Pacific Mackerel

Stock Assessment Review (STAR) Panel Meeting Report

National Oceanic and Atmospheric Association (NOAA) / Southwest Fisheries Science Center (SWFSC)
La Jolla, California
April 11-13, 2023

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Tien-Shui Tsou, SSC, WDFW
Christopher Free, SSC, Univ. California Santa Barbara
Joseph Powers, Center of Independent Experts (CIE)

Pacific Fishery Management Council (Council) Representatives:
Jessi Doerpinghaus, Council Staff
Mark Fina, Coastal Pelagic Species Advisory Subpanel (CPSAS) Advisor to STAR Panel
Lisa Hillier, CPS Management Team (CPSMT) Advisor to STAR Panel

Pacific Mackerel Stock Assessment Team:
Peter Kuriyama, NOAA / SWFSC
Juan Zwolinski, Univ. California Santa Cruz, affiliated to NOAA/ SWFSC
Caitlin Allen Akselrud, NOAA / SWFSC
Kevin Hill, NOAA / SWFSC

1) Overview

The Pacific mackerel Stock Assessment and Review (STAR) Panel (Panel) met at the Southwest Fisheries Science Center (SWFSC), La Jolla, CA from April 11-13, 2023 to review a draft assessment by the Stock Assessment Team (STAT) for the US stock of Pacific mackerel (*Scomber japonicus*). Introductions were made (see list of attendees, Appendix 1), and the agenda was adopted. A draft assessment document and background materials were provided to the Panel in advance of the meeting on the Council web site (www.pcouncil.org).

Drs Emmanis Dorval and Brad Erisman first described updates on how age estimates are obtained for Pacific mackerel and updated information on length- and age-at-maturity. Dr. Juan Zwolinski then described aspects of the acoustic-trawl (AT) survey-based method for estimating biomass and its associated age structure. Dr. Peter Kuriyama then presented the assessment methodology and the results described in the draft assessment.

The proposed base model in the draft assessment provided to the Panel was based on the Stock Synthesis Assessment Tool V3.20.20. It differed from the model on which the 2019 assessment (Crone et al., 2019) was based by: (a) including age-composition data for the AT survey based on age data from the survey, (b) using a new age-reading error matrix for the AT survey age-composition data, (c) including a revised age-specific maturity ogive, (d) giving equal weight to the AT and fishery age-composition data, (e) modelling natural mortality (M) using the Lorenzen function with the base M estimated using a prior based on the Hamel and Cope (2022) method with a prior mean of 0.675 yr^{-1}, (f) estimating an offset parameter for the initial recruitment, (g) specifying survey Q for the most recent (2021) AT survey estimate of biomass and allowing for time-blocks in survey Q, (h) allowing for fishery selectivity to vary over time, (i) modifying the survey weight-at-age values to reflect the length-weight relationship published in Palance et al. (2019), (j) updating the AT survey biomass values to reflect this length-weight relationship, and (k) imposing a prior on survey Q values for blocks based on the 2021 AT survey biomass estimate.

The review and subsequent discussions of the proposed base model were motivated primarily by the need to justify the specifications related to survey Q, including the value specified for 2021 and any time variation in survey Q, and to refine the basis for the time variation in fishery selectivity. Based on further analysis, the STAT proposed a revised base model that has a simplified fishery age-specific selectivity pattern (but still fits the fishery age-composition data adequately) and a simplified set of assumptions related to time-variation in survey Q. The STAT also revised the prior for survey Q, which removed the assumption in the proposed base model that survey Q is known, and calculated the prior SD incorporating the uncertainties in US core, US nearshore, and Mexico core biomass observations from 2021.

The final base model matched the intentions of the STAT, namely that it provides a reliable estimate of terminal year biomass and hence the biomass estimates needed to set Overfishing Limits (OFLs) for the 2023 and 2024 fishing years, and it correctly (given the fishery age-composition data) removes the catches by age. However, this approach to stock assessment means that estimates of early (pre-2016) biomass are very uncertain and that the future applications of this approach to stock assessment relies on the continuation of the AT survey, and collection and reading of age structures for the fishery and survey.

The STAR Panel thanked the STAT for their hard work and willingness to respond to Panel requests, and the staff at the SWFSC La Jolla laboratory for their usual exceptional support and provisioning during the STAR meeting.

2) Requests to the STAT
Day 1 requests made to the STAT during the meeting - Tuesday April 11, 2023

Request No. 1: Provide histograms or bubble plots of the age-reading error data for the fishery.
Rationale: The age-reading error standard deviations differed markedly between the fishery and survey, even for young ages. The Panel was provided with information on the distribution of ages among agers for the survey data, but not for the fishery data.
Response: The STAT provided several new figures examining age-reading errors for the fishery data. These figures are provided and summarized below. The Panel raised request 14 to examine this issue further and recommended that the final report include the information in Table 1.

