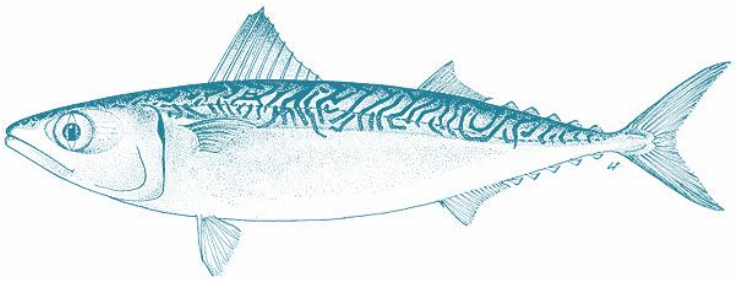
PACIFIC MACKEREL (*Scomber japonicus*) STOCK ASSESSMENT FOR USA MANAGEMENT IN THE 2015-16 FISHING YEAR



by

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PREFACE

A Pacific mackerel stock assessment is conducted every two years to provide management advice 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 USA Pacific coast. The HG for Pacific mackerel applies to a fishing/management season that spans from July 1st and ends on June 30th of the subsequent year (henceforth, presented as a 'fishing year'). For example, in this report, both two-year (2014-15) and single-year (2014) references refer to the same fishing year that spanned from July 1, 2014 to June 30, 2015. 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 setting HGs. For details regarding this harvest control rules applicable to this species, see Amendment 8 of the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP), section 4.0 (PFMC 1998). Also, for additional harvest stipulations and estimated quantities that have been recently adopted for management of the small pelagic fisheries, such as overfishing limits, acceptable biological catches, etc., see the CPS FMP-Amendment 13 (PFMC 2011). The last full stock assessment, review, and management advice for this species occurred in 2011 (Crone et al. 2011; STAR 2011a), with a HG serving for two fishing years. In April 2013 and 2014, catch-based projection assessments were conducted and used to determine the HG for the upcoming fishing year (Crone 2013; Crone and Hill 2014). The stock assessment report presented here was reviewed in April 2015 for purposes of advising management for two consecutive fishing years, 2015-16 and 2016-17 (STAR 2015). In 2017, a catch-based projection assessment is to be conducted for management for the following two consecutive fishing years, 2017-18 and 2018-19, with a full assessment scheduled for 2019.

This report is based on the most recent stock assessment review (STAR), which was held from April 27-29, 2015 at the Southwest Fisheries Science Center (SWFSC/NOAA/NMFS) in La Jolla, CA to evaluate the ongoing Pacific mackerel stock assessments that are used to provide management guidance on a systematic basis following PFMC procedures (PFMC 2014a). The first draft of the assessment report was distributed prior to the review meeting in April, which highlighted candidate models for consideration that addressed five primary areas related to both the quality of data and parameterizations included in the assessment, particularly, in the context of meeting the overriding goal to provide an estimate of current abundance annually for management purposes. An important area of discussion during the review was determination of the utility of fishery-independent data from a newly-implemented acoustic-trawl (AT) survey conducted by (SWFSC) in formal assessments of the stock. Given conclusions from the STAR panel regarding the adequacy (representativeness) of information from the AT survey for informing abundance estimation in the assessment at this time, data from this survey were not included in the model H3 proposed by the stock assessment team (STAT). Rather, noting unresolved areas and lack of consensus regarding a final model (STAR 2015), the STAT selected model H3 as the most objective configuration for advising management in the short-term, given: 1) it represented an updated configuration that closely resembled the previously accepted model (XA) for management in 2011; 2) was a plausible configuration ('state of nature'), with reasonable fits to input time series; 3) was stable in diagnostic-related perturbations; 4) was consistent with external information concerning stock availability to the fisheries, including results that reflected historically low estimates of recent stock biomass as indicated in the AT survey index of abundance time series, recent history of unrealized quotas by the USA commercial fishery, and limited catches reported in Mexico; and finally, 5) resulted in generally similar derived quantities useful to management as analogous models that included the AT survey data. Following the CPS terms of reference, this report focuses on data and

parameterizations included in model H3, and presents summary information for the candidate models also reviewed.

