Pacific Mackerel

Stock Assessment Review (STAR) Panel Meeting Report

NOAA / Southwest Fisheries Science Center
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1) Overview

The Pacific Mackerel Stock Assessment Review (STAR) Panel (Panel) met at the Southwest Fisheries Science Center, La Jolla, CA from April 23-25, 2019 to review a draft assessment by the Stock Assessment Team (STAT) for Pacific mackerel. 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 a PFMC FTP site.

The STAT presented the assessment methodologies to the Panel. These included results from a draft assessment with approaches utilizing the acoustic-trawl (AT) survey alone or the Stock Synthesis (SS) Assessment Tool, (Version 3.30.12). Dr. Juan Zwolinski presented aspects of the methodology and results for the AT surveys of coastal pelagic species, and in particular Pacific mackerel, that are conducted annual by the SWFSC. Dr. Paul Crone presented the model-based approach using the Stock Synthesis (SS) modeling framework. The assessment report included several model runs. The major changes between the pre-STAR draft assessment base model (labeled ALT_19_16 henceforth) and the model selected during the last full assessment reviewed in 2015 (model H3) were: (a) the start year of the assessment changed from 1983 to 2008, (b) the Commercial Passenger Fishing Vessel (CPFV) index and its associated length composition data were excluded from the assessment, and (c) the AT index and its associated age (derived from length) composition data were introduced into the assessment. Additionally, (d) empirical weight-at-age data were used instead of estimating growth in terms of length-at-age internally in the model, (e) natural mortality (M) was estimated (with a prior) rather than fixed at 0.5, (f) stock recruitment steepness (h) was fixed at 0.75 rather than estimated, (g) a prior on catchability q was implemented, (h) fishery selectivity was allowed to be dome-shaped, while survey selectivity was forced to be asymptotic, and (i) no offset for initial equilibrium recruitment was estimated.

The review and subsequent explorations of the assessment through sensitivity analyses were motivated primarily by the desire to find a model that fit the data adequately, made realistic assumptions regarding selectivity and was consistent with prior expectations for M and other parameters. Considerable time was spent attempting to reconcile the conflicting age data from the fishery and the survey, as well as find a better fit to the survey indices. The latter was of particular importance given the STAT's stated preference for an AT survey-based management control rule. Understanding the model configuration(s) necessary to fit the survey index reasonably well would inform the assumptions necessary to adopt such a survey-based control rule. The Panel and STAT ultimately agreed on down-weighting the fishery age composition data in the final base model (henceforth: ALT_19).

Ages were not determined directly for the AT survey; rather, a length-to-age key developed from the commercial fishery from 2008-2018 was used to convert lengths from the AT survey to ages. It was necessary to have age composition data, given the decision to rely on empirical weight-at-age data rather than modeling growth via a length-at-age relationship, eliminating potentially confounding relationships between time-varying growth and length-selectivity. The fishery average weight-at-age data were also applied to the AT survey, requiring the assumption that the commercial fishery data are representative of fish captured in the AT survey (or, at the very least,

that they experienced similar environmental conditions and timing of capture). The reliability of applying weight-at-age from the fishery to the survey samples is supported by comparable length compositions between the two. Length-to-age transition matrices can attribute fish of a given size proportionally to many ages. However, a single combined-year length-age key, the information on relative strength of year-classes, as reflected within length bins (and thus correct proportionality of ages-at-length), is removed. If there is substantial observation error from year-to year in the data underlying length-to-age transition matrices, however, a combined-year matrix may be warranted.

The fit to the AT survey index was poor for the pre-STAR base model ALT_19_16. This lack-of fit to the survey index contrasted strongly with the STAT's stated preference for an AT survey-based management procedure. The fit to the AT survey index improved substantially with complete removal of the fishery age composition data.

The fit to the fishery age composition data was variable across the years of the data. The fit to the AT survey age composition data was generally poor, but without the extreme variance in fit seen in the fishery data (i.e. the model was unable to fit some years of the fishery data). Both the fishery and survey data appeared to reflect variable selectivity of age-0 fish. The variable fit to the fishery ages may also be related to annual variation in timing, location and density of fishing trips as well as the location of the mackerel. The poor fits to the survey derived age-composition data may be related to the translation of the observed lengths to ages, which are used as input to the model.