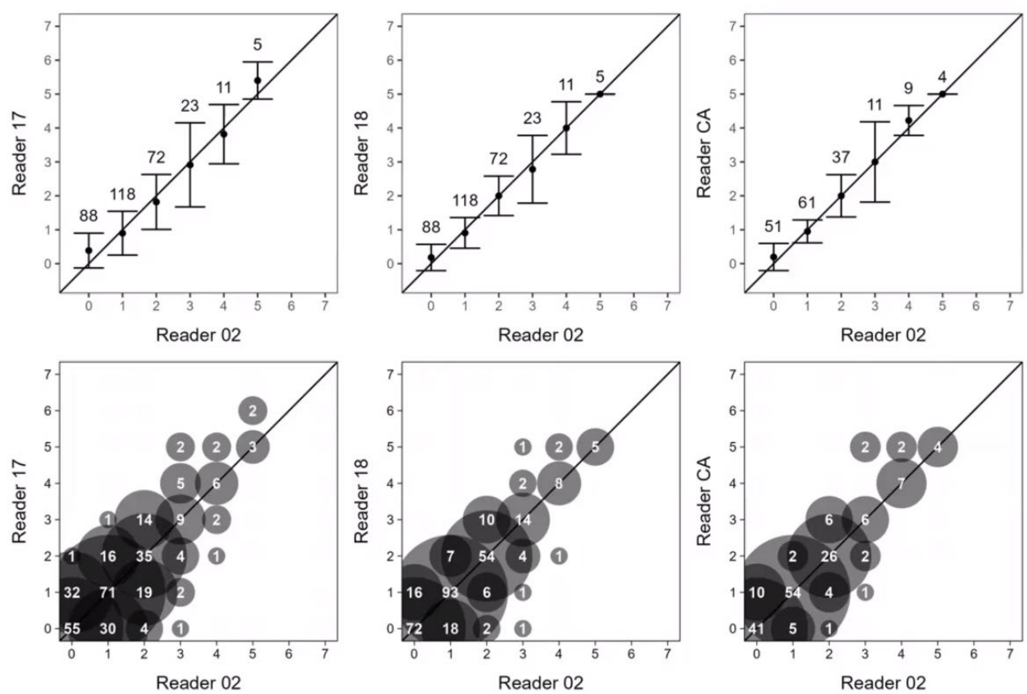

Figure 1. Correlation between ages from one California Department of Fish and Wildlife (CDFW) reader (reader 17) and three SWFSC readers (readers 02, 18, CA).

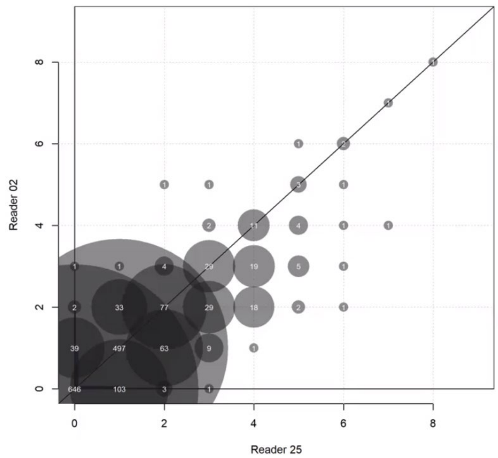

Figure 2. Bubble scatter plot illustrating correlation in age estimates from two readers.

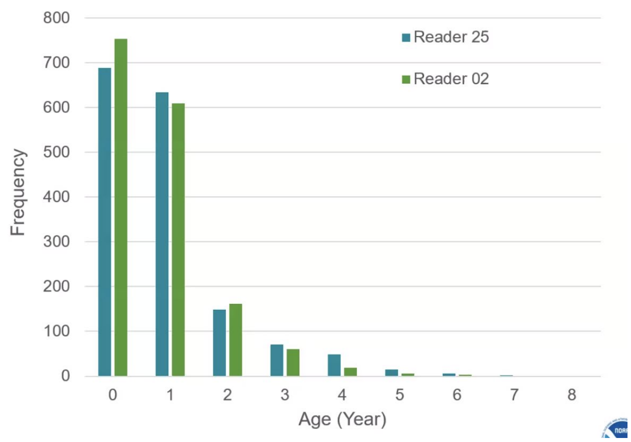

Figure 3. Histogram showing the age composition estimated by readers 02 and 25.

Component	Fishery Ageing Data	Survey Ageing Data
Ageing criteria	Same as survey	Same as fishery
Sample selection for Double readings	Every third- fourth Sample	Every trawl
Ageing precision	Up to 75% agreement	Up to 100% agreement
Data used to compute agieng errors	Double readings before 75% agreement	At 100% agreement
Rationale	Not possible to adjust/drop assessment ages after double reading readings	Possible to adjust/drop age after double reading
	Data are not submitted by reader to the assessment	Data are submitted by reader
	Avoid bias in CV	Improved/better precision

Table 1. Differences in aging methods between samples collected from the fishery and the survey.

Request No. 2: Provide a paragraph justifying using weight as the indicator of reproductive potential.

Rationale: Reproductive potential is assumed to be proportional to weight. However, there is information that suggests that, for example, survival of larvae is higher for older fish. The Panel wished to understand what is known about reproductive potential as a function of age.

