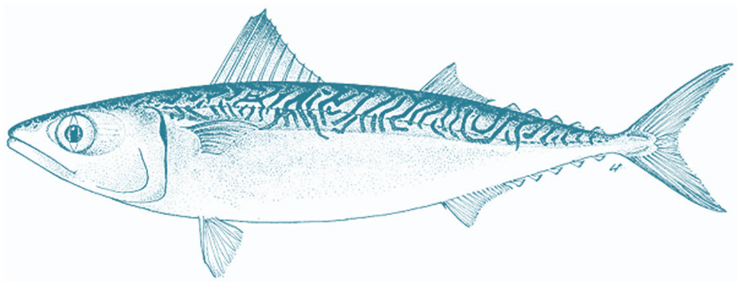
PACIFIC MACKEREL (*Scomber japonicus*) CATCH-ONLY STOCK ASSESSMENT FOR U.S. MANAGEMENT IN THE 2021-22 AND 2022-23 FISHING YEARS



by

Kevin T. Hill[1] and Juan P. Zwolinski[1,2]

[1]NOAA Fisheries
Southwest Fisheries Science Center
8901 La Jolla Shores Dr.
La Jolla, CA 92037
USA

[2]Institute of Marine Sciences
University of California Santa Cruz
Earth and Marine Sciences Building
Santa Cruz, CA 95064, USA
(affiliated with SWFSC)

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EXECUTIVE SUMMARY

Introduction

Beginning in 2015, the Pacific Fishery Management Council (Council) began an assessment/management schedule for Pacific mackerel (*Scomber japonicus*) based on: 1) conducting a full (benchmark) assessment every four years starting in 2015; 2) conducting a catch-only (biomass) projection assessment every four years starting in 2017; and 3) setting harvest and management guidelines as biennial specifications that serve for two consecutive (fishing) years. In 2015, a benchmark assessment was conducted for purposes of providing management advice that served for two (fishing) years, 2015-16 and 2016-17. A catch-only projection assessment was conducted in 2017, which provided harvest guidelines (HG) for fishing years 2017-18 and 2018-19. In 2019, a benchmark assessment was conducted that provided harvest metrics for two fishing years, 2019-20 and 2020-21. A catch-only projection assessment is presented here, which provides HGs for managing the Pacific mackerel resource for fishing years 2021-22 and 2022-23. The next benchmark assessment and review will take place during the spring 2023 for management in two consecutive fishing years, 2023-24 and 2024-25. Recent management specifications regarding allowable catches for Pacific mackerel through the 2020-21 fishing year are presented in Table 1.

Stock structure

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. 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 (Baja California, Mexico); and one along the Pacific coast north of Punta Abreojos (Baja California) that extends north to areas off southern California, and even further during favorable oceanographic periods to waters off the U.S. Pacific Northwest. The latter sub-stock is harvested by fishermen in the U.S. and Mexico, and is the population considered in this assessment.

Fishery

Pacific mackerel are primarily landed by commercial purse-seine vessels operating along the U.S Pacific coast, as well as a Mexican commercial fishery based in Ensenada, Baja California (Table 2). A minor recreational fishery, including commercial passenger fishing vessel (CPFV), small private boat, pier, beach, etc. has traditionally operated in California waters, with limited landings of Pacific mackerel relative to the commercial fishery operations (Table 2). Catch time series from 2008-20 were used in this assessment, based on landings from both commercial (U.S. and Mexico) and recreational (U.S.) fisheries. Recent and assumed landings for purposes of conducting this catch-only projection, including detailed footnotes, are summarized in Table 2.

Recent assessments

In the past, various age-structured population dynamics models have been used to assess the status of Pacific mackerel off the U.S. Pacific coast, which were generally based on fishery landings, age/length compositions, and relative indices of abundance from fisheries and/or research surveys. A benchmark assessment for Pacific mackerel was conducted in 2015 for providing management advice for two consecutive (fishing, July-June) years, 2015-16 and 2016-17. A catch-only projection assessment was conducted in 2017 that served for fishing years 2017-18 and 2018-19.

