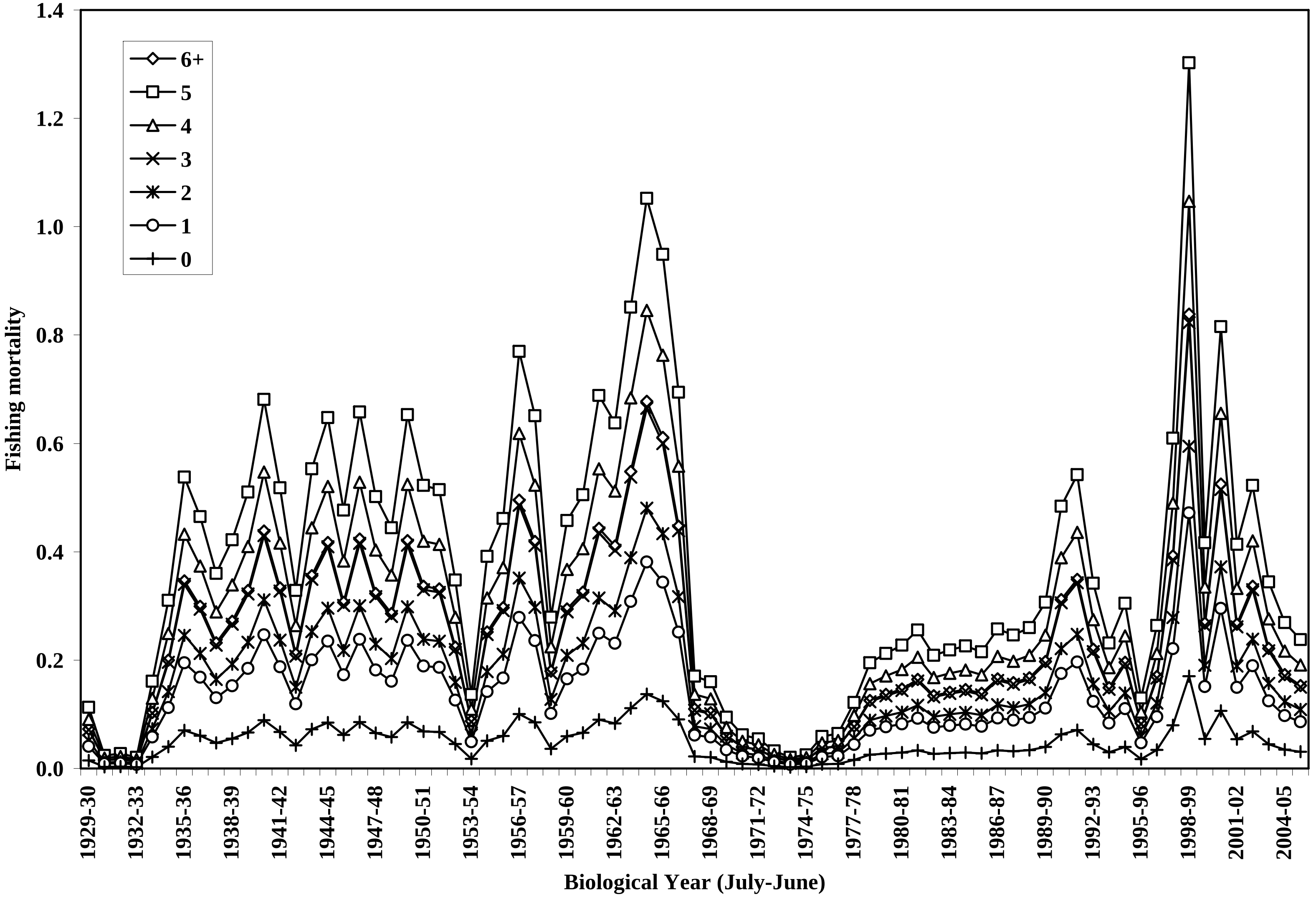

Figure 15. Estimated instantaneous fishing mortality (total) F at age of Pacific mackerel generated from the baseline ASAP model. Age '5' fish were fully selected (Figure 14). See also Table 12.

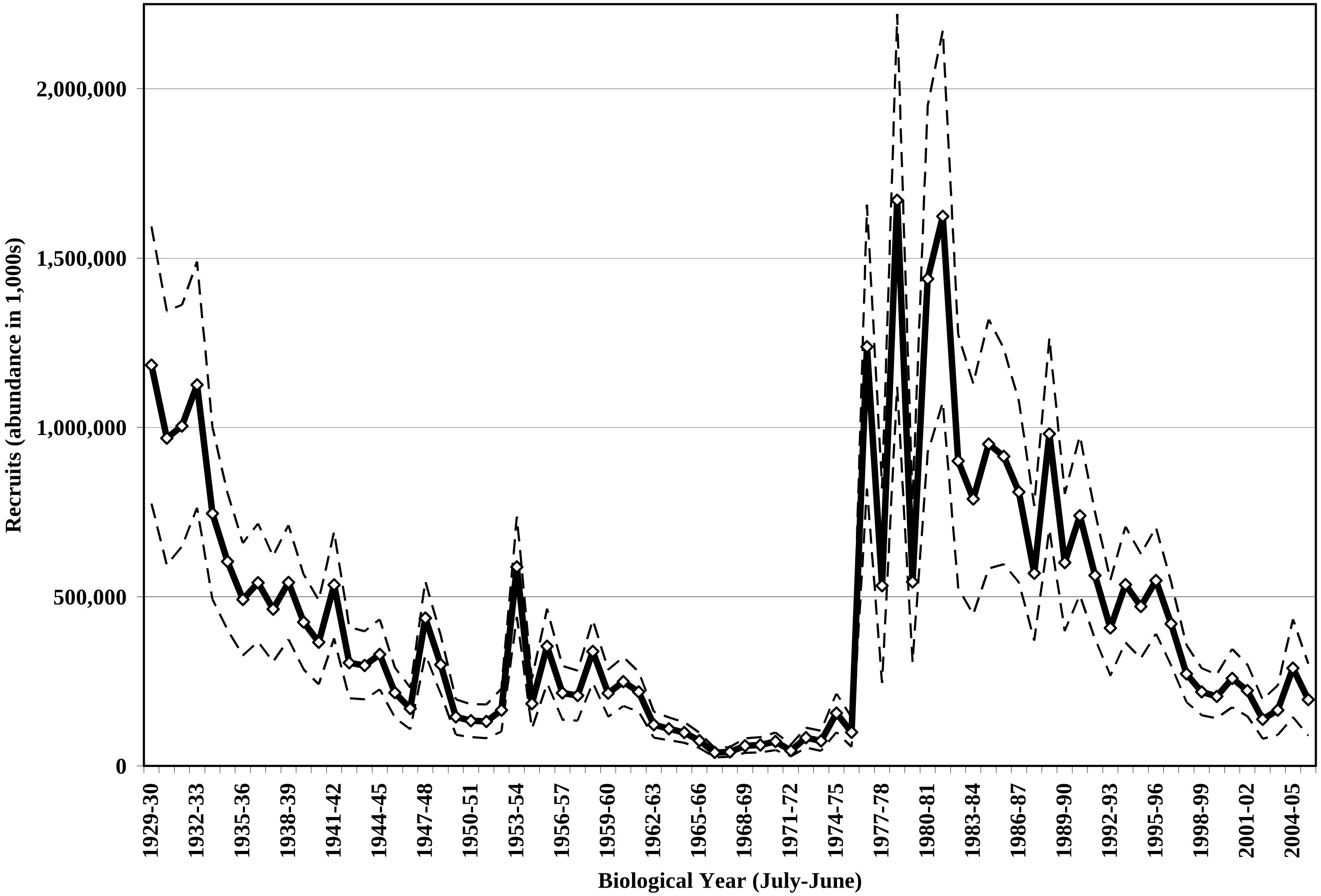

Figure 16. Pacific mackerel recruitment estimates (age 0 abundance in 1,000s) from the ASAP baseline model (diamonds) along with a 2-standard deviation uncertainty envelope. See also Tables 13 and 14.

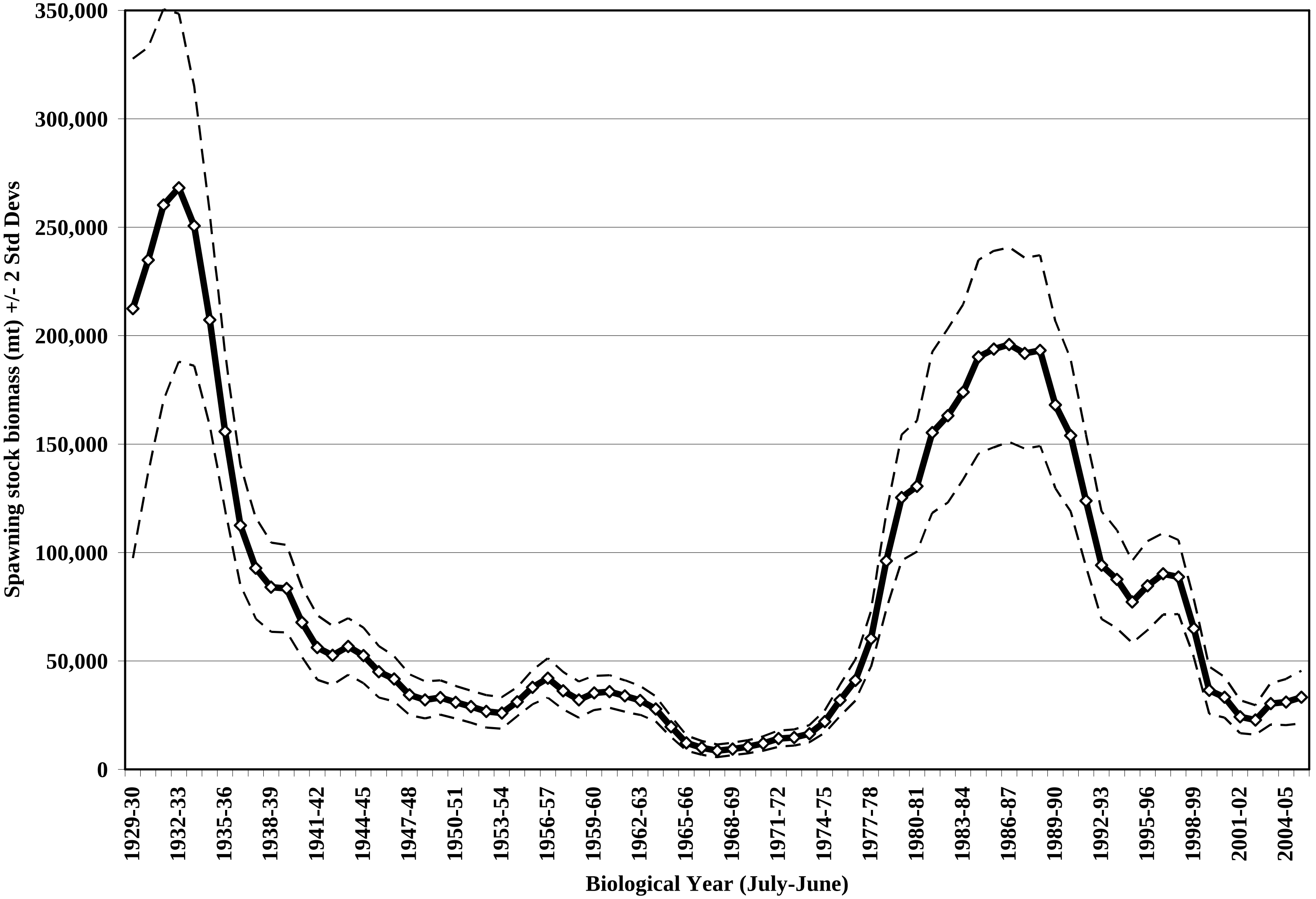

Figure 17. Estimated SSB (mt) of Pacific mackerel generated from the baseline ASAP model (diamonds) along with a 2-standard deviation uncertainty envelope. See also Table 14.

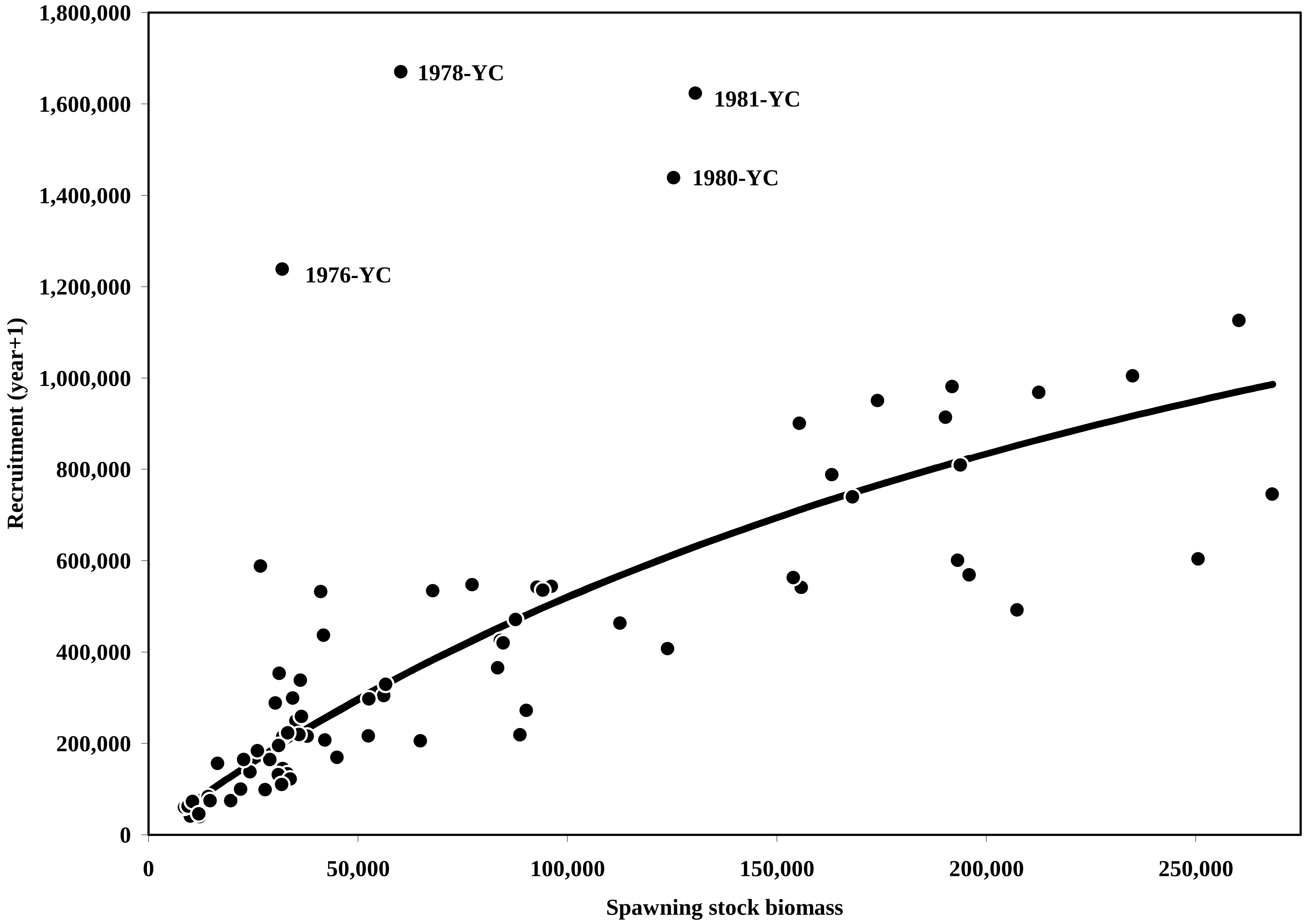

Figure 18. Pacific mackerel SSB (year) and recruitment estimates (year+1) from the ASAP baseline model. Line represents estimated Beverton-Holt stock-recruitment relationship (steepness=0.32).

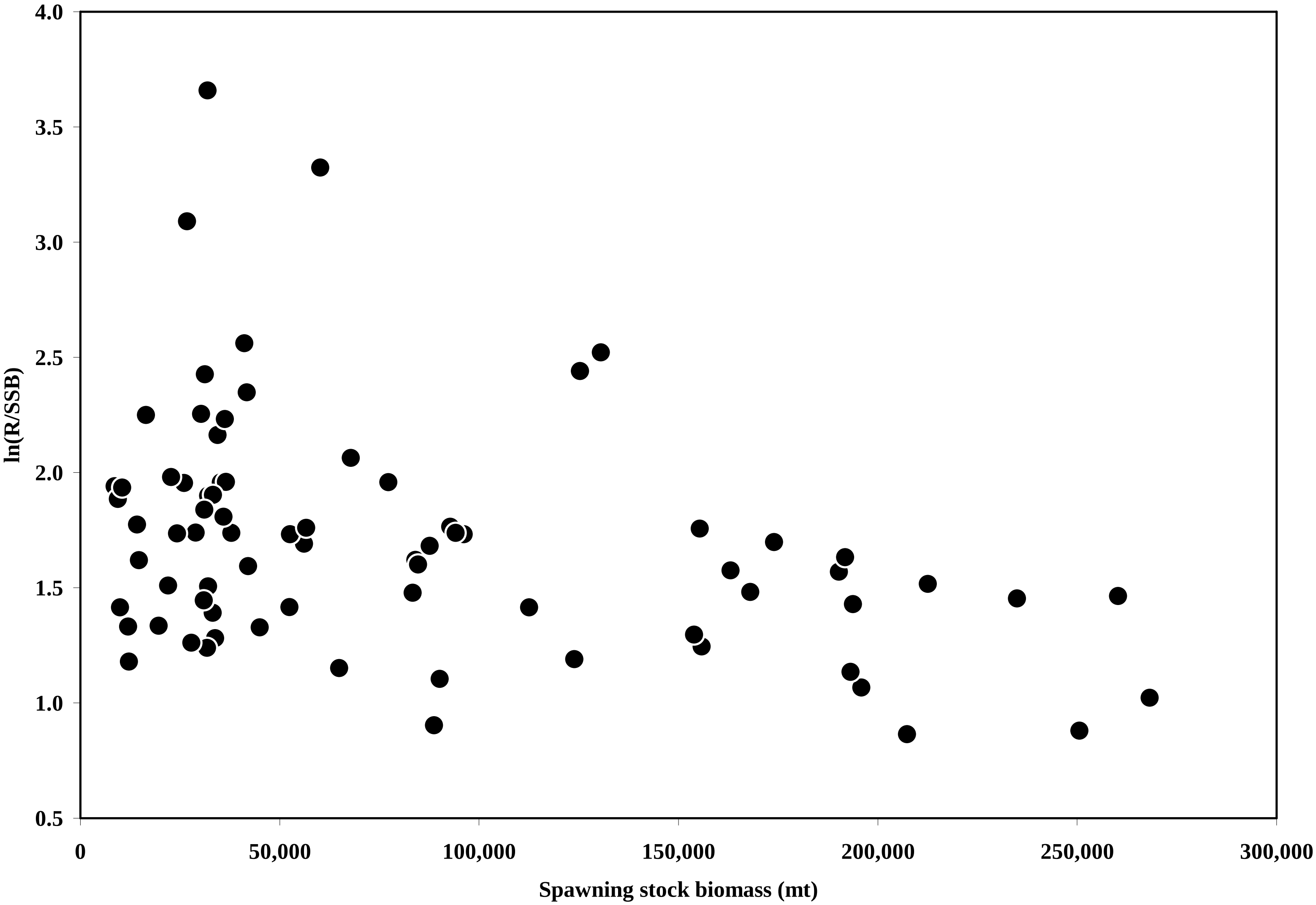

Figure 19. Recruitment success (Ln(R/SSB), year+1) relative to SSB (mt, year).

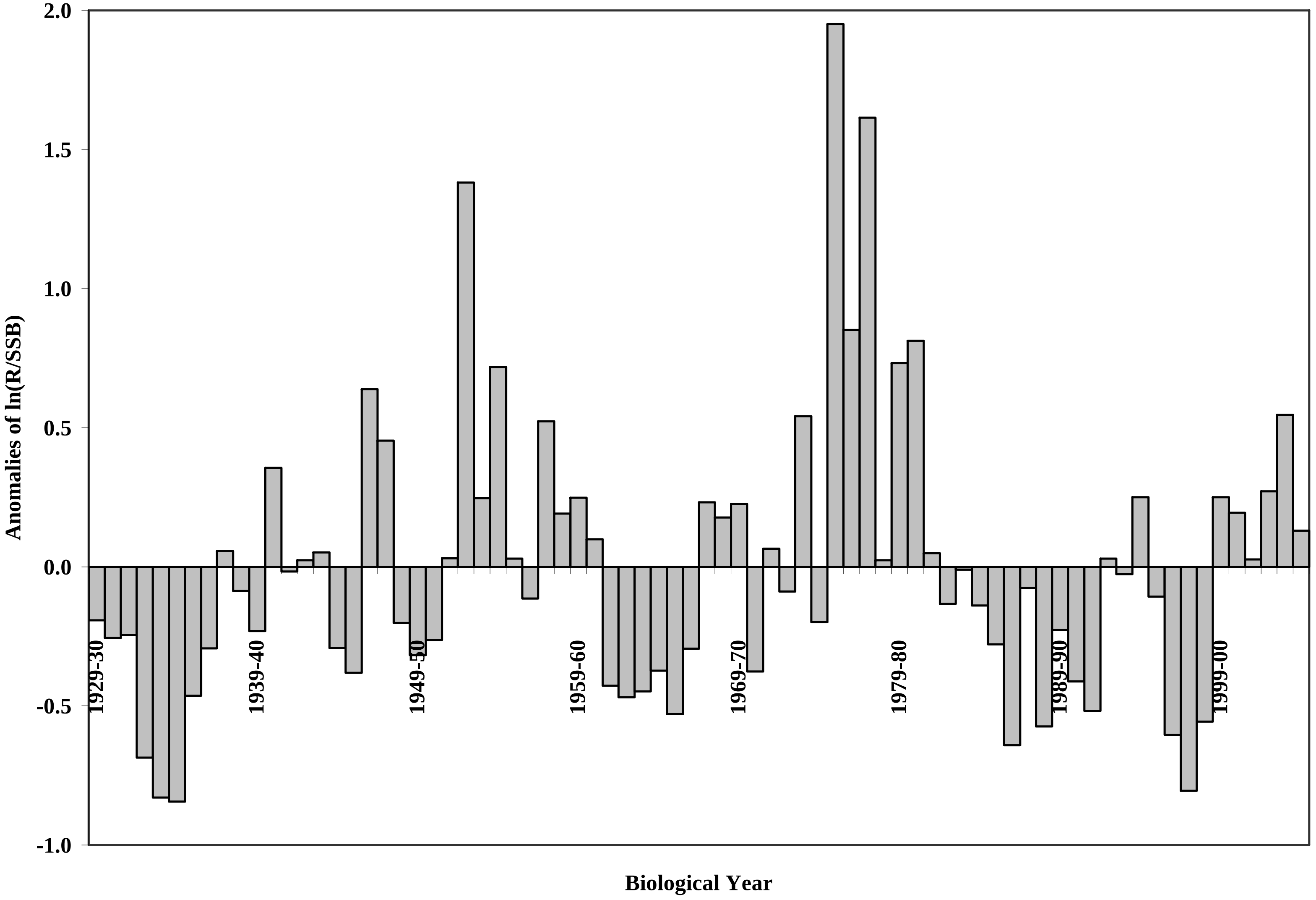

Figure 20. Relative reproductive success of Pacific mackerel presented as anomalies of Ln(R/SSB).

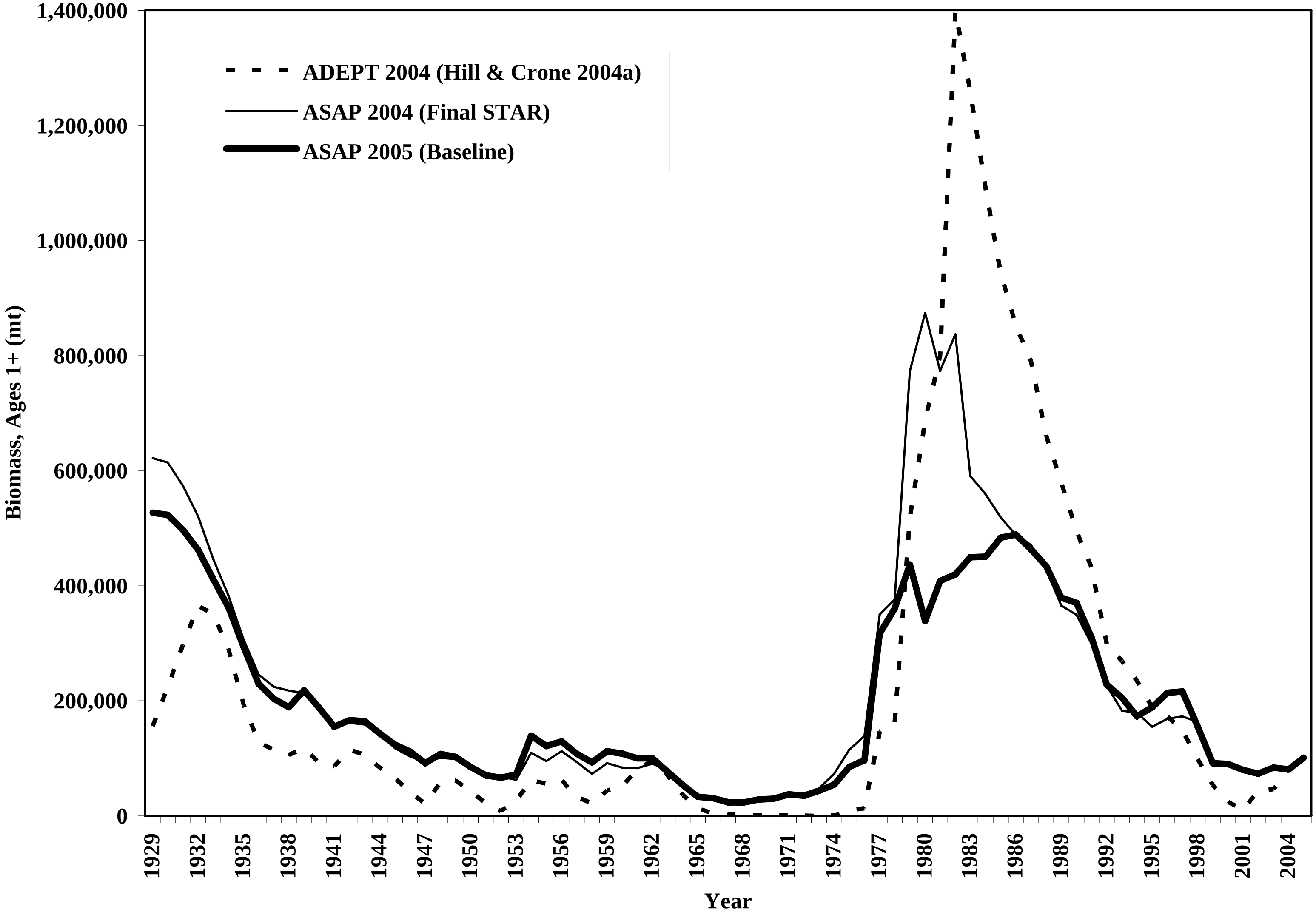

Figure 21. Estimated population biomass (age 1+, mt) of Pacific mackerel generated from the ASAP 2005 baseline model. Population estimates from ASAP 2004 (Final STAR) and ADEPT 2004 (Hill and Crone 2004a) models are included for comparison.

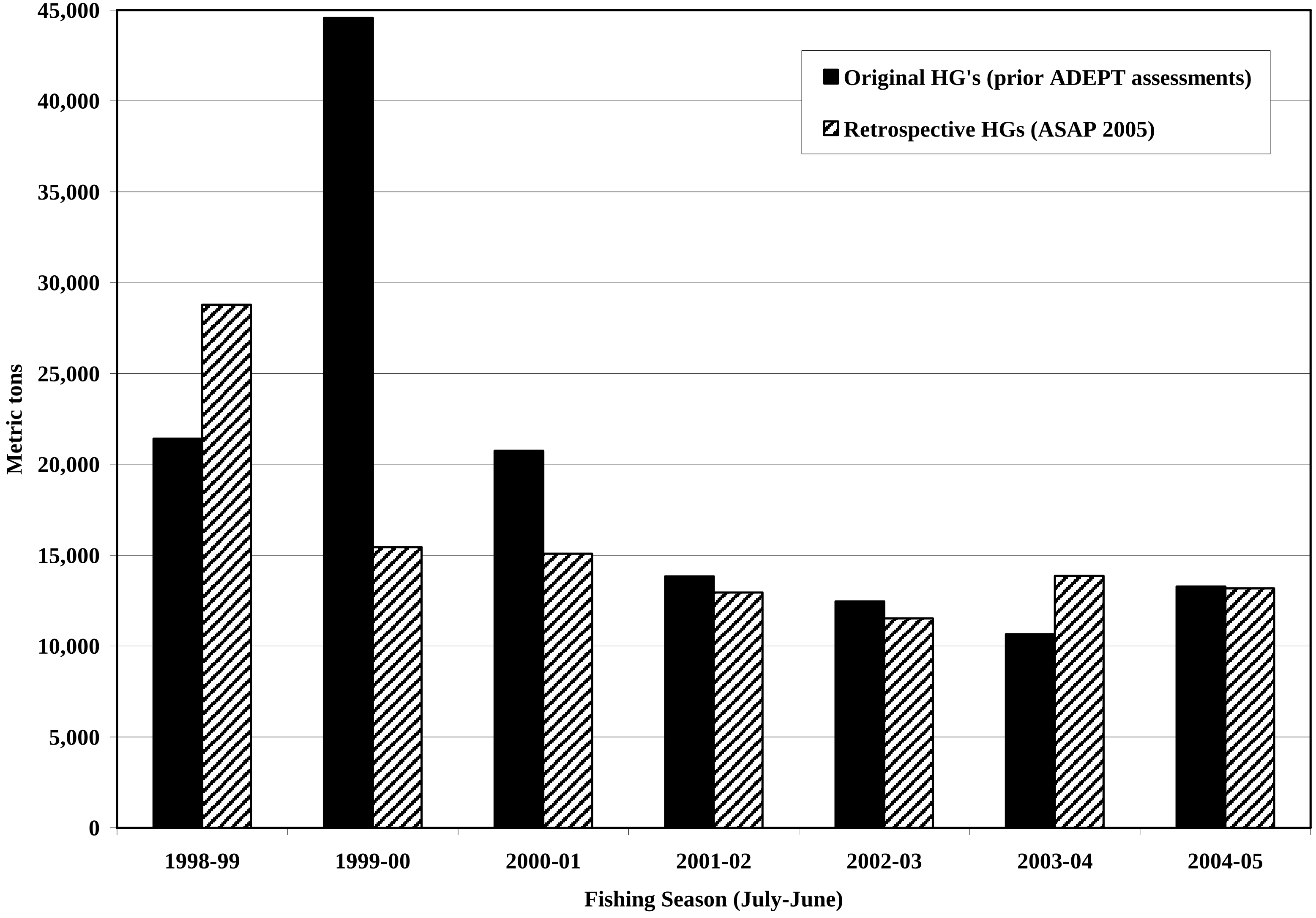

Figure 22. Harvest guidelines (HGs) issued to the Pacific mackerel fishery since 1998-99 based on annual stock assessments using the VPA model ‘ADEPT’ and retrospective HGs based biomasses estimated from the 2005 ASAP baseline model.