Response: The STAT incorporated references to two new papers related to justifying the use of weight as the indicator of reproductive potential. Specifically, the following underlined text was added to the report:

"As exhibited by similar CPS, Pacific mackerel have indeterminate fecundity and appear to spawn whenever sufficient food is available and favorable oceanographic conditions prevail. Individual fish may spawn eight times or more per year and can release batches of at least 8,000 eggs per spawning. Actively spawning fish appear capable of spawning daily or every other day (Dickerson et al. 1992). New research on Mediterranean Sea *S. japonicus* reproduction showed a wide range of relative fecundity by length and weight (420 to 2,553 eggs per cm for total length, and 76 to 379 eggs per gram for total weight; Farrag et al., 2022). The length at 50% maturity for this population was 19.7 cm for females and 19.5 cm for males. Farrag et al. (2022) also include a literature summary of length at first maturity for global *S. japonicus* populations, which ranges from about 18-30 cm. Research from the western North Pacific Ocean shows an effect of maternal age on egg and larval success (Yoneda et al., 2022). Yoneda et al. (2022) found significantly larger and more nutrient-rich eggs, higher starvation tolerance, larger body size, and faster growth rates of larvae from 3 year-old females compared to 1 year-old females. Currently, Stock Synthesis does not provide an option for directly increasing egg or larval survival based on female age, therefore any model explorations would have to indirectly address this relationship by increasing the number of eggs by length or weight."

Request No 3. Develop alternative approaches for specifying survey Q and allowing for time-variation in survey Q, conduct assessment model runs for each approach, and select the most appropriate parameterization.
Rationale: The specifications for survey Q determine the scale of the biomass and its trend over time. The draft assessment was based on pre-specifying the survey Q for 2021 and time-blocking survey Q. However, the assessment report did not document the basis for these highly influential decisions nor was sensitivity explored to alternative assumptions. The options could include extrapolating the 2021 estimate of biomass for the US and Mexico based on the ratio of offshore to inshore biomass off the US, ignoring estimates of biomass considered unrepresentative, etc.
Response: The STAT provided a detailed review of AT survey coverage (Table 2) as the evidence basis for identifying alternative approaches for specifying survey Q and conducted new assessment model runs for each of the identified approaches. The review revealed variability in the spatial extent of the survey and in the distribution of Pacific mackerel. The survey occurred coastwide in most years but stopped north of Morro Bay during 2012 and 2017 and extended into Baja during 2021. Pacific mackerel were consistently observed off northern California, Oregon, and southern Washington and were regularly observed off southern California. There were often no observations of Pacific mackerel off central California.

The STAT reported that survey Q could vary over time because (1) low abundance results in patchy distributions; (2) logistical challenges result in a variable survey grid; and/or (3) movement results in geographical shifts in distribution along the coast.

The STAT identified three general approaches for handling survey Q in the assessment and evaluated eight ways of implementing these approaches (Table 3). These approaches pertain to (1) making survey Q time-invariant; (2) modify the blocking for a time-varying survey Q; and (3) modeling survey Q as deviations. All approaches rely on a survey Q prior based on the 2021 survey, which the STAT rederived as having a mean of 0.309 by dividing the US core biomass by the total US biomass. The STAT assumed a standard deviation of 0.6, which results in an uninformative prior for Q.

On the basis of these results, the STAT argued to retain all the survey data, rather than remove data for the years 2013-2015 or 2012-2015. Removing these years results in high natural mortality estimates and results in higher Q during the early period (2008-2015) rather than during the later period (2016-2021), which conflicts with the 2021 data point. The STAT argued, and the Panel agreed, that it was not worth pursuing models with time-varying *M*.

Year	**Survey coverage**	**Primary areas where mackerel were observed**	**Estimated biomass**
2008	Coastwide	Oregon	58,511 mt
2012	North of Morro Bay	Oregon/Washington	109,951 mt
2014	N/A	N/A	10,423 mt
2015	Coastwide	Oregon	1,224 mt
2016	Coastwide	Coastwide	32,956 mt
2017	North of Morro Bay	No observed biomass south of Monterey	41,139 mt
2018	Coastwide	No observed biomass Mendocino-Monterey	31,211 mt
2019	Coastwide	No observed biomass Mendocino-Morro Bay	24,643 mt (core)
2021	Coastwide w/ extensive Baja coverage	Southern California and Mexico	

Table 2. Summary of the survey coverage and the estimates of biomass.

Code	**Model**	**Brief summary**
consQ	Time-invariant Q	High *M* (0.92 yr^{-1}), misses 2012, 2013, 2015 index
drop1315	Time-invariant Q, drop 2013-15 AT estimates	High *M* (1.00 yr^{-1}), fits index well
tvM	Time-invariant Q, time-	Implausibly high *M* (>>0.9 yr^{-1}), no Hessian, misses

	varying *M*	2012, 2013, 2015 index
upweight	Upweight AT survey	Low Q (0.02 yr^{-1}), biomass much larger than base model, fits index extremely well
twoblock Q	Modify Q blocking	High *M* (0.96 yr^{-1}), misses 2012, 2015 index, Q is ~0.1 in first block and ~0.35 in second block
twoQdrop	Modify Q blocking, drop 2013-15 AT estimates	High *M* (0.99 yr^{-1}), biomass trend is different in middle years relative to base model, Q reverses relative to scenario above (high then low), fits index well
drop1215	Time-invariant Q, drop 2012-15 AT estimates	Lower *M* (0.82 yr^{-1}), fits index well, trend similar to base model and scale slightly higher
devQ	Estimate Q with deviations	Q low (0.01-0.11), scale much higher than in base model, fits index well

Table 3. Summary of the results of the alternative models.

Request No 4. Report estimates of 2022, 2023, and 2024 age 1+ biomass and their standard errors (SE).
Rationale: The OFLs will be based on age 1+ biomass and the buffer between the OFL and Acceptable Biological Catch may depend on the CV of 1+ biomass.
Response: The STAT added estimates of age 1+ biomass and their SE. The final report will include these estimates.