In 2019, a benchmark assessment was conducted for purposes of advising management for fishing years 2019-20 and 2020-21 (Crone et al. 2019). Final base model ALT_19 represented the supported/recommended model from the formal review conducted in April 2019. The age-structured modeling framework Stock Synthesis was used to develop final base model ALT_19, which included the following data (2008-18): fishery landings, age-composition time series associated with the fishery and acoustic-trawl (AT) survey; fishery empirical weight-at-age data; and AT index of abundance (Crone et al. 2019).

Catch-only projections

Details regarding the assessment model *ALT_19*, which has served as the baseline model for advising management since 2019, are presented in the latest stock assessment report (Crone et al. 2019). The projection model this year (*Baseline model 2021*) was parameterized similarly as the previous catch-only projections conducted in 2017 (Crone and Hill 2017), whereby only catch time series were updated in model *ALT_19*, with no other changes to data or parameterizations in the model. As per previous catch-only projection assessments, sensitivity analysis was conducted to address uncertainty regarding forecasted: 1) catch; and 2) recruitment strength, which is typically variable and not well informed in the model.

Important assessment model information follows, including data, parameterizations, and sensitivity analyses:

- Recent Pacific mackerel landings (catch) are presented in Table 2. See detailed table footnotes for specific catch estimate information.
- No other data or parameterizations were changed in the baseline model, including no changes to the underlying stock-recruitment relationship (e.g., estimates of virgin recruitment, steepness, and recruitment deviations), growth estimates, natural mortality assumptions, selectivity parameterizations, etc.
- Sensitivity analyses:
    - As in past Pacific mackerel projection analyses, estimated biomass and derived management quantities were robust to alternative catch time series assumed in the model. This sensitivity analysis was conducted to evaluate how uncertainty in predicting future catches (2021-22 and 2022-23) affects estimated management quantities (metrics such as OFL, ABC, and HG) from the projection model. Model scenarios assuming both reduced and fully utilized levels for forecasted catch had relatively little influence on estimates of abundance and associated stock status, primarily given that landings have remained at low levels over an extended timeframe.
        - Decreasing forecasted landing by using average catches (2017-19) instead of the HGs associated with USA commercial fisheries had a minor impact on projected biomass and only for the 2nd year of the projection period (Figure 1).
        - Uncertainty surrounding future catches of Pacific mackerel is largely related to Mexico's contribution to the overall landings in very recent years, with more certainty associated with predicting landings for USA commercial fisheries, which have not realized management-set catch limits for nearly two decades.
    - Derived management quantities were also relatively robust to alternative assumptions regarding projected recruitment strength, which resulted in generally similar estimated stock biomass (age 1+ fish, mt) time series used for advising management (Figure 1):

- In addition to the default projection for the *Baseline model 2021*, which assumed forecasted recruitment was related to estimated spawning biomass via the spawner-recruit relationship, two alternative recruitment scenarios were evaluated, including assuming forecasted recruitment was equal to: 1) recent 3-yr average recruitment (2015-17) associated with the main recruitment era in the model (2015-17); and 10-yr average recruitment (2008-17) associated with the entire main recruitment era in the model (Figure 2). Assumed levels of average recruitment translated to slightly lower estimates of stock biomass (Figure 1).

Recruitment

Recruitment was modeled using the Beverton-Holt (B-H) spawner-recruit relationship, with fixed recruitment variance (σ_R = 0.75) and steepness (h = 0.75) and with estimated virgin recruitment (R_0) and recruitment deviations (2008-18). Estimated recruitment time series indicated relatively high recruitment success for years 2011, 2016, and 2018 (Figure 2). It is important to note that a major area of uncertainty associated with ongoing Pacific mackerel assessments (as well as CPS assessments in general) is estimation of highly variable recent recruitment (age-0 fish), given the contribution of widely fluctuating estimates (pulses) of age-0 fish to estimated stock biomass (age-1+ fish, mt) used for management in subsequent years, e.g., age 0-2 fish typically comprise roughly 80% of the total population biomass in any given year.