It is important to note that the STAR panel concluded the AT survey potentially represents the most objective information available for monitoring the inherently variable abundance of this species on a systematic basis. However, recommendations from the review found that the utility of these data for informing management at this time is limited due to assumptions regarding the extensive range of the stock related to the spatial boundaries of the survey, i.e., uncertainty surrounding the variable portion of the stock biomass in the area surveyed and determination of appropriate bounds for survey catchability for this species. Further, the STAT concurred with the STAR panel that further modeling investigations would benefit future development of an AT-based assessment that provides justifiable estimates of catchability (both inside and outside the model), includes plausible/supported biological assumptions and internal consistency among data sources used in the model, and generates robust results for management. Important areas of general consensus, unresolved sample/modeling uncertainties, and recommendations for future research are presented in the Model selection and evaluation, Unresolved problems and major uncertainties, and Research and Data Needs sections below. Finally, although model H3 did not include AT survey data, baseline information and related displays associated with candidate models that did incorporate these fishery-independent data are presented in the final assessment report here for purposes of more fully documenting relevant work conducted prior and during the review in April 2015.

EXECUTIVE SUMMARY

Stock

The full range of Pacific mackerel in the northeastern Pacific Ocean is from southeastern Alaska to Banderas Bay (Puerto Vallarta), Mexico, including the Gulf of California (Figure 1). The majority of the fish are typically distributed from Monterey Bay, California to Cabo San Lucas, Baja California Sur, being most abundant south of Point Conception, California. Although stock structure of this species off the Pacific coast of North America is not known definitively, it is generally hypothesized that three spawning aggregations exist currently: one in the Gulf of California; one in the vicinity of Cabo San Lucas; and one along the Pacific coast north of Punta Abreojos, Baja California Sur, extending north to waters off southern California, and even further off the Pacific Northwest, depending on oceanographic conditions. The latter sub-stock is harvested by fishermen in the USA and Baja California, Mexico, and is the population addressed in this assessment.

Catches

Pacific mackerel are primarily landed by commercial purse-seine vessels operating along the USA Pacific coast (California ports primarily, but also Oregon and Washington in more recent years), as well as off Baja California by a fleet based in Mexico (Figure ES-1 and Table ES-1). A minor recreational fishery, including commercial passenger fishing vessel (CPFV), small private boat, pier, beach, etc. has traditionally operated in California waters, but has contributed <5% to the total annual landings of Pacific mackerel in most years (Table ES-1). Catch time series from 1983 to 2014 were used in this assessment, based on landings from both commercial (USA and Mexico) and recreational (USA) fisheries. Landings were combined into a single fishery in model H3.