Request No 5. Compute the survey age-composition data for 2021 using only the aging data for 2021 and conduct a sensitivity analysis with these data and excluding the survey age-composition data for 2013-2015.
Rationale: The survey age-composition data for 2021 and 2022 were combined to compute the 2021 age-compositions while the 2013-2015 age compositions were computed using a pooled age-length key. It is undesirable to compute age compositions using age-length keys with data pooled over years, especially for the terminal years of the analysis.
Response: There was insufficient time to complete this request given the time to conduct request No 3. See request 13.

Request No 6. Update the estimates of total removals based on catches by the at-sea whiting fleet and by pro-rating any unidentified mackerel landings and re-run the assessment.
Rationale: The catch records on which the assessment was based may have excluded some of the historical removals.
Response: The STAT reported that the landings were revised to include total removals by the Pacific whiting at-sea fishery for 2008-2022. In addition, Washington state landings in 2012 were corrected to exclude 126 mt of ‘unspecified’ mackerel previously ascribed to Pacific mackerel in the PacFIN database. The results of the assessment were robust to the updated catch time series.

FISHING_ YEAR	OLD_MT	REVISED_MT	DIFFERENCE (REVISED – OLD)
2008	5346.2	5346.2	0.0
2009	3656.1	3656.2	0.1
2010	4229.4	4229.4	0.0
2011	4305.8	4305.9	0.1
2012	12997.6	12874.1	-123.5
2013	14461.8	14461.8	0.0
2014	9691.6	9707.1	15.5
2015	13865.2	13891.8	26.6
2016	14464.0	14473.7	9.7
2017	4617.1	4703.9	86.8
2018	18252.5	18352.9	100.4
2019	22989.9	22989.9	0.0
2020	32059.6	32062.5	2.9
2021	10415.6	10528.9	113.3
2022	16000.0	16128.1	128.1

Table 4. Differences between original and revised catch time series.

Request No 7. Explore sensitivity to various choices for the age at which selectivity for the reference period is constant.
Rationale: The selectivity of age-4 fish is lower than that of age-5 fish for all years in Figure 15 of the draft assessment report, which is unexpected.
Response: There was insufficient time to complete this request given the time to conduct request No 3. See request 11.

Request No 8. Explore sensitivity of standard errors for the selectivity deviations for the 2dAR selectivity pattern and justify the value for the base model.
Rationale: The draft assessment did not explore this uncertainty and did not document nor justify the base level of variation.
Response: There was insufficient time to complete this request given the time to conduct request No 3. See request 12.

Day 2 requests made to the STAT during the meeting - Wednesday April 12, 2023

Request No 9. Update the standard deviation of the survey Q prior based on a Monte Carlo study.
Rationale: The standard deviation for the log-Q prior of 0.6 used for request 3 was arbitrary and meant that the prior on survey Q was very uninformative.
Response: The revised CV of the survey Q was 0.28.

Request No 10. Revise the survey Q estimation procedure to follow the following decision points: (1) determine the mean Q for 2021; (2) determine whether the Q is fixed or specified with a prior; (3) decide what data to include in the model fitting process; and (4) decide how to appropriately block survey Q.
Rationale: This is a follow-up to request 3.

Response: The STAT proposed the following blocked approach for specifying survey Q based on the feedback from the Panel and the results of the sensitivity analyses: (1) Q for 2008-2015, the survey years with more uncertainty, is estimated as deviations using the updated Q prior and a SE for survey Q deviations of 0.25; (2) Q for 2016-2019 is estimated using the updated Q prior; and (3) Q for 2021 is fixed at the mean of the Q prior. The resulting model shows a similar trend but slightly higher scale relative to the original base model. It fits the survey data well and estimates Q values ranging from ~0.04 to ~0.35. The STAT investigated the sensitivity of the results to a few alternative specifications to this model, summarized below:

Code	Model	Brief summary
Qopt1	2008-15: Q deviates w/ SE=0.25; 2016-19: Q prior; 2021: @ fixed	Trend is similar to the original base model through scale is a little higher; fits index well
Qopt1low	2008-15: Q deviates w/ SE=0.15; 2016-19: Q prior; 2021: @ fixed	Biomass estimates are very similar to "Qopt1" but fits index a little less well
Qopt1all	2008-19: Q deviates w/ SE=0.25; 2021: @ fixed	Biomass estimates are a little higher than "Qopt1" and fits index well

The Panel agreed with the justification and performance of the proposed new base model. The STAT and Panel examined the Stock Synthesis output and the STAT and Panel agreed that the model fit was satisfactory. This change was made to the base model and this model formed the basis for later model explorations.

Request No 11. Complete request 7 (Explore sensitivity to various choices for the age at which selectivity for the reference period is constant)
Rationale: There was insufficient time to complete request 7 given the time to conduct request No 3.
Response: With Q fixed in 2021 and blocked at 2016-2020, fishery selectivity parameters were dropped one at a time. The consequence of changing the number of selectivity parameters was reflected mainly in the fit to the fishery age-composition data and the effective N. The summary biomass is higher when the last few parameters for fishery selectivity were fixed. The STAT proposed setting the last fishery selectivity and the Panel supported the change.

Request No 12. Complete request 8 (Explore sensitivity of SE for the selectivity deviations for the 2dAR selectivity pattern and justify the value for the base model.)
Response: That STAT provided results from runs using SE of 0.2, 0.5, 0.7, and 1 (base value). Lower SE led to smoother selectivity curves, but poorer fits to the age-composition data. The STAT recommended retaining the standard deviation of 1 for base model given the aim of fitting the age-composition data well. The Panel agreed with this decision.