Stock biomass

Pacific mackerel stock biomass (age 1+ fish, mt) used to advise management generally declined from 2008 to 2018, with the exception of 2012 that reflected abundance that included a large recruitment pulse estimated in 2011 (Figure 1). Stock biomass projections for this update varied slightly, depending on assumptions about catch and recruitment occurring during the recent and forecast periods (Figure 1). Stock biomass from the baseline 2021 projection model was projected to be 57,832 mt in July 2021 and 45,925 mt in July 2022 (Figure 1).

Exploitation status

Estimated rates of instantaneous fishing mortality (F, yr-1) for Pacific mackerel have fluctuated over the last decade (2008-18), from roughly 0.1 to 0.9, with recent Fs <0.4 (Crone et al. 2019). Exploitation rate (calendar year catch/mid-year total biomass) time series generally followed the estimated Fs over time, with annual removal rates (including Mexico catches) that ranged from roughly 5 to 25% over the modeled timeframe (Crone et al. 2019).

Ecosystem considerations

Pacific mackerel are part of the CPS assemblage of the northeastern Pacific Ocean, which represents an important forage base in the California Current. Pacific mackerel grow rapidly, feeding on plankton (plants and animals) and other CPS, including smaller northern anchovy, Pacific sardine, market squid etc. The species is prey for various larger fish (shark and tuna spp.), marine mammals, and seabirds. Pacific mackerel do not typically represent a dominant species of the CPS assemblage in most years, with absolute abundance likely less than that characterizing the more productive CPS, such as Pacific sardine and particularly, northern anchovy. However, population biomass can increase to relatively high levels during periods of favorable oceanographic conditions, which are hypothesized to be the driving mechanisms related to recruitment success and associated stock abundance of this species, as well as CPS in general.

Harvest control rules

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 be set according to the following harvest control rule (HCR):

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

where Harvest is the harvest guideline (HG), Biomass is age 1+ stock biomass (mt) in the respective fishing year (57,832 mt in July 2021 and 45,925 mt in July 2022), 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 stock biomass (ages 1+) assumed in U.S. waters (PFMC 1998). Harvest stipulations under the federal FMP are applied to a July-June fishing year. The HG estimate associated with the projection model for July 2021 was 8,323 mt (Table 3a) and 5,822 mt for July 2022 (Table 3b). Additional HCR statistics are also included in Tables 3a-b for specifying overfishing limits (OFL), 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.

Management performance

It is important to note that management performance metrics applicable to Pacific mackerel have changed over time, including final stipulated quotas based on HGs or ACLs, depending on the year, e.g., see Table 1 for quotas from 2015-20. The U.S. CPS fishery has not fully utilized quotas since the early 2000s, with total landings notably below management-recommended catch limits (Figure 3).

Unresolved problems and major uncertainties

In this assessment, the most objective source of abundance data (AT survey) available presently for assessing population dynamics of the Pacific mackerel stock is used in the context of both survey- and model-based assessments. However, it is important to recognize that: 1) inherent uncertainty regarding the portion of the hypothesized stock's distribution in U.S. waters each year (i.e., availability in surveyed areas) will never be known definitively, given its extensive range dictated largely by environmental factors; and as importantly, 2) the distribution portion is necessarily not constant over time, but changing in concert with prevailing oceanographic drivers. Spatial uncertainty regarding fish vs. survey distribution each year is primarily in terms of the species' latitudinal distribution south of San Diego into waters off Baja California and less so but still not well understood, its longitudinal distribution west of the survey's offshore boundaries. Given this underlying survey catchability (q) uncertainty, AT abundance time series was modeled using an informative prior in final base model (ALT_19; Crone et al. 2019), with plausible bounded estimates of q based on: life history assumptions; catch and larval density evaluations north-south of San Diego; and distribution metrics previously established and used presently in harvest control rules for the stock.

Research and data needs

The most important research and associated data needed for improving the quality of the ongoing Pacific mackerel stock assessments (both survey- and model-based) follow: 1) continuing/bolstering support of the AT survey operations conducted annually by the SWFSC, given its importance as a data collection program for developing a suitable index of abundance for this species and other CPS; 2) 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 coast of Baja California, likely requiring improving relations with Mexico's federal administration and related marine science institutions; and 3) using final base model ALT_19 to further evaluate important areas of uncertainty, including time-varying selectivity, recent recruitment variability/estimation assumptions, and data weighting considerations for composition time series.