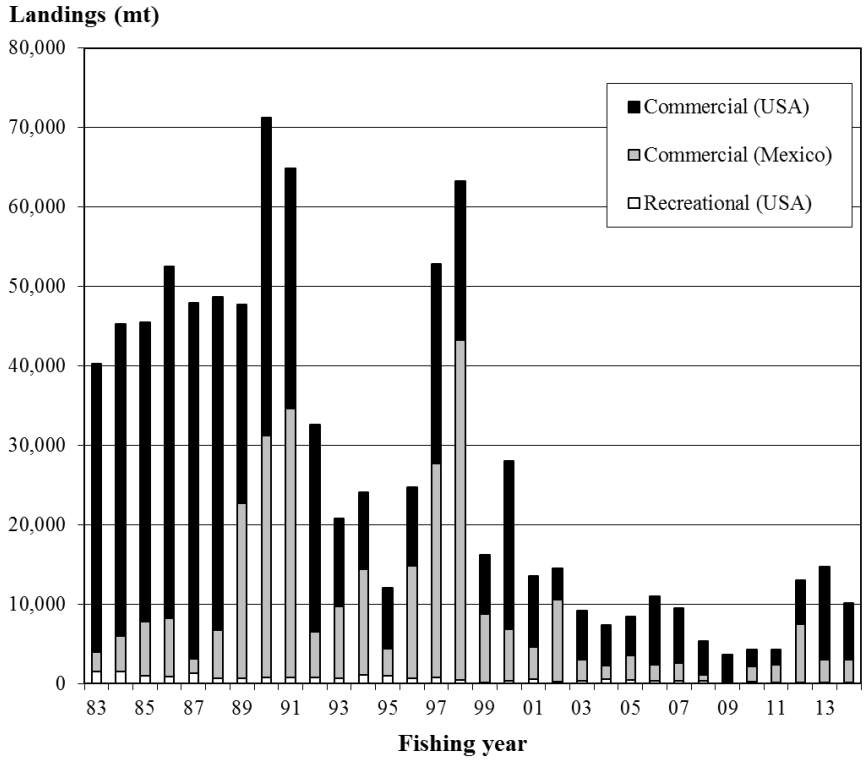

Figure ES-1. Landings of Pacific mackerel by fishery (1983-14). Model H3 is based on a single, combined fishery (see total estimates in Table ES-1).

Table ES-1. Landings (mt) of Pacific mackerel by fishery (1983-14). Recreational fishery proportion of total landings is also presented. Model H3 is based on a single, combined fishery (see total estimates).

	Commercial				Recreational		Recreational
Fishing year	MX	CA	OR	WA	CA	Total	Proportion
2004	1,711.4	5,011.8	110.4	23.7	544.0	7,401.3	0.07
2005	3,084.9	4,572.1	314.3	22.3	412.0	8,405.5	0.05
2006	1,986.1	7,870.2	669.4	41.8	372.0	10,939.5	0.03
2007	2,218.4	6,208.4	697.8	37.5	310.4	9,472.5	0.03
2008	803.1	4,203.9	57.6	9.0	280.3	5,353.9	0.05
2009	49.4	3,278.7	54.4	4.9	268.6	3,656.0	0.07
2010	1,916.7	2,047.0	47.8	1.6	216.6	4,229.7	0.05
2011	2,232.0	1,665.2	201.9	83.0	127.0	4,309.0	0.03
2012	7,390.0	3,201.5	1,587.8	693.4	100.2	12,972.9	0.01
2013	2,825.2	11,165.3	437.9	178.5	139.9	14,746.9	0.01
2014	2,825.0	5,445.5	1,172.3	544.8	136.4	10,124.0	0.01
Avg. (2004-14)	2,458.4	4,970.0	486.5	149.1	264.3	8,328.3	0.04

Data and assessment

Historically, various age-structured population dynamics models have been used to assess the status of Pacific mackerel off the USA Pacific coast, which were generally based on fishery landings, length/age compositions, and relative indices of abundance from fisheries and/or research surveys. The last full stock assessment of Pacific mackerel was completed in 2011 for USA management in the 2011-12 fishing year (Crone et al. 2011). All candidate model scenarios (configurations) presented in this assessment report were based on an age-structured modeling framework (Stock Synthesis) and age-based selectivity using both age data (commercial fishery) and depending on the configuration, length data from either the CPFV fleet alone (e.g., model H3) or including acoustic-trawl survey length data as well. Primary sources of sample data included in model H3 follow: catch time series (see Catches above); age compositions from the commercial fishery operating out of California (1983-14); and an index of abundance from the CPFV fleet (1983-14), with associated length compositions (1992-14). Note that some candidate models also included length composition (2005-13) and index of abundance time series from the acoustic-trawl (AT) survey (2005-2013). Model H3 closely resembled model XA (model from last full assessment conducted in 2011), including updated data/time series and generally similar assumptions and parameterizations.

Spawning stock biomass and recruitment

Recruitment was modeled using the Beverton-Holt (B-H) stock-recruitment relationship in all candidate models, with fixed recruitment variance ($\sigma_R = 0.75$) and estimated steepness ($h = 0.48$, model H3). Virgin recruitment (R_0) for model H3 was estimated to be roughly 0.54 billion age-0 fish, based on a virgin (female) spawning stock biomass estimate of approximately 78,425 mt. Since the mid-1980s, SSB has continually declined, remaining consistently low over the last decade (Table ES-2, Figure ES-2). Periods of high recruitment success were last observed in the mid-1980s and mid-1990s (1-2.7 billion fish), followed by very low recruitment success from the mid-1990s to 2012, with somewhat higher levels estimated most recently, noting that estimates are highly uncertain (Figure ES-3, Table ES-2).

