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Attachment 1
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PACIFIC MACKEREL (*Scomber japonicus*) STOCK ASSESSMENT FOR U.S. MANAGEMENT IN THE 2006-07 FISHING YEAR

by

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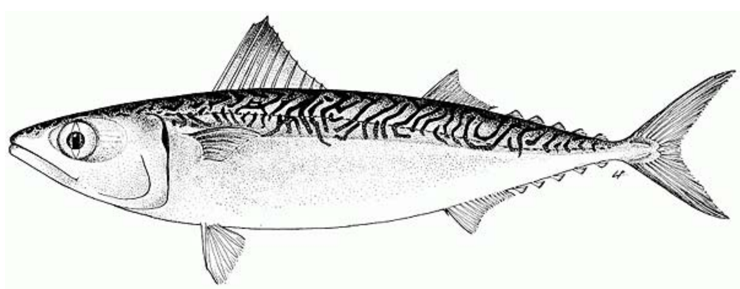

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PREFACE

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 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 quotas. 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 2005—setting a 2005-06 'fishing year' (July 1, 2005 – June 30, 2006) quota of 17,419 mt. The 2006-07 stock assessment presented here is an 'update' based on the ASAP model presented to the PFMC in 2005 (see Hill and Crone 2005). In this context, this updated assessment includes an additional year of data associated with sample information used in the overall assessment (e.g., from ongoing fishery-dependent and fishery-independent sampling programs), with similar model parameterizations as the analysis conducted in 2005. Also, sensitivity analysis related to the ASAP (2006) baseline model was conducted based on recommendations from previous reviews within the Science and Statistical Committee (SSC) and Coastal Pelagic Species Management Team (CPSMT) forums. In this context, an 'updated' stock assessment is presented here that follows PFMC protocols for 'off year' (i.e., years in which no Stock Assessment Review, STAR, takes place) population assessments of coastal pelagic species. Readers interested in further details regarding the sample data and model parameterizations used in this assessment should consult Hill and Crone (2005). The next formal STAR for Pacific mackerel is scheduled for 2007. Finally, electronic versions of model programs, input data, and displays (table and figures) can be obtained from the authors directly.

Stock distribution

There are possibly three spawning stocks of Pacific mackerel (*Scomber japonicus*) 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. The latter "northeastern Pacific Ocean" stock is harvested by fishers in the U.S. and Baja California, Mexico, and is considered in this assessment.

In terms of the U.S.-related management of this species through the PFMC, the northeastern Pacific Ocean population assessed here is considered an independent stock, 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, see PFMC (1998) and Management below.

Data

<u>Landings</u>

Pacific mackerel landings from both commercial and recreational fisheries in California and commercial landings in Baja California represent the catch time series (1929-06) used in the assessment, with estimates from all three fishing sectors pooled and treated as a single fishery within the model. Landings were aggregated on a fishing year (see Preface above) basis (Figure 1). For purposes of providing a HG for the 2006 fishing year (July 1, 2006-June 30, 2007), we assumed landings for April-June 2006 and July 2006-June 2007 would be similar to analogous periods in the previous 2005 fishing year; namely, April-June 2005 and then subsequently, July 2005-June 2006.

Additionally, biological data are collected through a California Department of Fish and Game (CDFG) port (commercial) sampling program. The CDFG has collected biological data on Pacific mackerel landed in the San Pedro (southern California) fishery since 1929. Biological data include the following specimen-based information: weight (whole in g), length (fork in mm), sex, maturity, and otoliths for age determination. Further, to some degree, port sampling data have been collected by researchers from Ensenda, Mexico (Instituto Nacional de la Pesca, INP) since 1989, but this information has not been made available to U.S.-based research teams. Thus, particular stock parameter assumptions (e.g., catch-at-age and weight-at-age distributions) used in the assessment model necessarily are based on using (assuming) sample data applicable to the California commercial fishery. We feel that a lack of Baja California port sampling data is not a serious problem for years when catches from the Mexico fleet are relatively low; however, recently, landings from both fisheries are assumed to be roughly equivalent, which potentially could introduce substantial bias inherent in unrepresentative sampling efforts (see Research and data needs below). The CDFG sample sizes relative to total landings are presented Hill and Crone (2005).

Biological parameters

Catch-at-age

Various sources were used to reconstruct a catch-at-age time series for Pacific mackerel (Hill and Crone 2005). For the most part, age determinations involved ageing research based on otoliths. Seven age classes represent the overall population, beginning with age-0 fish and ending with a 'plus group' for age 6 and older (Figure 2)

Weight-at-age

Year-specific weight-at-age distributions (i.e., a matrix) from fishery samples were developed for inclusion in the assessment model. This matrix was used to calculate population biomass ($\geq$ age-1 fish, *B*) and spawning stock biomass (*SSB*) from estimated population abundance (by age in numbers of fish, *N*) generated from the model efforts. While it is possible that the weight estimates associated with the population-at-large differ from those derived through commercial fishery samples, no such fishery-independent data exist to further explore this uncertainty and thus, we assumed growth was similar for both the population and the fisheries that exploit it.

Maturity-at-age

Maturity schedules were not year-specific, but rather assumed consistent from year-to-year (1929-06): age 0=0%; age 1=7%; age 2=25%; age 3=47%; age 4=73%; ages $\geq$5=100%.

Natural mortality-at-age

Natural mortality estimates were assumed constant across all ages (0-$\geq$6) and years (1929-05), M=0.5 yr^{-1}.

Survey indices of abundance

Fishery-independent survey data used in the ASAP model include (Figure 3): (1) an index ('proportion positive') of spawning abundance based on ichthyoplankton data collected through the ongoing CalCOFI survey; (2) a standardized, catch-per-unit-effort (CPUE) index from California-based commercial passenger fishing vessel (CPFV) logbooks; and (3) a standardized, index of total abundance from aerial 'spotter' plane survey data. The selectivity distributions associated with these three indices are presented in Figure 4 (bottom display). Ultimately, the three survey abundance indices for Pacific mackerel vary in quality both spatially and temporally; however, following recommendations from the previous STAR (conducted in 2004), no single index is proposed to be superior with respect to comprehensiveness or sampling design. Strengths and weaknesses of each survey program are presented in Hill and Crone (2005).

Assessment model

The stock assessment model for Pacific mackerel was developed 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. Hill and Crone (2005) and Legault and Restrepo (1998) provide additional details concerning the ASAP modeling platform.

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 (see above). Fishery-independent data used in the model consisted of three relative abundance time series (survey indices) described above. In general, parameterization of the ASAP (2006) baseline model was similar to the final configuration accepted in the previous assessment conducted in 2005. That is, this year's modeling efforts included sensitivity analysis that resulted in a relatively robust baseline model that generally mimicked the model scenario developed in 2005. Sensitivity analysis addressed both time-varying effective sample sizes (1929-60 and 1961-05) and selectivity (1929-65 and 1966-05) associated with the fishery (catch-at-age) data included in the model (Table 1B). Additionally, preliminary sensitivity analysis involved further examining error assumptions associated with recruitment estimation (recruitment 'deviations' from the stock-recruitment relationship), as well as steepness associated with the stock-recruitment relationship. Finally, given the limited scope of this updated assessment, further details (diagnostics, related parameterizations, and results say) regarding the ASAP (2006) baseline model will be made available at the upcoming meeting in May 2006.