References

Crone, P.R., K.T. Hill. 2017. Pacific mackerel biomass projection estimate for USA management in 2017-18 and 2018-19. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220, USA. 13 p. https://www.pcouncil.org/documents/2017/12/appendix-b-pacific-mackerel-stock-assessment-december-2017.pdf/

Crone, P. R., K.T. Hill, J.P. Zwolinski, M.J. Kinney. 2019. Pacific mackerel (*Scomber japonicus*) stock assessment for U.S. management in the 2019-20 and 2020-21 fishing years. Pacific Fishery Management Council, Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR 97220. 112 p. https://www.pcouncil.org/documents/2019/06/appendix-b-pacific-mackerel-stock-assessment-june-2019.pdf/

Table 1. Pacific mackerel harvest specifications (metric tons) for fishing years 2015-20. Acronyms follow: OFL is overfishing limit; $ABC_{0.45}$ is acceptable biological catch for P-star 0.45; ACL is annual catch limit; HG is harvest guideline; Incidental is incidental catch allowed; and ACT is annual catch target.

Harvest specifications (metric tons)	Fishing year					
	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Biomass	120,435	118,968	143,403	131,724	71,099	56,058
OFL	25,291	24,983	30,115	27,662	14,931	11,772
$ABC_{0.45}$ (Tier 2)	23,104	22,822	27,510	25,269	13,169	10,289
ACL (=ABC)	23,104	22,822	27,510	25,269	13,169	10,289
HG	21,469	21,161	26,293	23,840	11,109	7,950
Incidental	1,000	1,000	1,000	1,000	1,000	1,000
ACT	20,469	20,161	25,293	22,840	10,109	6,950

Table 2. Pacific mackerel landings (mt) for fishing years 2008 to 2022. Landings for 2017-18 and 2018-19 represent final and previous (parentheses) data values.

Fishing year	Commercial				Recreational	Total
	MX	CA	OR	WA	CA	
2008-09	803.1	4,331.6	57.6	9.0	251.1	5,452.3
2009-10	49.3	2,956.9	53.1	4.9	231.1	3,295.3
2010-11	1,916.8	2,052.7	49.0	1.6	187.2	4,207.3
2011-12	2,231.8	1,753.6	201.9	83.0	112.5	4,382.7
2012-13	7,390.0	3,171.0	1,587.8	719.2	76.0	12,944.0
2013-14	2,552.5	11,262.5	437.8	173.2	108.9	14,535.0
2014-15	4,098.8	4,409.7	1,214.6	502.2	197.2	10,422.5
2015-16	9,178.8	4,395.5	7.2	1.2	203.0	13,785.8
2016-17	11,706.8	2,490.0	3.7	21.6	149.6	14,371.8
2017-18[a]	585.1 (*2,794.3*)	1,388.4 (*1,309.4*)	45.4	4.2	244.5 (*167.6*)	2,267.6 (*4,320.9*)
2018-19[a]	12,329.1 (*6,066.3*)	2,195.5 (*4,773.4*)	111.6 (*341.8*)	10.2 (*140.5*)	179.6 (*165.3*)	14,826.0 (*11,487.2*)
2019-20[b]	2,334.4	3,784.2	50.1	5.0	77.6	6,251.3
2020-21[c]	5,263.9	696.6	115.1	4.3	110.5	6,190.4
2021-22[d]	5,082.9	NA	NA	NA	167.2	13,576.8
2022-23[e]	5,082.9	NA	NA	NA	167.2	11,074.2

[a]2017-18 and 2018-19 catch estimates were updated, given landings in last benchmark assessment (2019) reflected average landings for fishing years 2013-17 (old catch estimates in parentheses).

[b]2019-20 catch estimates were updated, given landings in assessment (2019) reflected forecasted estimates equal to fishing year 2018 estimates.

[c]2020-21 catch estimates were updated: 1) given landings in assessment (2019) reflected forecasted estimates equal to fishing year 2019 forecasted estimate; and 2) landings reflect preliminary estimates, given landings for Jan-Jun 2021 represent forecasted estimates (avg. catch Jan-Jun 2017-19 for each fishery).