Retrospective analysis shows a not quite consistent retrospective pattern. It appears the final estimated biomass for each retrospective year tends to be revised towards the last couple remaining years of AT survey index (Figure 1).

In the time available, the STAT and Panel could not fully explore alternative data and model configurations, including full exploration of time-varying selectivity for both the fishery and survey, nor separating an age 1+ biomass index and age composition from an age-0 recruitment index for the survey.

The Panel highlights the research recommendations, in particular those related to improving the coverage of the AT surveys, validation of the AT methods, and the use of aggregate vs. annual length-to-age transition matrices.

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

2) Requests to the STAT

Day 1 requests made to the STAT during the meeting - Monday April 23, 2019

Request 1: Provide information about year-specific mean length-at-age compiled from the fishery sources.
Rationale: Descriptions of length-at-age pooled across years (2008-2018) were presented in the draft stock assessment report. The STAR panel wanted to understand the variation in the raw length-at-age data to determine if there was additional value in incorporating variation in size among years. This variation among years should help inform the value in using pooled data in the length to age conversion.
Response: The STAT provided a plot of year-specific mean length-at-age. The data summary shown included year-round data, whereas the length-to-age key was restricted to data from July-December. The graph indicated considerable variability in length-at-age, including in 0 to 3 year olds, where sample size is substantial. There were few fish years 5 and older, but the plot showed a consistent pattern of among-years variation in size, with some years having consistently larger fish for each of ages 4 and above, and others, smaller fish at those ages.
Conclusion: Alternative conclusions can be drawn from this. One could conclude that there is considerable variability in size-at-age in each year, which, coupled with differences in year-class strength, would indicate that using year-specific length-to-age keys would be preferred. Alternatively, one could conclude that the data are too variable, partially due to timing and location of fisheries in each year, and the data should be pooled to make a single length-to-age key.

Request 2: Investigate sensitivity of ALT_19 to aspects of age-composition.

Request 2a: Remove AT survey age-composition data from the assessment while fixing AT survey selectivity from model ALT_19.
Rationale: The panel was interested in investigating the relative influence of fishery vs. survey data. The quality of the AT survey age data in the model may be questionable due to both small sample size and the single year-aggregated fishery-based length-to-age key used to develop the age data from the length data.
Response: Model results showed that the estimated fishery selectivity changed to increase the selectivity of ages 0 and 1. Changes to older ages were relatively small. With the AT survey age data removed, the large 2018 year-class estimated in the pre-STAR base model (ALT_19_16) is no longer supported. Diagnostics showed no notable improvement in fit to AT survey index of abundance. In terms of parameters, the age data from the AT survey are influential (e.g., estimated M declined from approximately 0.77 in ALT_19_16 to 0.46 when the AT survey age data were removed, and the patterns of estimated recruitment changed dramatically).
Conclusion: The AT survey age data provide substantial information to the model.

Request 2b: Remove fishery age-composition data from the assessment while fixing fishery selectivity from model ALT_19.
Rationale: The panel was interested in investigating how much influence the fishery age data had on the model relative to the survey data.
Response: Removing fishery age-composition data resulted in small changes to the age-0 selectivity for AT survey. Recruitment estimates from years prior to 2012 became more uncertain because there are no composition data from the 2008 AT survey. This model produces the closest fit between the model biomass and the AT survey estimate, though the model still

over-predicts the 2013 biomass index. Estimates of other main parameters were not substantially changed.
Conclusion: There is conflict between the fishery age-composition data and AT survey data.