Table ES-2. Estimated stock biomass (*B* in mt, age 1+ fish), recruitment (*R* in 1,000s, age-0 fish), spawning stock biomass (male and female *SSB*), and fishing mortality (*F*) time series for Pacific mackerel based on model H3 (2004-14).

Fishing year	*B (mt)*	*R* (1,000s of fish)	*SSB* (mt)	*F* (yr^{-1})
2004	31,714	179,264	12,948	0.21
2005	38,649	314,605	13,108	0.18
2006	58,056	221,319	16,139	0.17
2007	67,254	160,740	21,364	0.14
2008	68,392	125,712	26,957	0.08
2009	66,763	54,106	31,632	0.06
2010	57,925	158,783	33,506	0.07
2011	57,122	263,888	31,247	0.07
2012	69,164	225,612	29,970	0.18
2013	71,723	499,332	28,474	0.18
2014	97,395	387,989	30,807	0.09
2015	120,435	300,935	40,777	0.18
2016	118,968	327,350	47,178	0.18
Avg. 2004-16	71,043	247,664	28,008	0.14

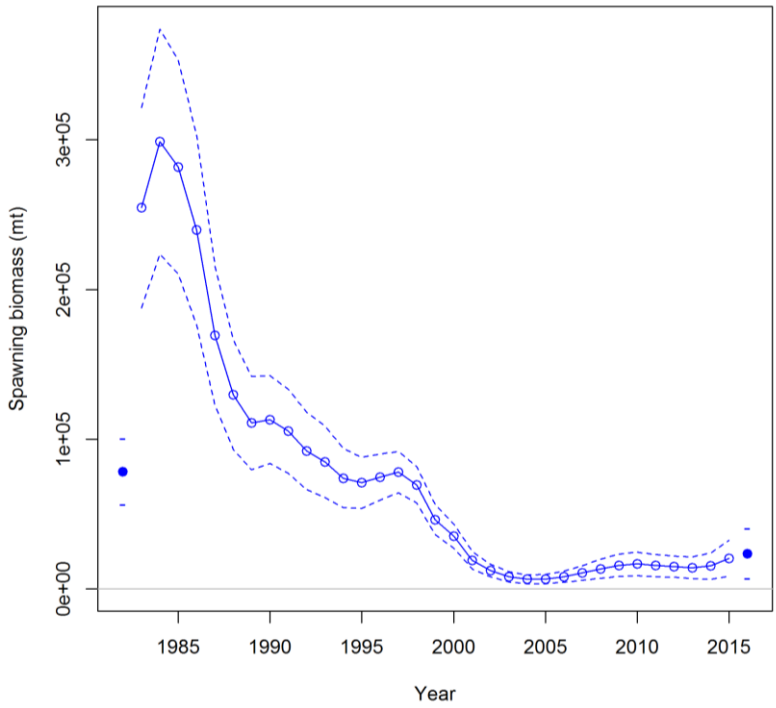

Figure ES-2. Estimated spawning stock biomass (female SSB) time series and 95% confidence intervals for Pacific mackerel for model H3. Solid dots reflect estimate of virgin (female) SSB and forecasted (female) SSB in July 2016.