Request No 13. Complete request 5 (Compute the survey age-composition data for 2021 using only the aging data for 2021 and conduct a sensitivity analysis with these data and excluding the survey age-composition data for 2013-2015.)
Rationale: There was insufficient time to complete request 5 given the time to conduct request No 3.
Response: The STAT computed the survey age-composition data for 2021 using only the aging data for 2021 and conducted two sensitivity analyses: (1) one with these data and (2) one excluding

the survey age-composition data for 2013-2015. The differences relative to the updated base model were small, which suggests that these age-compositions are not influential on the results, and the base model included the original age-composition data

Request No 14. Update the age-reading error vector to incorporate between-lab (CDFW and SWFSC) variability and conduct a sensitivity run with the revised age-reading error vector.
Rationale: The comparison of variability between CDFW and SWFSC readers is a better reflection of variability than between SWFSC readers, because readers within the same lab are trained similarly and therefore have similar biases.
Response: The STAT updated the vector of age-reading standard deviations and included them in an additional assessment run. The new age vector includes CDFW reader 2 as well as the three SWFSC readers (CA, 15, 17, 18). The estimates of ag 1+ biomass were insensitive to the age-reading error standard deviations, and the base model continued to be based on the age-reading error matrices in the proposed base model.

Request No 15. Identify the parameter(s) that determine the parameter penalty in the likelihood profile for *h* (Figure 35 of the draft assessment report).
Rationale: The Panel was surprised that a parameter penalty could be so influential.
Response: The STAT performed and presented a variety of profile tests to understand the sensitivity of the results to specifications of key parameters. Specifically, the STAT and Panel reviewed profiles for steepness, survey Q, and *M*. No R_0 profile was provided because the SR_regime offset parameter is highly correlated with R_0. The profiles behaved as expected, were smooth, and showed no odd discontinuities. The STAT also showed the results of a retrospective analysis, which showed no concerning patterns.

Day 3 requests made to the STAT during the meeting - Thursday April 13, 2023
No requests were made to the STAT during day three of the meeting.

3) Technical Merits and/or Deficiencies of the Assessment
The final base model incorporates the following specifications:

- Time period from 2008-2021, with projections to 2025.
- Sexes combined and maximum modelled age of 8 years.
- Natural mortality estimated with a diffuse prior with median M=0.675 yr^{-1} and standard deviation 0.31 and a Lorenzen function of age.
- AT survey catchability (survey Q) estimated for 2016-2021 with a prior with mean 0.308 and CV 0.28 and time-varying (deviations) with a SE of 0.25 for 2008-2015.
- Maturity pre-specified with fecundity based on average weight-at-age.
- Commercial and recreational fisheries combined.
- Empirical weight-at-age.
- Selectivity
    - Fishery selectivity: age-based, time-varying, and modelled using a non-parametric base form with random (and independent) annual and age-based deviates.
    - AT survey selectivity: age-based and assumed asymptotic and time-invariant with selectivity for age 0 estimated.
- Virgin recruitment (R_0) estimated; underlying recruitment variability (σ_R) and steepness (h) both set to 0.75.

- Initial equilibrium (“SR regime” parameter) estimated.
- Recruitment deviations estimated from 2008-2021.

Unlike the 2019 assessment, the model fits the commercial age-composition data well, because the model now allows for time-varying fishery selectivity. In contrast, while the model fits the AT age-composition data well at the aggregated level, some of the individual fits are poor. Commercial fishery age-composition data are only available for the California commercial fishery. Although commercial removals of Pacific mackerel off Washington and Oregon are generally small relative to those from California, these fisheries tend to capture older fish that are more northerly distributed, given the stock’s hypothesized seasonal movement patterns during the late summer through fall in any given year. The survey age-compositions only include data for Baja California, Mexico in 2021.

The assessment is based on the empirical weight-at-age approach. This approach reduces the number of estimable parameters, especially for a stock with time-varying growth. However, it was necessary to interpolate some weight-at-age values and the weights-at-age are not actually “known” given sampling error and age-reading error. The assumption of known weight-at-age means that any uncertainty associated with weight-at-age is not reflected in the measures of uncertainty, especially for age 1+ biomass.

Some key parameters are assumed to be known exactly (e.g., stock recruitment steepness and the extent to which recruitment varies about the stock-recruitment relationship). Given the high value for natural mortality in the base model (an estimated average value of 0.811, SD 0.107), a large proportion of the 2023 and 2024 estimates of age 1+ biomass is based on “generated” fish. This proportion would have been lower had the data from the 2022 survey been usable, but this will also be a feature of the assessment.

The estimate of M for Pacific mackerel is larger than the estimate of M for anchovy and Pacific sardine. This is perhaps unexpected even though the value for M in this assessment is clearly supported by the few age 2+ Pacific mackerel found in the AT survey, which is assumed to have asymptotic selectivity, and the estimate is within the Hamel-Cope prior. Future work should explore what is known about M for the similar CPS with a view of reflecting this information in future assessments.

4) Areas of Disagreement

There were no major areas of disagreement between the STAT and Panel, nor among members of the Panel.