Request 2c: Use fishery year-specific age-at-length distributions to generate age composition time-series for the AT survey. Incorporate in model.
Rationale: The AT survey input age data were developed assuming a year-aggregated fishery-based length-to-age matrix. The annual length-to-age transition matrices should reflect both year-to-year variation in size at age, and variation in relative year-class strength, although year-to-year variation in actual fishery selectivity (insofar as it is actually age-based rather than length-based), and small sample may cause spurious differences across years.
Response: There was adequate information to develop these transition matrices on an annual basis, although the STAT expressed concern about small sample sizes for some ages in some years. Use of year-specific versus pooled length-age relationships does generate change in the age composition information that is used in the model. The use of year-specific age composition results in similar overall model estimates.
Conclusion: While there are some differences among the derived age composition data developed in these two alternative ways (Figure 2), neither approach was clearly superior to the other.

Request 3: Remove all survey data, both biomass index and age composition, to investigate the influence of fishery data alone.
Rationale: The panel was interested in seeing how the fishery data drive the model in the absence of survey data.
Response: This run resulted in higher biomass estimates, though generally of the same order of magnitude, and a very different recruitment series. In addition, the parameter estimates changed dramatically. The survey data are driving this assessment more so than fishery age data, although that has some influence as seen in request 2b.
Conclusion: Include AT survey data.

Request 4: Allow selectivity for the AT survey to be dome-shaped.
Rationale: There was no direct information presented by the STAT on the shape of the selectivity curve for the AT survey. This request was intended to investigate the sensitivity of model results to alternative shapes of the AT survey selectivity curve.
Response: The AT survey selectivity was estimated to be strongly dome-shaped when estimated as a random walk over ages. However, the influence on other parameters: M, h, q, etc., was very small. This is largely because age 4+ mackerel represent very small proportions of the population in both the fishery and AT survey samples.
Conclusion: The influence of these changes is not great, so there is no concern about the AT survey selectivity being specified as asymptotic in the base model.

Request 5: Modify model H3_19_3 and remove CPFV data add AT survey data; or take ALT_19_16 model and add fishery data back to 1983 while using average weight at age.
Rationale: This request was an attempt by the STAR panel to understand the scale of biomass estimated in the ALT model compared to historical information used in previous assessments. It was also an attempt to examine recent age composition patterns relative to historical observations.

Response: The STAT was able to add these data to the ALT_19_16 model. However, they were unsuccessful in getting the model to converge. Addressing this correctly would require quite a bit of exploration. The model is driven by the early data, which is less applicable to recent dynamics
Conclusion: The STAR panel agreed that leaving out the earlier data was reasonable. However, this suggests that HCRs and reference points need to be revisited (see research recommendations).

Request 6: Fix selectivity for fishery to be constant for ages 4+ instead of 5+
Rationale: The empirical weight-at-age shows that fish ages 4 and older are of roughly equivalent size. If the fish are of equivalent size, it seems they are likely to be of similar or equivalent selectivity. The STAR panel was interested in determining if forcing age 4+ to have the same selectivity affected model estimates.
Response: This change had virtually no effect on any estimates or results.
Conclusion: The STAT and STAR panel agreed to continue with ages 5+ for constant selectivity.

Day 2 requests made to the STAT during the meeting - Wednesday April 24, 2019

Request 7: Consider the double-normal parameterization, time-invariant for the fishery selectivity.
Rationale: The non-monotonic increase in the time-invariant fishery selection from ages 1 to 3 is unexpected and does not have a good explanation related either to biology or fishery operations.
Response: The change resulted in constant selectivity at ages 1-3, with almost identical results in terms of biomass trajectory, recruitment deviations, and other diagnostics. Upon further inspection, the double normal parameterization with six parameters was difficult to estimate and caused difficulties in convergence. More time would be needed to explore this.
Conclusion: The STAT elected to stay with the random walk approach to fishery selectivity, and the STAR panel agreed.

Request 8: Come to a consensus on the use of year-specific versus pooled length-age relationship for transforming AT survey length compositions to age composition data.
Rationale: The STAR panel prefers the annual length-age transformation matrix, to reflect time-varying growth and relative cohort strength, while recognizing that variance in the fishery and sampling across years, as well as small sample sizes, can lessen the quality of the individual year data.
Response: The STAT preferred to continue using the pooled length-age transformation matrix.
Conclusion: The pooled-length-age transformation matrix was used going forward.