Results

Overview

As stated previously, sensitivity analysis resulted in a robust ASAP (2006) baseline model. Results are presented under several broad categories, including likelihood component estimates (Table 1A), as well as other pertinent model-related estimates (e.g., fishery selectivity, fits to survey indices, and stock-recruitment relationship for Figures 4-6, respectively) and finally, management-related estimated time series (e.g., fishing mortality, biomass, spawning stock biomass, and recruitment for Figures 7-10, respectively). Model scenarios associated with sensitivity analysis (conducted resulted in generally similar findings as the baseline model; critical statistics from these model runs are presented in Table 1B.

Fishery selectivity

In general, an asymptotic fishery (catch-at-age distribution) selectivity ogive was estimated within the ASAP (2006) baseline model, with full selection at age 5 and slightly lower selectivity for the plus group (≥age-6 fish), see Figure 4 (top display).

Fits to survey indices

Fits to survey indices are presented in Figure 5. For all of the indices, recent data points were fit relatively well, with some poorly fit years earlier in the time series depending on the index of interest. For example, the abbreviated (i.e., ends in 2000) spotter index of abundance was poorly fit in the middle of the time series in the baseline configuration, as well as other scenarios in the overall sensitivity analysis.

Stock-recruitment relationship

The estimated Beverton-Holt (B-H) stock-recruitment relationship for the ASAP (2006) baseline model is presented in Figure 6. As indicated in last year's assessment findings, the baseline model configuration in 2006 resulted in a relatively low estimated steepness (0.36), i.e., minor compensatory processes acting on the spawning stock at low absolute levels of abundance.

Fishing mortality-at-age

Estimated fishing mortality (*F*)-at-age time series for the ASAP (2006) baseline model are presented in Figure 7.

Biomass

The estimated time series of population biomass (≥age-1 fish, *B*) for the ASAP (2006) baseline model is presented in Figure 8. Estimated *B* for the 2006 fishing year (July 2006-June 2007) was 112,700 mt. As stated previously, the overall *B* time series from this year's baseline model generally mimicked that estimated in 2005.

Spawning stock biomass

The estimated time series of spawning stock biomass (*SSB*) for the ASAP (2006) baseline model is presented in Figure 9.

Recruitment

In general, estimated recruitment (age-0 fish, *R*) was loosely constrained to a B-H stock-recruitment relationship (see above) in the ASAP (2006) baseline model (Figure 10). That is, given that these models are typically highly parameterized, 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.

Management

A federal FMP for CPS, including Pacific mackerel, was implemented by the PFMC in January 2000 (PFMC 1998), see Preface above. The FMP's harvest policy for Pacific mackerel, originally implemented by the State of California, is based on MacCall et al. (1985) simulation analysis, with the addition of a proration to nominally account for the portion of the stock assumed to inhabit U.S.-based waters. In Amendment 8 to the CPS FMP (PFMC 1998), the recommended maximum sustainable yield (MSY) harvest control rule for Pacific mackerel was:

$$HARVEST_{06} = (BIOMASS_{06} - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION,$$

where $HARVEST_{06}$ is the U.S. HG_{06} for the 2006 fishing year (July 2006-June 2007), CUTOFF (18,200 mt) is the lowest level of estimated biomass (*B*) at which harvest is allowed, FRACTION (0.3) is the fraction of *B* above the CUTOFF that can be harvested by fisheries, and DISTRIBUTION (0.7) is the average fraction of total *B* in U.S. waters. $BIOMASS_{06}$ (112,700 mt) is the estimated B_{06} as of July 1, 2006. Based on this harvest control rule, the HG_{06} is 19,845 mt, which reflects a quota that pertains to the 2006 fishing year (July 2006-June 2007):

B_{06} (mt)	Cutoff (mt)	Fraction	Distribution	HG_{06} (mt)
112,700	18,200	0.3	0.7	**19,845**

Finally, it is important to note that over the last several fishing years, the U.S.-based commercial fishery has not realized the recommended HGs (Figure 11, top display). However, uncertainty (to some degree) still exists concerning the magnitude of fisheries in Mexico that harvest Pacific mackerel and thus, caution is recommended when interpreting catch vs. HG statistics (see Landings above and Research and data needs below). In this context, total landings (including U.S. commercial, U.S. recreational, and Mexico commercial fisheries) vs. 'hypothetical,' population-wide HGs (i.e., ignoring the 'U.S. Distribution' parameter in the harvest control) are presented in Figure 11 (bottom display).

Research and data needs

Since the late 1920s, California's Pacific mackerel fishery has been sampled by CDFG for purposes of collecting biological (size/age) data that largely serve as the foundation for catch-at-age modeling efforts. However, as previous assessments have noted, biological data from the Mexico-based fishery are generally lacking and further, coalescing catch statistics from this fishery is also somewhat problematic. Thus, NOAA Fisheries (Southwest Fisheries Science Center) continues to emphasize collaborative data exchange with Mexico (INP, Ensenada) researchers to ensure assessment-related results accurately reflect this trans-boundary fish population. Finally, although the ASAP model is a sound modeling platform for analyzing fishery-related data, it is not possible to evaluate some parameterization (including diagnostics) issues inherent in fishery assessments and thus, efforts have begun to develop a length-based, age-structured population analysis for this stock using the Stock Synthesis 2 (SS2) modeling platform (Methot 2005a, 2005b). It is expected that alternative, SS2 model configurations for Pacific mackerel will be presented at the next formal STAR scheduled in 2007.

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Methot, R. D. 2005b. User manual for the assessment program Stock Synthesis 2 (SS2): Version 1.19 (April 27, 2005). NOAA Fisheries, Northwest Fisheries Science Center, 2725 Montlake Blvd. East , Seattle, WA 98112. 47 p.

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Table 1. Estimated likelihood components for the ASAP (2006) baseline model, display (A): *n*=number of observations in that component; λ=weight given that component, *RSS*=residual sum of squared deviations; and *L*=likelihood value. Sensitivity analysis associated with ASAP (2006) baseline model, display (B): scenario=parameterization revision; SSB_0=estimated virgin SSB (mt); SSB_{06}=estimated 2006 SSB (mt); steepness=estimated steepness from stock-recruitment relationship; and L_{total}=total likelihood value.

(A)

Component	*n*	λ	*RSS*	*L*	% of Total
Catch (weight) - fishery	78	101	0.0196	1.98	0.2%
Catch-at-age (proportions) - fishery	546	na	na	395.92	33.8%
Fits - Survey indices					
Spotter	37	1	81.92	452.63	
CPFV	63	1	16.78	58.74	
CalCOFI	45	1	27.04	129.28	
All	145	3	125.78	640.89	54.8%
Recruitment (deviations)	78	1	20.08	20.08	1.7%
Stock-recruit fit	78	1	20.08	110.95	9.5%
F penalty	546	0.001	0.5017	0.0005	<1%
Number of estimated parameters (Total)	181	na	na	na	
Objective function (Total)	na	na	na	1,169.81	100%

(B)

Scenario[1]	SSB_0	SSB_{06}	Steepness	L_{total}
(1) Baseline model	212,783	32,171	0.36	1,169.81
(2) Time-varying selectivtiy - Fishery	236,515	34,873	0.35	1,076.78
(3) Time-varying effective sample sizes - Fishery	272,185	39,119	0.34	1,219.23

[1]Scenario denotes: (1) final, ASAP (2006) baseline model configuration; (2) model configuration with fishery-related selectivity parameterization based on two time periods (1929-65 and 1966-05); and (3) model configuration with fishery-related effective sample sizes (catch-at-age) based on two time periods (1929-60 and 1961-05).