APPENDICES

Appendix I. ASAP Model Documentation (Legault and Restrepo 1998).

ICCAT WORKING DOCUMENT
SCRS/98/58

A Flexible Forward Age-Structured Assessment Program

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September 1998

Sustainable Fisheries Division Contribution SFD-98/99-16

Summary

This paper documents an age-structured assessment program (ASAP) which incorporates various modeling features that have been discussed by the SCRS in recent years, particularly during meetings of the bluefin tuna species group. The software was developed using the commercial package AD Model Builder, an efficient tool for optimization that uses an automatic differentiation algorithm in order to find a solution quickly using derivatives calculated to within machine precision, even when the number of parameters being estimated is rather large. The model is based on forward computations assuming separability of fishing mortality into year and age components. This assumption is relaxed by allowing for fleet-specific computations and by allowing the selectivity at age to change smoothly over time. The software can also allow the catchability associated with each abundance index to vary smoothly with time. The problem's dimensions (number of ages, years, fleets and abundance indices) are defined at input and limited by hardware only. We illustrate an application of ASAP using data for western Atlantic bluefin tuna.

Introduction

Stock assessment algorithms explain observed data through a statistical estimation procedure based on a number of assumptions. The number and severity of these assumptions are determined by the algorithm and reflect not only the user's paradigms but also the amount and quality of the available data. We present an age-structured assessment program (ASAP) which allows easy comparison of results when certain assumptions are made or relaxed. Specifically, ASAP is a flexible forward program that allows the assumption of separability of gear specific fishing mortality into year and age components to be relaxed and change over time. The assumption of constant catchability coefficients for scaling observed indices of abundance can also be relaxed to change over time. The advantage of this flexibility is an increased ability to fit models and less reliance on assumptions that are thought to be too strict. The disadvantage of such an approach is exactly this ability to explain the data in more (and possibly contradictory) ways through different choices in the amount of variability in the changing parameters. Explicit choices for relative weightings amongst the different parts of the objective function must be made. Slight changes in these parameter weightings in a complex model can produce vastly different results, while a simpler model will be more consistent (not necessarily more accurate) relative to changes in the parameter weightings.

Allowing flexibility in selectivity and catchability greatly increases the number of parameters to be estimated. We use the commercial software package AD Model Builder to estimate the relatively large number of parameters. The software package is based on a C++ library of automatic differentiation code (see Greiwank and Corliss 1991) which allows relatively fast convergence by calculating derivatives to machine precision accuracy. These derivatives are used in a quasi-Newton search routine to minimize the objective function. The array sizes for parameters are defined on input and limited only by hardware. Currently, ASAP is compiled to estimate a maximum of 5,000 parameters, but this can be increased by changing one line of code.

The AD Model Builder software package allows many matrix operations to be programmed easily in its template language and allows for the estimation of parameters to occur in phases. The phases work by estimating only some parameters initially and adding more parameters in a stepwise fashion until all parameters are estimated. When new parameters are added by incrementing the phase, the previously estimated parameters are still estimated, not fixed at the previous values. These phases also allow easy switching between simple and complex models by simply turning on or off phases through the input file. For example, index specific catchability coefficients can be allowed to change or have a constant value over time. An additional feature of the AD Model Builder software is easy likelihood profiling of specified variables, although this can be time consuming for models with large numbers of parameters. We first describe ASAP with all the features and then compare two analyses for bluefin tuna using different levels of complexity in the program.

The Model

Population dynamics

The model's population dynamics follow a standard form common to forward-projection methods such as those of Fournier and Archibald (1982), Deriso et al. (1985), Methot (1998), Ianelli and Fornier (1998), and Porch and Turner (In Press). Catches and fishing mortalities can be modeled as being fleet-specific.

Let a = age, 1…A,
y = year, 1…Y
g = fleet 1….G
u = abundance index series, 1….U

Selectivity (*S*) at age within a year by a fleet can be limited to a range of ages and averages one, as opposed to having a maximum of one,

$$\frac{\sum_{a(g_{start})}^{a(g_{end})} S_{a,y,g}}{a(g_{end})-a(g_{start})+1} = 1.0 \tag{1}$$

where $a(g_{start})$ and $a(g_{end})$ denote the starting and ending ages for the gear's selectivity. The output of the program makes the simple conversion from averaging one to having a maximum of one in order to simplify comparisons with other models.

Fishing mortality is modeled as the product of the selectivity at age within a year by a fleet and a year and fleet specific fishing mortality multiplier ($Fmult_{y,g}$)

$$F_{a,y,g} = S_{a,y,g} Fmult_{y,g} \ . \tag{2}$$

Total fishing mortality at age and year is the sum of the fleet specific fishing mortality rates

$$Ftot_{a,y} = \sum_{g} F_{a,y,g} \tag{3}$$

and adding the natural mortality rate (*M*) produces the total mortality rate

$$Z_{a,y} = Ftot_{a,y} + M_{a,y} \ . \tag{4}$$

The catch by age, year and fleet is

$$C_{a,y,g} = \frac{N_{a,y} F_{a,y,g} (1-e^{-Z_{a,y}})}{Z_{a,y}} \tag{5}$$

where *N* denotes population abundance at the start of the year.

The yield by age, year and fleet is

$$Y_{a,y,g} = C_{a,y,g} W_{a,y} \tag{6}$$

where $W_{a,y}$ denotes weight of an individual fish of age *a* in year *y*.

The proportion of catch at age within a year for a fleet is

$$P_{a,y,g} = \frac{C_{a,y,g}}{\sum_{a} C_{a,y,g}} . \tag{7}$$

The forward projections begin by computing recruitment as deviations from an average value

$$N_{1,y} = \overline{N}_1 e^{u_y} \tag{8}$$

where $?_y$~N(0,$s_{Ny}{}^2$) and the other numbers at age in the first year as deviations from equilibrium

$$\begin{aligned} N_{a,1} &= N_{1,1} e^{-\sum_{i=1}^{a-1} Z_{i,1}} e^{y_a} && for\, a < A \\ N_{a,1} &= \frac{N_{1,1} e^{-\sum_{i=1}^{a-1} Z_{i,1}}}{1 - e^{-Z_{A,1}}} e^{y_a} && for\, a = A \end{aligned} \tag{9}$$

where $?_a$~N(0,$s_{Na}{}^2$). The remaining population abundance at age and year is then computed

$$\begin{aligned} N_{a,y} &= N_{a-1,y-1} e^{-Z_{a-1,y-1}} && for\ a < A \\ N_{a,y} &= N_{a-1,y-1} e^{-Z_{a-1,y-1}} + N_{a,y-1} e^{-Z_{a,y-1}} && for\ a = A . \end{aligned} \tag{10}$$

Predicted indices of abundance ($\hat{I}$) are a measure of the population scaled by catchability coefficients (q) and selectivity at age (S)

$$\hat{I}_{u,y} = q_{u,y} \sum_{a(u_{start})}^{a(u_{end})} S_{u,a,y} N^{*}_{a,y} \tag{11}$$

where $a(u_{start})$ and $a(u_{end})$ are the index specific starting and ending ages, respectively, and N^* corresponds to the population abundance in either numbers or weight at a specific time during the year. The abundance index selectivity at age can either be input or linked to a specific fleet. If the latter is chosen, the age range can be smaller than that of the fleet and the annual selectivity patterns are rescaled to equal 1.0 for a specified age (a_{ref})such that the catchability coefficient is linked to this age

$$S_{u,a,y} = \frac{S_{a,y,g}}{S_{a_{ref},y,g}} . \tag{12}$$

Time-varying parameters

Fleet specific selectivity and catchability patterns are allowed to vary over time in the model. Changes in selectivity occur each t_g years through a random walk for every age in a given fleet

$$S_{a,y+t,g} = S_{a,y,g} e^{e_{a,y,g}} \tag{13}$$

where $e_{a,y,g}$~N(0,s_{Sg}^{2}) and are then rescaled to average one following equation (1). If t_g is greater than one, then the selectivity at age for the fleet is the same as previous values until t_g years elapse. The catchability coefficients also follow a random walk

$$q_{u,y+1} = q_{u,y}e^{w_{u,y}} \ , \tag{14}$$

as do the fleet specific fishing mortality rate multipliers

$$Fmult_{y+1,g} = Fmult_{y,g}e^{h_{y,g}} \tag{15}$$

where $?_{u,y}$~N(0,s_{qu}^{2}) and $?_{y,g}$~N(0,s_{Fg}^{2}).

<u>Parameter estimation</u>

The number of parameters estimated depends upon the values of t_g and whether or not changes in selectivity or catchability are considered. When time varying selectivity and catchability are not considered the following parameters are estimated: *Y* recruits, *A*-1 population abundance in first year, *YG* fishing mortality rate multipliers, *AG* selectivities (if all ages selected by all gears), *U* catchabilities, and 2 stock recruitment parameters. Inclusion of time varying selectivity and catchability can increase the number of parameters to be estimated by a maximum of (*Y*-1)*AG* + (*Y*-1)*U*. Sensitivity analyses can be conducted to determine the tradeoffs between number of parameters estimated and goodness of fit caused by changes in the t_g values.

The likelihood function to be minimized includes the following components (ignoring constants): total catch in weight by fleet (lognormally distributed)

$$L_1 = l_1[\ln(\sum_a Y_{a,y,g}) - \ln(\sum_a \hat{Y}_{a,y,g})]^2 \ ; \tag{16}$$

catch proportions in numbers of fish by fleet (multinomially distributed)

$$L_2 = -\sum_y \sum_g l_{2,y,g} \sum_a P_{a,y,g} \ln(\hat{P}_{a,y,g}) - P_{a,y,g} \ln(P_{a,y,g}) \ ; \tag{17}$$

and indices of abundance (lognormally distributed)

$$L_3 = \sum_g l_{3,g} \sum_y [\ln(I_{y,g}) - \ln(\hat{I}_{y,g})]^2 / 2s_{y,g}^{2} + \ln(s_{y,g}) \ , \tag{18}$$

where variables with a hat are estimated by the model and variables without a hat are input as observations. The second term in the catch proportion summation causes the likelihood to equal zero for a perfect fit. The sigmas in equation 18 are input by the user and can optionally be set to all equal 1.0 for equal weighting of all index points. The weights (?) assigned to each component of the likelihood function correspond to the inverse of the variance assumed to be associated with that component. Note that the year and fleet subscripts for the catch proportion lambdas allow zero weights to be assigned to specific year and fleet combinations such that only the total catch in weight by that fleet and year would be incorporated in the objective function. Priors for the variances of the time varying parameters are also included in the likelihood by setting *?* equal to the inverse of the assumed variance for each component

$$L_4 = \sum_g l_{4,g} \sum_a \sum_y e_{a,y,g}^2 \qquad (selectivity) \tag{19}$$

$$L_5 = \sum_u l_{5,u} \sum_y w_{u,y}^2 \qquad (catchability) \tag{20}$$

$$L_6 = \sum_g l_{6,g} \sum_y h_{y,g}^2 \qquad (F\ multipliers) \tag{21}$$

$$L_7 = l_7 \sum_y u_y^2 \qquad (recruitment) \tag{22}$$

$$L_8 = l_8 \sum_y y_y^2 \qquad (N\ year 1)\,. \tag{23}$$

Additionally, there is a prior for fitting a Beverton and Holt type stock-recruitment relationship

$$L_9 = l_9 \sum_y [\ln(N_{1,y}) - \ln\left(\frac{a\ SSB_{y-1}}{b + SSB_{y-1}}\right)]^2 \tag{24}$$

where *SSB* denotes the spawning stock biomass and *a* and *ß* are parameters to be estimated. Penalties are used to determine the amount of curvature allowed in the fleet selectivity patterns, both at age

$$r_1 = l_{r1} \sum_y \sum_g \sum_{a(g_{start})}^{a(g_{end})-2} (S_{a,y,g} - 2S_{a+1,y,g} + S_{a+2,y,g})^2 \tag{25}$$

and over time

$$r_2 = l_{r2} \sum_a \sum_g \sum_{y=1}^{Y-2} (S_{a,y,g} - 2S_{a,y+1,g} + S_{a,y+2,g})^2\,. \tag{26}$$

The function to be minimized is then the sum of the likelihoods and penalties

$$L = L_1 + L_2 + L_3 + L_4 + L_5 + L_6 + L_7 + L_8 + L_9 + r_1 + r_2\,. \tag{27}$$

An additional penalty is utilized in early phases of the minimization to keep the average total fishing mortality rate close to the natural morality rate. This penalty ensures the population abundance estimates do not get exceedingly large during early phases of the minimization. The final penalty added to the objective function forces the parameters for fleet selectivities in the first year to average 1.0. This penalty prevents multiple parameter sets from having the same objective function value, which would cause difficulty for the minimization routine. Each component of the objective function is reported in the output file along with the corresponding number of observations, weight assigned to that component, and residual sum of squared deviations (if appropriate).

Additional Features

The model optionally does some additional computations once the likelihood function has been minimized. These "extras" do not impact the solution, they are merely provided for reference. Each fleet can be designated as either directed or nondirected for the projections and F reference point calculations, with the option to modify the nondirected F in the future. The directed fleets are combined to form an overall selectivity pattern that is used to solve for common fishing mortality rate reference points ($F_{0.1}$, F_{max}, $F_{30\%SPR}$, $F_{40\%SPR}$ and F_{msy}) and compared to the terminal year F estimate. The inverse of the SPR for each of these points is also given so replacement lines corresponding to these reference values can be plotted on the spawner-recruit relationship. Projections are computed using either the stock-recruitment relationship or input values to generate future recruitment. The projections for each successive year can be made using either a total catch in weight or the application of a static $F_{X\%SPR}$, where X is input. A reference year is also input that allows comparison of the spawning stock biomass (SSB) in the terminal year and that in the final projection year as SSB_y/SSB_{ref}. Likelihood profiles for these SSB ratios can optionally be generated.

Example: Western Atlantic Bluefin Tuna

Two analyses of western Atlantic bluefin tuna data using ASAP are presented here. The first analysis (simple) did not allow selectivity and catchability to change over time (225 parameters estimated). The second analysis (complex) used the full complexity allowed by the model, with fleet selectivities allowed to change every two years and index catchabilities allowed to change every year (914 parameters estimated). In both analyses the model was structured for years 1970-1995, ages 1-10+, five fleets, and seven tuning indices (each point input with a variance) with all likelihood component weightings equal between the analyses. The natural mortality rate was set at 0.14 for all ages (for data details see Restrepo and Legault In Press). The number of observations associated with, and the weights given to, each part of the likelihood function are shown in Table 1. In this example, the weights assigned to each component were chosen arbitrarily. In an actual assessment, these weights will need to be selected by the assessment working group.

The overall fit of the complex analysis was better than the simple analysis (lower objective function value) as expected due to the greater number of parameters (Table 1). The complex analysis fits the indices better than the simple analysis, especially the US Rod and Reel Large, US Longline Gulf of Mexico, and the Japan Longline Gulf of Mexico indices. (Figure 1). Recruitment estimates from the two analyses are similar to the estimates from the 1996 SCRS assessment, which used virtual population analysis (VPA) with the main differences occurring in the early years of the time series (Figure 2). The estimates of spawning stock biomass (SSB) differ between the analyses, the complex one is similar in magnitude to the SCRS96 results, while the simple analysis estimates larger values (Figure 3). However, standardizing the SSB trends (dividing by the SSB in 1975) produces similar trends for all three analyses (Figure 3). The resulting stock-recruitment relationship is shown in figure 4. The total fishing mortality rates by year and age differ in both magnitude and pattern, with the complex analysis more closely matching the 1996 SCRS assessment (Figure 5). These differences in F are due to the assumptions about selectivity, fixed for the simple analysis and allowed to vary for the complex one (Figure 6). Note in particular the large change in selectivity of the purse seine fleet, mainly young fish in the early years and old fish in recent years. The catchability values also reflect the difference in assumptions, constant for the simple analysis and allowed to vary in the complex analysis (Figure 7). Note the large lambda given to the larval index causes the catchability coefficients to vary only slightly in the complex analysis. The catch at age proportions are fit relatively well in both analyses, the input and effective sample sizes are similar, even though this is the largest part of the total likelihood. The estimated effective sample size can be computed as

$$Effective\, N_g = \frac{\sum_a \sum_y \hat{p}_{a,y,g}(1-\hat{p}_{a,y,g})}{\sum_a \sum_y (p_{a,y,g}-\hat{p}_{a,y,g})^2} \tag{28}$$

(for details see McAllister and Ianelli, 1997 Appendix 2).

Discussion

The flexibility afforded by ASAP is a continuation of the trend in stock assessment programs from the relatively simple structure of Fournier and Archibald (1982) to the more flexible structure found in Methot (1998), Ianelli and Fournier (1998), and Porch and Turner (In Press). In fact, ASAP is based on the same logic as these more flexible programs, but combines the advantages of the AD Model Builder software with the more general input flexibility of stock synthesis and CATCHEM. J. Ianelli (NMFS, Seattle, pers. comm.) also provided guidance in the formulation of certain model components, specifically the logic of linking fleet specific indices with a specific age in the tuning process (see equation 12). The distinguishing feature between this approach and that found in virtual population analysis (VPA) (Gavaris 1988, Powers and Restrepo 1992) is that VPA assumes the catch at age is measured without error, while ASAP assumes the observed catch at age varies about its true value.

The flexibility of ASAP can also cause problems however. Slight changes in the weights assigned to each likelihood component can produce different results, both in magnitude and trend. The large number of parameters, in the complex model especially, required the solutions in each phase to progress towards a satisfactory region in the solution space. If any phase led the solution away from this region, the final result will not be believable (e.g. total F<1e-5). This problem was not found in multiple tests using simulated data that did not contain errors or only small observation errors. Thus, the ability to fit highly complex models depends upon the quality of the data available, especially the consistency between the catch at age and the tuning indices. Nevertheless, the flexible nature of ASAP allows for easy exploration of the data to determine what level of complexity can appropriately be modeled.

Acknowledgments

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Table 1. Likelihood function components for two ASAP analyses. nobs=number of observations in that component, ?=weight given to that component, RSS=residual sum of squared deviations, L=likelihood value

			Simple		**Complex**	
Component	nobs	?	RSS	L	RSS	L
Total Catch in Weight						
Rod and Reel	26	100.5	0.0005	0.0479	0.0001	0.0147
Japan Longline	26	100.5	0.0015	0.1558	0.0003	0.0322
Other Longline	26	100.5	0.0001	0.0069	0.0001	0.0070
Purse Seine	26	100.5	0.0002	0.0183	0.0039	0.3913
Other	26	100.5	0.0001	0.0065	0.0000	0.0026
Total	130	100.5	0.0023	0.2353	0.0045	0.4477
Catch at Age Proportions	1300	N/A	N/A	874.40	N/A	396.47
Index Fits						
Larval Index	16	1	5.26	11.95	5.29	11.61
US Rod and Reel Small	15	1	3.95	9.33	2.02	-1.02
Canadian Tended Line	15	1	2.08	3.05	0.64	-5.95
US Rod and Reel Large	13	1	1.76	1.22	0.39	-5.74
US Longline Gulf of Mexico	9	1	6.13	15.26	0.31	-3.79
Japan Longline Gulf of Mexico	8	1	0.74	1.10	0.58	1.05
Japan Longline NW Atlantic	20	1	3.22	9.51	0.58	-9.19
Total	96	7	23.15	51.43	9.80	-13.02
Selectivity Deviations						
Rod and Reel	12	0.1	0	0	2.52	0.25
Japan Longline	12	0.1	0	0	4.42	0.44
Other Longline	12	0.1	0	0	3.56	0.36
Purse Seine	12	0.1	0	0	8.74	0.87
Other	12	0.1	0	0	3.00	0.30
Total	60	0.5	0	0	22.25	2.22
Catchability Deviations						
Larval Index	16	1000	0	0	0.00	0.29
US Rod and Reel Small	15	6.7	0	0	0.51	3.43
Canadian Tended Line	15	6.7	0	0	0.37	2.45
US Rod and Reel Large	13	6.7	0	0	0.18	1.20
US Longline Gulf of Mexico	9	6.7	0	0	0.21	1.39
Japan Longline Gulf of Mexico	8	6.7	0	0	0.00	0.03
Japan Longline NW Atlantic	20	6.7	0	0	0.35	2.35
Total	96	1040.2	0	0	1.62	11.14
Fmult Deviations						
Rod and Reel	25	0.1	5.26	0.53	5.01	0.50
Japan Longline	25	0.1	21.44	2.14	19.67	1.97
Other Longline	25	0.1	24.30	2.43	23.97	2.40
Purse Seine	25	0.1	5.24	0.52	8.07	0.81
Other	25	0.1	5.60	0.56	6.84	0.68
Total	125	0.1	61.84	6.18	63.56	6.36
Recruitment	26	0.01	10.14	0.10	14.51	0.15
N in Year 1	9	1.44	3.34	4.82	3.08	4.43
Stock-Recruit Fit	25	0.001	9.47	0.01	3.94	0.00
Selectivity Curvature over Age	40	1.44	12.03	17.32	17.19	24.76
Selectivity Curvature over Time	1200	1.44	0	0	52.03	74.92
F penalty	260	0.001	3.0E-01	3.0E-4	2.3E-02	2.3E-02
Mean Sel Year 1 Penalty	50	1	4.5E-12	4.5E-12	4.7E-12	4.7E-12
Objective Function Value				**954.50**		**507.87**

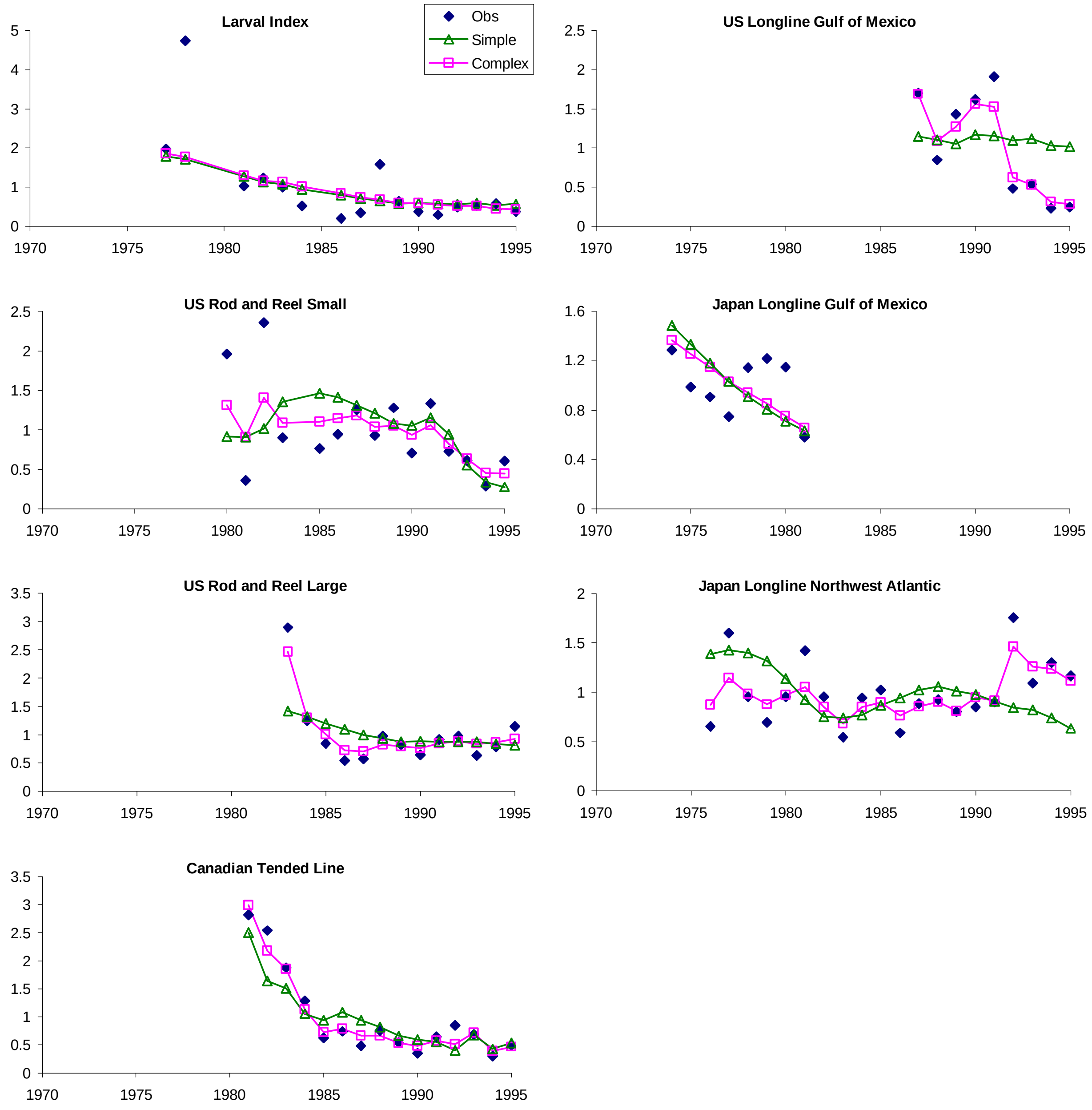

Figure 1. Observed and predicted indices for the simple and complex ASAP analyses.

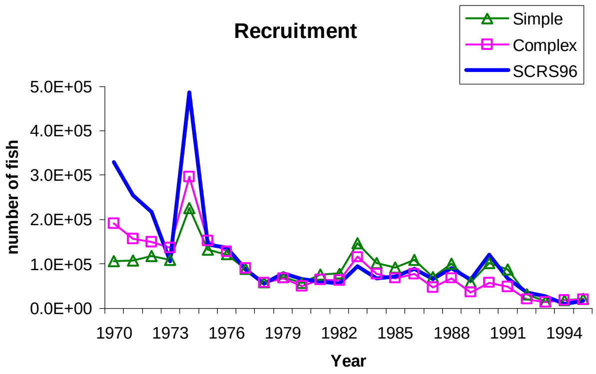

Figure 2. Estimated recruitment from two ASAP analyses and the SCRS 1996 assessment.

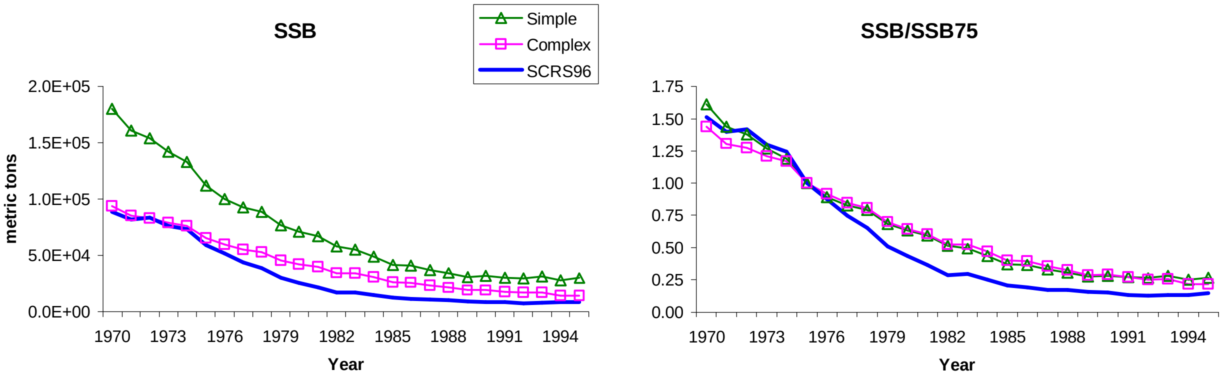

Figure 3. Spawning stock biomass (SSB) from two ASAP analyses and SCRS 1996.

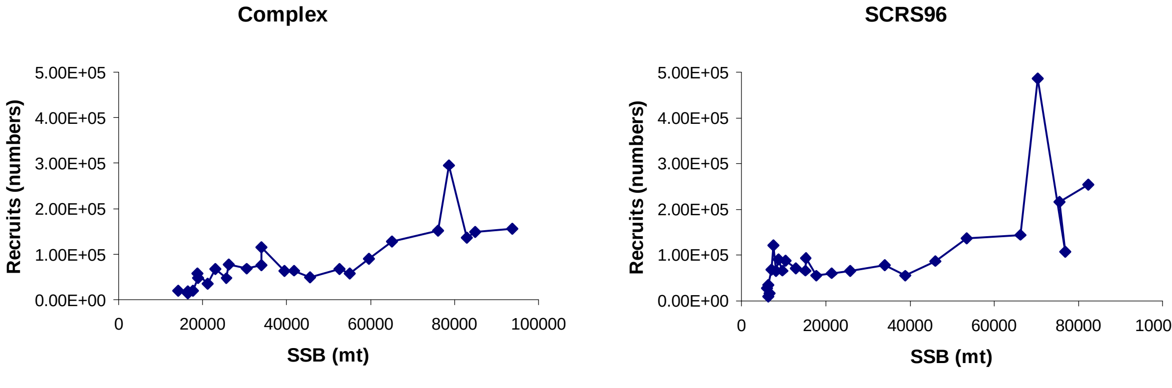

Figure 4. Complex ASAP analysis and SCRS 1996 stock-recruitment relationships.