[d]2021-22 catch estimates are as follows: MX=avg. catch 2017-19; CA/OR/WA=HG 2021-22 (8,323 mt); Recreational=avg. catch 2017-19.

[e]2022-23 catch estimates are as follows: MX=avg. catch 2017-19; CA/OR/WA=HG 2022-23 (5,822 mt); Recreational=avg. catch 2017-19.

Table 3. Pacific mackerel harvest control rules (HCR) for fishing years from the base model: A) 2021-22; and B) 2022-23. Acronyms follow: OFL is overfishing limit; ABC is acceptable biological catch; HG is harvest guideline; E_{MSY} is proxy for exploitation rate at maximum sustainable yield; σ is sigma uncertainty level; and P* is the overfishing probability value for ABC calculation.

a) Fishing year 2021-22

Harvest Control Rule Formulas									
OFL = BIOMASS * E_{MSY} * DISTRIBUTION									
$ABC_{P\text{-}star}$ = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION									
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	**57,832**								
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\ 1}$	0.9391	0.8810	0.8248	0.7694	0.7137	0.6565	0.5956	0.5269	0.4394
ABC $Buffer_{Tier\ 2}$	0.8819	0.7762	0.6802	0.5919	0.5094	0.4310	0.3547	0.2776	0.1930
ABC $Buffer_{Tier\ 3}$	0.7778	0.6025	0.4627	0.3504	0.2595	0.1858	0.1258	0.0771	0.0373
E_{MSY}≡FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.70								
Harvest Control Rule Values (MT)									
OFL =	**12,145**								
$ABC_{Tier\ 1}$ =	11,405	10,700	10,017	9,344	8,668	7,973	7,233	6,399	5,336
$ABC_{Tier\ 2}$ =	10,711	9,427	8,261	7,189	6,187	5,235	4,308	3,371	2,344
$ABC_{Tier\ 3}$ =	9,446	7,317	5,620	4,255	3,152	2,256	1,528	936	453
HG =	**8,323**								

b) Fishing year 2022-23

Harvest Control Rule Formulas									
OFL = BIOMASS * E_{MSY} * DISTRIBUTION									
$ABC_{P\text{-}star}$ = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION									
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION									
Harvest Formula Parameters									
BIOMASS (ages 1+, mt)	**45,925**								
P-star	0.45	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05
ABC $Buffer_{Tier\ 1}$	0.9391	0.8810	0.8248	0.7694	0.7137	0.6565	0.5956	0.5269	0.4394
ABC $Buffer_{Tier\ 2}$	0.8819	0.7762	0.6802	0.5919	0.5094	0.4310	0.3547	0.2776	0.1930
ABC $Buffer_{Tier\ 3}$	0.7778	0.6025	0.4627	0.3504	0.2595	0.1858	0.1258	0.0771	0.0373
E_{MSY}≡FRACTION	0.30								
CUTOFF (mt)	18,200								
DISTRIBUTION (U.S.)	0.70								
Harvest Control Rule Values (MT)									
OFL =	**9,644**								
$ABC_{Tier\ 1}$ =	9,057	8,497	7,954	7,420	6,883	6,332	5,744	5,081	4,237
$ABC_{Tier\ 2}$ =	8,505	7,486	6,560	5,709	4,913	4,157	3,421	2,677	1,862
$ABC_{Tier\ 3}$ =	7,501	5,811	4,463	3,379	2,503	1,792	1,213	743	359
HG =	**5,822**								