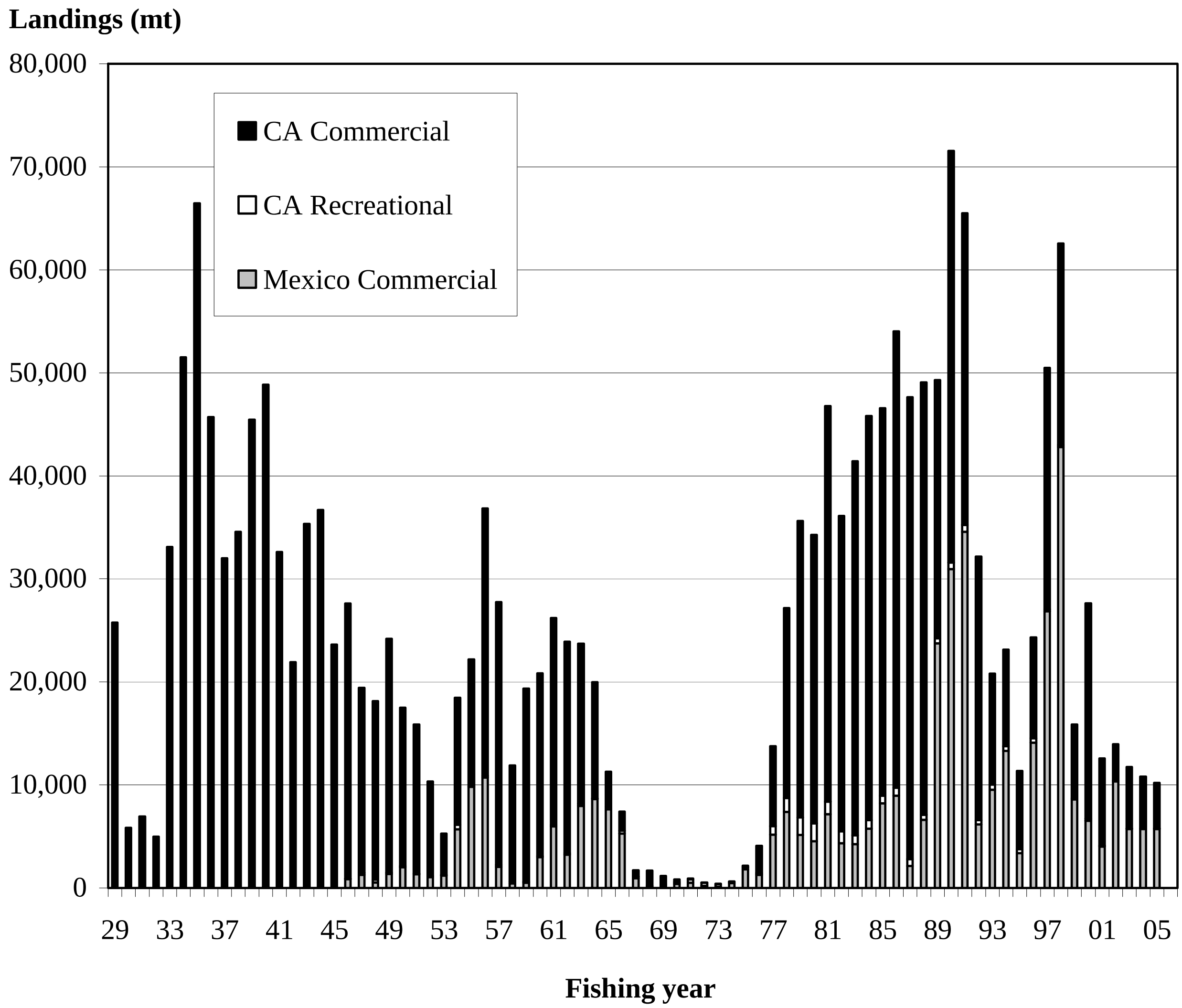

Figure 1. Commercial and recreational landings (mt) of Pacific mackerel in California (CA) and Baja California (MX), for 1929-05. Data from 1929-76 are based on a May-April 'fishing year,' and data from 1977-05 are based on a July-June 'fishing year.'

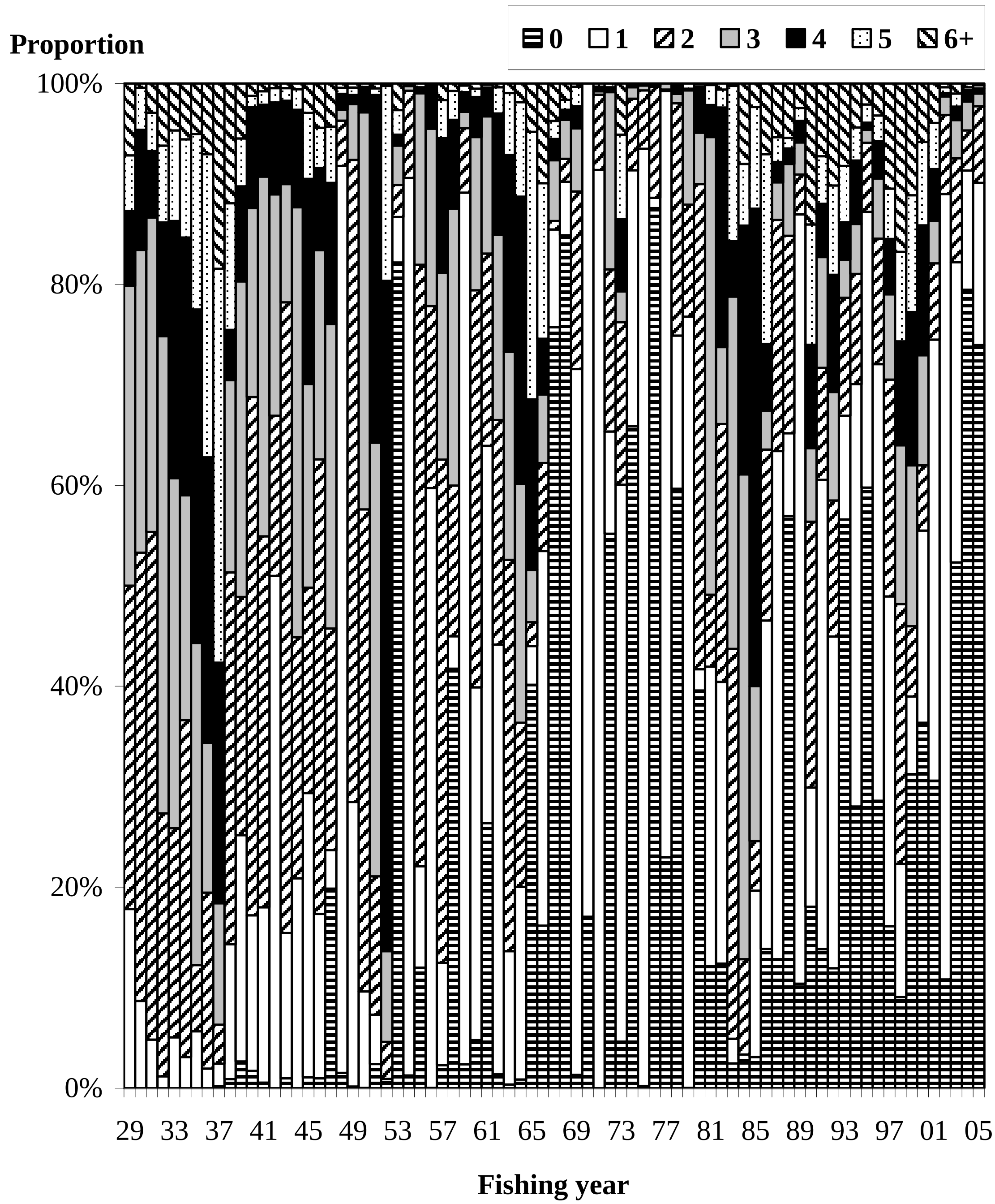

Figure 2. Pacific mackerel catch-at-age (in proportion) estimates used in the ASAP (2006) baseline model (1929-05).