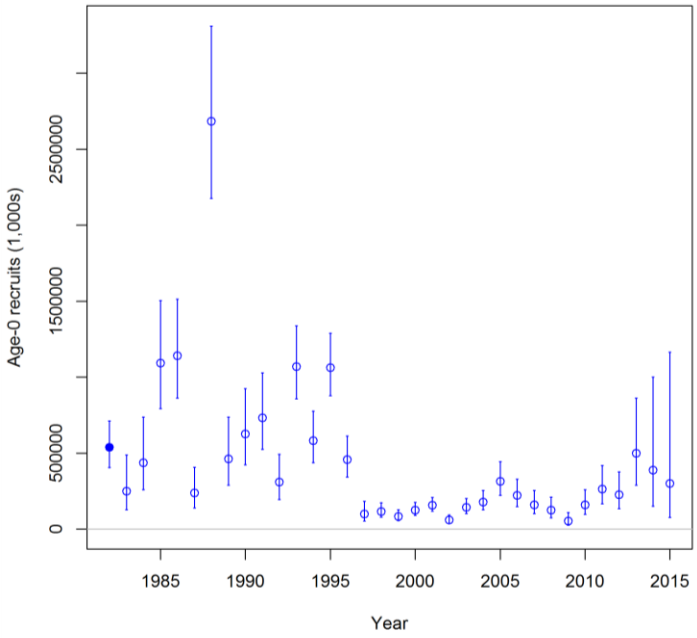

Figure ES-3. Estimated recruitment (1,000s of age-0 fish) time series and 95% confidence intervals for Pacific mackerel for model H3. Solid dots reflects estimate of virgin recruitment.

Stock biomass

Estimated stock biomass (mt, age 1+ fish) of Pacific mackerel is used for setting management specifications on an annual basis. Similar to estimated SSB, estimates of stock biomass have continually declined since the mid-1980s, remaining at low levels since 2004, with some increase noted in the last few years (Table ES-2, Figure ES-4). Past and present assessments of this stock indicate that since at least the late 1990s, abundance has remained at historically low levels (<150,000 mt).

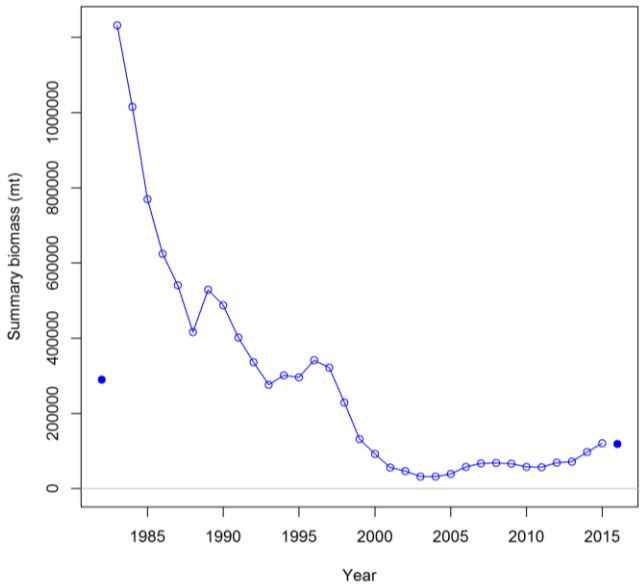

Figure ES-4. Estimated stock biomass (age 1+ fish, mt) time series for Pacific mackerel for model H3. Solid dots reflect estimate of virgin stock biomass and forecasted stock biomass in July 2016.

Exploitation status

Estimated rates of instantaneous fishing mortality (F, yr^{-1}) for this stock have fluctuated over time, from <0.1 to nearly 0.4 observed from the late 1990s to early 2000s. Recent estimates of fishing intensity indicate F has been generally <0.2 over the last decade (Table ES-2). Exploitation rate (annual catch/mid-year total biomass) time series closely follow the estimated Fs over time, with annual removal rates (including Mexico catches) reaching roughly 25-35% from the late 1990s to mid-2000s and <5 to 20% over the last decade (Figure ES-5).