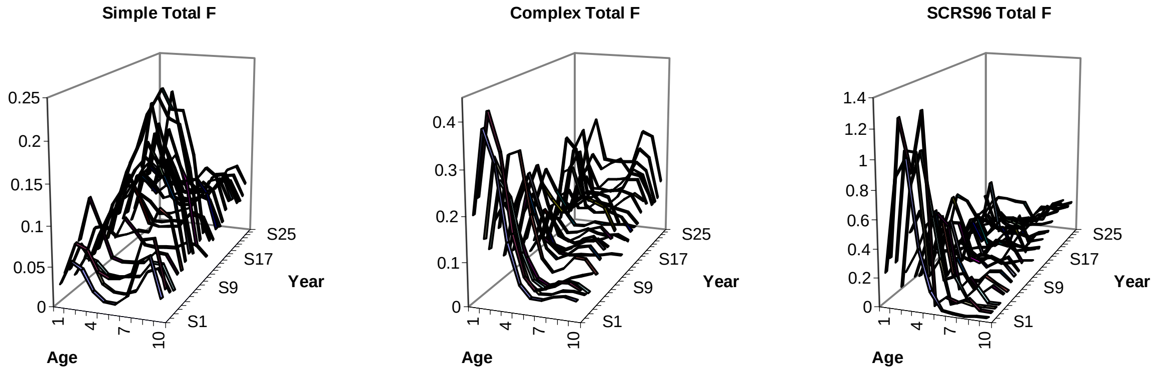

Figure 5. Estimated fishing mortality rates by age and year for two ASAP analyses and SCRS 1996.

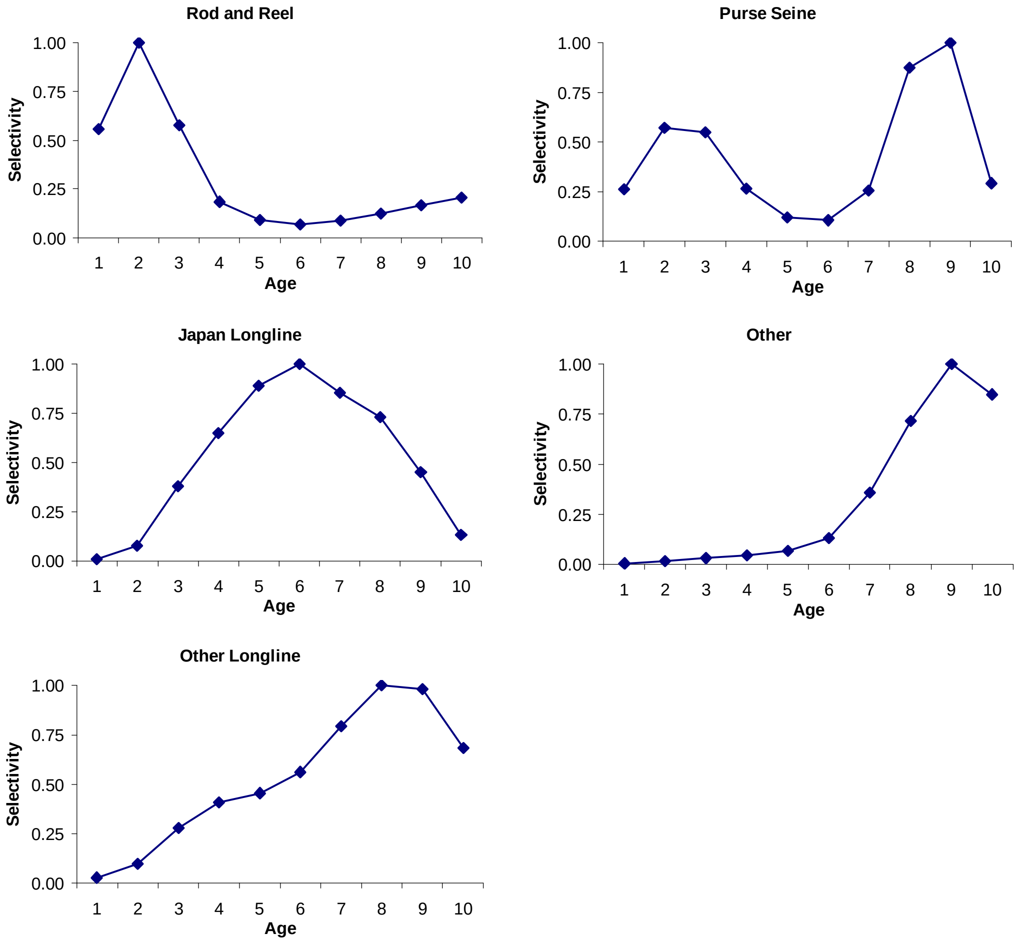

Figure 6a. Selectivity at age for the simple ASAP analysis, constant over all years for each fleet.

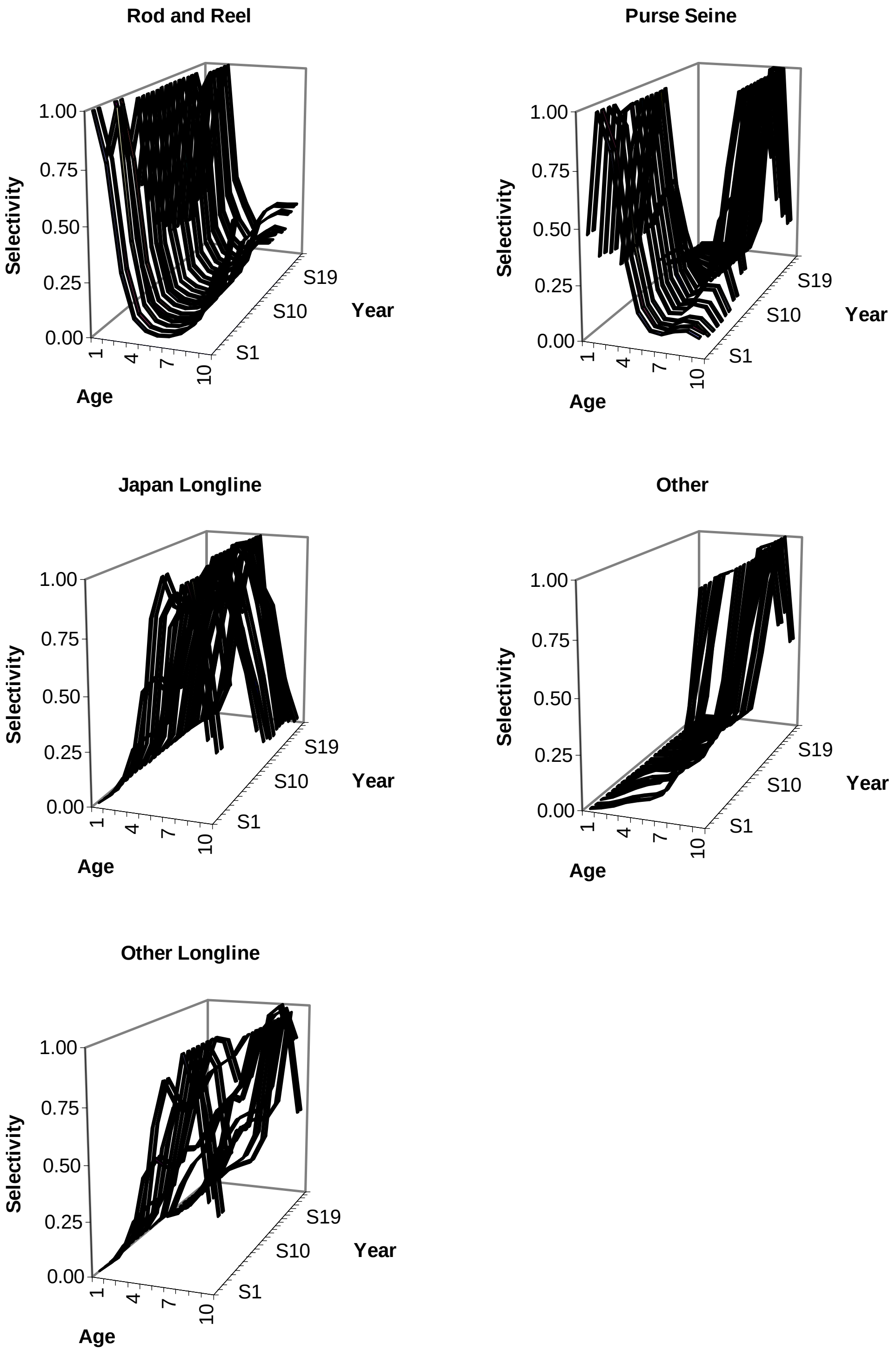

Figure 6b. Selectivity at age for the complex ASAP analysis.

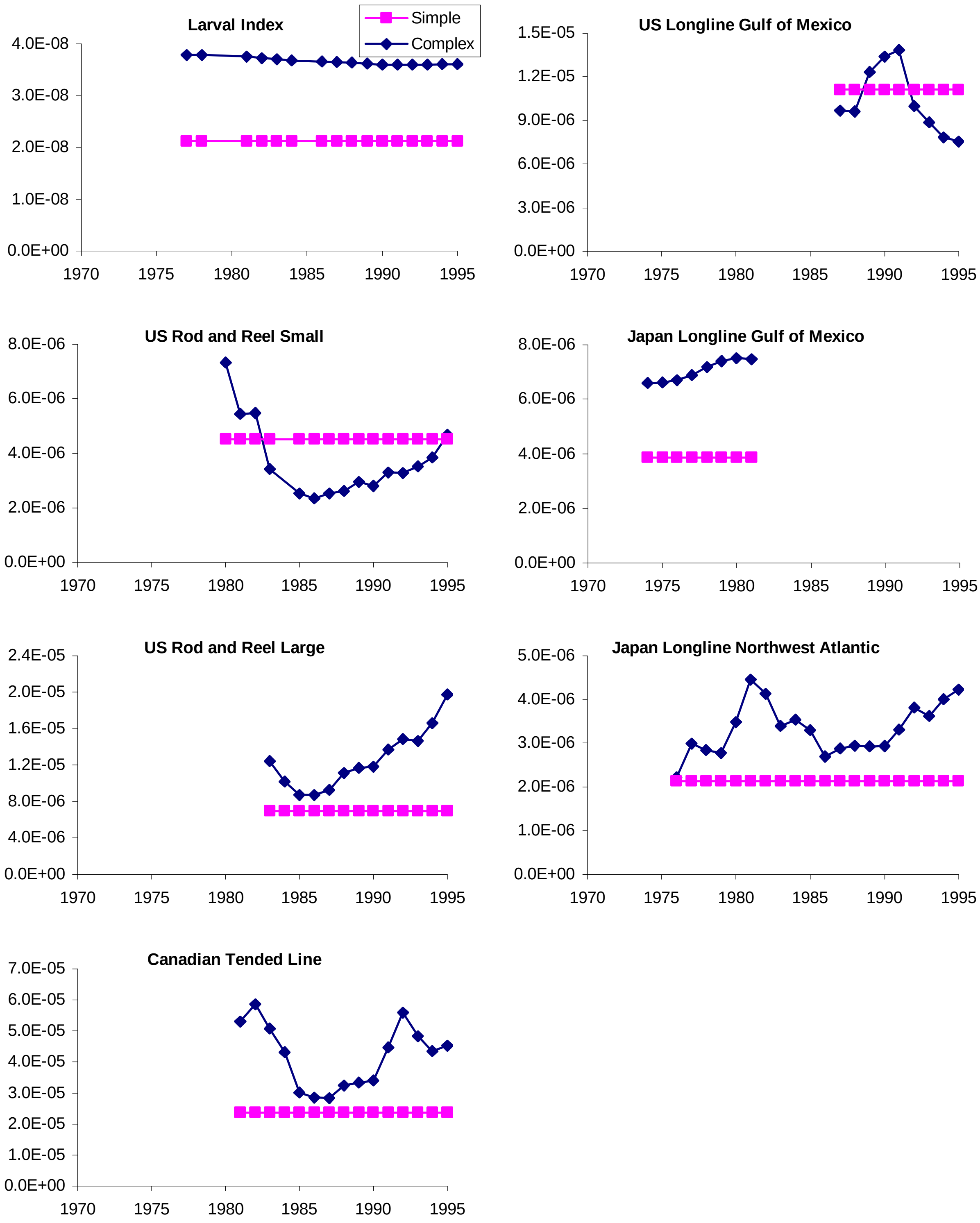

Figure 7. Catchability for each tuning index from the two ASAP analyses.