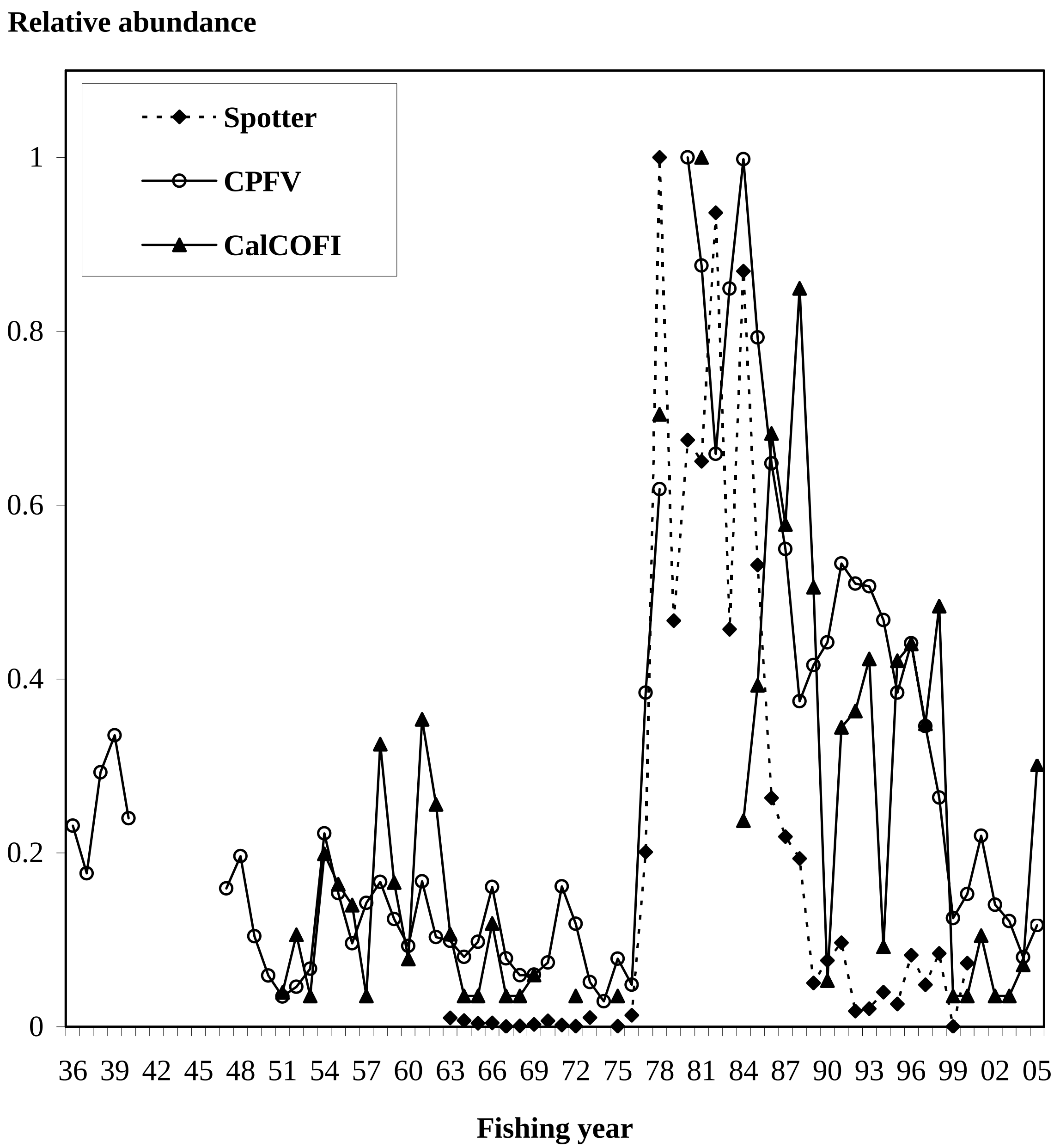

Figure 3. Indices of abundance time series for Pacific mackerel used in the ASAP (2006) baseline model. Indices are rescaled (normalized) to a maximum of 1.