5) Unresolved Problems and Major Uncertainties

The assessment is based almost entirely on the information from the AT survey (index and age-composition data) because the AT survey is considered the most reliable method available for indexing Pacific mackerel. The survey has been reviewed by the PFMC SSC and has been endorsed to provide a relative index of abundance. The survey biomass indices (in conjunction with assumptions about survey Q) provide information on trend and biomass scale, while the survey age-composition data provide information on M (and, to some extent, year-class strength). The fishery age-composition data provide little information on trend and biomass, and are primarily informing the correct removal of catches by age-class.

The AT survey is considered the best source of information for understanding the dynamics of Pacific mackerel. However, there are limited data for Mexico, where in some years (e.g., 2021), the bulk of the population resides. In addition, there are marked changes in where Pacific mackerel are found during the surveys due to movement or simply the patchy distribution of the stock. Moreover, the survey did not cover the entire range of the US stock in 2012 and 2017 and only surveyed in Mexico's waters in 2021. Previous reviews of the AT survey have identified factors that could lead to variability in survey Q (PFMC, 2011, 2018) including (but not limited to):

- Differences in relative catchability of species by acoustics and trawl net
- Effects of relative and absolute population sizes across species on behavior and relative trawl catchability by species as well as selectivity
- CPS in the surface layer not observed by acoustics
- CPS avoidance of and escape from the trawl net
- Uncertainty in target strength
- Uncertainty and bias in ageing methods
- An unknown and variable fraction of the stock is outside of the survey area, primarily south of the US-Mexico border.

The Panel reiterates the importance of implementing previous research recommendations related to the AT survey to improve the confidence in the AT survey estimates. It also notes that it would be impossible to implement the current assessment model in the future without a continuing series of AT estimates of biomass and age-composition. The survey Q is based on the results of the 2021 survey which obtained data from Mexico and the US. Continued surveying in Mexican waters will help to refine the prior for survey Q and what proportion of the population is in US waters varies over time.

The assessment makes the assumption that age-composition information collected in the US (for the fishery California) is representative of the entire stock. This makes the assumption that these catch age-composition data are representative of the component of the population in Mexican waters. The age-composition data for the survey suggest slightly older fish in Mexico, but at present there is no basis to infer the age structure of the fishery in Mexico and collection of biological samples from Mexico should be a priority.

Several of the key parameters of the model could not be estimated given the short time-series of data used in the assessment.

6) Issues raised by the CPSMT and CPSAS representatives during the meeting

a) CPSMT issues

The CPSMT representative greatly appreciates efforts by the STAT and the comprehensive STAR panel discussion and requests. The representative supports the assessment approach and final model to inform management of the 2023-2024 and 2024-2025 Pacific mackerel fishery seasons.

For this assessment the importance of the AT survey was highlighted multiple times by both the STAT and the STAR panel. The lack of survey data available to this assessment from the 2022 AT survey year impacted several parameters and the STAR panel noted this as a deficiency in the assessment. The CPSMT representative reiterates the importance of a viable survey that encompasses the full distribution of this stock including into the Mexican portion of its range. The uncertainty surrounding possible significant Pacific mackerel biomass off Baja California is a concern and the CPSMT representative reiterates support for continued efforts to work with fishery institutions from Mexico to expand or collaborate survey operations and to acquire fishery data from Mexico.

Improvement in the collection process of biological samples for Pacific mackerel by including samples from the Pacific Northwest would help determine whether there are older and larger fish found in the northern extent of their range. Data from the northern portion of its range is limited due to the lack of CPS directed fishing. The CPSMT representative supports the STAT working with state agencies to provide estimates of recreational harvest and biological data. The STAR panel sees value in having additional (i.e., non-CPS fishery) age information to inform the assessment. The CPSMT representative understands the SWFSC may work with Northwest Fisheries Science Center on the collection of biological data including otoliths from incidentally caught Pacific mackerel in the Pacific whiting fishery. Age structures collected from this fishery have not been prioritized for aging due to reduced age reading capacity and expertise for Pacific mackerel. Discussion relative to the workload associated with aging samples from this fishery for the assessment is encouraged.

The CPSMT representative thanks the STAT for their hard work modelling this stock and responding to all requests in a timely manner and thinks that the Council will be provided with an assessment in June that will be useful for managing the fishery.

b) CPSAS issues

As a potentially constraining species, Pacific mackerel are an important component of the CPS complex despite the low recent catches from the fishery. Annual landings in US fisheries have not exceeded 5,000 metric tons since 2015. These low landings pose a minimal threat to the biomass and cannot justify extensive efforts to achieve substantial improvements in the certainty in the stock assessment and management. On the other hand, much of the current uncertainty seems to stem from lack of information. Work needed to improve that information would not be specific to Pacific mackerel. It would likely address uncertainties in the management of other CPS species. For example, a source of uncertainty in the assessment seems to be gaps and differences in the spatial coverage of CPS surveys interannually. Improving the consistency of coverage will provide benefits for management of all of the CPS complex. As with many of the CPS species, the stock structure and dynamics of West Coast Pacific mackerel are not well understood. The stock recruitment relationship and differences in movements and distribution of different sizes and ages in high and low abundance are not well established. Improved data on CPS generally may significantly reduce the research effort needed to improve our understanding.