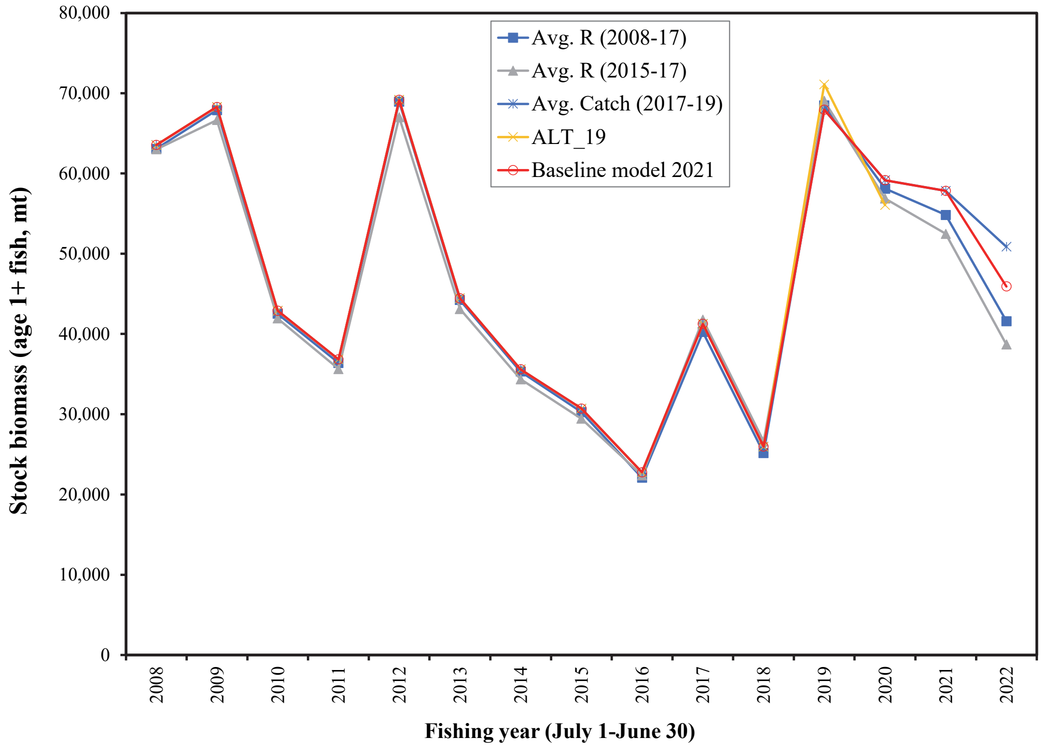

Figure 1. Pacific mackerel stock biomass (age 1+ fish, mt) time series associated with alternative assumptions (scenarios) regarding recruitment and catch levels.