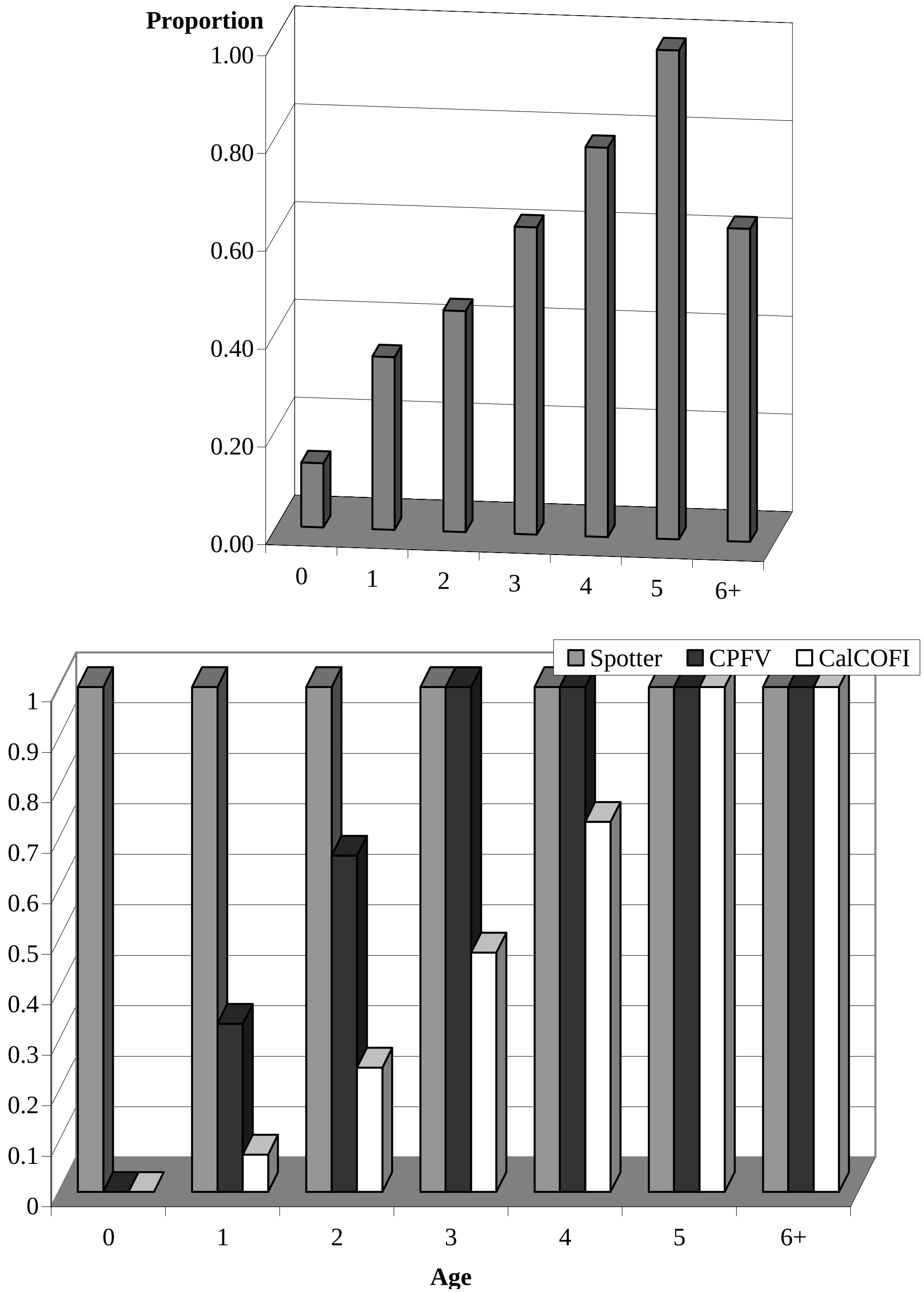

Figure 4. Estimated selectivity schedule for fishery (catch-at-age) data (top display) and assumed selectivity ogives for survey-related indices of abundance (Spotter, CPFV, and CalCOFI) from the ASAP (2006) baseline model. Note that CPFV ogive represents (1990-05), with ogive for 1929-89 parameterized with slightly different probabilities for ages 1 and 2.

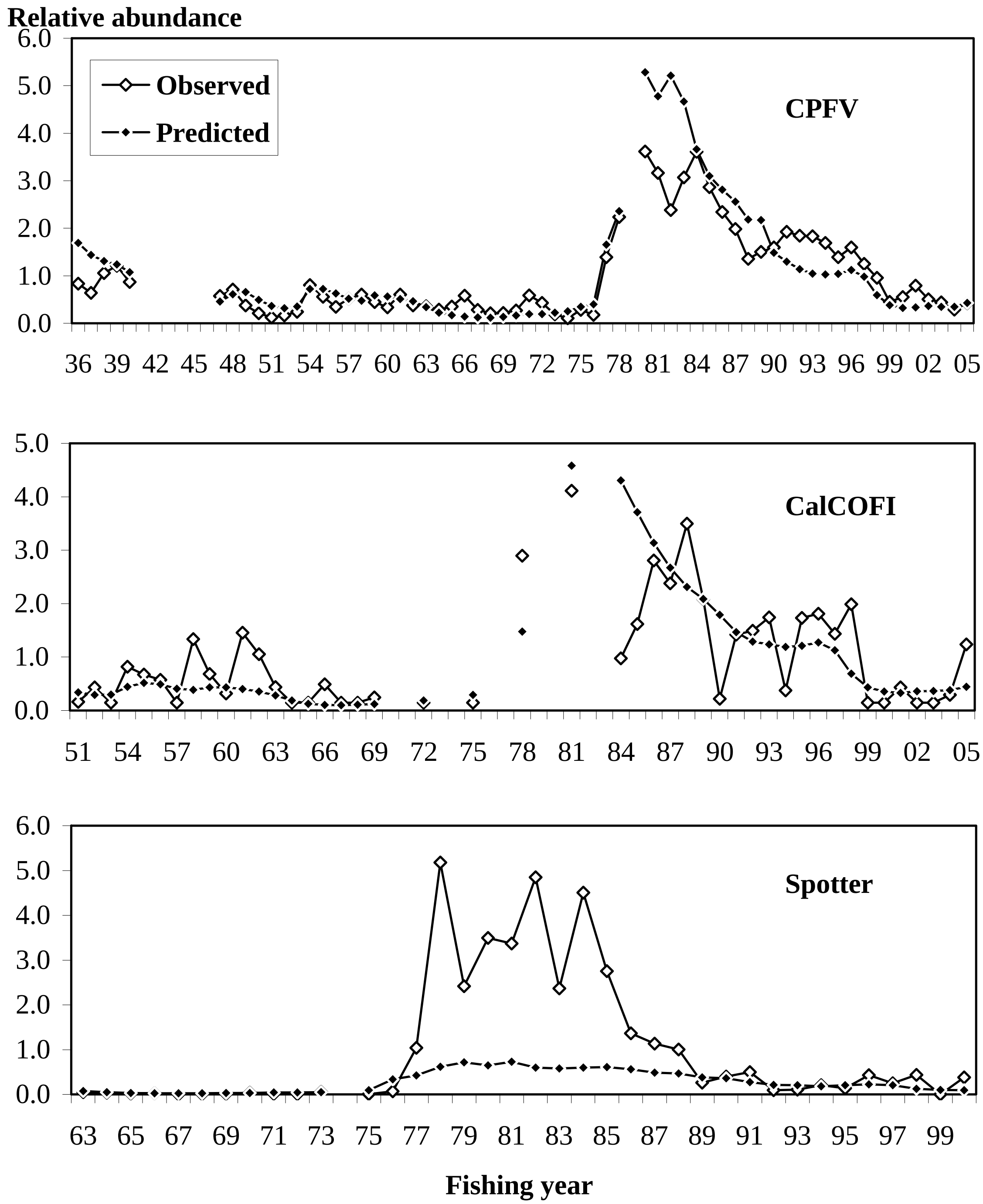

Figure 5. Observed and predicted estimates from survey index fits generated from the ASAP (2006) baseline model: CPFV (top display); CalCOFI (middle); and Spotter (bottom).