Appendix II. ASAP ADMB Template (.TPL) File.

```
// ASAP (Age Structured Assessment Program)
// by Christopher Legault and Victor Restrepo

TOP_OF_MAIN_SECTION
// set buffer sizes
  arrmblsize=5000000;
//  gradient_structure::set_GRADSTACK_BUFFER_SIZE(9000000);
//  gradient_structure::set_CMPDIF_BUFFER_SIZE(90000000);
  gradient_structure::set_MAX_NVAR_OFFSET(50000);
  gradient_structure::set_NUM_DEPENDENT_VARIABLES(5000);

DATA_SECTION
  int iyear
  int iage
  int ifleet
  int ind
  int i
  int j
  int iloop
  init_int nyears
  init_int year1
  init_int nages
  init_vector M(1,nages)
  init_number isfecund
  init_matrix mature(1,nyears,1,nages)
  init_matrix WAA(1,nyears,1,nages)
  matrix fecundity(1,nyears,1,nages)
 LOCAL_CALCS
  if (isfecund==1)
     fecundity=mature;
  else
     fecundity=elem_prod(WAA,mature);
 END_CALCS
  init_int nfleets
  init_ivector sel_start_age(1,nfleets)
  init_ivector sel_end_age(1,nfleets)
  init_ivector sel_est_start_age(1,nfleets)
  init_ivector sel_est_end_age(1,nfleets)
  init_vector release_mort(1,nfleets)
  init_ivector dim_sel_fleet(1,nfleets)
  init_matrix fleet_sel_change_year(1,nfleets,1,dim_sel_fleet)
  init_matrix CAA_ini(1,nyears*nfleets,1,nages+1)
  init_matrix Discard_ini(1,nyears*nfleets,1,nages+1)
  init_matrix proportion_release_ini(1,nyears*nfleets,1,nages)
  3darray CAA_obs(1,nfleets,1,nyears,1,nages)
  3darray Discard_obs(1,nfleets,1,nyears,1,nages)
  3darray proportion_release(1,nfleets,1,nyears,1,nages)
  3darray CAA_prop_obs(1,nfleets,1,nyears,sel_start_age,sel_end_age)
  3darray Discard_prop_obs(1,nfleets,1,nyears,sel_start_age,sel_end_age)
  matrix sum_p_lnp(1,nfleets,1,nyears)
  matrix sum_Discard_p_lnp(1,nfleets,1,nyears)
  matrix Catch_tot_fleet_obs(1,nfleets,1,nyears)
  matrix Discard_tot_fleet_obs(1,nfleets,1,nyears)
  matrix CAA_prop_obs_sum(1,nfleets,1,nyears)
  matrix Discard_prop_obs_sum(1,nfleets,1,nyears)
 LOCAL_CALCS
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     for (iyear=1;iyear<=nyears;iyear++)
     {
         CAA_obs(ifleet,iyear)(1,nages)=CAA_ini((ifleet-1)*nyears+iyear)(1,nages);
         Discard_obs(ifleet,iyear)(1,nages)=Discard_ini((ifleet-1)*nyears+iyear)(1,nages);
         proportion_release(ifleet,iyear)=proportion_release_ini((ifleet-1)*nyears+iyear)(1,nages);
         Catch_tot_fleet_obs(ifleet,iyear)=CAA_ini((ifleet-1)*nyears+iyear,nages+1);
         Discard_tot_fleet_obs(ifleet,iyear)=Discard_ini((ifleet-1)*nyears+iyear,nages+1);
     }
  }
  CAA_prop_obs=0.0;
```

```
  Discard_prop_obs=0.0;
  sum_p_lnp=0.0;
  sum_Discard_p_lnp=0.0;
  CAA_prop_obs_sum=0.0;
  Discard_prop_obs_sum=0.0;
  for (iyear=1;iyear<=nyears;iyear++)
  {
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
       if (Catch_tot_fleet_obs(ifleet,iyear)>0.0)
       {
          for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++)
             CAA_prop_obs_sum(ifleet,iyear)+=CAA_obs(ifleet,iyear,iage);
          if (CAA_prop_obs_sum(ifleet,iyear)==0.0)
          {
             CAA_prop_obs(ifleet,iyear)=0.0;
          }
          else
          {

CAA_prop_obs(ifleet,iyear)=CAA_obs(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))/CAA_prop_ob
s_sum(ifleet,iyear);
          }
       }
       for (iage=1;iage<=nages;iage++)
       {
          if(CAA_prop_obs(ifleet,iyear,iage)>1.0e-15)

sum_p_lnp(ifleet,iyear)+=CAA_prop_obs(ifleet,iyear,iage)*log(CAA_prop_obs(ifleet,iyear,iage));
       }
       if (Discard_tot_fleet_obs(ifleet,iyear)>0.0)
       {
          for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++)
             Discard_prop_obs_sum(ifleet,iyear)+=Discard_obs(ifleet,iyear,iage);
          if (Discard_prop_obs_sum(ifleet,iyear)==0.0)
          {
             Discard_prop_obs(ifleet,iyear)=0.0;
          }
          else
          {

Discard_prop_obs(ifleet,iyear)=Discard_obs(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))/Dis
card_prop_obs_sum(ifleet,iyear);
          }
       }
       for (iage=1;iage<=nages;iage++)
       {
          if(Discard_prop_obs(ifleet,iyear,iage)>1.0e-15)

sum_Discard_p_lnp(ifleet,iyear)+=Discard_prop_obs(ifleet,iyear,iage)*log(Discard_prop_obs(ifleet,iyear,
iage));
       }
    }
  }
 END_CALCS
  init_int nindices
  init_int index_weight_flag // 1=equal, 2=input
  init_vector index_units(1,nindices) // 1=biomass, 2=numbers
  init_vector index_month(1,nindices) // -1=average pop
  init_ivector index_start_age(1,nindices)
  init_ivector index_end_age(1,nindices)
  init_ivector index_fix_age(1,nindices)
  init_ivector index_sel_choice(1,nindices) // -1=fixed
  init_matrix index_ini(1,nyears*nindices,1,3+nages)
  ivector index_nobs(1,nindices)
 LOCAL_CALCS
  for (ind=1;ind<=nindices;ind++)
  {
     j=0;
     for (iyear=1;iyear<=nyears;iyear++)
     {
```

```
         if (index_ini((ind-1)*nyears+iyear,2)>-999.)
             j+=1;
     }
     index_nobs(ind)=j;
  }
 END_CALCS
  matrix index_time(1,nindices,1,index_nobs)
  matrix index_obs(1,nindices,1,index_nobs)
  matrix index_cv(1,nindices,1,index_nobs)
  matrix index_sigma2(1,nindices,1,index_nobs)
  matrix index_sigma(1,nindices,1,index_nobs)
  3darray index_sel_input(1,nindices,1,nyears,1,nages)
  vector index_mean(1,nindices)
 LOCAL_CALCS
  for (ind=1;ind<=nindices;ind++)
  {
     j=0;
     for (iyear=1;iyear<=nyears;iyear++)
     {
         i=(ind-1)*nyears+iyear;
         index_sel_input(ind,iyear)=--(--(--index_ini(i)(4,3+nages)));
         if (index_ini(i,2)>-999.)
         {
             j+=1;
             index_time(ind,j)=index_ini(i,1)-year1+1;
             index_obs(ind,j)=index_ini(i,2);
             index_cv(ind,j)=index_ini(i,3);
             if (index_weight_flag==1)
             {
                 index_sigma2(ind,j)=1.0;
             }
             else
             {
                 index_sigma2(ind,j)=log(index_cv(ind,j)*index_cv(ind,j)+1.0);
             }
             index_sigma(ind,j)=sqrt(index_sigma2(ind,j));
         }
     }
     index_mean(ind)=mean(index_obs(ind));
     index_obs(ind)/=index_mean(ind);       // rescale indices so mean=1
  }
 END_CALCS
//  init_int test_value
// !! cout << "test value = " << test_value << endl;
// !! cout << "asap2 read in" << endl;
// !! ad_comm::change_datafile_name("phase.ctl");
  init_int phase_sel_year1
  init_int phase_sel_devs
  init_int phase_Fmult_year1
  init_int phase_Fmult_devs
  init_int phase_recruit_devs
  init_int phase_N_year1_devs
  init_int phase_q_year1
  init_int phase_q_devs
  init_int phase_SRR
  init_int phase_steepness
  init_vector recruit_CV(1,nyears)
  vector recruit_sigma2(1,nyears)
  vector recruit_sigma(1,nyears)
 LOCAL_CALCS
  for (iyear=1;iyear<=nyears;iyear++)
  {
    recruit_sigma2(iyear)=log(recruit_CV(iyear)*recruit_CV(iyear)+1.0);
    recruit_sigma(iyear)=sqrt(recruit_sigma2(iyear));
  }
 END_CALCS
  init_vector lambda_ind(1,nindices)
  init_number lambda_catch_tot
  init_number lambda_Discard_tot
  init_matrix lambda_catch_ini(1,nyears,1,nfleets)
  init_matrix lambda_Discard_ini(1,nyears,1,nfleets)
```

```
  matrix lambda_catch(1,nfleets,1,nyears)
  matrix lambda_Discard(1,nfleets,1,nyears)
 LOCAL_CALCS
  for(iyear=1;iyear<=nyears;iyear++)
  {
   for(ifleet=1;ifleet<=nfleets;ifleet++)
   {
     lambda_catch(ifleet,iyear)=lambda_catch_ini(iyear,ifleet);
     lambda_Discard(ifleet,iyear)=lambda_Discard_ini(iyear,ifleet);
   }
  }
 END_CALCS
  init_vector lambda_Fmult_devs(1,nfleets)
  init_number lambda_N_year1_devs
  init_number lambda_recruit_devs
  init_vector lambda_q_devs(1,nindices)
  init_vector lambda_sel_devs(1,nfleets)
  init_number lambda_curve_sel_at_age
  init_number lambda_curve_sel_over_time
  init_number lambda_steepness
  init_number lambda_log_virgin_S
  init_vector NAA_year1_ini(1,nages)
  init_vector log_Fmult_year1_ini(1,nfleets)
  init_vector log_q_year1_ini(1,nindices)
  init_number log_SRR_virgin_ini
  init_number steepness_ini
  init_matrix select_year1_ini(1,nages,1,nfleets)
  init_number where_extras
  init_number ignore_guesses
  number delta
//  init_int test_value3
// !! cout << "test value3 = " << test_value3 << endl;
// !! cout << "phase.ctl read in   " << endl;
// !! ad_comm::change_datafile_name("project.ctl");
  init_int year_SSB
  init_ivector directed_fleet(1,nfleets)
  init_number nfinalyear
  int nprojyears
 !! nprojyears=nfinalyear-year1-nyears+1;
  init_matrix project_ini(1,nprojyears,1,5)
  vector proj_recruit(1,nprojyears)
  ivector proj_what(1,nprojyears)
  vector proj_target(1,nprojyears)
  vector proj_F_nondir_mult(1,nprojyears)
 LOCAL_CALCS
  for (iyear=1;iyear<=nprojyears;iyear++)
  {
    proj_recruit(iyear)=project_ini(iyear,2);
    proj_what(iyear)=project_ini(iyear,3);
    proj_target(iyear)=project_ini(iyear,4);
    proj_F_nondir_mult(iyear)=project_ini(iyear,5);
  }
 END_CALCS
//  init_int test_value2
// !! cout << "test value2 = " << test_value2 << endl;
// !! cout << "project.ctl read in   " << endl;

PARAMETER_SECTION
  init_bounded_matrix log_sel_year1(1,nfleets,sel_est_start_age,sel_est_end_age,-6.,1.,phase_sel_year1)
  3darray log_sel_devs(1,nfleets,1,dim_sel_fleet,sel_est_start_age,sel_est_end_age)
 !! int ns=size_count(log_sel_devs);
  init_bounded_vector log_sel_devs_vector(1,ns,-15.,15.,phase_sel_devs)
  init_bounded_vector log_Fmult_year1(1,nfleets,-15.,15.,phase_Fmult_year1)
  init_bounded_matrix log_Fmult_devs(1,nfleets,2,nyears,-15.,15.,phase_Fmult_devs)
  init_bounded_dev_vector log_recruit_devs(1,nyears,-15.,15.,phase_recruit_devs)
  init_bounded_vector log_N_year1_devs(2,nages,-15.,15.,phase_N_year1_devs)
  init_bounded_vector log_q_year1(1,nindices,-30,5,phase_q_year1)
  init_bounded_matrix log_q_devs(1,nindices,2,index_nobs,-15.,15.,phase_q_devs)
  init_bounded_number log_SRR_virgin(-1.0,200,phase_SRR)
  init_bounded_number SRR_steepness(0.20001,1.0,phase_steepness)
  matrix log_Fmult(1,nfleets,1,nyears)
```

```
matrix NAA(1,nyears,1,nages)
matrix temp_NAA(1,nyears,1,nages)
matrix FAA_tot(1,nyears,1,nages)
matrix Z(1,nyears,1,nages)
matrix S(1,nyears,1,nages)
matrix Catch_tot_fleet_pred(1,nfleets,1,nyears)
matrix Discard_tot_fleet_pred(1,nfleets,1,nyears)
3darray CAA_pred(1,nfleets,1,nyears,1,nages)
3darray Discard_pred(1,nfleets,1,nyears,1,nages)
3darray CAA_prop_pred(1,nfleets,1,nyears,sel_start_age,sel_end_age)
3darray Discard_prop_pred(1,nfleets,1,nyears,sel_start_age,sel_end_age)
3darray FAA_by_fleet_dir(1,nfleets,1,nyears,1,nages)
3darray FAA_by_fleet_Discard(1,nfleets,1,nyears,1,nages)
3darray log_sel(1,nfleets,1,nyears,sel_start_age,sel_end_age)
3darray sel_by_fleet(1,nfleets,1,nyears,1,nages)
vector temp_sel_over_time(1,nyears)
number temp_sel_fix
vector temp_sel_max(1,nfleets)
number sel_max_pen
number temp_Fmult_max
number Fmult_max_pen
matrix q_by_index(1,nindices,1,index_nobs)
matrix temp_sel(1,nyears,1,nages)
matrix index_pred(1,nindices,1,index_nobs)
number ntemp
number SRR_S0
number SRR_virgin
number SRR_rnot
number SRR_alpha
number SRR_beta
vector SRR_pred_recruits(1,nyears+1)
number RSS_SRR
number RSS_SRR_sigma
number likely_SRR_sigma
vector RSS_sel_devs(1,nfleets)
vector RSS_catch_tot_fleet(1,nfleets)
vector RSS_Discard_tot_fleet(1,nfleets)
number likely_catch
number likely_Discard
vector RSS_ind(1,nindices)
vector RSS_ind_sigma(1,nindices)
vector likely_ind(1,nindices)
number fpenalty
number sel_centered_pen
vector Fmult_pen(1,nfleets)
number N_year1_pen
number recruit_pen
vector q_pen(1,nindices)
vector sel_devs_pen(1,nfleets)
number curve_sel_at_age
number curve_sel_over_time
number nobs_curve_age
number nobs_curve_time
matrix effective_sample_size(1,nfleets,1,nyears)
matrix effective_Discard_sample_size(1,nfleets,1,nyears)
vector temp_Fmult(1,nfleets)
sdreport_vector SSB(1,nyears)
sdreport_vector recruits(1,nyears)
sdreport_vector plus_group(1,nyears)
vector final_year_total_sel(1,nages)
vector dir_F(1,nages)
vector Discard_F(1,nages)
vector proj_nondir_F(1,nages)
vector proj_dir_sel(1,nages)
vector proj_Discard_sel(1,nages)
matrix proj_NAA(1,nprojyears,1,nages)
vector proj_Fmult(1,nprojyears)
vector Ftemp(1,nages)
vector Ztemp(1,nages)
vector proj_SSB(1,nprojyears)
number SSBtemp
```

```
  number denom
  matrix proj_F_dir(1,nprojyears,1,nages)
  matrix proj_F_Discard(1,nprojyears,1,nages)
  matrix proj_F_nondir(1,nprojyears,1,nages)
  matrix proj_Z(1,nprojyears,1,nages)
  matrix proj_catch(1,nprojyears,1,nages)
  matrix proj_Discard(1,nprojyears,1,nages)
  matrix proj_yield(1,nprojyears,1,nages)
  vector proj_total_yield(1,nprojyears)
  vector proj_total_Discard(1,nprojyears)
  vector output_prop_obs(1,nages)
  vector output_prop_pred(1,nages)
  vector output_Discard_prop_obs(1,nages)
  vector output_Discard_prop_pred(1,nages)
  number temp_sum
  number temp_sum2
  number A
  number B
  number C
  number f
  number z
  number SPR_Fmult
  number YPR_Fmult
  number SPR_virgin
  number SPR
  number SPRatio
  number YPR
  number S_F
  number R_F
  number slope_origin
  number slope
  number F30SPR
  number F40SPR
  number Fmsy
  number Foy
  number F01
  number Fmax
  number Fcurrent
  number F30SPR_slope
  number F40SPR_slope
  number Fmsy_slope
  number F01_slope
  number Fmax_slope
  number Fcurrent_slope
  number SSmsy
  number SSoy
  number OY
  sdreport_number MSY
  sdreport_number SSB_ratio
  sdreport_number proj_SSB_ratio
  sdreport_number SSmsy_ratio
  sdreport_number Fmsy_ratio
  number SSB_ratiop
  number proj_SSB_ratiop
  likeprof_number MSYp

  objective_function_value obj_fun

PRELIMINARY_CALCS_SECTION                  // this section requires ;
  if (ignore_guesses==0)
  {
    NAA(1)=NAA_year1_ini;
    log_Fmult_year1=log_Fmult_year1_ini;
    log_q_year1=log_q_year1_ini;
    log_SRR_virgin=log_SRR_virgin_ini;
    SRR_steepness=steepness_ini;
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
      for (iage=sel_est_start_age(ifleet);iage<=sel_est_end_age(ifleet);iage++) // last age set to last
age-1
         log_sel_year1(ifleet,iage)=log(select_year1_ini(iage,ifleet));
```

```
    }
  }
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     if(sel_start_age(ifleet)<sel_est_start_age(ifleet))
     {
        for (iage=sel_start_age(ifleet);iage<sel_est_start_age(ifleet);iage++)
        {
           for (iyear=1;iyear<=nyears;iyear++)
              sel_by_fleet(ifleet,iyear,iage)=select_year1_ini(iage,ifleet);
        }
     }
     if(sel_end_age(ifleet)>sel_est_end_age(ifleet))
     {
        for (iage=sel_est_end_age(ifleet)+1;iage<=sel_end_age(ifleet);iage++)
        {
           for (iyear=1;iyear<=nyears;iyear++)
              sel_by_fleet(ifleet,iyear,iage)=select_year1_ini(iage,ifleet);
        }
     }
  }
  ntemp=1.0;
  SRR_S0=0.0;
  for (iage=1;iage<nages;iage++)
  {
     SRR_S0+=ntemp*fecundity(1,iage);
     ntemp*=mfexp(-M(iage));
  }
  ntemp/=(1.0-mfexp(-M(nages)));
  SRR_S0+=ntemp*fecundity(1,nages);
  delta=0.00001;

PROCEDURE_SECTION                          // this section requires ;
  get_SRR();
  fill_seldevs();
  get_selectivity();
  get_mortality_rates();
  get_numbers_at_age();
  get_predicted_catch();
  get_q();
  get_predicted_indices();
  compute_the_objective_function();
  if (where_extras==1)
  {
    if (last_phase())
    {
       get_proj_sel();
       get_Fref();
       project_into_future();
    }
  }

FUNCTION fill_seldevs
  if (active(log_sel_devs_vector))
  {
     j=0;
     for (ifleet=1;ifleet<=nfleets;ifleet++)
     {
       for (i=1;i<=dim_sel_fleet(ifleet);i++)
       {
          for (iage=sel_est_start_age(ifleet);iage<=sel_est_end_age(ifleet);iage++)
          {
             j++;
             log_sel_devs(ifleet,i,iage)=log_sel_devs_vector(j);
          }
       }
     }
  }

FUNCTION get_selectivity
  for (ifleet=1;ifleet<=nfleets;ifleet++)
```

```
  {

log_sel(ifleet,1)(sel_est_start_age(ifleet),sel_est_end_age(ifleet))=log_sel_year1(ifleet)(sel_est_star
t_age(ifleet),sel_est_end_age(ifleet));
  }
  if (active(log_sel_devs_vector))
  {
     for (ifleet=1;ifleet<=nfleets;ifleet++)
     {
         i=1;
         for (iyear=2;iyear<=nyears;iyear++)
         {
             if ((iyear+year1-1-fleet_sel_change_year(ifleet,i))==0)
             {

log_sel(ifleet,iyear)(sel_est_start_age(ifleet),sel_est_end_age(ifleet))=log_sel(ifleet,iyear-
1)(sel_est_start_age(ifleet),sel_est_end_age(ifleet))+log_sel_devs(ifleet,i)(sel_est_start_age(ifleet),
sel_est_end_age(ifleet));
                 i++;
                 if (i>dim_sel_fleet(ifleet))
                    i=dim_sel_fleet(ifleet);
             }
             else
             {

log_sel(ifleet,iyear)(sel_est_start_age(ifleet),sel_est_end_age(ifleet))=log_sel(ifleet,iyear-
1)(sel_est_start_age(ifleet),sel_est_end_age(ifleet));
             }
         }
     }
  }
  else
  {
     for (ifleet=1;ifleet<=nfleets;ifleet++)
     {
         for (iyear=2;iyear<=nyears;iyear++)

log_sel(ifleet,iyear)(sel_est_start_age(ifleet),sel_est_end_age(ifleet))=log_sel(ifleet,iyear-
1)(sel_est_start_age(ifleet),sel_est_end_age(ifleet));
     }
  }
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     for (iyear=1;iyear<=nyears;iyear++)
     {
         for (iage=sel_est_start_age(ifleet);iage<=sel_est_end_age(ifleet);iage++)
             sel_by_fleet(ifleet,iyear,iage)=mfexp(log_sel(ifleet,iyear,iage));
     }
  }

FUNCTION get_mortality_rates
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     log_Fmult(ifleet,1)=log_Fmult_year1(ifleet);
     if (active(log_Fmult_devs))
     {
         for (iyear=2;iyear<=nyears;iyear++)
             log_Fmult(ifleet,iyear)=log_Fmult(ifleet,iyear-1)+log_Fmult_devs(ifleet,iyear);
     }
     else
     {
         for (iyear=2;iyear<=nyears;iyear++)
             log_Fmult(ifleet,iyear)=log_Fmult_year1(ifleet);
     }
  }
  FAA_tot=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     for (iyear=1;iyear<=nyears;iyear++)
     {
       for (iage=1;iage<=nages;iage++)
```

```
       {

FAA_by_fleet_dir(ifleet,iyear,iage)=(mfexp(log_Fmult(ifleet,iyear))*sel_by_fleet(ifleet,iyear,iage))*(1
.0-proportion_release(ifleet,iyear,iage));

FAA_by_fleet_Discard(ifleet,iyear,iage)=(mfexp(log_Fmult(ifleet,iyear))*sel_by_fleet(ifleet,iyear,iage)
)*(proportion_release(ifleet,iyear,iage)*release_mort(ifleet));
       }
     }
     FAA_tot+=FAA_by_fleet_dir(ifleet)+FAA_by_fleet_Discard(ifleet);
  }
  for (iyear=1;iyear<=nyears;iyear++)
     Z(iyear)=FAA_tot(iyear)+M;
  S=mfexp(-1.0*Z);

FUNCTION get_numbers_at_age
  SRR_pred_recruits(1)=SRR_rnot;
  NAA(1,1)=SRR_pred_recruits(1)*mfexp(log_recruit_devs(1));
  if (phase_N_year1_devs>0)
  {
    for (iage=2;iage<=nages;iage++)
       NAA(1,iage)=NAA(1,iage-1)*mfexp(-1.0*M(iage-1));
    NAA(1,nages)/=(1.0-mfexp(-1.0*M(nages)));
    for (iage=2;iage<=nages;iage++)
       NAA(1,iage)*=mfexp(log_N_year1_devs(iage));
  }
  SSB(1)=NAA(1)*fecundity(1);
  for (iyear=2;iyear<=nyears;iyear++)
  {
     SRR_pred_recruits(iyear)=SRR_alpha*SSB(iyear-1)/(SRR_beta+SSB(iyear-1));
     NAA(iyear,1)=SRR_pred_recruits(iyear)*mfexp(log_recruit_devs(iyear));
     for (iage=2;iage<=nages;iage++)
         NAA(iyear,iage)=NAA(iyear-1,iage-1)*S(iyear-1,iage-1);
     NAA(iyear,nages)+=NAA(iyear-1,nages)*S(iyear-1,nages);
     SSB(iyear)=NAA(iyear)*fecundity(iyear);
  }
  SRR_pred_recruits(nyears+1)=SRR_alpha*SSB(nyears)/(SRR_beta+SSB(nyears));
  for (iyear=1;iyear<=nyears;iyear++)
  {
    recruits(iyear)=NAA(iyear,1);
    plus_group(iyear)=NAA(iyear,nages);
  }
  if (SSB(year_SSB-year1+1)>0.0)
  {
    SSB_ratio=SSB(nyears)/SSB(year_SSB-year1+1);
  }
  else
  {
    SSB_ratio=-1.0;
  }
  SSB_ratiop=SSB_ratio;
  if (SSmsy>0.0)
    SSmsy_ratio=SSB(nyears)/SSmsy;

FUNCTION get_predicted_catch
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     CAA_pred(ifleet)=elem_prod(elem_div(FAA_by_fleet_dir(ifleet),Z),elem_prod(1.0-S,NAA));
     Discard_pred(ifleet)=elem_prod(elem_div(FAA_by_fleet_Discard(ifleet),Z),elem_prod(1.0-S,NAA));
  }

  for (iyear=1;iyear<=nyears;iyear++)
  {
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
       CAA_prop_pred(ifleet,iyear)=0.0;
       Discard_prop_pred(ifleet,iyear)=0.0;

Catch_tot_fleet_pred(ifleet,iyear)=sum(CAA_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet)
));
```

```
Discard_tot_fleet_pred(ifleet,iyear)=sum(Discard_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(i
fleet)));
       if (Catch_tot_fleet_pred(ifleet,iyear)>0.0)

CAA_prop_pred(ifleet,iyear)=CAA_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))/Catch_tot
_fleet_pred(ifleet,iyear);
       if (Discard_tot_fleet_pred(ifleet,iyear)>0.0)

Discard_prop_pred(ifleet,iyear)=Discard_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))/D
iscard_tot_fleet_pred(ifleet,iyear);

Catch_tot_fleet_pred(ifleet,iyear)=CAA_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))*WA
A(iyear)(sel_start_age(ifleet),sel_end_age(ifleet));

Discard_tot_fleet_pred(ifleet,iyear)=Discard_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(iflee
t))*WAA(iyear)(sel_start_age(ifleet),sel_end_age(ifleet));
       for (iage=1;iage<=nages;iage++)
       {
          if (CAA_prop_pred(ifleet,iyear,iage)<1.e-15)
             CAA_prop_pred(ifleet,iyear,iage)=1.0e-15;
          if (Discard_prop_pred(ifleet,iyear,iage)<1.e-15)
             Discard_prop_pred(ifleet,iyear,iage)=1.0e-15;
       }
    }
  }

FUNCTION get_q
  for (ind=1;ind<=nindices;ind++)
  {
     q_by_index(ind,1)=mfexp(log_q_year1(ind));
     if (active(log_q_devs))
     {
         for (i=2;i<=index_nobs(ind);i++)
             q_by_index(ind,i)=q_by_index(ind,i-1)*mfexp(log_q_devs(ind,i));
     }
     else
     {
         for (i=2;i<=index_nobs(ind);i++)
             q_by_index(ind,i)=q_by_index(ind,1);
     }
  }

FUNCTION get_predicted_indices
  for (ind=1;ind<=nindices;ind++)
  {
     if (index_sel_choice(ind)==-1)
     {
         temp_sel=index_sel_input(ind);
     }
     else
     {
         temp_sel=sel_by_fleet(index_sel_choice(ind));
         for (iyear=1;iyear<=nyears;iyear++)
         {
             temp_sel_fix=temp_sel(iyear,index_fix_age(ind));
             temp_sel(iyear)/=temp_sel_fix;
         }
     }
     if (index_month(ind)==-1)
     {
         temp_NAA=elem_prod(NAA,elem_div(1.0-S,Z));
     }
     else
     {
         temp_NAA=elem_prod(NAA,mfexp(-1.0*(index_month(ind)/12.0)*Z));
     }
     if (index_units(ind)==1)
     {
         temp_NAA=elem_prod(temp_NAA,WAA);
     }
```

```
      for (i=1;i<=index_nobs(ind);i++)
      {
          j=index_time(ind,i);
          index_pred(ind,i)=q_by_index(ind,i)*sum(elem_prod(
              temp_NAA(j)(index_start_age(ind),index_end_age(ind)) ,
              temp_sel(j)(index_start_age(ind),index_end_age(ind))));
      }

   }

FUNCTION get_SRR
  SRR_virgin=mfexp(log_SRR_virgin);
  SRR_rnot=SRR_virgin/SRR_S0;
  SRR_alpha=4.0*SRR_steepness*SRR_rnot/(5.0*SRR_steepness-1.0);
  SRR_beta=SRR_virgin*(1.0-SRR_steepness)/(5.0*SRR_steepness-1.0);

FUNCTION get_proj_sel
  dir_F=0.0;
  Discard_F=0.0;
  proj_nondir_F=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     if (directed_fleet(ifleet)==1)
     {
        dir_F+=FAA_by_fleet_dir(ifleet,nyears);
        Discard_F+=FAA_by_fleet_Discard(ifleet,nyears);
     }
     else
     {
        proj_nondir_F+=FAA_by_fleet_dir(ifleet,nyears);
     }
  }
  proj_dir_sel=dir_F/max(dir_F);
  proj_Discard_sel=Discard_F/max(dir_F);

FUNCTION get_Fref
  get_SPR_virgin();
  A=0.0;
  B=5.0;
  for (iloop=1;iloop<=20;iloop++)
  {
     C=(A+B)/2.0;
     SPR_Fmult=C;
     get_SPR();
     if (SPR/SPR_virgin<0.30)
     {
        B=C;
     }
     else
     {
        A=C;
     }
  }
  F30SPR=C;
  F30SPR_slope=1.0/SPR;
  A=0.0;
  B=5.0;
  for (iloop=1;iloop<=20;iloop++)
  {
     C=(A+B)/2.0;
     SPR_Fmult=C;
     get_SPR();
     if (SPR/SPR_virgin<0.40)
     {
        B=C;
     }
     else
     {
        A=C;
     }
  }
```

```
  F40SPR=C;
  F40SPR_slope=1.0/SPR;
  A=0.0;
  B=3.0;
  for (iloop=1;iloop<=20;iloop++)
  {
    C=(A+B)/2.0;
    SPR_Fmult=C+delta;
    get_SPR();
    S_F=SRR_alpha*SPR-SRR_beta;
    R_F=S_F/SPR;
    YPR_Fmult=C+delta;
    get_YPR();
    slope=R_F*YPR;
    SPR_Fmult=C;
    get_SPR();
    S_F=SRR_alpha*SPR-SRR_beta;
    R_F=S_F/SPR;
    YPR_Fmult=C;
    get_YPR();
    slope-=R_F*YPR;
//    slope/=delta; only care pos or neg
    if(slope>0.0)
    {
       A=C;
    }
    else
    {
       B=C;
    }
  }
  Fmsy=C;
  SSmsy=S_F;
  MSY=YPR*R_F;
  MSYp=MSY;
  SPR_Fmult=Fmsy;
  get_SPR();
  Fmsy_slope=1.0/SPR;
    Foy=Fmsy*0.75;
    SPR_Fmult=Foy;
    get_SPR();
    SSoy=SRR_alpha*SPR-SRR_beta;
    R_F=SSoy/SPR;
    YPR_Fmult=Foy;
    get_YPR();
    OY=R_F*YPR;
  YPR_Fmult=delta;
  get_YPR();
  slope_origin=YPR/delta;
  A=0.0;
  B=5.0;
  for (iloop=1;iloop<=20;iloop++)
  {
     C=(A+B)/2.0;
     YPR_Fmult=C+delta;
     get_YPR();
     slope=YPR;
     YPR_Fmult=C;
     get_YPR();
     slope-=YPR;
     slope/=delta;
     if (slope<0.10*slope_origin)
     {
        B=C;
     }
     else
     {
        A=C;
     }
  }
  F01=C;
```

```
  SPR_Fmult=F01;
  get_SPR();
  F01_slope=1.0/SPR;
  A=0.0;
  B=10.0;
  for (iloop=1;iloop<=20;iloop++)
  {
     C=(A+B)/2.0;
     YPR_Fmult=C+delta;
     get_YPR();
     slope=YPR;
     YPR_Fmult=C;
     get_YPR();
     slope-=YPR;
     slope/=delta;
     if (slope<0.0)
     {
        B=C;
     }
     else
     {
        A=C;
     }
  }
  Fmax=C;
  SPR_Fmult=Fmax;
  get_SPR();
  Fmax_slope=1.0/SPR;
  Fcurrent=max(FAA_tot(nyears)-proj_nondir_F-Discard_F);
  SPR_Fmult=Fcurrent;
  get_SPR();
  Fcurrent_slope=1.0/SPR;
  if (Fmsy>0.0)
    Fmsy_ratio=Fcurrent/Fmsy;

FUNCTION get_YPR
  YPR=0.0;
  ntemp=1.0;
  for (iage=1;iage<nages;iage++)
  {
    f=YPR_Fmult*proj_dir_sel(iage);
    z=M(iage)+f+proj_nondir_F(iage)+YPR_Fmult*proj_Discard_sel(iage);
    YPR+=ntemp*f*WAA(nyears,iage)*(1.0-mfexp(-1.0*z))/z;
    ntemp*=mfexp(-1.0*z);
  }
  f=YPR_Fmult*proj_dir_sel(nages);
  z=M(nages)+f+proj_nondir_F(nages)+YPR_Fmult*proj_Discard_sel(nages);
  ntemp/=(1.0-mfexp(-1.0*z));
  YPR+=ntemp*f*WAA(nyears,nages)*(1.0-mfexp(-1.0*z))/z;

FUNCTION project_into_future
  get_SPR_virgin();
  for (iyear=1;iyear<=nprojyears;iyear++)
  {
    proj_F_nondir(iyear)=proj_nondir_F*proj_F_nondir_mult(iyear);
    if (proj_recruit(iyear)<0.0)  // use stock-recruit relationship
    {
       if (iyear==1)
       {
          proj_NAA(iyear,1)=SRR_alpha*SSB(nyears)/(SRR_beta+SSB(nyears));
       }
       else
       {
          proj_NAA(iyear,1)=SRR_alpha*proj_SSB(iyear-1)/(SRR_beta+proj_SSB(iyear-1));
       }
    }
    else
    {
       proj_NAA(iyear,1)=proj_recruit(iyear);
    }
    if (iyear==1)
```

```
    {
       for (iage=2;iage<=nages;iage++)
          proj_NAA(1,iage)=NAA(nyears,iage-1)*S(nyears,iage-1);
       proj_NAA(1,nages)+=NAA(nyears,nages)*S(nyears,nages);
    }
    else
    {
       for (iage=2;iage<=nages;iage++)
          proj_NAA(iyear,iage)=proj_NAA(iyear-1,iage-1)*mfexp(-1.0*proj_Z(iyear-1,iage-1));
       proj_NAA(iyear,nages)+=proj_NAA(iyear-1,nages)*mfexp(-1.0*proj_Z(iyear-1,nages));
    }
    if (proj_what(iyear)==1) // match directed yield
    {
       proj_Fmult(iyear)=3.0;  // first check to see if catch possible
       proj_F_dir(iyear)=proj_Fmult(iyear)*proj_dir_sel;
       proj_F_Discard(iyear)=proj_Fmult(iyear)*proj_Discard_sel;
       proj_Z(iyear)=M+proj_F_nondir(iyear)+proj_F_dir(iyear)+proj_F_Discard(iyear);
       proj_catch(iyear)=elem_prod(elem_div(proj_F_dir(iyear),proj_Z(iyear)),elem_prod(1.0-mfexp(-
1.0*proj_Z(iyear)),proj_NAA(iyear)));
       proj_Discard(iyear)=elem_prod(elem_div(proj_F_Discard(iyear),proj_Z(iyear)),elem_prod(1.0-
mfexp(-1.0*proj_Z(iyear)),proj_NAA(iyear)));
       proj_yield(iyear)=elem_prod(proj_catch(iyear),WAA(nyears));
       proj_total_yield(iyear)=sum(proj_yield(iyear));
       proj_total_Discard(iyear)=sum(elem_prod(proj_Discard(iyear),WAA(nyears)));
       if (proj_total_yield(iyear)>proj_target(iyear))  // if possible, what F needed
       {
          proj_Fmult(iyear)=0.0;
          for (iloop=1;iloop<=20;iloop++)
          {
             Ftemp=proj_Fmult(iyear)*proj_dir_sel;
             denom=0.0;
             for (iage=1;iage<=nages;iage++)
             {

Ztemp(iage)=M(iage)+proj_F_nondir(iyear,iage)+proj_Fmult(iyear)*proj_Discard_sel(iage)+Ftemp(iage);
                denom+=proj_NAA(iyear,iage)*WAA(nyears,iage)*proj_dir_sel(iage)*(1.0-mfexp(-
1.0*Ztemp(iage)))/Ztemp(iage);
             }
             proj_Fmult(iyear)=proj_target(iyear)/denom;
          }
       }
    }
    else
    {
     if (proj_what(iyear)==2)      // match F%SPR
     {
       A=0.0;
       B=5.0;
       for (iloop=1;iloop<=20;iloop++)
       {
          C=(A+B)/2.0;
          SPR_Fmult=C;
          get_SPR();
          SPRatio=SPR/SPR_virgin;
          if (SPRatio<proj_target(iyear))
          {
             B=C;
          }
          else
          {
             A=C;
          }
       }
       proj_Fmult(iyear)=C;
     }
     else
     {
      if (proj_what(iyear)==3)   // project Fmsy
      {
        proj_Fmult=Fmsy;
      }
```

```
      else
      {
        if (proj_what(iyear)==4) // project Fcurrent
        {
            proj_Fmult=Fcurrent;
        }
        else
        {
           if (proj_what(iyear)==5) // project input F
           {
               proj_Fmult=proj_target(iyear);
           }
           else               // project default MSY (6) or OY (7) control rule
           {
               if(iyear==1)
               {
                  SSBtemp=SSB(nyears);
               }
               else
               {
                  SSBtemp=proj_SSB(iyear-1);
               }
               if((M(nages)+(SSBtemp/SSmsy))<=1)
               {
                    proj_Fmult=Fmsy*(SSBtemp/SSmsy)/(1.0-M(nages));
               }
               else
               {
                    proj_Fmult=Fmsy;
               }
               if (proj_what(iyear)==7)
                    proj_Fmult*=0.75;
           }
        }
      }
     }
    }
    proj_F_dir(iyear)=proj_Fmult(iyear)*proj_dir_sel;
    proj_F_Discard(iyear)=proj_Fmult(iyear)*proj_Discard_sel;
    proj_Z(iyear)=M+proj_F_nondir(iyear)+proj_F_dir(iyear)+proj_F_Discard(iyear);
    proj_catch(iyear)=elem_prod(elem_div(proj_F_dir(iyear),proj_Z(iyear)),elem_prod(1.0-mfexp(-
1.0*proj_Z(iyear)),proj_NAA(iyear)));
    proj_Discard(iyear)=elem_prod(elem_div(proj_F_Discard(iyear),proj_Z(iyear)),elem_prod(1.0-mfexp(-
1.0*proj_Z(iyear)),proj_NAA(iyear)));
    proj_yield(iyear)=elem_prod(proj_catch(iyear),WAA(nyears));
    proj_total_yield(iyear)=sum(proj_yield(iyear));
    proj_total_Discard(iyear)=sum(elem_prod(proj_Discard(iyear),WAA(nyears)));
    proj_SSB(iyear)=proj_NAA(iyear)*fecundity(nyears);
  }
  proj_SSB_ratio=proj_SSB(nprojyears)/SSB(year_SSB-year1+1);
  proj_SSB_ratiop=proj_SSB_ratio;

FUNCTION get_SPR_virgin
  ntemp=1.0;
  SPR_virgin=0.0;
  for (iage=1;iage<nages;iage++)
  {
    SPR_virgin+=ntemp*fecundity(nyears,iage);
    ntemp*=mfexp(-1.0*(M(iage)));
  }
  ntemp/=(1.0-mfexp(-1.0*(M(nages))));
  SPR_virgin+=ntemp*fecundity(nyears,nages);

FUNCTION get_SPR
  ntemp=1.0;
  SPR=0.0;
  for (iage=1;iage<nages;iage++)
  {
    SPR+=ntemp*fecundity(nyears,iage);
    z=M(iage)+proj_nondir_F(iage)+SPR_Fmult*proj_dir_sel(iage)+SPR_Fmult*proj_Discard_sel(iage);
    ntemp*=mfexp(-1.0*z);
```

```
  }
  z=M(nages)+proj_nondir_F(nages)+SPR_Fmult*proj_dir_sel(nages)+SPR_Fmult*proj_Discard_sel(nages);
  ntemp/=(1.0-mfexp(-1.0*z));
  SPR+=ntemp*fecundity(nyears,nages);

FUNCTION compute_the_objective_function
// residuals and likelihoods
  for (ind=1;ind<=nindices;ind++)
  {
     RSS_ind(ind)=0.0;
     RSS_ind_sigma(ind)=0.0;
     for (i=1;i<=index_nobs(ind);i++)
     {
         RSS_ind(ind)+=square(log(index_obs(ind,i)+0.0001)-log(index_pred(ind,i)+0.0001));
         RSS_ind_sigma(ind)+=((square(log(index_obs(ind,i)+0.0001)-
log(index_pred(ind,i)+0.0001)))/index_sigma2(ind,i))+log(index_sigma(ind,i));
     }
     likely_ind(ind)=0.5*lambda_ind(ind)*RSS_ind_sigma(ind);
  }
  obj_fun=sum(likely_ind);
  likely_catch=0.0;
  likely_Discard=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    RSS_catch_tot_fleet(ifleet)=norm2(log(Catch_tot_fleet_obs(ifleet)+1.0)-
log(Catch_tot_fleet_pred(ifleet)+1.0));
    RSS_Discard_tot_fleet(ifleet)=norm2(log(Discard_tot_fleet_obs(ifleet)+1.0)-
log(Discard_tot_fleet_pred(ifleet)+1.0));
    for (iyear=1;iyear<=nyears;iyear++)
    {
       temp_sum=0.0;
       temp_sum2=0.0;
       for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++)
       {
          temp_sum+=CAA_prop_obs(ifleet,iyear,iage)*log(CAA_prop_pred(ifleet,iyear,iage));
          if(proportion_release(ifleet,iyear,iage)>0.0)
             temp_sum2+=Discard_prop_obs(ifleet,iyear,iage)*log(Discard_prop_pred(ifleet,iyear,iage));
       }
       likely_catch+=-1.0*lambda_catch(ifleet,iyear)*(temp_sum-sum_p_lnp(ifleet,iyear));
       likely_Discard+=-1.0*lambda_Discard(ifleet,iyear)*(temp_sum2-sum_Discard_p_lnp(ifleet,iyear));
    }
  }
  obj_fun+=lambda_catch_tot*sum(RSS_catch_tot_fleet);
  obj_fun+=lambda_Discard_tot*sum(RSS_Discard_tot_fleet);
  obj_fun+=likely_catch;
  obj_fun+=likely_Discard;
// stock-recruitment relationship
  RSS_SRR=0.0;
  RSS_SRR_sigma=0.0;
  for (iyear=1;iyear<=nyears;iyear++)
  {
     RSS_SRR+=square(log(recruits(iyear)+0.001)-log(SRR_pred_recruits(iyear)+0.001));
     RSS_SRR_sigma+=((square(log(recruits(iyear)+0.001)-
log(SRR_pred_recruits(iyear)+0.001)))/recruit_sigma2(iyear))+log(recruit_sigma(iyear));
  }
  likely_SRR_sigma=0.5*lambda_recruit_devs*RSS_SRR_sigma;
  obj_fun+=likely_SRR_sigma;
  obj_fun+=lambda_steepness*square(log(steepness_ini)-log(SRR_steepness));
  obj_fun+=lambda_log_virgin_S*square(log_SRR_virgin_ini-log_SRR_virgin);
// penalties
  if (last_phase())
  {
    fpenalty=0.001*square(log(mean(FAA_tot))-log(mean(M)));
  }
  else
  {
    fpenalty=100.0*square(log(mean(FAA_tot))-log(mean(M)));
  }
  for (ifleet=1;ifleet<=nfleets;ifleet++)
    Fmult_pen(ifleet)=lambda_Fmult_devs(ifleet)*norm2(log_Fmult_devs(ifleet));
  N_year1_pen=lambda_N_year1_devs*norm2(log_N_year1_devs);
```

```
  recruit_pen=lambda_recruit_devs*norm2(log_recruit_devs);
  for (ind=1;ind<=nindices;ind++)
    q_pen(ind)=lambda_q_devs(ind)*norm2(log_q_devs(ind));
  obj_fun+=fpenalty+sum(Fmult_pen)+N_year1_pen+recruit_pen+sum(q_pen);
// penalty for first year selectivity not centered on 1
  sel_centered_pen=0.0;
  obj_fun+=sel_centered_pen;
// curvature penalties
  curve_sel_at_age=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    if ((sel_end_age(ifleet)-sel_start_age(ifleet))>2)
    {
      curve_sel_at_age+=norm2(first_difference(first_difference(log_sel(ifleet,1))));
      if (active(log_sel_devs_vector));
      {
         for (i=1;i<=dim_sel_fleet(ifleet);i++)
            curve_sel_at_age+=norm2(first_difference(first_difference(log_sel_devs(ifleet,i))));
      }
    }
  }
  obj_fun+=lambda_curve_sel_at_age*curve_sel_at_age;
  curve_sel_over_time=0.0;
  if (active(log_sel_devs_vector));
  {
     for (ifleet=1;ifleet<=nfleets;ifleet++)
     {
       RSS_sel_devs(ifleet)=norm2(log_sel_devs(ifleet));
       sel_devs_pen(ifleet)=lambda_sel_devs(ifleet)*RSS_sel_devs(ifleet);
     }
     obj_fun+=sum(sel_devs_pen);
     for (ifleet=1;ifleet<=nfleets;ifleet++)
     {
        for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++)
        {
           for (iyear=1;iyear<=nyears;iyear++)
              temp_sel_over_time(iyear)=log_sel(ifleet,iyear,iage);
           curve_sel_over_time+=norm2(first_difference(first_difference(temp_sel_over_time)));
        }
     }
  }
  obj_fun+=lambda_curve_sel_over_time*curve_sel_over_time;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
    temp_sel_max(ifleet)=max(mfexp(log_sel_year1(ifleet)));
  if (max(temp_sel_max)<=100)
  {
      sel_max_pen=0.0;
  }
  else
  {
      sel_max_pen=100.*(max(temp_sel_max)-100.0)*(max(temp_sel_max)-100.);
  }
  obj_fun+=sel_max_pen;
  Fmult_max_pen=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    for (iyear=1;iyear<=nyears;iyear++)
    {
       temp_Fmult_max=mfexp(log_Fmult(ifleet,iyear))*temp_sel_max(ifleet);
       if(temp_Fmult_max>5.0)
          Fmult_max_pen+=1000.*(temp_Fmult_max-5.0)*(temp_Fmult_max-5.0);
    }
  }
  obj_fun+=Fmult_max_pen;

REPORT_SECTION                             // this section requires ;
  if (where_extras==2)
  {
    get_proj_sel();
    get_Fref();
    project_into_future();
```

```
  }
  report << "obj_fun        = " << obj_fun << endl;
  report << "Component          RSS      nobs  Lambda  Likelihood" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
    report << "  Catch_Fleet_" << ifleet << "        " << RSS_catch_tot_fleet(ifleet) << "   " <<
nyears << "   " << lambda_catch_tot << "   " << lambda_catch_tot*RSS_catch_tot_fleet(ifleet) << endl;
  report << "Catch_Fleet_Total     " << sum(RSS_catch_tot_fleet) << "   " << nfleets*nyears << "   " <<
lambda_catch_tot << "   " << lambda_catch_tot*sum(RSS_catch_tot_fleet) << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
    report << "  Discard_Fleet_" << ifleet << "        " << RSS_Discard_tot_fleet(ifleet) << "   " <<
nyears << "   " << lambda_Discard_tot << "   " << lambda_Discard_tot*RSS_Discard_tot_fleet(ifleet) <<
endl;
  report << "Discard_Fleet_Total     " << sum(RSS_Discard_tot_fleet) << "   " << nfleets*nyears << "
" << lambda_Discard_tot << "   " << lambda_Discard_tot*sum(RSS_Discard_tot_fleet) << endl;
  report << "CAA_proportions   " << "   N/A         " << "    " << size_count(CAA_prop_obs) << "
see_below      " << likely_catch << endl;
  report << "Discard_proportions   " << "   N/A         " << "    " << size_count(Discard_prop_obs) << "
see_below      " << likely_Discard << endl;
  for (ind=1;ind<=nindices;ind++)
    report << "  Index_Fit_" << ind << "         " << RSS_ind(ind) << "   " << index_nobs(ind) << "   "
<< lambda_ind(ind) << "   " << likely_ind(ind) << endl;
  report << "Index_Fit_Total     " << sum(RSS_ind) << "   " << sum(index_nobs) << "   " <<
sum(lambda_ind) << "   " << sum(likely_ind) << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
    report << "  Selectivity_devs_fleet_" << ifleet << "   " << RSS_sel_devs(ifleet) << "  " <<
dim_sel_fleet(ifleet) << "   " << lambda_sel_devs(ifleet) << "  " << sel_devs_pen(ifleet) << endl;
  report << "Selectivity_devs_Total   " << sum(RSS_sel_devs) << "  " << sum(dim_sel_fleet) << "   " <<
sum(lambda_sel_devs) << "  " << sum(sel_devs_pen) << endl;
  for (ind=1;ind<=nindices;ind++)
    report << "  Catchability_devs_index_" << ind << "  "  << norm2(log_q_devs(ind)) << "  " <<
index_nobs(ind) << "  " << lambda_q_devs(ind) << "  " << q_pen(ind) << endl;
  report << "Catchability_devs_Total  "  << norm2(log_q_devs) << "  " << sum(index_nobs) << "  " <<
sum(lambda_q_devs) << "  " << sum(q_pen) << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
    report << "  Fmult_fleet_" << ifleet << "     " << norm2(log_Fmult_devs(ifleet)) << "   " <<
nyears-1 << "   " << lambda_Fmult_devs(ifleet) << "  " << Fmult_pen(ifleet) << endl;
  report << "Fmult_fleet_Total   " << norm2(log_Fmult_devs) << "   " << nfleets*(nyears-1) << "   " <<
sum(lambda_Fmult_devs) << "  " << sum(Fmult_pen) << endl;
  report << "N_year_1            " << norm2(log_N_year1_devs) << "   " << nages-1 << "   " <<
lambda_N_year1_devs << "   " << N_year1_pen << endl;
  report << "Stock-Recruit_Fit   " << RSS_SRR << "  " << nyears << "   " << lambda_recruit_devs << "
"  << likely_SRR_sigma << endl;
  report << "Recruit_devs        " << norm2(log_recruit_devs) << "   " << nyears << "   " <<
lambda_recruit_devs << "   " << lambda_recruit_devs*norm2(log_recruit_devs) << endl;
  report << "SRR_steepness       " << square(log(steepness_ini)-log(SRR_steepness)) << "  " << "     1
" << lambda_steepness << "   " << lambda_steepness*square(log(steepness_ini)-log(SRR_steepness)) <<
endl;
  report << "SRR_virgin_stock    " << square(log_SRR_virgin_ini-log_SRR_virgin) << "  " << "    1 " <<
lambda_log_virgin_S << "  " << lambda_log_virgin_S*square(log_SRR_virgin_ini-log_SRR_virgin) << endl;
  nobs_curve_age=0.0;
  nobs_curve_time=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    if (sel_end_age(ifleet)-sel_start_age(ifleet)>2)
    {
       if (phase_sel_devs>0)
       {
          nobs_curve_age+=(sel_end_age(ifleet)-sel_start_age(ifleet)-1)*dim_sel_fleet(ifleet);
       }
       else
       {
          nobs_curve_age+=(sel_end_age(ifleet)-sel_start_age(ifleet)-1);
       }
    }
    nobs_curve_time+=(sel_end_age(ifleet)-sel_start_age(ifleet)+1)*(nyears-2);
  }
  report << "Curvature_over_age  " << curve_sel_at_age << "   " << nobs_curve_age << "   " <<
lambda_curve_sel_at_age << "   " << lambda_curve_sel_at_age*curve_sel_at_age << endl;
  report << "Curvature_over_time " << curve_sel_over_time << "   " << nobs_curve_time << "   " <<
lambda_curve_sel_over_time << "   " << lambda_curve_sel_over_time*curve_sel_over_time << endl;
```

```
  report << "F_penalty           " << fpenalty/0.001 << "    " << nyears*nages << "     0.001     " <<
fpenalty << endl;
  report << "Mean_Sel_year1_pen  " << sel_centered_pen/1000. << "   " << sum(sel_end_age-
sel_start_age+1) << "      1000  " << sel_centered_pen << endl;
  report << "Max_Sel_penalty     " << max(temp_sel_max) << "   " << "     1 " << "      100 " <<
sel_max_pen << endl;
  report << "Fmult_Max_penalty   " << Fmult_max_pen/100. << "   " << "     ? " << "      100 " <<
Fmult_max_pen << endl;
  report << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     for (iyear=1;iyear<=nyears;iyear++)
     {
       effective_sample_size(ifleet,iyear)=CAA_prop_pred(ifleet,iyear)*(1.0-
CAA_prop_pred(ifleet,iyear))/norm2(CAA_prop_obs(ifleet,iyear)-CAA_prop_pred(ifleet,iyear));
       effective_Discard_sample_size(ifleet,iyear)=Discard_prop_pred(ifleet,iyear)*(1.0-
Discard_prop_pred(ifleet,iyear))/norm2(Discard_prop_obs(ifleet,iyear)-Discard_prop_pred(ifleet,iyear));
     }
  }
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     report << " Input and Estimated effective sample sizes for fleet " << ifleet << endl;
     for (iyear=1;iyear<=nyears;iyear++)
        report << iyear+year1-1 << "  " << lambda_catch(ifleet,iyear) << "  " <<
effective_sample_size(ifleet,iyear) << endl;
     report << " Total  " << sum(lambda_catch(ifleet)) << "  " << sum(effective_sample_size(ifleet)) <<
endl;
  }
  report << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     report << " Input and Estimated effective Discard sample sizes for fleet " << ifleet << endl;
     for (iyear=1;iyear<=nyears;iyear++)
        report << iyear+year1-1 << "  " << lambda_Discard(ifleet,iyear) << "  " <<
effective_Discard_sample_size(ifleet,iyear) << endl;
     report << " Total  " << sum(lambda_Discard(ifleet)) << "  " <<
sum(effective_Discard_sample_size(ifleet)) << endl;
  }
  report << endl;
  report << "Observed and predicted total fleet catch by year" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    report << " fleet " << ifleet << " total catches" << endl;
    for (iyear=1;iyear<=nyears;iyear++)
    {
      report << iyear+year1-1 << "  " << Catch_tot_fleet_obs(ifleet,iyear) << "  " <<
Catch_tot_fleet_pred(ifleet,iyear) << endl;
    }
  }
  report << "Observed and predicted total fleet Discards by year" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    report << " fleet " << ifleet << " total Discards" << endl;
    for (iyear=1;iyear<=nyears;iyear++)
    {
      report << iyear+year1-1 << "  " << Discard_tot_fleet_obs(ifleet,iyear) << "  " <<
Discard_tot_fleet_pred(ifleet,iyear) << endl;
    }
  }
  report << endl << "Index data" << endl;
  for (ind=1;ind<=nindices;ind++)
  {
     report << "index number " << ind << endl;
     report << "units = " << index_units(ind) << endl;
     report << "month = " << index_month(ind) << endl;
     report << "starting and ending ages for selectivity = " << index_start_age(ind) << "  " <<
index_end_age(ind) << endl;
     report << "selectivity choice = " << index_sel_choice(ind) << endl;
     report << " year, sigma2, obs index, pred index" << endl;
     for (j=1;j<=index_nobs(ind);j++)
```

```
         report << index_time(ind,j)+year1-1 << "  " << index_sigma2(ind,j) << "  " << index_obs(ind,j)
<< "  " << index_pred(ind,j) << endl;
  }
  report << endl;
  report << "Selectivity by age and year for each fleet rescaled so max=1.0" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     report << " fleet " << ifleet << " selectivity at age" << endl;
     for (iyear=1;iyear<=nyears;iyear++)
       report << sel_by_fleet(ifleet,iyear)/max(sel_by_fleet(ifleet,iyear)) << endl;
  }
  report << endl;
  report << "Fmult by year for each fleet" << endl;
  for (iyear=1;iyear<=nyears;iyear++)
  {
     for (ifleet=1;ifleet<=nfleets;ifleet++)
         temp_Fmult(ifleet)=mfexp(log_Fmult(ifleet,iyear))*max(sel_by_fleet(ifleet,iyear));
     report << iyear+year1-1 << "  " << temp_Fmult << endl;
  }
  report << endl;
  report << "Directed F by age and year for each fleet" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     report << " fleet " << ifleet << " directed F at age" << endl;
     for (iyear=1;iyear<=nyears;iyear++)
         report << FAA_by_fleet_dir(ifleet,iyear) << endl;
  }
  report << "Discard F by age and year for each fleet" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     report << " fleet " << ifleet << " Discard F at age" << endl;
     for (iyear=1;iyear<=nyears;iyear++)
         report << FAA_by_fleet_Discard(ifleet,iyear) << endl;
  }
  report << "Total F" << endl;
  for (iyear=1;iyear<=nyears;iyear++)
     report << FAA_tot(iyear) << endl;
  report << endl;
  report << "Population Numbers at the Start of the Year" << endl;
  for (iyear=1;iyear<=nyears;iyear++)
     report << NAA(iyear) << endl;
  report << "q by index" << endl;
  for (ind=1;ind<=nindices;ind++)
  {
     report << " index " << ind << " q over time" << endl;
     for (i=1;i<=index_nobs(ind);i++)
     {
         j=index_time(ind,i);
         report << j+year1-1 << "  " << q_by_index(ind,i) << endl;
     }
  }
  report << endl;
  report << "Proportions of catch at age by fleet" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    report << " fleet " << ifleet << endl;
    for (iyear=1;iyear<=nyears;iyear++)
    {
       output_prop_obs=0.0;
       output_prop_pred=0.0;
       output_prop_obs(sel_start_age(ifleet),sel_end_age(ifleet))=CAA_prop_obs(ifleet,iyear);
       output_prop_pred(sel_start_age(ifleet),sel_end_age(ifleet))=CAA_prop_pred(ifleet,iyear);
       report << "Year " << iyear << " Obs  = " << output_prop_obs << endl;
       report << "Year " << iyear << " Pred = " << output_prop_pred << endl;
    }
  }
  report << endl;
  report << "Proportions of Discards at age by fleet" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    report << " fleet " << ifleet << endl;
```

```
    for (iyear=1;iyear<=nyears;iyear++)
    {
       output_Discard_prop_obs=0.0;
       output_Discard_prop_pred=0.0;

output_Discard_prop_obs(sel_start_age(ifleet),sel_end_age(ifleet))=Discard_prop_obs(ifleet,iyear);

output_Discard_prop_pred(sel_start_age(ifleet),sel_end_age(ifleet))=Discard_prop_pred(ifleet,iyear);
       report << "Year " << iyear << " Obs  = " << output_Discard_prop_obs << endl;
       report << "Year " << iyear << " Pred = " << output_Discard_prop_pred << endl;
    }
  }
  report << endl;
  report << "F Reference Points Using Final Year Selectivity Scaled Max=1.0" << endl;
  report << " refpt           F       slope to plot on SRR" << endl;
  report << "  F0.1     " << F01 << "     " << F01_slope << endl;
  report << "  Fmax     " << Fmax << "     " << Fmax_slope << endl;
  report << "  F30%SPR  " << F30SPR << "     " << F30SPR_slope << endl;
  report << "  F40%SPR  " << F40SPR << "     " << F40SPR_slope << endl;
  report << "  Fmsy     " << Fmsy << "     " << Fmsy_slope << "    SSmsy    " << SSmsy << "     MSY   "
<< MSY << endl;
  report << "  Foy      " << Foy << "     " << "xxxxxx" << "    SSoy    " << SSoy << "     OY   " << OY
<< endl;
  report << "  Fcurrent " << Fcurrent << "     " << Fcurrent_slope << endl;
  report << endl;
  report << "Stock-Recruitment Relationship Parameters" << endl;
  report << " alpha     = " << SRR_alpha << endl;
  report << " beta      = " << SRR_beta << endl;
  report << " virgin    = " << SRR_virgin << endl;
  report << " steepness = " << SRR_steepness << endl;
  report << "Spawning Stock, Obs Recruits(year+1), Pred Recruits(year+1)" << endl;
  for (iyear=1;iyear<nyears;iyear++)
    report << iyear+year1-1 << "  " << SSB(iyear) << "  " << recruits(iyear+1) << "  "  <<
SRR_pred_recruits(iyear+1) << endl;
  report << nyears+year1-1 << "  " << SSB(nyears) << "       xxxx   " << SRR_pred_recruits(nyears+1) <<
endl;
  report << endl;
  report << "average F (ages 4 to 8 unweighted) by year" << endl;
  report << "Projection into Future" << endl;
  report << "Projected NAA" << endl;
  report << proj_NAA << endl;
  report << "Projected Directed FAA" << endl;
  report << proj_F_dir << endl;
  report << "Projected Discard FAA" << endl;
  report << proj_F_Discard << endl;
  report << "Projected Nondirected FAA" << endl;
  report << proj_F_nondir << endl;
  report << "Projected Catch at Age" << endl;
  report << proj_catch << endl;
  report << "Projected Discards at Age (in numbers)" << endl;
  report << proj_Discard << endl;
  report << "Projected Yield at Age" << endl;
  report << proj_yield << endl;
  report << "Year, Total Yield (in weight), Total Discards (in weight), SSB, proj_what, SS/SSmsy" <<
endl;
  for (iyear=1;iyear<=nprojyears;iyear++)
    report << year1+nyears-1+iyear << "  " << proj_total_yield(iyear) << "  " <<
proj_total_Discard(iyear) << "  " << proj_SSB(iyear) << "  " << proj_what(iyear) << "  " <<
proj_SSB(iyear)/SSmsy << endl;
  report << endl;
  report << "M = " << M << endl;
  report << "mature = " << mature << endl;
  report << "Weight at age" << endl;
  report << WAA << endl;
  report << "Fecundity" << endl;
  report << fecundity << endl;
  report << endl;
  report << "SSmsy_ratio = " << SSmsy_ratio << endl;
  report << "Fmsy_ratio =  " << Fmsy_ratio << endl;
  report << "that's all" << endl;
```

```
RUNTIME_SECTION
  convergence_criteria 1.0e-4
  maximum_function_evaluations 800,1600,10000
```