Ongoing efforts to improve the survey coverage and continuity may streamline the assessment process and reduce uncertainty by lowering the need for assessment authors to adopt analytical methods to overcome data shortfalls and inconsistencies. In addition, the recent extension of survey coverage into Mexico is also encouraging not only for the Pacific mackerel assessment, but also for the assessment other CPS with cross border stocks (such as Pacific sardines). The efforts of the NMFS to test and validate its survey (including consideration of nearshore aerial and acoustic data, tests of samples from purse seines and nighttime/daytime trawling, and work to examine the differences in distribution seasonally) should all be pursued to build confidence in survey results. In addition to these efforts, we support NMFS exploration of means of achieving efficiencies in data collection. Continuing these efforts (including both modifications to the survey and pursuing alternative sources of data that supplement survey data) are likely to be important to ensuring continued availability of data to effectively manage CPS fisheries. We strongly encourage the NMFS to continue its collaboration with industry as it develops these modifications, as industry expertise may aid in achieving effective and efficient data collections.

.

7) Research Recommendations

High priority

1. Improve collaboration with fishery researchers from Mexico. As noted in previous assessment reviews, a large fraction of the catch is taken off Mexico, and efforts should be made to obtain length, age, and related biological data from the Mexican fisheries. Inclusion of the AT surveys in the assessment has increased the need for continued comparable surveys within Mexican waters. This research recommendation was made by the STAR Panel in 2019 and remains a high priority.
2. Continue to refine indices of abundance. The Panel agrees that the AT survey remains an appropriate method to index the abundance of Pacific mackerel. However, there are several issues that still need to be addressed *as per* the reviews of the AT survey in 2011 (PFMC, 2011) and in 2018 (PFMC, 2018). Some of the recommendations from those reviews have been implemented (e.g., Zwolinski and Demer, 2014). The following are a subset of tasks to better realize the potential of the AT survey for Pacific mackerel:
    a. Trawl sampling during the day to address the potential for differences in fish represented by the signal from the acoustic sampling during the day versus trawl sampling at night to capture the species, length, and age compositions of the sampled fish.
    b. Refine the target strength estimates for Pacific mackerel.
    c. Provide separate estimates of age-0 and age-1+ Pacific mackerel biomass from the AT survey. There appears to be more uncertainty in the enumeration of age-0 mackerel than of other age classes due to the spatial distribution and age-specific selectivity patterns.
    d. Investigate the spatial distribution, especially the range, of the Pacific mackerel population over time and whether this changes with population size and/or environmental conditions. In particular, an environmentally based index of spatial distribution might prove useful for developing priors for AT survey catchability for use in future assessments.
3. Improve collection of age data, coordination of ageing laboratories, and cross validation efforts to standardize reads between laboratories and develop bias adjustments.
    a. Increase support for current port sampling and laboratory analysis programs for CPS, particularly in the Pacific Northwest. Biological (e.g., length, age, sex) data on mackerel caught in the Pacific Northwest should be collected. These data could further assist in understanding whether and to what extent selectivity for the commercial fishery is dome-shaped. The aging of Pacific sardine in the Pacific Northwest should be coordinated with laboratories conducting ageing in California. The next assessment should include a section on recent information regarding biological data for the Pacific Northwest.

b. Analysis of data from the multistage approach to age/length composition sampling has indicated that most of the variability occurs between commercial trips as opposed to replicate sampling of a landing within a landing. The number of trips sampled is relatively low due to the infrequent fishing and need to coordinate sampling with industry to increase the effective sample size. Many samples from the Pacific Northwest have not been processed and should be aged with methods consistent with those currently employed by the CDFW from the commercial fishery.

4. Revisit the harvest control rules and reference points for Pacific mackerel. The basis for the current harvest cutoff is derived from analyses performed by MacCall et al. (1985) over 30 years ago using data, biological assumptions (e.g., about selectivity and natural mortality), and methods (virtual population analysis) that are not reflected in the current stock assessment. If the underlying data and assumptions used by MacCall et al. (1985) are no longer considered relevant to the current population, it is likely time to revise the scientific basis for these reference points.
5. Refine the approach to quantifying age-reading error for the next stock assessment so that estimates of age-reading error are based on analysis of all available data on double-reads of otoliths. Consideration should be given to age-reading error matrices by reader.

Medium priority

1. Apply the state-space approach developed by Jim Ianelli for computing weight-at-age and quantifying uncertainty.
2. Develop a fecundity-weight relationship and include it in future assessments.
3. Further explore reasons for variability in survey Q.
4. Further explore spatial variability as it relates to stock structure and management.
5. Explore what is known about *M* for the full suite of CPS with a view of reflecting this information in future assessments.

Low priority

1. Explore the feasibility of modelling non-landed mortalities of sublegal-sized fish in the Mexican fishery.

References

Crone, P.R., Hill, K.T. Zwolinski, J.P., and Kinney, M.J. 2019. Pacific mackerel (*Scomber japonicus*) stock assessment in the 2019-20 and 2020-21 fishing years. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR, 97220 OR.

Dickerson, T.L., Macewicz, B.J., and Hunter, J.R. 1992. Spawning frequency and batch fecundity of chub mackerel, *Scomber japonicus*, during 1985. *CalCOFI Reports* 33: 130–140.

Farrag, M.M.S., Ismail, R.F., El-Haweet, A.A.K., Abdel Fattah, M., and Oman, A.G.M. 2022. Reproductive parameters of the chub mackerel, *Scomber japonicus* (Houttuyn, 1782) from the East Mediterranean Sea, Egypt. *Iranian Journal of Ichthyology* 9.2: 96-110.