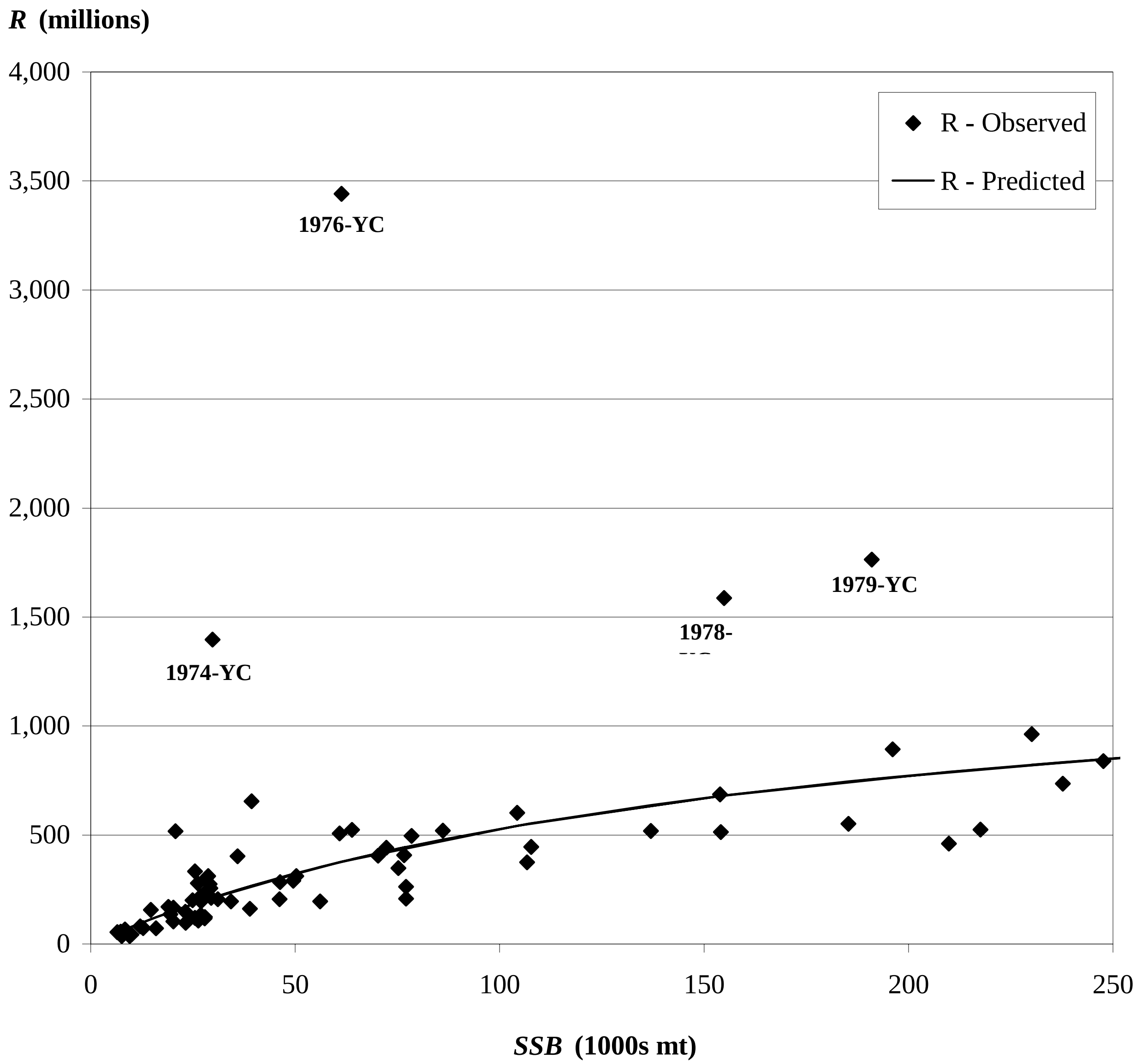

Figure 6. Beverton-Holt stock (SSB in 1000s mt)-recruitment (R in millions of fish) relationship for Pacific mackerel estimated in the ASAP (2006) baseline model (1929-05). Recruitment are presented as (year+1) values. Strong year classes are highlighted. Steepness=0.36

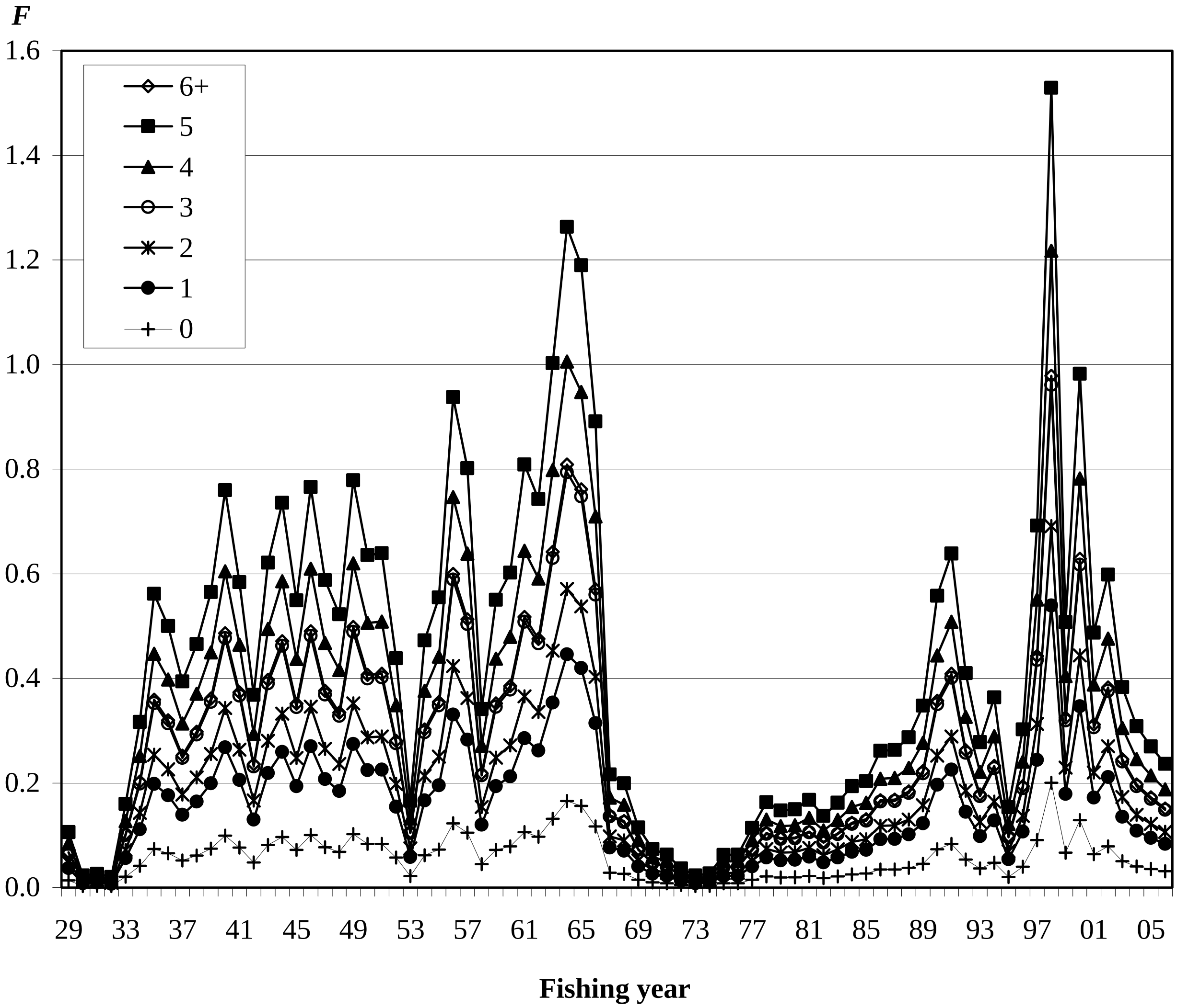

Figure 7. Estimated instantaneous fishing mortality (total) F-at-age for Pacific mackerel generated from the ASAP (2006) baseline model.