Appendix III. ASAP Baseline Model Input (.DAT) File.

```
# A1: new data, base case; STAR-G2h config
# Number of Years
   77
# First Year
   1929
# Number of Ages
   7
# Natural Mortality Rate by Age
   0.5   0.5   0.5   0.5   0.5   0.5   0.5
# Fecundity Option
   0
# Maturity Vector
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
```

```
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
   0.00   0.07   0.25   0.47   0.73   1.00   1.00
# Weight at Age Vector
   0.074   0.167   0.297   0.402   0.523   0.615   0.704
   0.060   0.139   0.301   0.422   0.511   0.603   0.698
   0.077   0.114   0.276   0.399   0.527   0.606   0.701
   0.058   0.081   0.277   0.379   0.508   0.604   0.711
   0.059   0.083   0.200   0.299   0.493   0.585   0.700
   0.065   0.142   0.198   0.233   0.431   0.538   0.683
   0.079   0.186   0.217   0.251   0.379   0.472   0.629
   0.086   0.193   0.284   0.338   0.393   0.453   0.574
   0.119   0.176   0.318   0.429   0.461   0.502   0.575
   0.124   0.174   0.310   0.448   0.532   0.582   0.633
   0.191   0.247   0.364   0.461   0.585   0.683   0.795
   0.181   0.261   0.340   0.444   0.529   0.643   0.748
   0.115   0.260   0.344   0.441   0.561   0.653   0.810
   0.180   0.237   0.374   0.473   0.548   0.629   0.744
   0.165   0.293   0.340   0.476   0.576   0.653   0.716
   0.144   0.272   0.380   0.474   0.589   0.663   0.797
   0.122   0.235   0.385   0.495   0.613   0.707   0.779
   0.125   0.261   0.385   0.488   0.619   0.682   0.765
   0.119   0.292   0.401   0.501   0.625   0.712   0.770
   0.107   0.227   0.355   0.507   0.618   0.709   0.813
   0.109   0.193   0.320   0.458   0.610   0.728   0.833
   0.084   0.250   0.324   0.457   0.567   0.667   0.797
   0.163   0.255   0.347   0.430   0.571   0.697   0.860
   0.173   0.298   0.387   0.473   0.570   0.723   0.951
   0.162   0.296   0.412   0.514   0.605   0.767   0.866
   0.084   0.258   0.388   0.507   0.588   0.744   0.764
   0.140   0.253   0.358   0.486   0.585   0.748   0.883
   0.111   0.249   0.374   0.487   0.600   0.756   0.874
   0.179   0.311   0.375   0.510   0.604   0.652   0.651
   0.176   0.293   0.397   0.490   0.620   0.688   0.779
   0.133   0.252   0.399   0.512   0.605   0.705   0.820
   0.102   0.276   0.393   0.509   0.613   0.703   0.771
   0.145   0.252   0.390   0.497   0.586   0.650   0.821
   0.276   0.320   0.420   0.540   0.622   0.712   0.782
   0.197   0.298   0.434   0.538   0.627   0.730   0.743
   0.181   0.300   0.400   0.503   0.612   0.748   0.812
   0.109   0.195   0.384   0.501   0.596   0.723   0.735
   0.149   0.273   0.419   0.525   0.658   0.790   0.834
   0.166   0.235   0.488   0.510   0.599   0.723   0.879
   0.138   0.266   0.391   0.562   0.593   0.709   0.955
   0.103   0.322   0.428   0.505   0.662   0.746   0.907
   0.099   0.232   0.402   0.584   0.730   0.837   0.852
   0.266   0.282   0.457   0.481   0.740   0.955   0.977
   0.147   0.266   0.449   0.508   0.552   0.746   0.975
   0.119   0.329   0.433   0.609   0.606   0.686   0.763
   0.107   0.303   0.604   0.740   0.837   0.800   0.781
   0.127   0.361   0.517   0.973   1.053   1.029   1.350
   0.170   0.297   0.672   0.864   1.291   1.223   1.531
   0.122   0.322   0.600   0.847   1.063   1.548   1.457
```

```
   0.062   0.334   0.473   0.705   0.908   1.308   1.841
   0.082   0.189   0.440   0.598   0.810   0.969   1.553
   0.072   0.176   0.270   0.437   0.598   0.874   1.066
   0.083   0.190   0.239   0.391   0.597   0.757   0.939
   0.032   0.151   0.237   0.345   0.516   0.773   0.916
   0.049   0.191   0.302   0.390   0.458   0.511   0.688
   0.120   0.235   0.351   0.396   0.505   0.614   0.643
   0.157   0.285   0.418   0.461   0.484   0.560   0.650
   0.148   0.290   0.408   0.508   0.561   0.595   0.658
   0.133   0.272   0.414   0.523   0.600   0.691   0.743
   0.101   0.301   0.415   0.576   0.666   0.734   0.841
   0.104   0.193   0.381   0.542   0.647   0.749   0.779
   0.094   0.267   0.377   0.554   0.649   0.680   0.775
   0.071   0.217   0.397   0.514   0.591   0.664   0.754
   0.087   0.175   0.330   0.459   0.544   0.661   0.715
   0.073   0.228   0.294   0.408   0.583   0.607   0.761
   0.100   0.156   0.248   0.361   0.493   0.597   0.690
   0.081   0.179   0.275   0.431   0.586   0.689   0.783
   0.105   0.182   0.318   0.471   0.589   0.649   0.702
   0.149   0.239   0.333   0.446   0.572   0.637   0.734
   0.139   0.267   0.325   0.419   0.530   0.615   0.660
   0.148   0.228   0.399   0.509   0.575   0.633   0.727
   0.114   0.266   0.370   0.550   0.590   0.608   0.675
   0.103   0.253   0.347   0.534   0.567   0.619   0.623
   0.133   0.218   0.303   0.412   0.552   0.529   0.656
   0.125   0.284   0.414   0.603   0.679   0.745   0.808
   0.131   0.267   0.397   0.594   0.688   0.782   0.812
   0.131   0.267   0.397   0.594   0.688   0.782   0.812
# Number of Fleets
   1
#$FLEET-1
# Selectivity Start Age
   1
# Selectivity End Age
   7
# Selectivity Est. Start Age
   1
# Selectivity Est. End Age
   7
# Release Mortality
   0.0
# Number of Selectivity Changes by Fleet
   1
# Selectivity Change Years
   1929
# Fleet 1 Catch at Age - Last Column is Total Weight
      9.28  12437.25  22473.58  20825.26   5209.57   3875.73   4979.67   25741.2
         0   1394.65   7173.77    4844.8   1918.78    671.12     68.37    5833.6
         0    961.74  10038.17   6219.56   1313.32    756.46    580.67    6922.9
         0    145.44   3243.34   5883.67   1402.95    946.49    766.36    4971.7
         0   4624.69  19035.82  31918.54  23386.44   8285.19   4254.32   33104.9
         0   4897.43  53387.69  35620.86  40833.75  15517.99   8829.63   51516.5
         0  10876.86  12743.67  61734.52  63851.09  33649.63   9663.72   66450.2
         0   2247.75  20403.77   17399.3  33062.36  35158.51   8174.96   45714.2
    128.53    1475.8   2592.22   8035.18  15910.37  26039.26  12242.31   31987.6
    771.57  11577.22  31967.43  16527.64   4309.46   10883.8  10285.85   34561.8
   2842.28  24197.76  25484.46  33732.82  10149.61   5127.62   5857.39     45454
   2264.02   20352.7  67854.07  24726.08  13264.05   1412.44   1618.98   48867.8
    469.19  14744.11  31185.78  30250.94   6036.98    1143.5     647.2   32597.4
         0  32188.88  10085.32  13913.89   5775.72    900.71     284.9   21922.3
    920.72  13724.84  59588.84  11185.16   7855.82   1191.64    433.93   35341.3
         0  17985.25  20691.29  36831.95   8377.76   1755.51    482.33   36693.7
    589.49  15163.47  10949.04  10876.94  10933.14   3528.46   1556.42     23638
    628.39  10469.46  28976.74  13321.92   5230.24   2574.16   2813.18   27616.3
    8864.2   1699.76   9850.48     13508   6279.38   2492.25   1914.55     19437
   1115.46  66580.37   3337.95     794.8   1161.71    451.02    306.99   18124.7
    142.87  22920.63  51712.72   4495.25    722.77    613.51    322.52   24188.9
      6.95   4463.76  22270.16  18329.91   1085.25     83.39    162.15     17493
    830.76   1710.14   4783.65  14985.09   12020.7    235.51    166.37   15857.1
    107.39     57.44    650.58   1605.85  11842.83   3441.46     41.21   10325.8
  18958.62   1047.32    735.91    903.23    249.44    568.59    605.77    5265.9
```

```
    862.94  61256.59   5956.44    318.25    108.63         0     59.67   18464.7
   7679.47   6456.05  38344.81  10911.12    369.75     27.19    230.18   22200.9
     28.38  66794.47  20237.39   19784.7   4920.16     83.78         0     36835
    1452.2   6525.45  31943.06  11873.22   8549.72   2411.94   1061.38   27753.4
  13849.68   1074.22   4975.76   9139.75   2938.35    946.36    244.79   11874.8
   1669.25   61283.1   4543.76   1132.97   1384.39    452.11    149.98   19332.5
   2689.15  19826.61  22303.81   8613.59    2251.8    465.39    289.32   20822.5
  23417.52   33337.8  17001.35  12120.59   2547.73    266.74     89.78   26199.2
     760.9  23880.04   12455.6  10283.85   6755.45   1448.63    205.65     23901
    177.31   6312.43  18516.66   9856.84   9313.89   2930.16    449.13     23703
    351.41   7789.68   6637.15   9667.13  11614.93    3822.4    752.28   19987.9
  13074.05   1264.81    766.75   1700.61   5524.52   8676.71   1562.99   11279.4
    2769.3    6376.8   1496.82   1168.02    948.06   2648.97   1697.75    7405.2
    5697.5    731.66      62.3    455.91    159.83    135.06     279.5    1713.3
   7572.85    475.06    202.94    346.36     90.62     85.44    145.77      1695
     44.33   2371.28    595.72    212.28     74.78     65.83     10.16    1168.2
    683.85   3325.72         0         0         0         0         0     835.5
         0   2804.45    229.76      10.5     14.09      9.39         0     911.3
   1097.81    202.03     321.4    350.91       9.6      7.33         0       532
      46.8    560.25    163.37     30.93     72.32     85.16     51.49     400.9
   2182.36    844.29     236.3     37.39     12.46         0         0     633.8
     15.17   6041.68    375.46     31.08      3.87      6.52      3.26    2149.3
  13973.68    164.16   1763.31      0.75     22.98         0     26.91    4091.7
  11070.92  36733.93     77.95    286.78         0         0         0   13751.3
  73773.14   18836.9  28597.94   1165.54   1006.01    257.27         0   27172.6
     27.23  102035.3  14823.58  15124.54    221.14    673.49         0   35612.1
   61969.2   3317.59  75641.61   7985.17   7150.07    397.21    123.42   34252.2
  18495.04   45248.5  10883.93  69199.36   4793.48   3063.74    199.94     46778
  16017.93  36157.53  33124.66   9886.72  30776.34   2299.63    767.27   36123.9
      2780   2765.84  43686.24  39482.54   6213.81  17433.79    247.22   41422.2
   2819.65    526.09    9506.2  48395.43  24817.52   6161.06    8031.4     45819
   3227.26  17399.02   5160.57  16156.07  49841.23  10646.34   2424.96   46567.4
  18776.69  44338.26  23015.83   5275.07   8989.95  25594.91   9538.53   54023.6
  18002.51  70986.46  32303.04   5260.19   2823.91   3468.69   7494.15   47632.2
  104388.7  15084.48  36010.37  13089.58   2841.37   1940.49   9882.55   49079.9
  21861.64    160807   8372.39   6711.28   4510.88   2716.45   5082.84   49308.8
  29559.33  19434.09  43284.43  11973.57  16877.91  19587.74     22962   71550.6
  27181.03  91781.73  21911.68  21684.28  10412.43   9327.48  14180.25   65504.9
  10893.24  30081.69  12326.78   9837.52  10631.12   8098.86    9247.3   32167.9
  51113.96   9311.29  10616.04   3438.54   3357.64   5040.94   7410.47   20807.4
   24847.8  37276.64   9743.15   4407.22   5595.63   2928.83   3867.63   23127.9
  43904.18   20162.5   5046.43    944.91    519.09   1329.41   1535.62     11371
  28544.83   43355.8  12446.94   5961.09   3718.34   2548.26   3165.91   24316.1
  24253.04  49396.52  32477.59  12788.79   8270.65   7515.97  15758.58   50477.3
  13537.24  19800.43  38611.02  23602.73  15463.22  13291.89  25018.04   62567.6
  11915.37   2943.13   2672.65   6103.29   5818.38   4436.54   4233.38     15863
  28945.38  15226.02   5152.53   8738.54  10277.12   6622.03   4606.32   27646.8
  13732.93  19687.98   3404.87   1883.01   2329.92   2051.19   1762.37   12561.4
   7026.46  50787.71   5123.51    1177.8    225.67    361.82     250.2   13947.8
  25649.82  14666.88   5067.14   1861.63    654.11    642.16    485.06   11755.8
  44230.69   6045.16   2094.29   1520.55    665.49    142.11    222.57    9850.4
         0         0         0         0         0         0         0    9850.4
# Fleet 1 Discards at Age - Last Column is Total Weight
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
# Fleet 1 Proportion Released at Age
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
```

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         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0
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         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
         0         0         0         0         0         0         0
# Number of Indices
   3
#$SPOTTER
#$CPFV
#$CALCOFI
```