Hamel, O.S., and Cope, J.M. 2022. Development and considerations for application of a longevity-based prior for the natural mortality rate. *Fisheries Research* 256: 106477

MacCall, A.D., Klingbeil, R.A., and Methot, R.D. 1985. Recent increased abundance and potential productivity of Pacific mackerel *Scomber japonicus*. *CalCOFI Reports* 18: 136–148

Palance, D.G., Macewicz, B.J., Stierhoff, K., Demer, D.A., and Zwolinski, J.P. 2019. Length conversions and mass–length relationships of five forage-fish species in the California current ecosystem. *Journal of Fish Biology* 95(4): 1116–1124

PFMC. 2011. Acoustic-Trawl Survey Method for Coastal Pelagic Species Report of Methodology Review Panel Meeting. Agenda Item C.3a Attachment 1, April 2011.

PFMC. 2018. Methodology review panel report: acoustic trawl methodology review for use in coastal pelagic species stock assessments. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR, 97220 OR. Agenda Item C.3, Attachment 2, April 2018. 75 p.

Yoneda, M., Kitano, H., Myuji, M., Nakamura, A., Matsyama, M., Shimizu, A., Tsuzaki, T., Togashi, H. and Kamimura, Y. 2022. Maternal spawning experience and thermal effects on offspring viability of chub mackerel and their influence on reproductive success. *Frontiers in Marine Science* 9: 2701.

Zwolinski, J., and Demer, D. 2014. Progress related to the recommendations from ATM survey review. Appendix 3 of the Pacific Sardine STAR Panel Meeting Report, Agenda Item H.1a Attachment 3, April 2014.

Appendix 1
Attendance List – Pacific Mackerel STAR Panel April 2023

Name	Affiliation
Stock Assessment Review Panel	
André Punt	SSC/University of Washington, Chair
Tien-Shui Tsou	SSC/WDFW
Christopher Free	SSC/University of California, Santa Barbara
Joseph Powers	CIE
Advisers	
Mark Fina	CWPA, CPSAS
Lisa Hillier	WDFW, CPSMT
Stock Assessment Team	
Peter Kuriyama	SWFSC
Juan Zwolinski	UC Santa Cruz / SWFSC
Kevin Hill	SWFSC
Caitlin Allen Akselrud	SWFSC
Other attendees (in person)	
Jessi Doerpinghaus	PFMC
Chales Hinchliffe	SWFSC / UC Santa Cruz
Brad Erisman	SWFSC
Josh Lindsay	NMFS WCR
Emmanis Dorval	SWFSC, Lynker
Trung Nguyen	CDFW, CPSMT
Briana Brady	CDFW
Steve Crooke	CPSAS
Kelsey James	SWFSC
Huihua Lee	SWFSC
Annie Yau	SWFSC
Brittany Schwartzkopf	SWFSC, CPSMT
James Hilger	SWFSC, CPSMT
Steve Teo	SWFSC
Kelsey James	SWFSC
Owyn Snodgrass	SWFSC
Other attendees (Online)	
Kirk Lynn	CPSMT,CDFW
Alan Byrne	IDFG, SSC
Alan Sarich	Quinault Indian Nation, CPSMT
Diana Porzio	CDFW
Fabio Caltabaellotta	FSUCML, WDFW

Jason Schaffler	SSC
Lynn Mattes	ODFW
Mike Okoniewski	CPSAS
Taylor Debevec	NMFS, CPSMT
Marlene Bellman	PFMC
Kirk Lynn	CDFW, CPSMT
Jon Walker	SWFSC, UC Santa Cruz
Michelle Horeczko	CDFW
Will Satterthwaite	SWFSC, SSC

CDFW = California Department of Fish and Wildlife
CIE = Center of Independent Experts
CPSAS = Coastal Pelagic Species Advisory Subpanel
CPSMT = Coastal Pelagic Species Management Team
FSUCML = Florida State University
IDFG = Idaho Fish and Game
NMFS WCR = National Marine Fisheries Service West Coast Region
NWFSC = Northwest Fisheries Science Center
PFMC = Pacific Fishery Management Council
SSC = Scientific and Statistical Committee
SWFSC = Southwest Fisheries Science Center

Appendix 2: Changes for the final assessment report

- Include the plots of the annual age-length keys for the survey in the final report.
- Replace the current labels (e.g., "1207") for the surveys by more descriptive text (e.g., 'July 2012").
- Include the long-term historical landing history in an appendix and list the data sources used in previous assessments but not in this assessment.
- Document the rationale for the model start year of 2008.
- Update the information on the largest and oldest Pacific mackerel based on information from Washington (69 cm and 16 years).
- Justify why it is appropriate to use the target strength relationship for South African horse mackerel when estimating biomass for Pacific mackerel.
- Conduct projections of age 1+ biomass based on a range of values for 2023 removals.
- Document what is known about how density-dependence for Pacific mackerel and the assumptions related to density-dependence underlying the current stock assessment.
- Redraft the basis for computing catch proportions for the fishery (simplify it).
- Update sources of commercial removal data and describe how total commercial removal is assembled.
- Add a table summarizing the original and revised catch resulting from Request #6.
- Add a summary of the table (Table 1 in Request #1 above) that documents the differences in aging methods between samples collected from the fishery and survey to Appendix A.
- Add an appendix documenting the basis for the prior for survey Q and the basis for time-varying survey Q.
- Add an *M* profile in which steepness is fixed at 0.75.
- Add a profile for final age 1+ biomass.