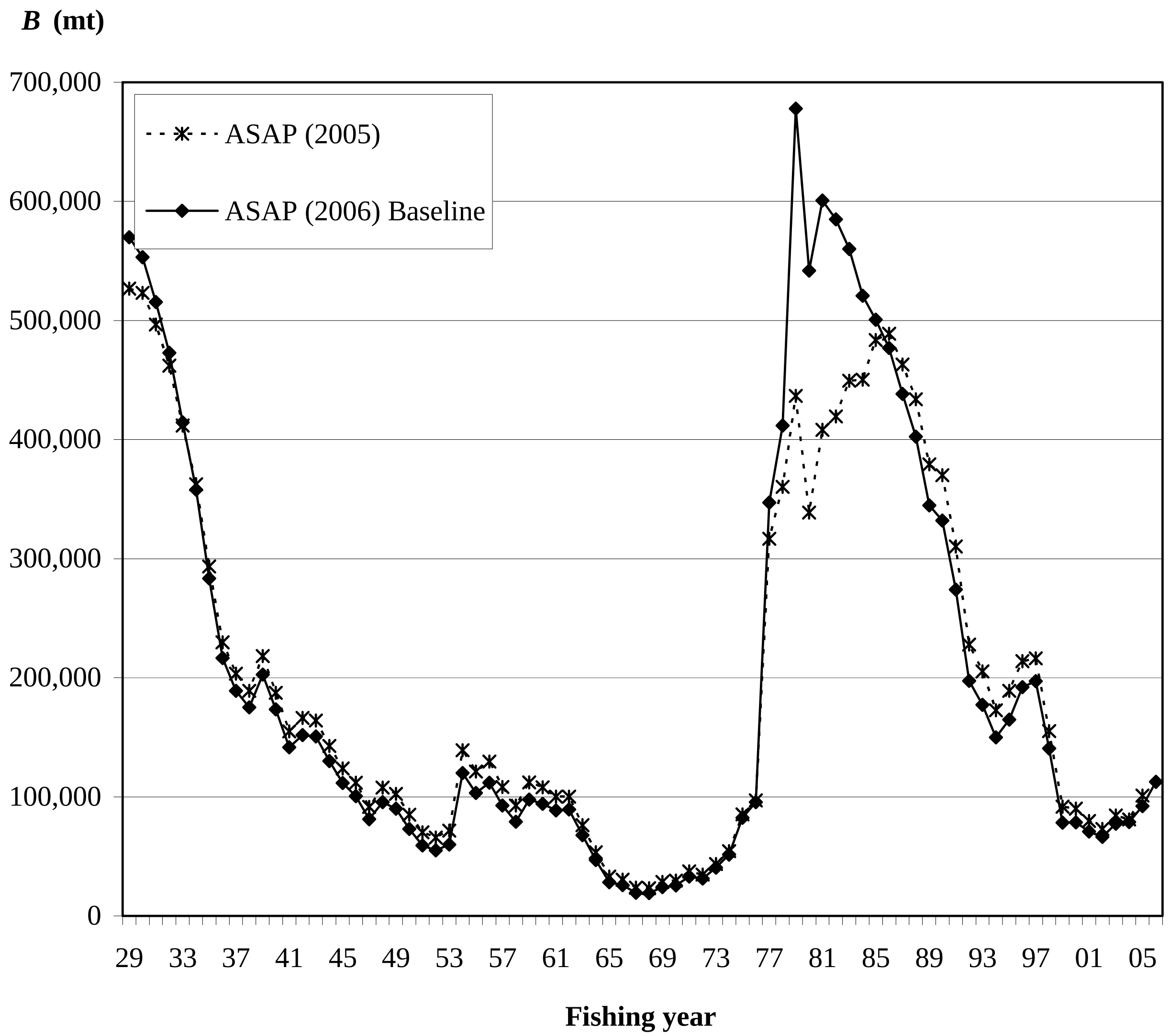

Figure 8. Estimated biomass (>age-1 fish, B in mt) of Pacific mackerel generated from the ASAP (2006) baseline model (1929-06). Estimated B for ASAP (2005) baseline model is also presented.

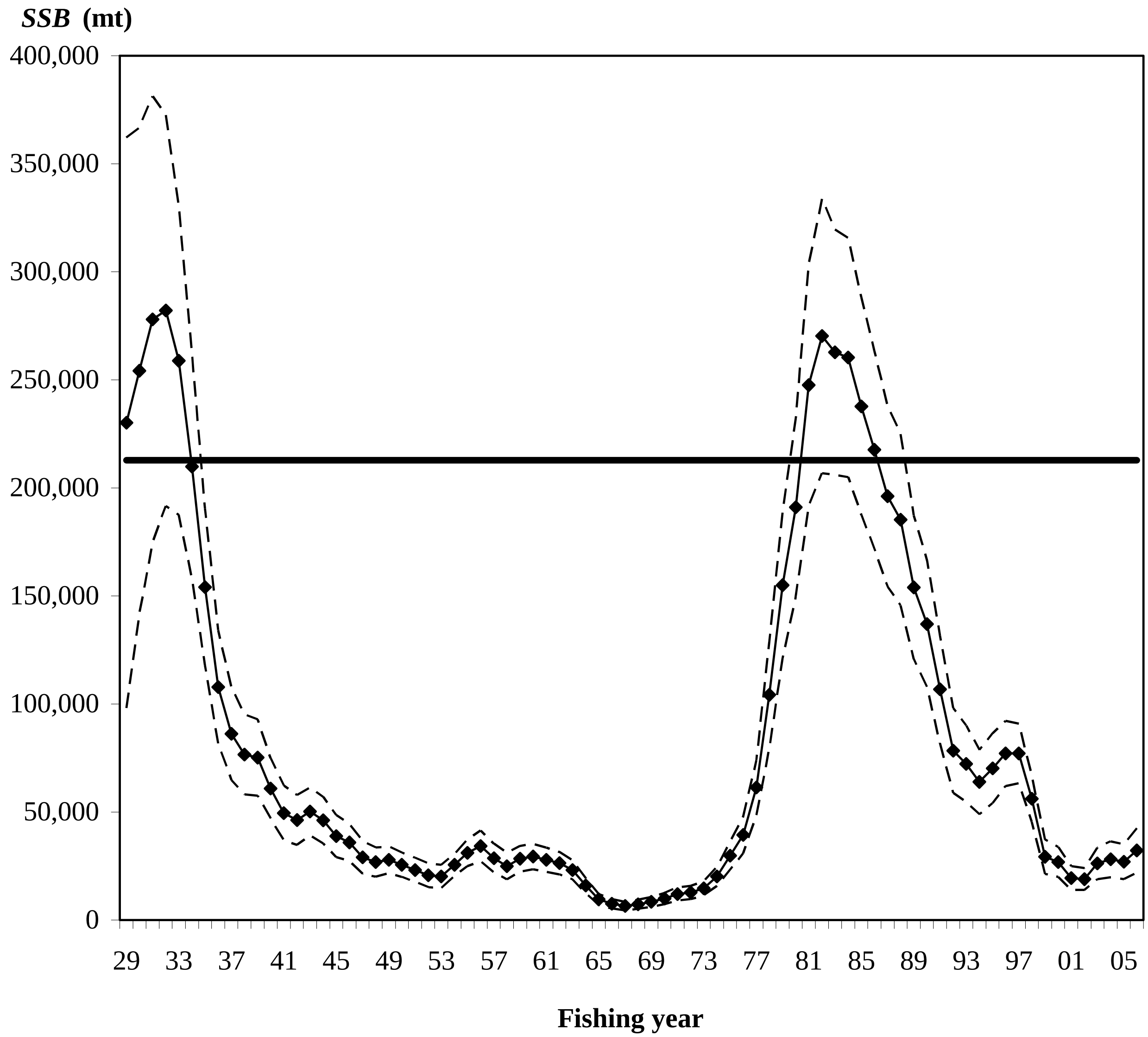

Figure 9. Estimated spawning stock biomass (SSB in mt) of Pacific mackerel generated from the ASAP (2006) baseline model (1929-06). The 95% CI associated with this time series is also presented. Estimated 'virgin' SSB from stock-recruitment relationship is presented as solid horizontal line (see Figure 6).