```
# Index Weight Flag
   2
# Index Units
   1   2   2
# Index Month
   -1   -1   -1
# Index Start Age
   1   2   2
# Index End Age
   7   7   7
# Index Fix Age
   -1   -1   -1
# Index Selectivity Choice
   -1   -1   -1
# Index Data - Year, Index, CV, Selectivity
# INDEX - 1
    1929      -999       0.3         1         1         1         1         1         1         1
    1930      -999       0.3         1         1         1         1         1         1         1
    1931      -999       0.3         1         1         1         1         1         1         1
    1932      -999       0.3         1         1         1         1         1         1         1
    1933      -999       0.3         1         1         1         1         1         1         1
    1934      -999       0.3         1         1         1         1         1         1         1
    1935      -999       0.3         1         1         1         1         1         1         1
    1936      -999       0.3         1         1         1         1         1         1         1
    1937      -999       0.3         1         1         1         1         1         1         1
    1938      -999       0.3         1         1         1         1         1         1         1
    1939      -999       0.3         1         1         1         1         1         1         1
    1940      -999       0.3         1         1         1         1         1         1         1
    1941      -999       0.3         1         1         1         1         1         1         1
    1942      -999       0.3         1         1         1         1         1         1         1
    1943      -999       0.3         1         1         1         1         1         1         1
    1944      -999       0.3         1         1         1         1         1         1         1
    1945      -999       0.3         1         1         1         1         1         1         1
    1946      -999       0.3         1         1         1         1         1         1         1
    1947      -999       0.3         1         1         1         1         1         1         1
    1948      -999       0.3         1         1         1         1         1         1         1
    1949      -999       0.3         1         1         1         1         1         1         1
    1950      -999       0.3         1         1         1         1         1         1         1
    1951      -999       0.3         1         1         1         1         1         1         1
    1952      -999       0.3         1         1         1         1         1         1         1
    1953      -999       0.3         1         1         1         1         1         1         1
    1954      -999       0.3         1         1         1         1         1         1         1
    1955      -999       0.3         1         1         1         1         1         1         1
    1956      -999       0.3         1         1         1         1         1         1         1
    1957      -999       0.3         1         1         1         1         1         1         1
    1958      -999       0.3         1         1         1         1         1         1         1
    1959      -999       0.3         1         1         1         1         1         1         1
    1960      -999       0.3         1         1         1         1         1         1         1
    1961      -999       0.3         1         1         1         1         1         1         1
    1962      -999       0.3         1         1         1         1         1         1         1
    1963    511.49       0.3         1         1         1         1         1         1         1
    1964    364.21       0.3         1         1         1         1         1         1         1
    1965    203.57       0.3         1         1         1         1         1         1         1
    1966    226.79       0.3         1         1         1         1         1         1         1
    1967     15.07       0.3         1         1         1         1         1         1         1
    1968     51.66       0.3         1         1         1         1         1         1         1
    1969    138.44       0.3         1         1         1         1         1         1         1
    1970    351.58       0.3         1         1         1         1         1         1         1
    1971    103.36       0.3         1         1         1         1         1         1         1
    1972     32.67       0.3         1         1         1         1         1         1         1
    1973    530.35       0.3         1         1         1         1         1         1         1
    1974      -999       0.3         1         1         1         1         1         1         1
    1975     35.19       0.3         1         1         1         1         1         1         1
    1976    673.39       0.3         1         1         1         1         1         1         1
    1977  10213.52       0.3         1         1         1         1         1         1         1
    1978  50808.33       0.3         1         1         1         1         1         1         1
    1979  23737.75       0.3         1         1         1         1         1         1         1
    1980  34293.81       0.3         1         1         1         1         1         1         1
    1981  33047.26       0.3         1         1         1         1         1         1         1
    1982  47574.73       0.3         1         1         1         1         1         1         1
    1983  23226.64       0.3         1         1         1         1         1         1         1
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    1984  44170.75       0.3         1         1         1         1         1         1         1
    1985   27000.7       0.3         1         1         1         1         1         1         1
    1986  13388.65       0.3         1         1         1         1         1         1         1
    1987  11113.77       0.3         1         1         1         1         1         1         1
    1988      9837       0.3         1         1         1         1         1         1         1
    1989   2563.95       0.3         1         1         1         1         1         1         1
    1990   3885.57       0.3         1         1         1         1         1         1         1
    1991   4912.79       0.3         1         1         1         1         1         1         1
    1992    914.04       0.3         1         1         1         1         1         1         1
    1993   1050.24       0.3         1         1         1         1         1         1         1
    1994   2027.98       0.3         1         1         1         1         1         1         1
    1995   1332.65       0.3         1         1         1         1         1         1         1
    1996   4193.14       0.3         1         1         1         1         1         1         1
    1997   2457.08       0.3         1         1         1         1         1         1         1
    1998   4293.78       0.3         1         1         1         1         1         1         1
    1999     15.07       0.3         1         1         1         1         1         1         1
    2000   3720.04       0.3         1         1         1         1         1         1         1
    2001      -999       0.3         1         1         1         1         1         1         1
    2002      -999       0.3         1         1         1         1         1         1         1
    2003      -999       0.3         1         1         1         1         1         1         1
    2004      -999       0.3         1         1         1         1         1         1         1
    2005      -999       0.3         1         1         1         1         1         1         1
# INDEX - 2
    1929      -999       0.3         0       0.5         1         1         1         1         1
    1930      -999       0.3         0       0.5         1         1         1         1         1
    1931      -999       0.3         0       0.5         1         1         1         1         1
    1932      -999       0.3         0       0.5         1         1         1         1         1
    1933      -999       0.3         0       0.5         1         1         1         1         1
    1934      -999       0.3         0       0.5         1         1         1         1         1
    1935      -999       0.3         0       0.5         1         1         1         1         1
    1936     1.282       0.3         0       0.5         1         1         1         1         1
    1937     0.977       0.3         0       0.5         1         1         1         1         1
    1938      1.62       0.3         0       0.5         1         1         1         1         1
    1939     1.859       0.3         0       0.5         1         1         1         1         1
    1940      1.33       0.3         0       0.5         1         1         1         1         1
    1941      -999       0.3         0       0.5         1         1         1         1         1
    1942      -999       0.3         0       0.5         1         1         1         1         1
    1943      -999       0.3         0       0.5         1         1         1         1         1
    1944      -999       0.3         0       0.5         1         1         1         1         1
    1945      -999       0.3         0       0.5         1         1         1         1         1
    1946      -999       0.3         0       0.5         1         1         1         1         1
    1947     0.881       0.3         0       0.5         1         1         1         1         1
    1948     1.086       0.3         0       0.5         1         1         1         1         1
    1949     0.576       0.3         0       0.5         1         1         1         1         1
    1950     0.327       0.3         0       0.5         1         1         1         1         1
    1951     0.192       0.3         0       0.5         1         1         1         1         1
    1952     0.254       0.3         0       0.5         1         1         1         1         1
    1953     0.369       0.3         0       0.5         1         1         1         1         1
    1954     1.229       0.3         0       0.5         1         1         1         1         1
    1955     0.849       0.3         0       0.5         1         1         1         1         1
    1956      0.53       0.3         0       0.5         1         1         1         1         1
    1957     0.789       0.3         0       0.5         1         1         1         1         1
    1958     0.923       0.3         0       0.5         1         1         1         1         1
    1959     0.688       0.3         0       0.5         1         1         1         1         1
    1960     0.516       0.3         0       0.5         1         1         1         1         1
    1961     0.927       0.3         0       0.5         1         1         1         1         1
    1962     0.571       0.3         0       0.5         1         1         1         1         1
    1963     0.548       0.3         0       0.5         1         1         1         1         1
    1964     0.446       0.3         0       0.5         1         1         1         1         1
    1965     0.541       0.3         0       0.5         1         1         1         1         1
    1966     0.891       0.3         0       0.5         1         1         1         1         1
    1967     0.437       0.3         0       0.5         1         1         1         1         1
    1968     0.328       0.3         0       0.5         1         1         1         1         1
    1969     0.332       0.3         0       0.5         1         1         1         1         1
    1970     0.411       0.3         0       0.5         1         1         1         1         1
    1971     0.895       0.3         0       0.5         1         1         1         1         1
    1972     0.647       0.3         0       0.5         1         1         1         1         1
    1973     0.276       0.3         0       0.5         1         1         1         1         1
    1974     0.161       0.3         0       0.5         1         1         1         1         1
    1975     0.434       0.3         0       0.5         1         1         1         1         1
    1976     0.269       0.3         0       0.5         1         1         1         1         1
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    1977      2.13       0.3         0       0.5         1         1         1         1         1
    1978     3.427       0.3         0       0.5         1         1         1         1         1
    1979      -999       0.3         0       0.5         1         1         1         1         1
    1980     5.552       0.3         0       0.5         1         1         1         1         1
    1981     4.864       0.3         0       0.5         1         1         1         1         1
    1982     3.659       0.3         0       0.5         1         1         1         1         1
    1983     4.716       0.3         0       0.5         1         1         1         1         1
    1984     5.553       0.3         0       0.5         1         1         1         1         1
    1985     4.406       0.3         0       0.5         1         1         1         1         1
    1986     3.599       0.3         0       0.5         1         1         1         1         1
    1987      3.05       0.3         0       0.5         1         1         1         1         1
    1988     2.087       0.3         0       0.5         1         1         1         1         1
    1989     2.307       0.3         0       0.5         1         1         1         1         1
    1990     2.454       0.3         0     0.333     0.666         1         1         1         1
    1991     2.959       0.3         0     0.333     0.666         1         1         1         1
    1992     2.831       0.3         0     0.333     0.666         1         1         1         1
    1993     2.812       0.3         0     0.333     0.666         1         1         1         1
    1994     2.599       0.3         0     0.333     0.666         1         1         1         1
    1995     2.133       0.3         0     0.333     0.666         1         1         1         1
    1996      2.45       0.3         0     0.333     0.666         1         1         1         1
    1997     1.922       0.3         0     0.333     0.666         1         1         1         1
    1998     1.466       0.3         0     0.333     0.666         1         1         1         1
    1999     0.694       0.3         0     0.333     0.666         1         1         1         1
    2000     0.845       0.3         0     0.333     0.666         1         1         1         1
    2001     1.217       0.3         0     0.333     0.666         1         1         1         1
    2002     0.781       0.3         0     0.333     0.666         1         1         1         1
    2003     0.642       0.3         0     0.333     0.666         1         1         1         1
    2004     0.466       0.3         0     0.333     0.666         1         1         1         1
    2005      -999       0.3         0     0.333     0.666         1         1         1         1
# INDEX - 3
    1929      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1930      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1931      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1932      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1933      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1934      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1935      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1936      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1937      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1938      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1939      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1940      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1941      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1942      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1943      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1944      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1945      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1946      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1947      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1948      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1949      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1950      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1951     0.885       0.3         0     0.074     0.246     0.474     0.733         1         1
    1952     2.362       0.3         0     0.074     0.246     0.474     0.733         1         1
    1953     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1954     4.444       0.3         0     0.074     0.246     0.474     0.733         1         1
    1955     3.659       0.3         0     0.074     0.246     0.474     0.733         1         1
    1956     3.125       0.3         0     0.074     0.246     0.474     0.733         1         1
    1957     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1958     7.258       0.3         0     0.074     0.246     0.474     0.733         1         1
    1959     3.704       0.3         0     0.074     0.246     0.474     0.733         1         1
    1960     1.739       0.3         0     0.074     0.246     0.474     0.733         1         1
    1961     7.895       0.3         0     0.074     0.246     0.474     0.733         1         1
    1962     5.714       0.3         0     0.074     0.246     0.474     0.733         1         1
    1963     2.381       0.3         0     0.074     0.246     0.474     0.733         1         1
    1964     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1965     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1966     2.655       0.3         0     0.074     0.246     0.474     0.733         1         1
    1967     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1968     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1969     1.333       0.3         0     0.074     0.246     0.474     0.733         1         1
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    1970      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1971      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1972     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1973      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1974      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1975     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1976      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1977      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
    1978     15.73       0.3         0     0.074     0.246     0.474     0.733         1         1
    1979     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1980     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1981    22.321       0.3         0     0.074     0.246     0.474     0.733         1         1
    1982     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1983     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    1984     4.233       0.3         0     0.074     0.246     0.474     0.733         1         1
    1985     8.772       0.3         0     0.074     0.246     0.474     0.733         1         1
    1986    14.286       0.3         0     0.074     0.246     0.474     0.733         1         1
    1987    12.903       0.3         0     0.074     0.246     0.474     0.733         1         1
    1988    18.966       0.3         0     0.074     0.246     0.474     0.733         1         1
    1989     11.29       0.3         0     0.074     0.246     0.474     0.733         1         1
    1990      1.19       0.3         0     0.074     0.246     0.474     0.733         1         1
    1991     7.692       0.3         0     0.074     0.246     0.474     0.733         1         1
    1992     8.108       0.3         0     0.074     0.246     0.474     0.733         1         1
    1993     9.449       0.3         0     0.074     0.246     0.474     0.733         1         1
    1994     2.051       0.3         0     0.074     0.246     0.474     0.733         1         1
    1995     9.402       0.3         0     0.074     0.246     0.474     0.733         1         1
    1996     9.836       0.3         0     0.074     0.246     0.474     0.733         1         1
    1997     7.784       0.3         0     0.074     0.246     0.474     0.733         1         1
    1998      10.8       0.3         0     0.074     0.246     0.474     0.733         1         1
    1999     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    2000     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    2001     2.344       0.3         0     0.074     0.246     0.474     0.733         1         1
    2002     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    2003     0.794       0.3         0     0.074     0.246     0.474     0.733         1         1
    2004     1.587       0.3         0     0.074     0.246     0.474     0.733         1         1
    2005      -999       0.3         0     0.074     0.246     0.474     0.733         1         1
# Phase Control Data
# Phase for Selectivity in 1st Year
   1
# Phase for Selectivity Deviations
   4
# Phase for F mult in 1st Year
   1
# Phase for F mult Deviations
   3
# Phase for Recruitment Deviations
   3
# Phase for N in 1st Year
   2
# Phase for Catchability in 1st Year
   1
# Phase for Catchability Deviations
   -5
# Phase for Stock Recruitment Relationship
   1
# Phase for Steepness
   1
# Recruitment CV by Year
   0.25
   0.25
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   0.25
#Lambda for Each Index (cv=0.4)
   1   1   1
# Lambda for Total Catch in Weight
   101
# Lambda for Total Discards at Age
   0
# Lambda for Catch at Age by Year & Fleet
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         0
# Lambda for Discards at Age by Year & Fleet
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# Lambda for F mult Deviations by Fleet
   0
# Lambda for N in 1st Year Deviations
   0
# Lambda for Recruitment Deviations
   1
# Lambda for Catchability Deviations by Index
   1   1   1
# Lambda for Selectivity Deviations by Fleet
   0
# Lambda for Selectivity Curvature at Age
   0
# Lambda for Selectivity Curvature Over Time
   0
# Lambda for Deviations from Initial Steepness
   0
# Lambda for Deviation from Initial log of Virgin Stock Size
   0
# NAA for Year 1
  100000  70000  50000  30000  20000  10000  5000
# Log of F mult in 1st year by Fleet
   -3
# log of Catchability in 1st year by index
   -7   -7   -7
# Initial log of Virgin Stock Size
   10
# Initial Steepness
   0.9
# Selectivity at Age in 1st Year by Fleet
     0.009
     0.092
     0.293
     0.703
         1
         1
         1
# Where to do Extras
   2
# Ignore Guesses
   0
# Projection Control Data
# Year for SSB ratio Calculation
   1929
# Fleet Directed Flag
   1
# Final Year of Projections
   2007
# Year Projected Recruits, What Projected, Target, non- directed F mult
      2006         2       0.3         1        -1
      2007         2       0.3         1        -1
# Test Value
   -23456
#####
# ---- FINIS ----
```

Appendix IV. ASAP Baseline Model Report (.REP) File.

```
obj_fun        = 1350.07
Component          RSS      nobs  Lambda  Likelihood
  Catch_Fleet_1        0.0178581   77   101   1.80367
Catch_Fleet_Total     0.0178581   77   101   1.80367
  Discard_Fleet_1        0   77   0   0
Discard_Fleet_Total     0   77   0   0
CAA_proportions      N/A            539    see_below      394.551
Discard_proportions      N/A            539    see_below      0
  Index_Fit_1         93.4513   37   1   519.526
  Index_Fit_2         15.1296   62   1   49.7857
  Index_Fit_3         53.2396   48   1   279.478
Index_Fit_Total     161.821   147   3   848.79
  Selectivity_devs_fleet_1   0  1   0  0
Selectivity_devs_Total   0  1   0  0
  Catchability_devs_index_1  0  37  1  0
  Catchability_devs_index_2  0  62  1  0
  Catchability_devs_index_3  0  48  1  0
Catchability_devs_Total  0  147  3  0
  Fmult_fleet_1     22.676   76   0  0
Fmult_fleet_Total   22.676   76   0  0
N_year_1            1.63829   6   0   0
Stock-Recruit_Fit   17.1809  77   1   87.74
Recruit_devs        17.1809   77   1   17.1809
SRR_steepness       1.09445       1 0   0
SRR_virgin_stock    6.07981      1 0  0
Curvature_over_age  1.07176   5   0   0
Curvature_over_time 0   525   0   0
F_penalty           0.684428    539     0.001     0.000684428
Mean_Sel_year1_pen  0   7      1000  0
Max_Sel_penalty     0.155812        1       100 0
Fmult_Max_penalty   0        ?       100 0

 Input and Estimated effective sample sizes for fleet 1
1929  15  12.6469
1930  15  7.33819
1931  15  5.03137
1932  15  4.79609
1933  15  7.00126
1934  15  10.4797
1935  15  7.12376
1936  15  6.14657
1937  15  3.4492
1938  15  8.33243
1939  15  12.2185
1940  15  6.26349
1941  15  5.13961
1942  15  17.1682
1943  15  5.26253
1944  15  7.76793
1945  15  19.6788
1946  15  10.6909
1947  15  8.84504
1948  15  2.92515
1949  15  6.23839
1950  15  8.13365
1951  15  5.72888
1952  15  1.87547
1953  15  4.55954
1954  15  6.0013
1955  15  10.7778
1956  15  8.66679
1957  15  6.42193
1958  15  8.98369
1959  15  3.0125
1960  15  15.6767
1961  15  70.2814
1962  15  31.1756
1963  15  11.6088
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1964  15  9.24013
1965  15  3.44084
1966  15  15.5562
1967  15  1.76426
1968  15  1.68774
1969  15  4.06838
1970  15  2.27132
1971  15  1.94355
1972  15  5.73359
1973  15  8.6724
1974  15  4.55251
1975  15  2.27405
1976  15  11.1938
1977  15  38.1904
1978  15  11.8528
1979  15  8.05036
1980  15  11.7893
1981  15  9.44429
1982  15  33.7351
1983  15  8.61901
1984  15  5.58725
1985  15  5.85707
1986  15  42.4547
1987  15  10.7025
1988  15  5.26576
1989  15  3.88816
1990  15  30.3236
1991  15  24.506
1992  15  40.9906
1993  15  4.35139
1994  15  19.7841
1995  15  4.00252
1996  15  15.9417
1997  15  47.0794
1998  15  24.1988
1999  15  10.2385
2000  15  20.4379
2001  15  29.8461
2002  15  3.37048
2003  15  5.01053
2004  15  2.46208
2005  0  3.06602
 Total  1140  920.893

 Input and Estimated effective Discard sample sizes for fleet 1
1929  0  1e+15
1930  0  1e+15
1931  0  1e+15
1932  0  1e+15
1933  0  1e+15
1934  0  1e+15
1935  0  1e+15
1936  0  1e+15
1937  0  1e+15
1938  0  1e+15
1939  0  1e+15
1940  0  1e+15
1941  0  1e+15
1942  0  1e+15
1943  0  1e+15
1944  0  1e+15
1945  0  1e+15
1946  0  1e+15
1947  0  1e+15
1948  0  1e+15
1949  0  1e+15
1950  0  1e+15
1951  0  1e+15
1952  0  1e+15
1953  0  1e+15
1954  0  1e+15
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1955  0  1e+15
1956  0  1e+15
1957  0  1e+15
1958  0  1e+15
1959  0  1e+15
1960  0  1e+15
1961  0  1e+15
1962  0  1e+15
1963  0  1e+15
1964  0  1e+15
1965  0  1e+15
1966  0  1e+15
1967  0  1e+15
1968  0  1e+15
1969  0  1e+15
1970  0  1e+15
1971  0  1e+15
1972  0  1e+15
1973  0  1e+15
1974  0  1e+15
1975  0  1e+15
1976  0  1e+15
1977  0  1e+15
1978  0  1e+15
1979  0  1e+15
1980  0  1e+15
1981  0  1e+15
1982  0  1e+15
1983  0  1e+15
1984  0  1e+15
1985  0  1e+15
1986  0  1e+15
1987  0  1e+15
1988  0  1e+15
1989  0  1e+15
1990  0  1e+15
1991  0  1e+15
1992  0  1e+15
1993  0  1e+15
1994  0  1e+15
1995  0  1e+15
1996  0  1e+15
1997  0  1e+15
1998  0  1e+15
1999  0  1e+15
2000  0  1e+15
2001  0  1e+15
2002  0  1e+15
2003  0  1e+15
2004  0  1e+15
2005  0  1e+15
 Total  0  7.7e+16

Observed and predicted total fleet catch by year
 fleet 1 total catches
1929  25741.2  25756.9
1930  5833.6  5834.75
1931  6922.9  6925.37
1932  4971.7  4971.59
1933  33104.9  33005.2
1934  51516.5  51025.2
1935  66450.2  65662.5
1936  45714.2  45387.8
1937  31987.6  31910.9
1938  34561.8  34428.1
1939  45454  45043.9
1940  48867.8  48892.7
1941  32597.4  32546.7
1942  21922.3  21860
1943  35341.3  35199.3
1944  36693.7  36207.3
```

```
1945  23638  23273.3
1946  27616.3  27805.5
1947  19437  19788.6
1948  18124.7  18211.2
1949  24188.9  23829.9
1950  17493  17018.6
1951  15857.1  15203
1952  10325.8  10278.1
1953  5265.9  5241.52
1954  18464.7  18229.5
1955  22200.9  21882.1
1956  36835  35509.5
1957  27753.4  27079.3
1958  11874.8  11802.6
1959  19332.5  19429.5
1960  20822.5  20826
1961  26199.2  25953
1962  23901  24014.4
1963  23703  24025.8
1964  19987.9  20137.6
1965  11279.4  11231.7
1966  7405.2  7639.51
1967  1713.3  1738.42
1968  1695  1712.29
1969  1168.2  1176.13
1970  835.5  838.283
1971  911.3  913.946
1972  532  532.23
1973  400.9  400.974
1974  633.8  633.228
1975  2149.3  2147.46
1976  4091.7  4069.84
1977  13751.3  13600.9
1978  27172.6  26797.5
1979  35612.1  35358.8
1980  34252.2  33969.2
1981  46778  46548.3
1982  36123.9  36061.6
1983  41422.2  40995.8
1984  45819  45223
1985  46567.4  46321.9
1986  54023.6  54029.5
1987  47632.2  48113.7
1988  49079.9  49821.5
1989  49308.8  50285.4
1990  71550.6  72116.9
1991  65504.9  65159.1
1992  32167.9  32389.9
1993  20807.4  20953.4
1994  23127.9  23372.6
1995  11371  11398.1
1996  24316.1  24420.6
1997  50477.3  51268.5
1998  62567.6  67860
1999  15863  16198.8
2000  27646.8  27600.8
2001  12561.4  12682.9
2002  13947.8  14222.8
2003  11755.8  11894.9
2004  9850.4  9874.84
2005  9850.4  9850.4
Observed and predicted total fleet Discards by year
 fleet 1 total Discards
1929  0  0
1930  0  0
1931  0  0
1932  0  0
1933  0  0
1934  0  0
1935  0  0
1936  0  0
```

```
1937  0  0
1938  0  0
1939  0  0
1940  0  0
1941  0  0
1942  0  0
1943  0  0
1944  0  0
1945  0  0
1946  0  0
1947  0  0
1948  0  0
1949  0  0
1950  0  0
1951  0  0
1952  0  0
1953  0  0
1954  0  0
1955  0  0
1956  0  0
1957  0  0
1958  0  0
1959  0  0
1960  0  0
1961  0  0
1962  0  0
1963  0  0
1964  0  0
1965  0  0
1966  0  0
1967  0  0
1968  0  0
1969  0  0
1970  0  0
1971  0  0
1972  0  0
1973  0  0
1974  0  0
1975  0  0
1976  0  0
1977  0  0
1978  0  0
1979  0  0
1980  0  0
1981  0  0
1982  0  0
1983  0  0
1984  0  0
1985  0  0
1986  0  0
1987  0  0
1988  0  0
1989  0  0
1990  0  0
1991  0  0
1992  0  0
1993  0  0
1994  0  0
1995  0  0
1996  0  0
1997  0  0
1998  0  0
1999  0  0
2000  0  0
2001  0  0
2002  0  0
2003  0  0
2004  0  0
2005  0  0

Index data
```

```
index number 1
units = 1
month = -1
starting and ending ages for selectivity = 1  7
selectivity choice = -1
 year, sigma2, obs index, pred index
1963  0.0861777  0.0521329  0.0824058
1964  0.0861777  0.0371216  0.0582657
1965  0.0861777  0.0207486  0.0338537
1966  0.0861777  0.0231153  0.0315458
1967  0.0861777  0.00153599  0.0291831
1968  0.0861777  0.00526537  0.0302005
1969  0.0861777  0.0141103  0.0340256
1970  0.0861777  0.0358343  0.0360704
1971  0.0861777  0.0105348  0.048536
1972  0.0861777  0.00332984  0.0464995
1973  0.0861777  0.0540552  0.0517999
1975  0.0861777  0.00358669  0.0958765
1976  0.0861777  0.0686343  0.302904
1977  0.0861777  1.041  0.370992
1978  0.0861777  5.17857  0.444917
1979  0.0861777  2.41944  0.456986
1980  0.0861777  3.49535  0.419172
1981  0.0861777  3.3683  0.511675
1982  0.0861777  4.84899  0.423905
1983  0.0861777  2.36734  0.460352
1984  0.0861777  4.50204  0.533823
1985  0.0861777  2.75201  0.595309
1986  0.0861777  1.36462  0.572303
1987  0.0861777  1.13276  0.506615
1988  0.0861777  1.00262  0.4996
1989  0.0861777  0.261327  0.408728
1990  0.0861777  0.396031  0.393105
1991  0.0861777  0.500729  0.308298
1992  0.0861777  0.0931622  0.242216
1993  0.0861777  0.107044  0.230317
1994  0.0861777  0.206699  0.2045
1995  0.0861777  0.135828  0.224939
1996  0.0861777  0.42738  0.24169
1997  0.0861777  0.250434  0.22384
1998  0.0861777  0.437638  0.14116
1999  0.0861777  0.00153599  0.11155
2000  0.0861777  0.37916  0.101739
index number 2
units = 2
month = -1
starting and ending ages for selectivity = 2  7
selectivity choice = -1
 year, sigma2, obs index, pred index
1936  0.0861777  0.827855  1.65796
1937  0.0861777  0.6309  1.42158
1938  0.0861777  1.04612  1.29283
1939  0.0861777  1.20045  1.22384
1940  0.0861777  0.858851  1.0672
1947  0.0861777  0.568908  0.474195
1948  0.0861777  0.701287  0.633031
1949  0.0861777  0.371954  0.691923
1950  0.0861777  0.211161  0.530921
1951  0.0861777  0.123985  0.398882
1952  0.0861777  0.164021  0.34616
1953  0.0861777  0.238283  0.381409
1954  0.0861777  0.79363  0.772945
1955  0.0861777  0.548244  0.783349
1956  0.0861777  0.342249  0.680223
1957  0.0861777  0.509499  0.561857
1958  0.0861777  0.59603  0.509111
1959  0.0861777  0.444278  0.61504
1960  0.0861777  0.333208  0.597531
1961  0.0861777  0.598613  0.534027
1962  0.0861777  0.368725  0.478874
1963  0.0861777  0.353872  0.357513
```

```
1964  0.0861777  0.288006  0.240345
1965  0.0861777  0.349352  0.181154
1966  0.0861777  0.575366  0.153404
1967  0.0861777  0.282194  0.133321
1968  0.0861777  0.211807  0.127652
1969  0.0861777  0.21439  0.145313
1970  0.0861777  0.265404  0.171069
1971  0.0861777  0.577949  0.198755
1972  0.0861777  0.417802  0.19769
1973  0.0861777  0.178228  0.218873
1974  0.0861777  0.103966  0.244376
1975  0.0861777  0.280257  0.326133
1976  0.0861777  0.173707  0.364335
1977  0.0861777  1.37545  1.36395
1978  0.0861777  2.21299  1.86139
1980  0.0861777  3.58522  2.73571
1981  0.0861777  3.14094  2.92582
1982  0.0861777  2.36281  3.62284
1983  0.0861777  3.04537  3.50124
1984  0.0861777  3.58586  2.97274
1985  0.0861777  2.84519  2.76691
1986  0.0861777  2.32406  2.68553
1987  0.0861777  1.96955  2.5223
1988  0.0861777  1.34769  2.18126
1989  0.0861777  1.48975  2.20419
1990  0.0861777  1.58468  1.53619
1991  0.0861777  1.91078  1.36578
1992  0.0861777  1.82813  1.21268
1993  0.0861777  1.81586  1.114
1994  0.0861777  1.67831  1.08465
1995  0.0861777  1.37739  1.0812
1996  0.0861777  1.58209  1.13956
1997  0.0861777  1.24114  0.991927
1998  0.0861777  0.946673  0.623429
1999  0.0861777  0.448152  0.415078
2000  0.0861777  0.545661  0.351582
2001  0.0861777  0.785881  0.351709
2002  0.0861777  0.504333  0.372813
2003  0.0861777  0.414573  0.343828
2004  0.0861777  0.300921  0.336388
index number 3
units = 2
month = -1
starting and ending ages for selectivity = 2  7
selectivity choice = -1
 year, sigma2, obs index, pred index
1951  0.0861777  0.178037  0.316371
1952  0.0861777  0.475168  0.27357
1953  0.0861777  0.15973  0.275282
1954  0.0861777  0.894008  0.394285
1955  0.0861777  0.736088  0.46395
1956  0.0861777  0.628662  0.448476
1957  0.0861777  0.15973  0.381279
1958  0.0861777  1.46011  0.360017
1959  0.0861777  0.74514  0.387544
1960  0.0861777  0.349838  0.388686
1961  0.0861777  1.58825  0.356702
1962  0.0861777  1.1495  0.315421
1963  0.0861777  0.47899  0.252472
1964  0.0861777  0.15973  0.172542
1965  0.0861777  0.15973  0.119789
1966  0.0861777  0.534111  0.0976434
1967  0.0861777  0.15973  0.0943795
1968  0.0861777  0.15973  0.100104
1969  0.0861777  0.268162  0.108855
1972  0.0861777  0.15973  0.157471
1975  0.0861777  0.15973  0.226965
1978  0.0861777  3.16443  0.965073
1979  0.0861777  0.15973  1.48094
1980  0.0861777  0.15973  1.80933
1981  0.0861777  4.49036  2.04594
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1982  0.0861777  0.15973  2.34666
1983  0.0861777  0.15973  2.54245
1984  0.0861777  0.85156  2.45712
1985  0.0861777  1.76468  2.32902
1986  0.0861777  2.87394  2.1684
1987  0.0861777  2.59572  2.00168
1988  0.0861777  3.81542  1.82332
1989  0.0861777  2.27123  1.70366
1990  0.0861777  0.239394  1.5048
1991  0.0861777  1.54741  1.27027
1992  0.0861777  1.6311  1.1389
1993  0.0861777  1.90087  1.09102
1994  0.0861777  0.412603  1.04847
1995  0.0861777  1.89142  1.05022
1996  0.0861777  1.97873  1.07893
1997  0.0861777  1.56592  0.951893
1998  0.0861777  2.17266  0.605741
1999  0.0861777  0.15973  0.394393
2000  0.0861777  0.15973  0.324481
2001  0.0861777  0.471547  0.293709
2002  0.0861777  0.15973  0.309383
2003  0.0861777  0.15973  0.306824
2004  0.0861777  0.31926  0.310877