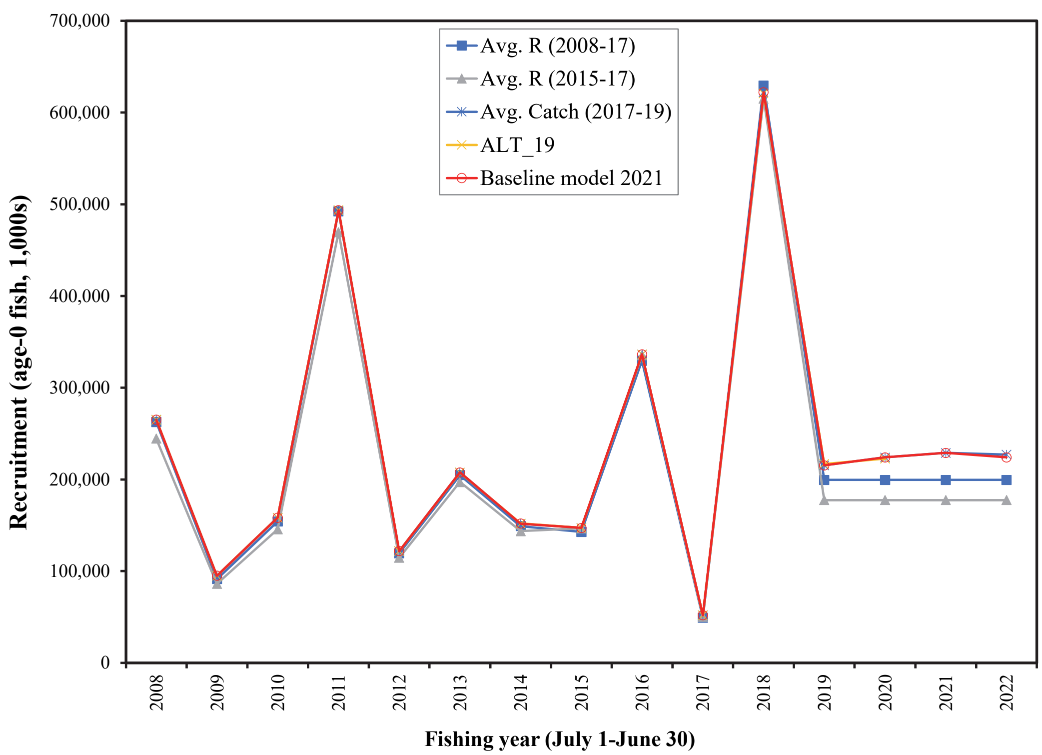

Figure 2. Pacific mackerel recruitment (age-0 fish, 1,000s) time series associated with alternative assumptions (scenarios) regarding recruitment and catch levels.

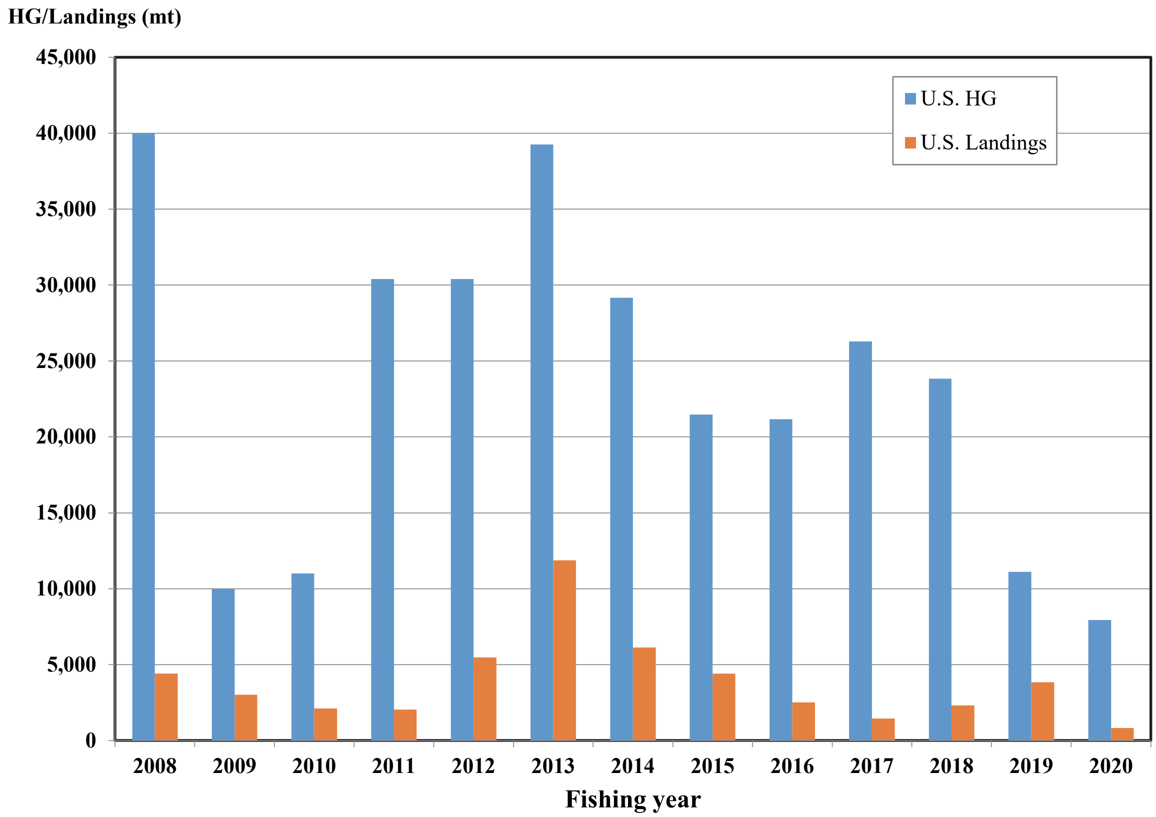

Figure 3. U.S. Pacific mackerel harvest guidelines and landings (mt) since fishing year 2008.