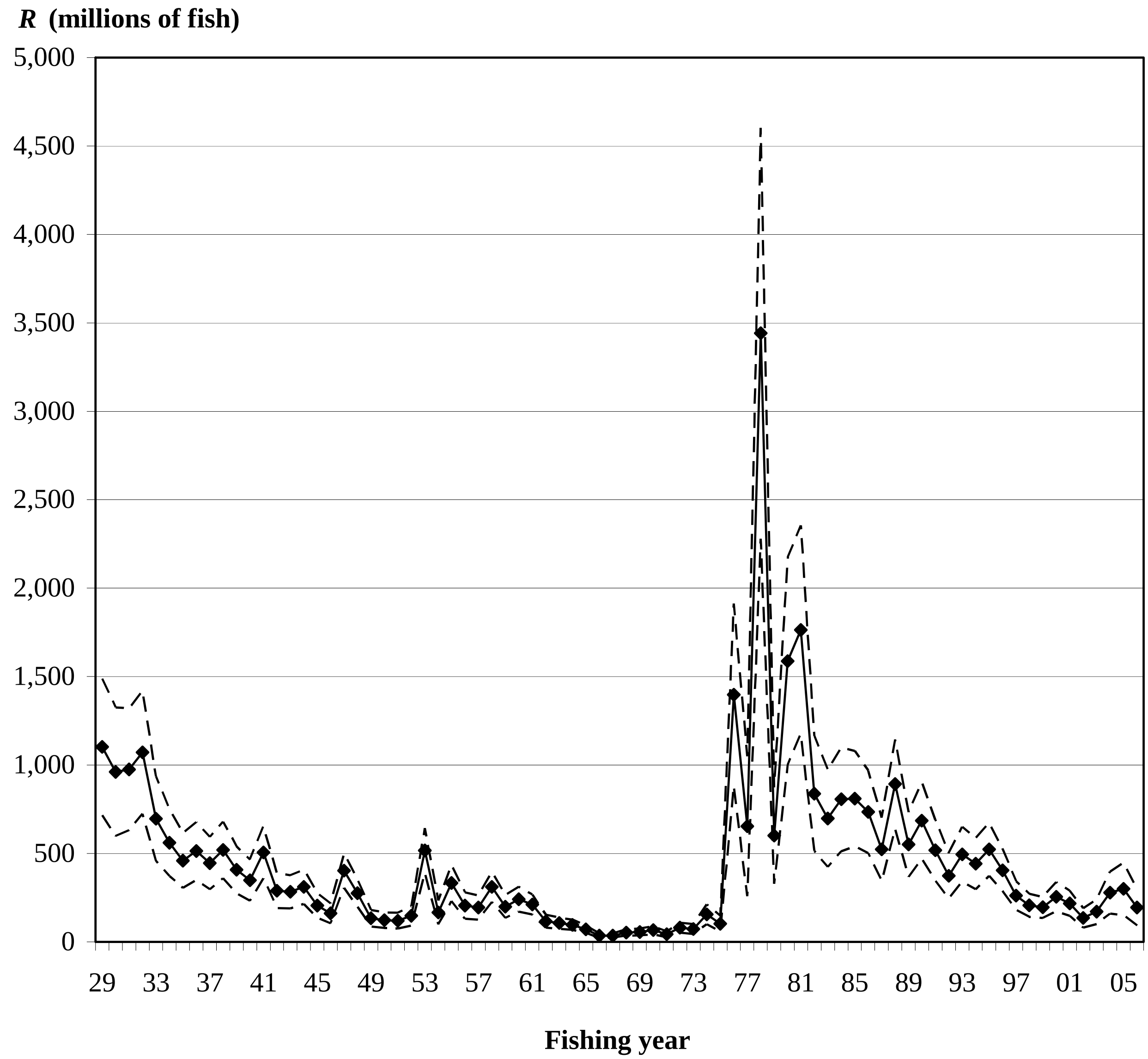

Figure 10. Estimated recruitment (age-0 fish in millions, R) of Pacific mackerel generated from the ASAP (2006) baseline model (1929-06). The 95% CI associated with this time series is also presented.

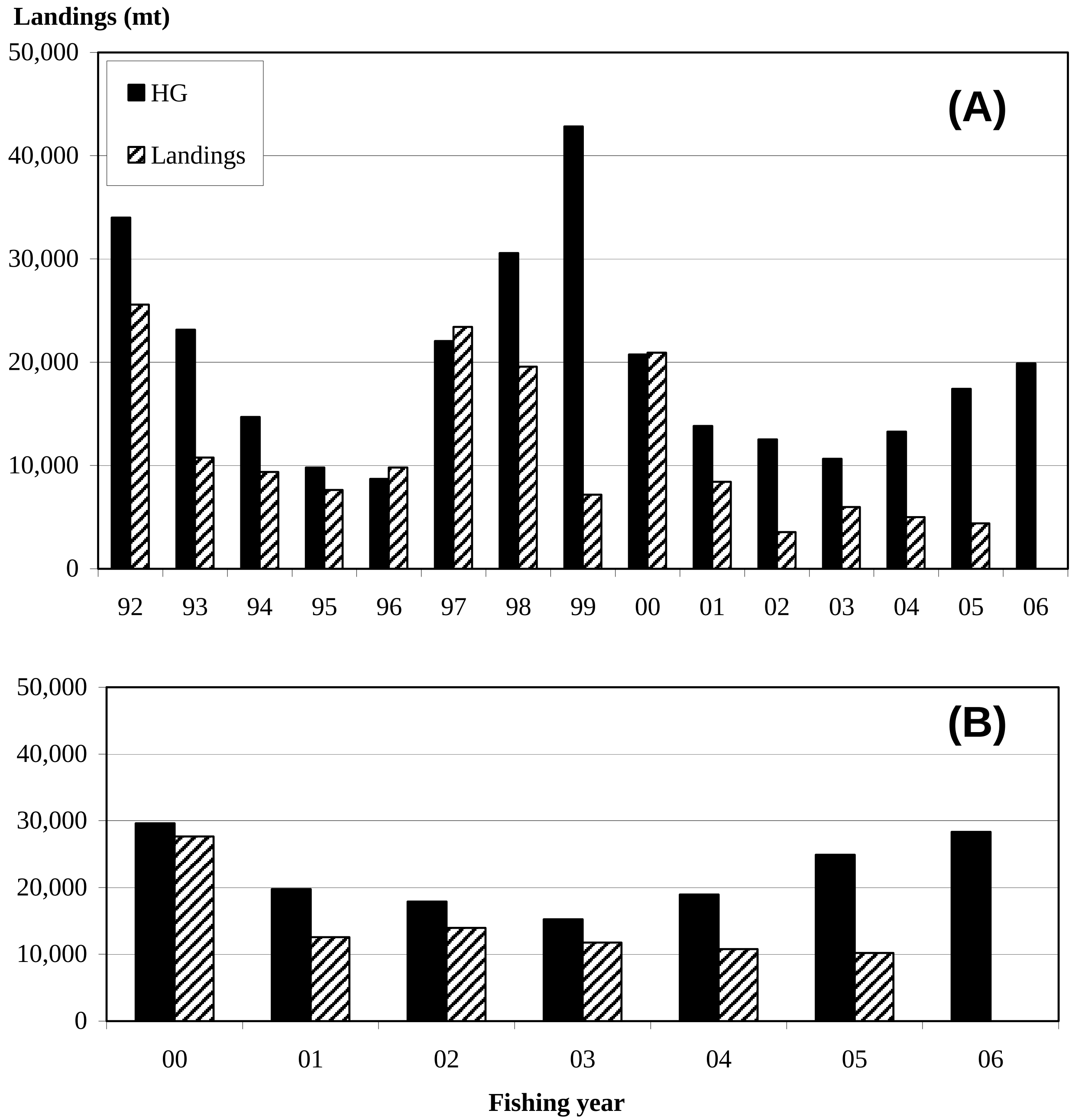

Figure 11. Commercial landings (California directed fishery in mt) and quotas (HGs in mt) for Pacific mackerel (1992-06), display (A). Total landings (mt) and hypothetical quotas for Pacific mackerel (2000-06) based on no U.S. Distribution parameter in harvest control rule, display (B). Incidental landings from Pacific Northwest fisheries are not included, but typically range 100 to 300 mt per year.