Selectivity by age and year for each fleet rescaled so max=1.0
 fleet 1 selectivity at age
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
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 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
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 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
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 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
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 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
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 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
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 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
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 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
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 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
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 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
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 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831
 0.130636 0.362287 0.456786 0.631685 0.803486 1 0.643831

Fmult by year for each fleet
1929   0.112987
1930   0.0240124
1931   0.0274591
1932   0.0205929
1933   0.160988
1934   0.310177
1935   0.537809
1936   0.465013
1937   0.360012
1938   0.42189
1939   0.510156
1940   0.680935
1941   0.518133
1942   0.328293
1943   0.552995
1944   0.64773
1945   0.476623
1946   0.657745
1947   0.501995
1948   0.444231
1949   0.652847
1950   0.522308
1951   0.51473
1952   0.347719
1953   0.136166
1954   0.391624
1955   0.46126
1956   0.769795
1957   0.651026
1958   0.279374
1959   0.457264
1960   0.50521
1961   0.688494
1962   0.637592
1963   0.851402
1964   1.05212
1965   0.949167
```

```
1966   0.694526
1967   0.170183
1968   0.159987
1969   0.0945672
1970   0.0622661
1971   0.0546857
1972   0.0323536
1973   0.020608
1974   0.0249742
1975   0.0588775
1976   0.0643762
1977   0.121864
1978   0.194763
1979   0.212393
1980   0.227636
1981   0.255723
1982   0.208958
1983   0.218835
1984   0.226148
1985   0.215421
1986   0.257329
1987   0.246272
1988   0.260128
1989   0.306615
1990   0.48401
1991   0.542252
1992   0.341796
1993   0.231645
1994   0.30469
1995   0.130198
1996   0.264046
1997   0.609778
1998   1.3027
1999   0.416789
2000   0.815438
2001   0.413573
2002   0.522686
2003   0.344008
2004   0.269423
2005   0.237874

Directed F by age and year for each fleet
 fleet 1 directed F at age
 0.0147602 0.0409338 0.051611 0.0713725 0.0907838 0.112987 0.0727448
 0.00313688 0.00869938 0.0109685 0.0151683 0.0192936 0.0240124 0.0154599
 0.00358714 0.00994807 0.0125429 0.0173455 0.022063 0.0274591 0.017679
 0.00269017 0.00746055 0.00940656 0.0130082 0.0165461 0.0205929 0.0132584
 0.0210308 0.0583238 0.073537 0.101694 0.129351 0.160988 0.103649
 0.0405202 0.112373 0.141684 0.195934 0.249223 0.310177 0.199701
 0.070257 0.194841 0.245663 0.339726 0.432122 0.537809 0.346258
 0.0607473 0.168468 0.212411 0.293742 0.373631 0.465013 0.29939
 0.0470304 0.130427 0.164448 0.227414 0.289264 0.360012 0.231787
 0.055114 0.152845 0.192714 0.266502 0.338983 0.42189 0.271626
 0.0666446 0.184823 0.233032 0.322258 0.409903 0.510156 0.328454
 0.0889545 0.246694 0.311042 0.430137 0.547122 0.680935 0.438407
 0.0676866 0.187713 0.236676 0.327297 0.416312 0.518133 0.33359
 0.0428868 0.118936 0.14996 0.207378 0.263779 0.328293 0.211365
 0.0722409 0.200343 0.2526 0.349319 0.444324 0.552995 0.356035
 0.0846167 0.234664 0.295874 0.409162 0.520442 0.64773 0.417029
 0.062264 0.172674 0.217715 0.301076 0.38296 0.476623 0.306865
 0.085925 0.238292 0.300449 0.415488 0.528489 0.657745 0.423477
 0.0655784 0.181866 0.229304 0.317103 0.403346 0.501995 0.3232
 0.0580325 0.160939 0.202919 0.280614 0.356934 0.444231 0.28601
 0.0852852 0.236518 0.298211 0.412394 0.524554 0.652847 0.420323
 0.0682321 0.189225 0.238583 0.329934 0.419667 0.522308 0.336278
 0.0672421 0.18648 0.235121 0.325147 0.413578 0.51473 0.331399
 0.0454245 0.125974 0.158833 0.219649 0.279387 0.347719 0.223872
 0.0177882 0.0493313 0.0621989 0.0860143 0.109408 0.136166 0.0876681
 0.0511601 0.14188 0.178888 0.247383 0.314665 0.391624 0.25214
 0.060257 0.167108 0.210697 0.291371 0.370616 0.46126 0.296973
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 0.0159197 0.0441496 0.0556655 0.0769794 0.0979156 0.121864 0.0784595
 0.025443 0.07056 0.0889649 0.123029 0.156489 0.194763 0.125394
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Discard F by age and year for each fleet
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Total F
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 0.0852852 0.236518 0.298211 0.412394 0.524554 0.652847 0.420323
 0.0682321 0.189225 0.238583 0.329934 0.419667 0.522308 0.336278
 0.0672421 0.18648 0.235121 0.325147 0.413578 0.51473 0.331399
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 0.0511601 0.14188 0.178888 0.247383 0.314665 0.391624 0.25214
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 0.111224 0.308452 0.388909 0.537818 0.68409 0.851402 0.548159
 0.137444 0.381169 0.480593 0.664608 0.845363 1.05212 0.677387
 0.123995 0.343871 0.433566 0.599575 0.762642 0.949167 0.611103
 0.0907299 0.251618 0.31725 0.438722 0.558042 0.694526 0.447157
 0.022232 0.061655 0.0777371 0.107502 0.136739 0.170183 0.109569
 0.0209 0.0579611 0.0730797 0.101061 0.128547 0.159987 0.103004
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Population Numbers at the Start of the Year
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1965  1.26164e-06
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1996  1.26164e-06
1997  1.26164e-06
1998  1.26164e-06
1999  1.26164e-06
2000  1.26164e-06
 index 2 q over time
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1937  3.8382e-06
1938  3.8382e-06
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1940  3.8382e-06
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2002  3.8382e-06
2003  3.8382e-06
2004  3.8382e-06
 index 3 q over time
1951  7.78815e-06
1952  7.78815e-06
1953  7.78815e-06
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1994  7.78815e-06
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1999  7.78815e-06
2000  7.78815e-06
2001  7.78815e-06
2002  7.78815e-06
2003  7.78815e-06
2004  7.78815e-06

Proportions of catch at age by fleet
 fleet 1
Year 1 Obs  =  0.000132932 0.178158 0.321923 0.298312 0.0746246 0.055518 0.0713314
Year 1 Pred =  0.153327 0.297206 0.221469 0.177669 0.0622064 0.0410286 0.0470943
Year 2 Obs  =  0 0.0867779 0.446366 0.301453 0.11939 0.0417584 0.00425412
Year 2 Pred =  0.126251 0.255203 0.221494 0.179631 0.130876 0.0442661 0.0422793
Year 3 Obs  =  0 0.0484018 0.505194 0.313014 0.0660959 0.0380706 0.0292236
Year 3 Pred =  0.131827 0.212511 0.194481 0.184499 0.137018 0.0972203 0.0424437
Year 4 Obs  =  0 0.0117402 0.261808 0.47494 0.113248 0.0764022 0.0618618
Year 4 Pred =  0.14869 0.221871 0.161906 0.162017 0.140777 0.101846 0.0628932
Year 5 Obs  =  0 0.0505403 0.20803 0.348817 0.255576 0.0905436 0.0464928
Year 5 Pred =  0.10596 0.263777 0.17726 0.139934 0.12696 0.106221 0.0798884
Year 6 Obs  =  0 0.0307845 0.335587 0.223908 0.256675 0.0975438 0.0555018
Year 6 Pred =  0.104665 0.206173 0.225669 0.161021 0.112457 0.0957465 0.0942689
Year 7 Obs  =  0 0.0564974 0.0661942 0.320666 0.33166 0.174786 0.0501961
Year 7 Pred =  0.112675 0.21119 0.177811 0.201626 0.123431 0.0783203 0.0949477
Year 8 Obs  =  0 0.0193028 0.17522 0.149419 0.283927 0.301928 0.0702035
Year 8 Pred =  0.1617 0.219613 0.17133 0.1484 0.141791 0.0774888 0.0796762
Year 9 Obs  =  0.001935 0.022218 0.0390255 0.120969 0.239529 0.392018 0.184306
Year 9 Pred =  0.16146 0.287619 0.164842 0.133857 0.0991572 0.085917 0.0671476
Year 10 Obs  =  0.00893818 0.134115 0.370324 0.191463 0.0499225 0.126082 0.119155
Year 10 Pred =  0.203966 0.267809 0.203553 0.121559 0.0849466 0.057394 0.0607728
Year 11 Obs  =  0.0264664 0.225322 0.237303 0.314109 0.09451 0.0477468 0.0545422
Year 11 Pred =  0.172885 0.332614 0.1842 0.144465 0.0733306 0.0461348 0.0463706
Year 12 Obs  =  0.0172179 0.154782 0.516031 0.188042 0.100873 0.0107416 0.0123124
Year 12 Pred =  0.173633 0.29629 0.236086 0.132647 0.0866387 0.0387494 0.0359559
Year 13 Obs  =  0.00555401 0.174533 0.36916 0.358094 0.0714624 0.0135361 0.00766119
Year 13 Pred =  0.266248 0.265569 0.184719 0.149653 0.0695471 0.0397847 0.0244791
Year 14 Obs  =  0 0.509726 0.159706 0.220333 0.0914612 0.0142632 0.00451152
Year 14 Pred =  0.153446 0.408612 0.171029 0.12376 0.0854803 0.0359196 0.0217537
Year 15 Obs  =  0.0097019 0.144623 0.627906 0.117861 0.0827792 0.0125567 0.00457245
Year 15 Pred =  0.166533 0.25989 0.294934 0.127626 0.0790103 0.0494362 0.0225701
Year 16 Obs  =  0 0.208829 0.24025 0.427661 0.0972755 0.0203835 0.00560041
Year 16 Pred =  0.207953 0.274724 0.176805 0.203565 0.0731966 0.0398443 0.0239127
Year 17 Obs  =  0.0109986 0.282917 0.204285 0.202939 0.203988 0.0658332 0.0290393
Year 17 Pred =  0.156248 0.350039 0.189636 0.124694 0.119502 0.0378866 0.0219944
Year 18 Obs  =  0.00981643 0.163549 0.452662 0.208109 0.0817045 0.0402124 0.0439463
Year 18 Pred =  0.148328 0.278997 0.260231 0.143528 0.0789869 0.0670389 0.0228898
Year 19 Obs  =  0.19871 0.0381038 0.22082 0.302811 0.140766 0.0558692 0.0429188
Year 19 Pred =  0.360638 0.205416 0.158077 0.150284 0.0688013 0.0332841 0.023498
Year 20 Obs  =  0.0151252 0.902805 0.0452614 0.0107772 0.0157524 0.00611567 0.00416267
Year 20 Pred =  0.213488 0.468713 0.111736 0.0887662 0.071474 0.0293661 0.0164572
Year 21 Obs  =  0.00176535 0.283215 0.638979 0.0555447 0.00893077 0.00758072 0.00398516
Year 21 Pred =  0.117625 0.361123 0.331556 0.080635 0.0538079 0.0385106 0.0167432
Year 22 Obs  =  0.000149779 0.0961985 0.479944 0.395028 0.0233882 0.00179714 0.00349449
Year 22 Pred =  0.139367 0.220869 0.277379 0.259262 0.0522914 0.0306432 0.0201883
Year 23 Obs  =  0.023919 0.0492379 0.137729 0.431446 0.346097 0.00678074 0.00479008
Year 23 Pred =  0.163741 0.247635 0.163352 0.210463 0.165453 0.0297255 0.019631
Year 24 Obs  =  0.00605125 0.00323665 0.0366591 0.0904869 0.667324 0.19392 0.00232211
Year 24 Pred =  0.218847 0.264609 0.167869 0.115055 0.126246 0.0896314 0.0177434
Year 25 Obs  =  0.821827 0.0453997 0.0319006 0.0391536 0.0108128 0.0246475 0.0262592
Year 25 Pred =  0.482672 0.214383 0.112098 0.0757737 0.0456937 0.0468729 0.0225072
Year 26 Obs  =  0.0125862 0.893441 0.086876 0.00464175 0.00158439 0 0.000870301
Year 26 Pred =  0.120402 0.61117 0.119332 0.0659356 0.0392952 0.022145 0.0217198
Year 27 Obs  =  0.119957 0.100847 0.598964 0.170437 0.00577567 0.000424721 0.00359552
Year 27 Pred =  0.240116 0.190182 0.409575 0.082946 0.0392076 0.0211798 0.0167931
Year 28 Obs  =  0.000253735 0.597185 0.180935 0.176888 0.0439894 0.000749046 0
Year 28 Pred =  0.156215 0.374797 0.123304 0.268477 0.0452476 0.018823 0.0131367
Year 29 Obs  =  0.0227557 0.102253 0.500542 0.186051 0.133973 0.0377946 0.0166316
Year 29 Pred =  0.185952 0.275001 0.264405 0.0871795 0.154151 0.0223189 0.0109928
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Year 30 Obs  =  0.41755 0.0323864 0.150013 0.275552 0.0885875 0.0285315 0.0073801
Year 30 Pred =  0.287444 0.264451 0.161611 0.161072 0.0448163 0.0709463 0.00965926
Year 31 Obs  =  0.0236386 0.867841 0.064345 0.0160442 0.0196046 0.00640241 0.00212389
Year 31 Pred =  0.171594 0.41837 0.165701 0.105693 0.0911586 0.0232564 0.0242264
Year 32 Obs  =  0.0476465 0.351289 0.39518 0.152616 0.0398975 0.0082458 0.00512618
Year 32 Pred =  0.210061 0.271665 0.278144 0.113496 0.0613343 0.0474719 0.017828
Year 33 Obs  =  0.263766 0.375504 0.191497 0.136522 0.0286966 0.00300445 0.00101125
Year 33 Pred =  0.197518 0.329779 0.176698 0.183499 0.0623583 0.0296917 0.0204557
Year 34 Obs  =  0.0136386 0.428033 0.223258 0.184331 0.121087 0.0259657 0.00368614
Year 34 Pred =  0.134082 0.346917 0.234748 0.126751 0.107915 0.0318121 0.0177744
Year 35 Obs  =  0.00372841 0.132736 0.389362 0.207266 0.195849 0.0616144 0.00944415
Year 35 Pred =  0.158887 0.250261 0.262016 0.176556 0.0775051 0.0567057 0.0180688
Year 36 Obs  =  0.00864797 0.191699 0.163336 0.237902 0.285836 0.0940667 0.0185131
Year 36 Pred =  0.193154 0.29156 0.179293 0.182291 0.096452 0.0351041 0.0221463
Year 37 Obs  =  0.401408 0.0388331 0.0235413 0.0522133 0.169618 0.266398 0.047988
Year 37 Pred =  0.195109 0.342179 0.197043 0.117109 0.0920271 0.0397315 0.0168017
Year 38 Obs  =  0.161893 0.372788 0.0875041 0.0682824 0.0554236 0.154859 0.0992504
Year 38 Pred =  0.136696 0.355364 0.243433 0.138651 0.0654517 0.0431897 0.0172141
Year 39 Obs  =  0.757469 0.0972724 0.00828264 0.0606121 0.021249 0.0179559 0.0371589
Year 39 Pred =  0.165543 0.241637 0.259283 0.185218 0.0893376 0.0379269 0.0210539
Year 40 Obs  =  0.849066 0.0532636 0.0227536 0.0388338 0.0101603 0.00957951 0.0163437
Year 40 Pred =  0.221477 0.24553 0.158388 0.182454 0.116491 0.0533441 0.0223157
Year 41 Obs  =  0.0131372 0.702731 0.176542 0.0629093 0.0221611 0.0195088 0.00301092
Year 41 Pred =  0.203573 0.319665 0.157255 0.109521 0.113437 0.0692176 0.0273321
Year 42 Obs  =  0.170554 0.829446 0 0 0 0 0
Year 42 Pred =  0.208942 0.295633 0.207998 0.111129 0.0702061 0.0701302 0.0359626
Year 43 Obs  =  0 0.914041 0.0748845 0.00342221 0.00459228 0.00306044 0
Year 43 Pred =  0.124969 0.331149 0.21086 0.16149 0.0785547 0.0480408 0.0449361
Year 44 Obs  =  0.551918 0.10157 0.161582 0.176418 0.00482635 0.00368512 0
Year 44 Pred =  0.213078 0.19228 0.229736 0.159583 0.111549 0.052669 0.0411041
Year 45 Obs  =  0.046322 0.554527 0.161701 0.0306141 0.0715813 0.0842901 0.0509641
Year 45 Pred =  0.167534 0.315753 0.128902 0.168363 0.107067 0.0728727 0.0395064
Year 46 Obs  =  0.658766 0.254857 0.0713294 0.0112865 0.00376117 0 0
Year 46 Pred =  0.284586 0.226582 0.19344 0.0863494 0.103332 0.0640298 0.0416811
Year 47 Obs  =  0.00234212 0.932784 0.0579678 0.00479849 0.000597495 0.00100663 0.000503316
Year 47 Pred =  0.154548 0.403833 0.145351 0.135292 0.0551629 0.0641024 0.0417097
Year 48 Obs  =  0.875994 0.010291 0.11054 4.70167e-05 0.00144059 0 0.00168696
Year 48 Pred =  0.690079 0.0920155 0.108205 0.0423692 0.0358903 0.0141582 0.0172823
Year 49 Obs  =  0.229832 0.762596 0.00161824 0.00595355 0 0 0
Year 49 Pred =  0.178947 0.685194 0.040988 0.0521846 0.0185041 0.0150815 0.00910054
Year 50 Obs  =  0.596692 0.152357 0.231306 0.00942713 0.00813682 0.00208085 0
Year 50 Pred =  0.39113 0.202213 0.343785 0.0220737 0.0251705 0.00848771 0.00713899
Year 51 Obs  =  0.000204883 0.767729 0.111535 0.113799 0.00166389 0.00506744 0
Year 51 Pred =  0.106678 0.525727 0.11948 0.216909 0.0123694 0.0132998 0.00553764
Year 52 Obs  =  0.395756 0.0211872 0.483073 0.050996 0.0456628 0.00253672 0.000788202
Year 52 Pred =  0.264291 0.159522 0.344589 0.083451 0.134169 0.00719295 0.00678484
Year 53 Obs  =  0.121771 0.297915 0.0716595 0.455607 0.0315601 0.0201716 0.0013164
Year 53 Pred =  0.243393 0.34281 0.0904134 0.207505 0.0443452 0.0667718 0.00476208
Year 54 Obs  =  0.124141 0.280226 0.25672 0.0766234 0.238521 0.0178224 0.00594644
Year 54 Pred =  0.1332 0.382193 0.234835 0.0659427 0.133646 0.0267792 0.0234051
Year 55 Obs  =  0.0246871 0.0245614 0.387945 0.350615 0.0551802 0.154816 0.00219538
Year 55 Pred =  0.126482 0.231109 0.290897 0.190627 0.0474526 0.0905099 0.0229225
Year 56 Obs  =  0.0281241 0.0052474 0.094818 0.482712 0.247538 0.0614525 0.0801078
Year 56 Pred =  0.164196 0.21728 0.17389 0.233182 0.135255 0.0316369 0.044559
Year 57 Obs  =  0.0307782 0.165933 0.049216 0.154079 0.475333 0.101533 0.0231267
Year 57 Pred =  0.162297 0.269515 0.156133 0.133179 0.15809 0.0861805 0.0346055
Year 58 Obs  =  0.138543 0.327149 0.169822 0.038922 0.0663322 0.188852 0.0703799
Year 58 Pred =  0.153594 0.276205 0.20072 0.123607 0.0931414 0.103656 0.0490767
Year 59 Obs  =  0.128279 0.505822 0.230179 0.037482 0.0201221 0.0247165 0.0534004
Year 59 Pred =  0.122343 0.275685 0.215892 0.166549 0.0903059 0.0635943 0.0656304
Year 60 Obs  =  0.569691 0.082322 0.196523 0.071435 0.0155065 0.01059 0.053933
Year 60 Pred =  0.217615 0.200006 0.196429 0.163219 0.110874 0.0561793 0.0556786
Year 61 Obs  =  0.104072 0.76552 0.0398567 0.031949 0.021474 0.0129316 0.0241968
Year 61 Pred =  0.137505 0.353684 0.141153 0.146469 0.106658 0.0673569 0.0471737
Year 62 Obs  =  0.180593 0.118733 0.264447 0.0731527 0.103116 0.119672 0.140287
Year 62 Pred =  0.188872 0.235798 0.259912 0.107899 0.096449 0.0640934 0.0469764
Year 63 Obs  =  0.138341 0.467133 0.111522 0.110364 0.0529952 0.0474732 0.0721719
Year 63 Pred =  0.163215 0.320121 0.166999 0.188867 0.06608 0.0527145 0.0420027
Year 64 Obs  =  0.119553 0.330145 0.135286 0.107966 0.116676 0.0888847 0.101489
Year 64 Pred =  0.139355 0.291131 0.238729 0.129262 0.124201 0.0391518 0.0381717
Year 65 Obs  =  0.566116 0.103128 0.117579 0.0380838 0.0371877 0.0558312 0.0820751
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Year 65 Pred =  0.192061 0.229403 0.206582 0.179223 0.0848214 0.0756235 0.032286
Year 66 Obs  =  0.280238 0.420412 0.109885 0.0497054 0.0631084 0.0330318 0.0436198
Year 66 Pred =  0.171205 0.307488 0.160075 0.152555 0.11633 0.0513349 0.0410116
Year 67 Obs  =  0.597806 0.274536 0.068713 0.012866 0.00706801 0.0181015 0.0209092
Year 67 Pred =  0.196451 0.269549 0.210574 0.117126 0.0986776 0.0706843 0.0369375
Year 68 Obs  =  0.286189 0.434683 0.124792 0.0597656 0.0372799 0.0255487 0.0317413
Year 68 Pred =  0.149976 0.31461 0.190908 0.159164 0.0788207 0.0627367 0.0437855
Year 69 Obs  =  0.161191 0.328301 0.215854 0.0849973 0.0549687 0.0499529 0.104735
Year 69 Pred =  0.116611 0.274533 0.246902 0.154795 0.110694 0.0497671 0.0466967
Year 70 Obs  =  0.0906565 0.1326 0.258571 0.158063 0.103554 0.0890134 0.167541
Year 70 Pred =  0.141501 0.239771 0.225497 0.196514 0.097864 0.0586848 0.0401684
Year 71 Obs  =  0.312553 0.0772014 0.0701065 0.160096 0.152622 0.116375 0.111046
Year 71 Pred =  0.191846 0.27774 0.177152 0.164677 0.111653 0.0457703 0.0311613
Year 72 Obs  =  0.363782 0.191359 0.0647564 0.109825 0.129162 0.0832249 0.0578917
Year 72 Pred =  0.251262 0.292176 0.176404 0.113677 0.0880835 0.0526342 0.0257637
Year 73 Obs  =  0.306181 0.438952 0.075913 0.0419825 0.0519465 0.0457321 0.0392928
Year 73 Pred =  0.223511 0.375583 0.175621 0.107823 0.0570679 0.0384795 0.0219151
Year 74 Obs  =  0.108177 0.781913 0.0788801 0.0181331 0.00347435 0.00557047 0.00385201
Year 74 Pred =  0.146742 0.359302 0.254799 0.122882 0.0641254 0.0305529 0.0215971
Year 75 Obs  =  0.52318 0.29916 0.103354 0.0379717 0.0133419 0.0130981 0.00989377
Year 75 Pred =  0.192458 0.243359 0.249736 0.183982 0.0755238 0.035575 0.0193654
Year 76 Obs  =  0.805353 0.11007 0.0381329 0.0276862 0.0121173 0.00258754 0.00405256
Year 76 Pred =  0.291634 0.260288 0.141606 0.153285 0.0984091 0.0373581 0.0174198
Year 77 Obs  =  0 0 0 0 0 0 0
Year 77 Pred =  0.176146 0.412183 0.160012 0.092412 0.0880273 0.0527888 0.0184316

Proportions of Discards at age by fleet
 fleet 1
Year 1 Obs  =  0 0 0 0 0 0 0
Year 1 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 2 Obs  =  0 0 0 0 0 0 0
Year 2 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 3 Obs  =  0 0 0 0 0 0 0
Year 3 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 4 Obs  =  0 0 0 0 0 0 0
Year 4 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 5 Obs  =  0 0 0 0 0 0 0
Year 5 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 6 Obs  =  0 0 0 0 0 0 0
Year 6 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 7 Obs  =  0 0 0 0 0 0 0
Year 7 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 8 Obs  =  0 0 0 0 0 0 0
Year 8 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 9 Obs  =  0 0 0 0 0 0 0
Year 9 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 10 Obs  =  0 0 0 0 0 0 0
Year 10 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 11 Obs  =  0 0 0 0 0 0 0
Year 11 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 12 Obs  =  0 0 0 0 0 0 0
Year 12 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 13 Obs  =  0 0 0 0 0 0 0
Year 13 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 14 Obs  =  0 0 0 0 0 0 0
Year 14 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 15 Obs  =  0 0 0 0 0 0 0
Year 15 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 16 Obs  =  0 0 0 0 0 0 0
Year 16 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 17 Obs  =  0 0 0 0 0 0 0
Year 17 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 18 Obs  =  0 0 0 0 0 0 0
Year 18 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 19 Obs  =  0 0 0 0 0 0 0
Year 19 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 20 Obs  =  0 0 0 0 0 0 0
Year 20 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 21 Obs  =  0 0 0 0 0 0 0
Year 21 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 22 Obs  =  0 0 0 0 0 0 0
```

```
Year 22 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 23 Obs  =  0 0 0 0 0 0 0
Year 23 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 24 Obs  =  0 0 0 0 0 0 0
Year 24 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 25 Obs  =  0 0 0 0 0 0 0
Year 25 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 26 Obs  =  0 0 0 0 0 0 0
Year 26 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 27 Obs  =  0 0 0 0 0 0 0
Year 27 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 28 Obs  =  0 0 0 0 0 0 0
Year 28 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 29 Obs  =  0 0 0 0 0 0 0
Year 29 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 30 Obs  =  0 0 0 0 0 0 0
Year 30 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 31 Obs  =  0 0 0 0 0 0 0
Year 31 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 32 Obs  =  0 0 0 0 0 0 0
Year 32 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 33 Obs  =  0 0 0 0 0 0 0
Year 33 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 34 Obs  =  0 0 0 0 0 0 0
Year 34 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 35 Obs  =  0 0 0 0 0 0 0
Year 35 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 36 Obs  =  0 0 0 0 0 0 0
Year 36 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 37 Obs  =  0 0 0 0 0 0 0
Year 37 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 38 Obs  =  0 0 0 0 0 0 0
Year 38 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 39 Obs  =  0 0 0 0 0 0 0
Year 39 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 40 Obs  =  0 0 0 0 0 0 0
Year 40 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 41 Obs  =  0 0 0 0 0 0 0
Year 41 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 42 Obs  =  0 0 0 0 0 0 0
Year 42 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 43 Obs  =  0 0 0 0 0 0 0
Year 43 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 44 Obs  =  0 0 0 0 0 0 0
Year 44 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 45 Obs  =  0 0 0 0 0 0 0
Year 45 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 46 Obs  =  0 0 0 0 0 0 0
Year 46 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 47 Obs  =  0 0 0 0 0 0 0
Year 47 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 48 Obs  =  0 0 0 0 0 0 0
Year 48 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 49 Obs  =  0 0 0 0 0 0 0
Year 49 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 50 Obs  =  0 0 0 0 0 0 0
Year 50 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 51 Obs  =  0 0 0 0 0 0 0
Year 51 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 52 Obs  =  0 0 0 0 0 0 0
Year 52 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 53 Obs  =  0 0 0 0 0 0 0
Year 53 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 54 Obs  =  0 0 0 0 0 0 0
Year 54 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 55 Obs  =  0 0 0 0 0 0 0
Year 55 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 56 Obs  =  0 0 0 0 0 0 0
Year 56 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 57 Obs  =  0 0 0 0 0 0 0
Year 57 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
```

```
Year 58 Obs  =  0 0 0 0 0 0 0
Year 58 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 59 Obs  =  0 0 0 0 0 0 0
Year 59 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 60 Obs  =  0 0 0 0 0 0 0
Year 60 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 61 Obs  =  0 0 0 0 0 0 0
Year 61 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 62 Obs  =  0 0 0 0 0 0 0
Year 62 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 63 Obs  =  0 0 0 0 0 0 0
Year 63 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 64 Obs  =  0 0 0 0 0 0 0
Year 64 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 65 Obs  =  0 0 0 0 0 0 0
Year 65 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 66 Obs  =  0 0 0 0 0 0 0
Year 66 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 67 Obs  =  0 0 0 0 0 0 0
Year 67 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 68 Obs  =  0 0 0 0 0 0 0
Year 68 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 69 Obs  =  0 0 0 0 0 0 0
Year 69 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 70 Obs  =  0 0 0 0 0 0 0
Year 70 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 71 Obs  =  0 0 0 0 0 0 0
Year 71 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 72 Obs  =  0 0 0 0 0 0 0
Year 72 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 73 Obs  =  0 0 0 0 0 0 0
Year 73 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 74 Obs  =  0 0 0 0 0 0 0
Year 74 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 75 Obs  =  0 0 0 0 0 0 0
Year 75 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 76 Obs  =  0 0 0 0 0 0 0
Year 76 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15
Year 77 Obs  =  0 0 0 0 0 0 0
Year 77 Pred =  1e-15 1e-15 1e-15 1e-15 1e-15 1e-15 1e-15