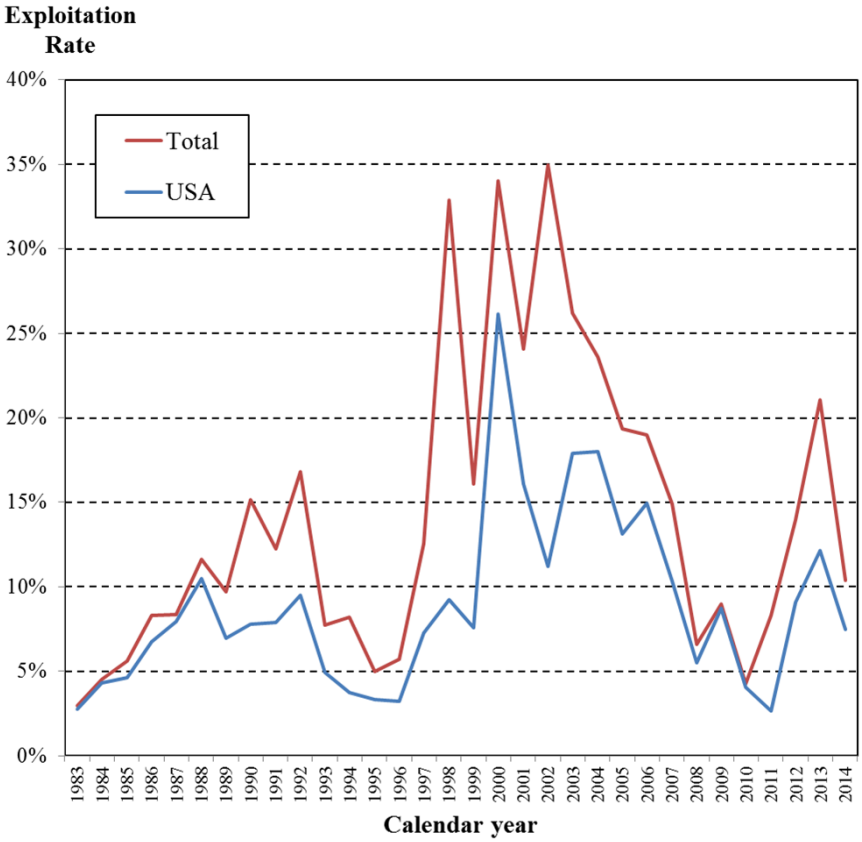

Figure ES-5. Estimated exploitation rate (catch/estimated stock biomass) time series (USA and total) for Pacific mackerel for model H3. Note that the reference year is the calendar not fishing year in this display.

Ecosystem considerations

Readers should consult PFMC (2014b, 2015) for information regarding environmental processes generally hypothesized to influence small pelagic finfish species, such as Pacific mackerel, that inhabit the California Current Ecosystem and broader northeastern Pacific Ocean. Also, see references included in AT survey index of abundance and Appendix A below.

Harvest control rules

The following harvest control rule results are applicable to model H3. Since 2000, the Pacific mackerel stock has been managed under a Federal Management Plan (FMP) harvest policy, stipulating that an optimum yield for this species should be set according to the following harvest control rule:

$$\text{Harvest} = (\text{Biomass-Cutoff}) \bullet E_{MSY} \bullet \text{Distribution},$$

where Harvest is the harvest guideline (HG), Biomass is age 1+ stock biomass (mt) in the respective fishing year (120,435 mt in July 2015 and 118,968 mt in July 2016), Cutoff (18,200 mt) is the lowest level of estimated biomass above which harvest is allowed, E_{MSY} (30%, also referred to as Fraction) is the proportion of biomass above the Cutoff that can be harvested by fisheries, and Distribution (70%) is the average proportion of total Biomass (ages 1+) assumed in USA waters (PFMC 1998). Harvest stipulations under the federal FMP are applied to a July-June fishing year. The HG estimate based on model H3 for July 2015 was 21,469 mt (Table ES-3a) and 21,161 mt for July 2016 (Table ES-3b). Note that the forecasted HG for 2016 was based on the assumption that the HG for 2015 (21,469 mt) would be fully utilized, with predicted recruitment (i.e., 2015 year-class) for the forecast period estimated directly from the stock-recruitment relationship (see STAR 2015). Landings and associated HGs since 2004 are presented in Figure ES-6. Finally, additional harvest control rule statistics recently required for USA Pacific coast fisheries (PFMC 2011) are also included in Table ES-3 for overfishing limits, as well as a range of acceptable biological catches and limits (ABCs and ACLs) based on different probability levels of overfishing using 'P-star' and associated ABC 'buffer' calculations.