Request 9: Implement two approaches for time-varying selectivity for age-0 in the AT survey.
Rationale: The fit to age-0 in both the fishery and the survey is relatively poor compared to other ages. Additionally, the STAT provided information suggesting that there were reasons why the AT surveys would vary among years in the detection of age-0 fish. There appears to be some information about age-0 fish in the AT survey, so the panel did not want to remove this information completely.

Request 9a: Implement the penalty approach for allowing age-0 selectivity to vary with time.
Rationale: See rationale for request 9 above.
Response: The time-varying approach with the penalty behaves well and is explicable. However, small movements in value of the penalty function can cause unexpected and unrealistic values. The STAT found that a choice of sigma=0.4 eliminated erratic behavior of the selectivity for age zeroes. Larger values of sigma (e.g. sigma =0.5) produced declining selectivity with age for certain years (2016, 2018; e.g. age-0 selectivity = 1.0, age 1+ selectivity = 0.8 or so). As the selectivity should not change for ages 1+ among years, unless *q* is also changed, the use of sigma = 0.4 was viewed as preferable. With sigma= 0.4, this model produced slightly better fit to age zeroes, and, generally, a better fit to the AT survey index. Upon later exploration, finding the model with the lowest likelihood under this configuration was not straightforward.
Conclusion: This approach appears promising, despite the ad-hoc choice of sigma and the convergence issues.

Request 9b: Implement the time-blocking approach for allowing age-0 selectivity to vary with time. This fixes selectivity at 1.0 for all ages in 2016 and 2018, the years where exceptionally high numbers of age zero were seen, and freely estimates age-zero selectivity in every other year.
Rationale: See rationale for request 9 above.
Response: Blocking requires more subjective decision making, in terms of which years to fix at selectivity = 1.0 for age-0 fish, and it may be an issue to make that decision in the future. This approach introduces a lot of flexibility. The resulting model fits the AT survey index a bit better, but does not fit the age data as well as expected. This removes more of the influence of age-0 data, which particularly affects the estimate of the 2018 recruitment for which age-0 data are the only age data.
Conclusion: This approach was considered more subjective than that in 9a, due to having to decide which years to set within the block, which could have a large influence, especially on the recruitment within the last year of data.

Request 10: Implement request 9 with fixed selectivity for the fishery and remove all fishery age data.
Rationale: There is concern that variability in selectivity of the fishery is resulting in spurious model behavior. Simpler approach than implementing time-varying fishery selectivity, which would also remove the data in terms of informing recruitment, etc. but would inform time-varying selectivity of removals.

Request 10a: Implement request 9a (penalty approach) with fixed selectivity for the fishery and remove all fishery age data.
Rationale: See rationales from 9a and 10.
Response: This results in a better fit to age comp and index.
Conclusion: Use of time-varying age-0 selectivity (or age-0 data as an index of recruitment independent of an age 1+ survey index) is an area that should be explored further.

Request 10b: Implement request 9b (time-blocking approach) with fixed selectivity for the fishery and remove all fishery age data.
Rationale: See rationales from 9b and 10.
Response: This results in a better fit to age comp and index as with 10a.

Conclusion: More work is needed to determine whether the fishery age data provide reliable information on year-class strength and removals, which will determine how to use this data.