F Reference Points Using Final Year Selectivity Scaled Max=1.0
 refpt           F       slope to plot on SRR
  F0.1     0.85073     10.9221
  Fmax     4.13686     78.8555
  F30%SPR  0.742917     9.66045
  F40%SPR  0.517755     7.24537
  Fmsy     0.210139     4.44785    SSmsy    168705     MSY   37828.7
  Foy      0.157604     xxxxxx    SSoy    217646     OY   35906.5
  Fcurrent 0.237874     4.6751

Stock-Recruitment Relationship Parameters
 alpha     = 2.10835e+06
 beta      = 305309
 virgin    = 259296
 steepness = 0.316156
Spawning Stock, Obs Recruits(year+1), Pred Recruits(year+1)
1929  212549  968370  865348
1930  234931  1.00434e+06  916844
1931  260308  1.12564e+06  970302
1932  268210  745767  985983
1933  250594  603627  950416
1934  207325  491982  852681
1935  155798  541154  712364
1936  112557  463112  567908
1937  92787.9  541674  491411
1938  84043.3  425070  455095
1939  83371  365434  452236
1940  67878.6  534288  383485
1941  56153.1  304750  327531
1942  52591.9  297157  309812
```

```
1943  56641  329229  329932
1944  52486.7  216156  309283
1945  45000.1  169720  270835
1946  41751  436570  253632
1947  34415.8  299084  213586
1948  32047.9  144554  200287
1949  33207.9  133451  206825
1950  30992.6  131424  194299
1951  28975.5  164839  182750
1952  26765.4  588022  169934
1953  26018.1  183752  165562
1954  31231.5  353398  195658
1955  37911.8  215555  232886
1956  42109.7  207312  255547
1957  36288.4  338075  223973
1958  32091.1  214428  200531
1959  35222.8  249293  218076
1960  35928.7  219017  221987
1961  33853.6  121849  210445
1962  31791.5  109744  198835
1963  27882  98356.8  176430
1964  19641.6  74648.7  127439
1965  12220.7  39722.7  81143.8
1966  9982.87  41061.5  66755.1
1967  8608.17  59912.9  57814.6
1968  9441.82  62225.7  63245.7
1969  10489.6  72586.5  70030.7
1970  12000.4  45439.2  79736.2
1971  14226.3  83808.2  93867.6
1972  14717.6  74319.1  96960.1
1973  16468.5  156175  107904
1974  22014.7  99584.7  141801
1975  31905.9  1.23815e+06  199483
1976  41148.7  532455  250408
1977  60222.7  1.67039e+06  347358
1978  96175.5  543524  505054
1979  125349  1.4384e+06  613665
1980  130530  1.6233e+06  631432
1981  155381  900339  711100
1982  163113  788149  734165
1983  174000  950719  765378
1984  190246  914011  809404
1985  193815  809059  818692
1986  195884  569055  824018
1987  191817  981320  813509
1988  193171  600686  817026
1989  168060  739386  748527
1990  153929  562710  706682
1991  123893  407257  608594
1992  94138.8  535284  496879
1993  87663  471093  470324
1994  77249.6  547406  425736
1995  84701  419737  457883
1996  90178  272027  480740
1997  88707.3  218857  474665
1998  64939.1  205370  369790
1999  36507  258792  225178
2000  33262.5  223046  207132
2001  24253.2  137504  155158
2002  22750.3  164803  146210
2003  30285.5  288667  190266
2004  31078.6  195380  194789
2005  33310.1       xxxx   207399

average F (ages 4 to 8 unweighted) by year
Projection into Future
Projected NAA
 2 114878 94056.7 28604 11674.5 8546.59 6292.78
 2 1.19998 67613.4 54926.3 16463.2 6624.24 8389.17
Projected Directed FAA
 0.0108404 0.0300633 0.037905 0.0524185 0.0666749 0.082982 0.0534264
```

```
 0.0120818 0.0335058 0.0422455 0.058421 0.0743098 0.0924843 0.0595442
Projected Discard FAA
 0 0 0 0 0 0 0
 0 0 0 0 0 0 0
Projected Nondirected FAA
 -0 -0 -0 -0 -0 -0 -0
 -0 -0 -0 -0 -0 -0 -0
Projected Catch at Age
 0.016977 2680.67 2757.43 1152.03 594.217 537.423 258.197
 0.0189103 0.0311591 2204.82 2458.77 930.685 462.255 382.566
Projected Discards at Age (in numbers)
 0 0 0 0 0 0 0
 0 0 0 0 0 0 0
Projected Yield at Age
 0.00222398 715.739 1094.7 684.305 408.822 420.265 209.656
 0.00247724 0.00831947 875.315 1460.51 640.311 361.483 310.643
Year, Total Yield (in weight), Total Discards (in weight), SSB, proj_what, SS/SSmsy
2006  3533.49  0  37124.4  0  0.220055
2007  3648.27  0  42305.6  0  0.250766

M =  0.5 0.5 0.5 0.5 0.5 0.5 0.5
mature =  0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
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 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
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 0 0.07 0.25 0.47 0.73 1 1
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 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
 0 0.07 0.25 0.47 0.73 1 1
Weight at age
 0.074 0.167 0.297 0.402 0.523 0.615 0.704
 0.06 0.139 0.301 0.422 0.511 0.603 0.698
 0.077 0.114 0.276 0.399 0.527 0.606 0.701
 0.058 0.081 0.277 0.379 0.508 0.604 0.711
 0.059 0.083 0.2 0.299 0.493 0.585 0.7
 0.065 0.142 0.198 0.233 0.431 0.538 0.683
 0.079 0.186 0.217 0.251 0.379 0.472 0.629
 0.086 0.193 0.284 0.338 0.393 0.453 0.574
 0.119 0.176 0.318 0.429 0.461 0.502 0.575
 0.124 0.174 0.31 0.448 0.532 0.582 0.633
 0.191 0.247 0.364 0.461 0.585 0.683 0.795
 0.181 0.261 0.34 0.444 0.529 0.643 0.748
 0.115 0.26 0.344 0.441 0.561 0.653 0.81
 0.18 0.237 0.374 0.473 0.548 0.629 0.744
 0.165 0.293 0.34 0.476 0.576 0.653 0.716
 0.144 0.272 0.38 0.474 0.589 0.663 0.797
 0.122 0.235 0.385 0.495 0.613 0.707 0.779
 0.125 0.261 0.385 0.488 0.619 0.682 0.765
 0.119 0.292 0.401 0.501 0.625 0.712 0.77
 0.107 0.227 0.355 0.507 0.618 0.709 0.813
 0.109 0.193 0.32 0.458 0.61 0.728 0.833
 0.084 0.25 0.324 0.457 0.567 0.667 0.797
 0.163 0.255 0.347 0.43 0.571 0.697 0.86
 0.173 0.298 0.387 0.473 0.57 0.723 0.951
 0.162 0.296 0.412 0.514 0.605 0.767 0.866
 0.084 0.258 0.388 0.507 0.588 0.744 0.764
 0.14 0.253 0.358 0.486 0.585 0.748 0.883
 0.111 0.249 0.374 0.487 0.6 0.756 0.874
 0.179 0.311 0.375 0.51 0.604 0.652 0.651
 0.176 0.293 0.397 0.49 0.62 0.688 0.779
 0.133 0.252 0.399 0.512 0.605 0.705 0.82
 0.102 0.276 0.393 0.509 0.613 0.703 0.771
 0.145 0.252 0.39 0.497 0.586 0.65 0.821
 0.276 0.32 0.42 0.54 0.622 0.712 0.782
 0.197 0.298 0.434 0.538 0.627 0.73 0.743
 0.181 0.3 0.4 0.503 0.612 0.748 0.812
 0.109 0.195 0.384 0.501 0.596 0.723 0.735
 0.149 0.273 0.419 0.525 0.658 0.79 0.834
 0.166 0.235 0.488 0.51 0.599 0.723 0.879
 0.138 0.266 0.391 0.562 0.593 0.709 0.955
 0.103 0.322 0.428 0.505 0.662 0.746 0.907
 0.099 0.232 0.402 0.584 0.73 0.837 0.852
 0.266 0.282 0.457 0.481 0.74 0.955 0.977
```

```
 0.147 0.266 0.449 0.508 0.552 0.746 0.975
 0.119 0.329 0.433 0.609 0.606 0.686 0.763
 0.107 0.303 0.604 0.74 0.837 0.8 0.781
 0.127 0.361 0.517 0.973 1.053 1.029 1.35
 0.17 0.297 0.672 0.864 1.291 1.223 1.531
 0.122 0.322 0.6 0.847 1.063 1.548 1.457
 0.062 0.334 0.473 0.705 0.908 1.308 1.841
 0.082 0.189 0.44 0.598 0.81 0.969 1.553
 0.072 0.176 0.27 0.437 0.598 0.874 1.066
 0.083 0.19 0.239 0.391 0.597 0.757 0.939
 0.032 0.151 0.237 0.345 0.516 0.773 0.916
 0.049 0.191 0.302 0.39 0.458 0.511 0.688
 0.12 0.235 0.351 0.396 0.505 0.614 0.643
 0.157 0.285 0.418 0.461 0.484 0.56 0.65
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 0.133 0.272 0.414 0.523 0.6 0.691 0.743
 0.101 0.301 0.415 0.576 0.666 0.734 0.841
 0.104 0.193 0.381 0.542 0.647 0.749 0.779
 0.094 0.267 0.377 0.554 0.649 0.68 0.775
 0.071 0.217 0.397 0.514 0.591 0.664 0.754
 0.087 0.175 0.33 0.459 0.544 0.661 0.715
 0.073 0.228 0.294 0.408 0.583 0.607 0.761
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 0.105 0.182 0.318 0.471 0.589 0.649 0.702
 0.149 0.239 0.333 0.446 0.572 0.637 0.734
 0.139 0.267 0.325 0.419 0.53 0.615 0.66
 0.148 0.228 0.399 0.509 0.575 0.633 0.727
 0.114 0.266 0.37 0.55 0.59 0.608 0.675
 0.103 0.253 0.347 0.534 0.567 0.619 0.623
 0.133 0.218 0.303 0.412 0.552 0.529 0.656
 0.125 0.284 0.414 0.603 0.679 0.745 0.808
 0.131 0.267 0.397 0.594 0.688 0.782 0.812
 0.131 0.267 0.397 0.594 0.688 0.782 0.812
Fecundity
 0 0.01169 0.07425 0.18894 0.38179 0.615 0.704
 0 0.00973 0.07525 0.19834 0.37303 0.603 0.698
 0 0.00798 0.069 0.18753 0.38471 0.606 0.701
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 0 0.01365 0.096 0.23547 0.43508 0.723 0.735
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 0 0.01624 0.1005 0.27448 0.5329 0.837 0.852
 0 0.01974 0.11425 0.22607 0.5402 0.955 0.977
 0 0.01862 0.11225 0.23876 0.40296 0.746 0.975
 0 0.02303 0.10825 0.28623 0.44238 0.686 0.763
 0 0.02121 0.151 0.3478 0.61101 0.8 0.781
 0 0.02527 0.12925 0.45731 0.76869 1.029 1.35
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 0 0.01771 0.08675 0.25098 0.41391 0.619 0.623
 0 0.01526 0.07575 0.19364 0.40296 0.529 0.656
 0 0.01988 0.1035 0.28341 0.49567 0.745 0.808
 0 0.01869 0.09925 0.27918 0.50224 0.782 0.812
 0 0.01869 0.09925 0.27918 0.50224 0.782 0.812

SSmsy_ratio = 0.132101
Fmsy_ratio =  1.13198
that's all
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Pacific Mackerel

STAR Panel Meeting Report

NOAA / Southwest Fisheries Science Center
La Jolla, California
June 21 – 24, 2004

STAR Panel
Tom Barnes, California Department of Fish and Game (Chair)
Andre Punt, University of Washington (SSC Representative)
Rodolfo Serra, IFOP, Valparaiso, Chile
John Wheeler, Department of Fisheries and Oceans, Canada (CIE, Rapporteur)

PFMC
Brian Culver, Washington Department of Fish and Wildlife, CPSMT
Diane Pleschner-Steele, CPSAS

STAT
Kevin Hill, NOAA / Southwest Fisheries Science Center
Paul Crone, NOAA / Southwest Fisheries Science Center

1) Overview

On June 21st to 24th, 2004, a STAR Panel (hereafter the Panel) met in La Jolla, CA for the first formal PFMC-sponsored stock assessment review of Pacific mackerel. The STAR Panel terms of reference were adhered to, in that the Panel worked with the STAT to ensure that the assessment was reviewed as needed and that meeting discussions were documented. However, it was noted that a recent SSC report on Pacific mackerel (June 2004, Supplemental SSC Report F.2.b.) recommended a separate future STAR panel to deal with issues of yield and harvest formula for CPS species. Therefore, summaries of stock status and harvest guidelines were not reviewed by this STAR panel as the focus of the meeting was to review assessment methodologies and not results.

The STAR Panel members received copies of all documentation approximately one week prior to the meeting, which provided sufficient time for review. The meeting commenced on June 21st with introductions (see list of attendees) followed by a brief overview by the Chair (Tom Barnes). Kevin Hill, with assistance from Paul Crone, led the presentation on assessment methodology. Nancy Lo gave a presentation on the aerial spotter program, an abundance index in the assessment.

The CPS fishery in California takes market squid, sardine and mackerel. The fishery has progressed from one focused primarily on mackerel in the early 1980's, to one that focuses substantially on sardine and squid, although the fishery still relies on all three species.

The most recent mackerel assessment, intended for PFMC management decisions for the period July 1, 2004 to June 30, 2005, used a modified virtual population analysis model (ADEPT) to estimate Pacific mackerel biomass. During the meeting, the Panel briefly reviewed the method and results from the ADEPT model. However, most discussion focused on a forward-projection age structured assessment program (ASAP) model which the STAT proposed for future assessments of Pacific mackerel. The ASAP model is intended as an alternative statistical model to evaluate more fully the relationship between the species' population dynamics and associated fishery operations than is possible using ADEPT.

For illustrative purposes and to provide a basis for discussion, the STAT presented two ASAP models. The baseline model attempted to mimic the ADEPT formulation for the 2004 assessment. It included the four indices used in ADEPT and fixed selectivity over the entire period (1929-2003). The alternative approach eliminated one index, combined two other indices, and separated selectivity into two time periods.

In examining the results of the illustrative ASAP models, it was noted that results from both the baseline and alternative approach are very similar. Population numbers and biomass increased through the late 1970's and early 1980's similar to the ADEPT model, but peaked at much lower levels.

The Panel and the STAT agreed that ASAP should form the basis for the 2005 assessment. For continuity purposes, future assessments should include an ADEPT analysis as a sensitivity test.

The Panel commended the STAT for their excellent presentations, well-written and complete documentation, and their willingness to respond to the Panel's requests for additional analyses.

2) Discussion and Requests Made to the STAT during the Meeting

a. There were questions regarding the length of the time series to be included in the ASAP model, given uncertainties regarding earlier landings data. **Request:** the Panel requested that a sensitivity analysis be conducted to compare starting the model in the 1920's versus starting it when the stock rebounded in 1978. **Response:** the STAT provided numerous runs during the meeting comparing model outputs based on the entire time series and a truncated time series commencing in 1978.
b. There were concerns regarding biological sample sizes on which the catch at age data for some years is based, in particular during the 1970's when the fishery was closed. There were also concerns regarding the temporal and spatial variability of sampling. **Request:** the Panel requested that sample sizes by year be provided. **Response:** these were provided during the meeting and it was decided that it was not necessary to conduct a sensitivity analysis since there are several sources of uncertainty associated with the catch at age data other than sampling error, such as potential seasonal sampling bias. However, given the small sample sizes during the 1970's, it was suggested that this may be a further reason to begin the ASAP model subsequent to this period.
c. Weight at age data exhibited considerable variability over time, in particular during the mid 1970's when landings were low and sampling was reduced. It was suggested that this is another reason to start the ASAP model subsequent to this period. No requests or recommendations were made.
d. There were questions regarding the comparability of the new aerial spotter index and the historical fishery-based spotter index. No requests or recommendations were made.
e. In examining abundance indices, it was difficult for the Panel to compare one index with another. **Request:** the Panel requested that the abundance indices be plotted against each other (X-Y plots) to examine the degree of agreement between them. **Response:** three plots were provided during the meeting: 1) aerial spotter index vs. CalCOFI index, 2) aerial spotter index vs. CPFV index, and 3) CalCOFI index vs. CPFV index. These plots (see Figure 1) suggest that the relationship between the aerial spotter index and the CalCOFI and CPFV indices is not linear.
f. There were questions regarding the use of the northern CPFV index in ADEPT because its trend is contradictory with that of the southern CPFV index. The Panel and STAT agreed that a single combined index be used in the ASAP model.
g. There was a discussion regarding the use of the triennial and impingement indices. The Panel and STAT agreed that these indices be eliminated from the ASAP model.
h. In discussing the CalCOFI and aerial spotter indices, it was noted that there are zero values in the indices. However, the ASAP model replaces zero values by 0.0001 after the indices are rescaled to 1. **Request:** the Panel requested that a sensitivity analysis be conducted to examine the impact of adding a small value to the zero values in the ASAP input file. **Response:** the STAT provided numerous runs that illustrated that the ASAP model was highly sensitive to the addition of small values to the zeros. It was suggested, that in the long term, a negative binomial error structure be incorporated in the model to

allow for zero values. However, after much discussion, it was concluded that, in the short term, zero values in an index be replaced with the smallest observed value in that index.

i. After an extensive discussion, several other issues were identified that required further evaluation and review. **Request:** the Panel requested that the following ASAP sensitivity analyses be conducted: 1) three indices (CalCOFI, CFPV, and aerial spotter) vs. two indices (CalCOFI and CFPV), and 2) the full time series vs. a truncated time series commencing in 1978. **Response:** the STAT presented each of the above sensitivity analyses. The exclusion of the spotter index did not change the model fit substantially. It was concluded that all three abundance indices be included in the model, that the full time series be used, that zero values in indices be replaced with the minimum estimate from the index, and that the same coefficients of variation be assigned to all data points.

j. The baseline model of ASAP did not mimic the catch in 1998. **Request:** the Panel requested that the STAT conduct analyses in which the weight assigned to the catch data was increased (lambda values of 100, 300, and 1000) and provide a table with predicted 1998 catch, and 1+ biomass in 2003. A bubble plot was also requested to examine residual patterns. **Response:** the STAT provided this information (Table 1 and Figure 2).

3) Technical Merits and/or Deficiencies of the Assessment

The lack of catch at age and weight at age data from the Mexican (Ensenada) fishery is a major source of uncertainty, especially in recent years when Mexican landings have been as large as or larger than Californian landings.

Pacific mackerel range from the Gulf of California to southeastern Alaska and are harvested from Ensenada to British Columbia. However, the abundance indices used in the assessment are all derived from the Southern California Bight, a relatively small area compared to the distributional range. It was also noted that even within this area, there may be a spatial bias as most abundance indices are derived from the northern part of the spawning range, which is thought to range from central Baja California to the Southern California Bight.

The Panel could not fully review the age composition data due to a lack of information on how they were developed. There is considerable inter-annual variation in the proportion of catch in different age classes and this results in systematic patterns in the residuals about the fit to the catch-at-age data. The ASAP model is based on the assumption that all of the discrepancy between the observed and model – predicted age proportions is due to observation error. There are, however, alternative explanations: ageing error (both systematic and random), non-random sampling of the landings, the impact of seasonal variation in the fishery, and random changes in availability. The Panel strongly recommends examination of the basis for the age composition data and the possible benefits of allowing for time dependent selectivity. The Panel noted that variance in age composition data could be partitioned into component parts to estimate observation error and process error. The fishery was not conducted year-round in all years, which may have introduced a source of variability in the annual catch-at-age data. A sensitivity analysis could be conducted by down-weighting years with only a partial year of fishing.

4) Areas of Disagreement

There were no areas of disagreement between the Panel and STAT.

5) Unresolved Problems and Major Uncertainties

Problems unresolved at the end of the meeting form the basis for the research recommendations in Section 6.

6) Research Recommendations

The following recommendations are not given in priority order.

a. There was a discussion regarding the overall lack of fishery independent survey data, in particular outside of the Southern California Bight. **Recommendation:** the Panel recommended a concerted approach to develop a coastwide synoptic survey, ideally on an annual basis, to estimate an index of mackerel biomass.
b. There was a discussion regarding the survey design of the new aerial spotter index. **Recommendation:** the Panel recommended that the survey design incorporate rigorous protocols. Attempts should be made to estimate school surface area. The Panel also recommended that an aerial spotter survey be initiated in the Pacific Northwest in conjunction with industry.
c. The Panel endorsed and encouraged overall greater collaboration with industry in the collection and analysis process for coastal pelagic species, including Pacific mackerel.
d. There is a lack of biological sampling data available from Mexico for inclusion in the assessment. The lack of Mexican catch-at-age data is more critical in recent years when the Mexican catch has been as large as or larger than that of California. **Recommendation:** the Panel recommended that fishery and survey (IMECOCAL) data be acquired from Mexico and incorporated into future assessments.
e. **Recommendation:** the Panel recommended that spawning biomass be defined in terms of the numbers at the end of the year.
f. There were questions regarding the length of the time series to be included in the ASAP model, given uncertainties regarding earlier landings data. Although it was decided to use the entire time series, it was considered that the use of a truncated time series be evaluated further. **Recommendation:** the Panel recommended that consideration be given to using the ASAP model for 1978 to the present.
g. There were questions regarding the use of fishery-based weights at age to estimate population parameters as they are derived from only part of the population. **Recommendation:** the Panel recommended that this be examined and that a Von Bertalanffy curve be used if it includes samples from throughout the stock range.
h. **Recommendation:** the Panel recommended that all indices be plotted with confidence intervals in future assessments.
i. **Recommendation:** the Panel recommended that the STAT evaluate year – area

interactions in the GLM used to standardize the catch – effort data.

j. There was a discussion regarding selectivity patterns for the CPFV index which were estimated outside of the ASAP model. **Recommendation:** the Panel recommended that selectivity within the model be estimated by treating CPFV as a separate fishery using available biological data.

k. There were questions regarding how the catch-at-age (in number) is developed. **Recommendation:** the Panel recommended that this requirement should be included in the STAR terms of reference.

l. There was a question whether the CPFV index includes estimates of discards. It was noted that discard rates were only available in logbooks since 1994. **Recommendation:** the Panel recommended that the magnitude of discards be examined for the next assessment.

m. There was a brief discussion on the catch at age matrix, whether it should be extended beyond age 5+. It was noted that this may be more feasible if a truncated time series is used in the ASAP model. **Recommendation:** the Panel recommended that these issues be examined for the next assessment.

n. The Panel strongly recommends examination of the basis for the age composition data and the possible benefits of allowing for time-dependent selectivity.

o. The spotter index was not fit well. **Recommendation:** the trade-offs for leaving this index in or out of the assessment are complex and not readily apparent, and this decision should be left to the STAT as work progresses on the next assessment.

p. There were questions regarding how an assumed birth date of July 1st is accounted for in a model with a calendar year basis. **Recommendation:** the Panel recommended that, if practicable, the model year commence on July 1st to match the assumed birth date.

q. Noting the lack of a linear relationship between the aerial spotter index and the remaining indices, there was a discussion whether the aerial spotter index should be included in the ASAP model even though it is the only “recruitment index” available. This index assumes full selectivity across all ages. **Recommendation:** the Panel requested that selectivity within the model be estimated by creating a ‘fleet’ with no catch and no sampling. It was considered that this may not work but would at least provide selectivity estimates that could then be examined.

r. Observed vs. predicted catch proportions were presented, derived from the baseline ASAP model. Problems were identified with data through the 1970's, as residual patterns were not random. **Recommendation:** the Panel requested that this or a similar plot be used as a standard diagnostic in the assessment report.

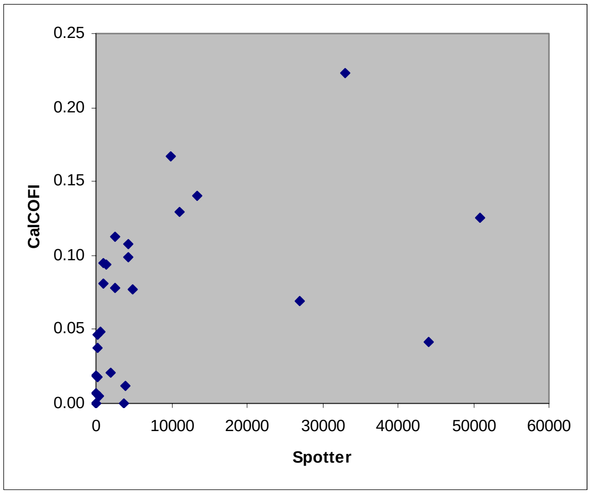
s. The specific details of the method used to develop catch-at-age data were not provided. **Recommendation**: the Panel requested that the STAT document how catch-at-age was estimated.

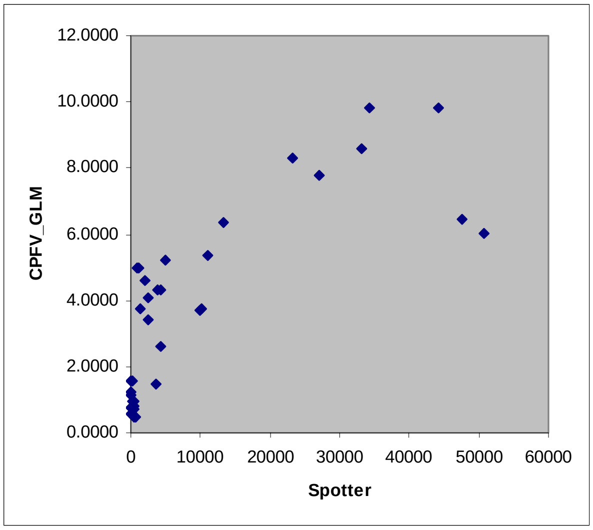
t. An error was made in summing catch-at-age data for annual estimates, due to misapplication of the July 1st birth date that is used in assigning ages. **Recommendation:** a correction needs to be made to account for the July 1 birth date that is used in assigning ages, when aggregating catch-at-age data over calendar year time periods.

u. Certain modifications are required to the ASAP model:
   - make allowance for fleet-specific weights-at-age (specifically the fishery weights-at-age for the fishery in the Pacific northwest);
   - define spawning biomass in terms of the numbers at the end of the year;

- explicitly include a zero age-class;
- include a log-normal bias-correction factor in the component of the objective function related to deviations about the stock-recruitment relationship; and
- quantify parameter uncertainty using the MCMC algorithm.

Figure 1. X-Y Plots of indices used in Mackerel assessment.





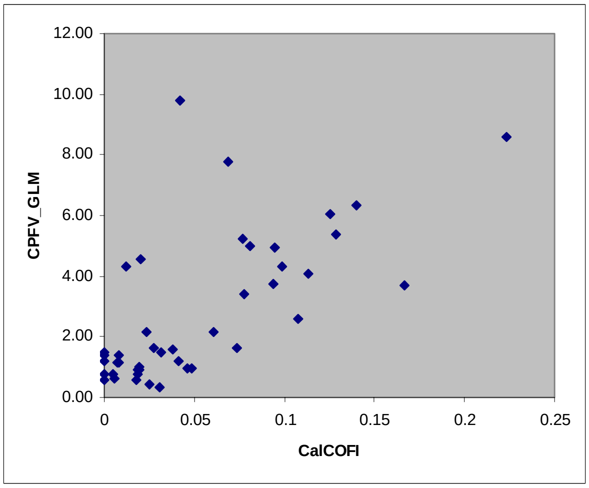


Figure 2. Bubble plots of residuals

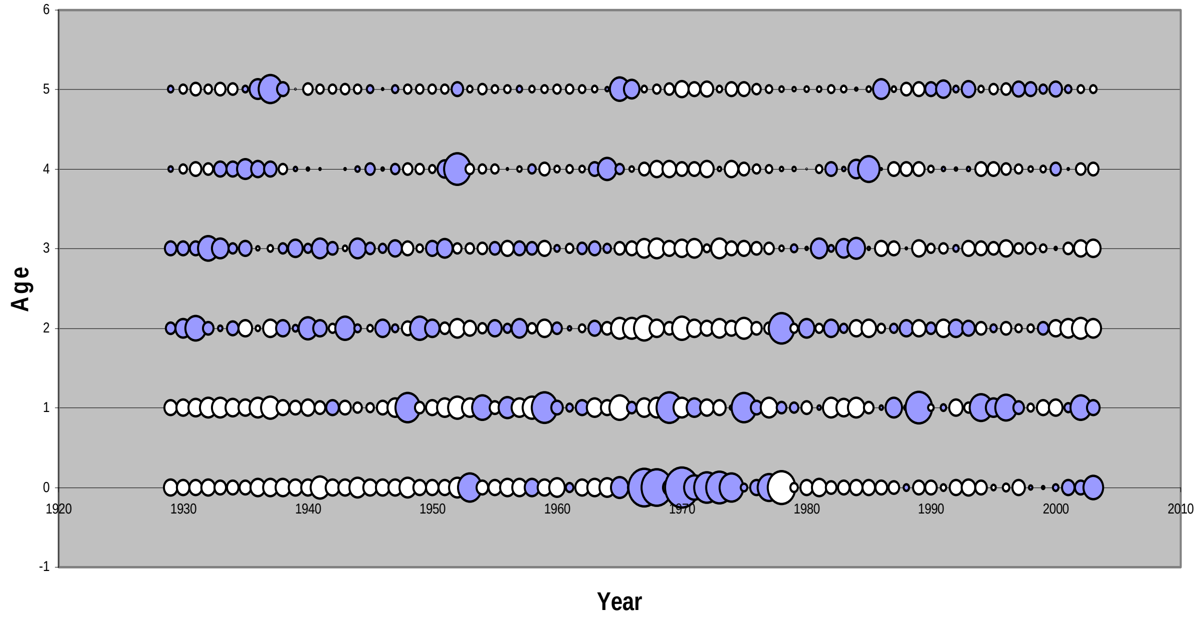


Table 1. New baseline results with increasing lambda catch.

G_2h Summary			
		1998 catch	
Lambda Catch	obj_fun	(obs-pred)	Biomass (Age 1+, Jan 2003)
100	1194.93	-8059.1	85,183
300	1197.07	-2673.2	87,138
1000	1197.84	-798.5	87,912