Table ES-3. Pacific mackerel harvest control rules for model H3: a) for 2015-16 management year based on estimated stock biomass in July 2015; and b) for 2016-17 management year based on estimated stock biomass in July 2016.

a)

Harvest Control Rule Formulas										
OFL = BIOMASS * E_{MSY} * DISTRIBUTION										
$ABC_{P\text{-}star}$ = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION										
HG = (BIOMASS - CUTOFF) * E_{MSY} * DISTRIBUTION										
Harvest Formula Parameters										
BIOMASS (ages 1+, mt)	120,435									
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05	
ABC $Buffer_{Tier\ 1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531	
ABC $Buffer_{Tier\ 2}$	0.9135	0.8333	0.7577	0.6855	0.6153	0.5455	0.4741	0.3974	0.3060	
E_{MSY}	0.30									
CUTOFF (mt)	18,200									
DISTRIBUTION (U.S.)	0.70									
Harvest Control Rule Values (mt)										
OFL =	25,291									
$ABC_{Tier\ 1}$ =	24,173	23,087	22,016	20,940	19,839	18,681	17,415	15,944	13,990	
$ABC_{Tier\ 2}$ =	23,104	21,074	19,164	17,338	15,562	13,798	11,992	10,052	7,738	
HG =	21,469									

b)

Harvest Control Rule Formulas										
OFL = BIOMASS * E_{MSY} * DISTRIBUTION										
$ABC_{P\text{-}star}$ = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION										
HG = (BIOMASS - CUTOFF) * E_{MSY} * DISTRIBUTION										
Harvest Formula Parameters										
BIOMASS (ages 1+, mt)	118,968									
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05	
ABC $Buffer_{Tier\ 1}$	0.9558	0.9128	0.8705	0.8280	0.7844	0.7386	0.6886	0.6304	0.5531	
ABC $Buffer_{Tier\ 2}$	0.9135	0.8333	0.7577	0.6855	0.6153	0.5455	0.4741	0.3974	0.3060	
E_{MSY}	0.30									
CUTOFF (mt)	18,200									
DISTRIBUTION (U.S.)	0.70									
Harvest Control Rule Values (mt)										
OFL =	24,983									
$ABC_{Tier\ 1}$ =	23,878	22,805	21,747	20,685	19,597	18,453	17,203	15,750	13,819	
$ABC_{Tier\ 2}$ =	22,822	20,817	18,930	17,127	15,372	13,629	11,846	9,929	7,644	
HG =	21,161									

Management performance

From 1985 to 1991, the biomass exceeded 136,000 mt and no state quota restrictions were in effect. State of California quotas for 1992-00 fishing years averaged roughly 24,000 mt. The harvest guidelines (HG) averaged roughly 15,000 mt from 2001-06. In 2007, the HG was increased substantially to 40,000 mt and remained at this quota until 2009, when the calculated HG (55,408 mt) was reduced by management (PFMC) to 10,000 mt based on limited landings in recent years, with the quota applicable through the 2010-11 fishing year. Following the full stock assessment conducted in 2011, a harvest guideline of roughly 31,000 mt was implemented for two consecutive fishing years. Catch-based projection assessments were used to set quotas for 2013-14 (~39,000 mt) and 2014-15 (~29,000 mt). From a management context, the fishery has not fully utilized HGs recently, with average yields over the last decade of roughly 5,000 mt. Landings and associated HGs since 2004 are presented in Figure ES-6.

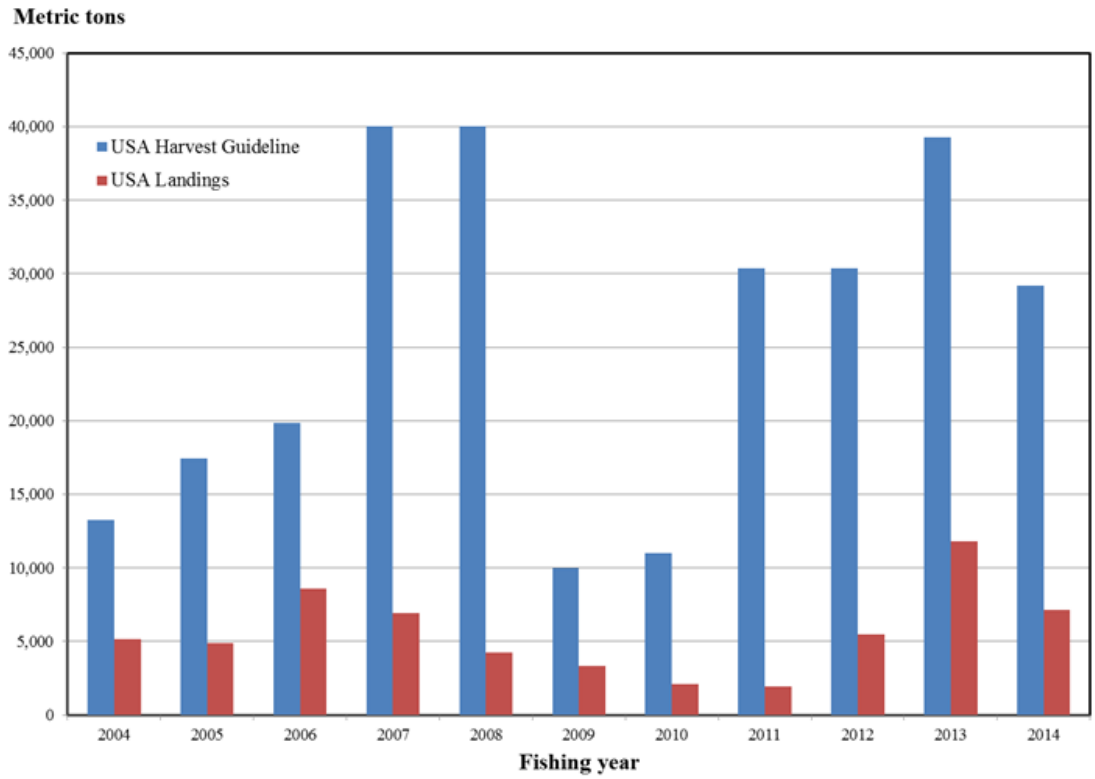

Figure ES-6. USA harvest guidelines (mt) and landings (mt) for Pacific mackerel since 2004.

Unresolved problems and major uncertainties

Overall, review criticisms focused on (STAR 2015): 1) the limitations of the AT survey data for assessing the status of the Pacific mackerel stock at this time for management, including justifying catchability coefficient (q) estimates, given the assumed, but uncertain distribution of this species in the context of the spatial boundaries of the survey area; and 2) problematic scaling within the model associated with assumptions regarding selectivity forms (dome-shaped vs. asymptotic) for the fishery age composition time series. Further discussion is presented in Unresolved problems and major uncertainties, and Research and Data Needs below.

Research and data needs

The most important research and associated data needed for improving the quality of the ongoing stock assessment of Pacific mackerel follow: 1) continued support of the AT survey effort conducted annually by the SWFSC, given its importance as the best scientific data collection program for developing a meaningful index of abundance for small pelagic fish stocks; 2) improving relations with Mexico federal administration and marine science institutions for purposes of expanding the present coverage of the AT survey operations for this transboundary stock, as well as to provide biological samples from both survey and fishery operations off the Pacific coast of Baja and mainland Mexico; 3) bolstering age/growth studies and production ageing efforts for this stock, including obtaining age samples systematically from the Pacific Northwest fisheries; 4) further model development that addresses an AT-based assessment model that provides justifiable estimates of catchability (both inside and outside the model), is based on plausible/supported biological assumptions, includes internally consistent sources of data (e.g., addresses selectivity tension among data sources and problematic scaling), and generates robust derived quantities useful to management; and finally, 5) revisiting harvest control rules for this fish population based on formal management strategy evaluations that consider the historical and recently available data, productivity/vulnerability of the stock, uncertainty surrounding recruitment/abundance, small pelagic fish assemblage at large, and economic factors. See Research and Data Needs below.