Day 3 requests made to the STAT during the meeting - Thursday April 25, 2019

Request 11: Conduct 6 runs as follows. Down-weight fishery age composition data by setting λ = 0.5 or 0.25. Also, use Francis weighting for both fishery and survey age data. Implement each of these starting with the pre-STAR base model (ALT_19_16) and with the model coming out of request 9a.
Rationale: The STAR panel and STAT were working to arrive at potential base model considerations. One big question is the value (thus weighting) of fishery age data, and another is whether there should be time-varying age-0 selectivity for the AT survey age data.
Response: The discussion focused on the down-weighting of the fishery age data. Due to issues with convergence that could not be resolved at the STAR panel, the STAT preferred not to move forward with the time-varying age-0 selectivity for the AT survey (as in request 9a). The response to down-weighting the fishery age data was as expected, as λ was decreased from 1 to 0, the fit of the model to the AT survey index of abundance improved (Figure 3) and the end-year biomass estimate increased (Figure 4).
Conclusion: The STAT and STAR panel agreed that the model with λ on the fisheries age data set to 0.5 was an acceptable base model, and that of time-varying age-0 AT survey selectivity would be included in the sensitivities in the final assessment document.
The STAR panel asked for seven sensitivity analyses in the next version of the assessment document beyond the 13 sensitivities outlined in the pre-STAR assessment. These include the four sensitivities implied by request 11: λ = 1, 0.5, 0.25, or 0 on the fishery age composition data, or use of Francis weighting for all age data. In addition are the following: 1) A sensitivity incorporating the penalty approach to time-varying AT survey age zero selectivity with sigma = 0.4 (See Request 9a). 2) A sensitivity to dome-shaped AT survey selectivity (see Request 4). 3) A sensitivity to the year specific length-to-age key to develop AT age compositions (see Request 2c).

3) Technical Merits and/or Deficiencies of the Assessment

The base model proposed by the STAT (model ALT_19 in the assessment report) incorporates the following specifications:

- Time period from 2008-2018.
- Sexes combined and maximum modelled age of 8 years.
- Natural mortality M = 0.81 estimated with a diffuse prior with median M=0.61yr^{-1}, and constant over age and time.
- AT survey catchability q = 0.67 estimated using a prior with median q = 0.65.
- Maturity pre-specified with fecundity based on average weight-at-age.
- Commercial and recreational fisheries combined.
- Empirical weight-at-age.
- Fishery selectivity age-based, time-invariant, and modelled using a random-walk non-parametric form from age 0 to age 5+.

- AT survey selectivity age-based, assumed asymptotic, time-invariant and modeled using a random walk, non-parametric form from age 0 to age 1+. Fitted to age data derived from AT survey length data using a time-invariant fishery-derived length-to-age key.
- Virgin recruitment (R_0) estimated; underlying recruitment variability (σ_R) and steepness (h) both set to 0.75.
- Recruitment deviations estimated from 2008-2018.

The issues with the Pacific mackerel stock assessment relate to the information content of the available data, and the STAT investigated alternative model configurations that might provide a credible assessment. The decisions made to this end were all appropriate and supported by the available information, although the limited time during the STAR panel precluded full exploration of some proposed approaches.

Modeling a single fishery is appropriate given age-composition data are available from only the California commercial fishery, and the recreational fishery is relatively small (<5% of total catch, US and Mexico combined) with only length-composition data. Fishery age composition data continued to be weighted by monthly landings (in numbers).

The fits to the AT survey index and age-composition data were poor for model ALT-19_16, and improved as fishery age-composition data were down-weighted or removed. The poor fit to the survey indices could be due to a variable proportion of the stock biomass in the area surveyed. The poor fits to the survey age-composition data may be related the use of a fishery-based length-to-age key to derive the age-composition data. However, the seemingly clear progression of cohorts through the length-composition data from the AT surveys suggests that the samples sizes are at least adequate to monitor general trends in length over time.

Despite not being able to explore and come to a conclusion about time-varying selectivity for either the fishery or the AT survey, nor separate the AT survey into a 1+ biomass index and age composition and an age-0 recruitment index, the STAT and Panel did agree upon a model configuration for the Pacific mackerel assessment. This involved down-weighting the fishery age data by half relative to model ALT_19_16, the base model proposed by the STAT in the pre-STAR draft assessment report.

Commercial fishery composition data (age and length) are only available for the California commercial fishery. Although commercial landings of Pacific mackerel off Washington and Oregon are generally small relative to those from California, these fisheries may 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. As such, the fishery-based length-to-age key used for developing AT survey age composition data may be incomplete, biased, or simply poorly defined for larger fish.

In principle, an AT survey, conducted during the summer months, is an appropriate way to index the abundance of Pacific mackerel. This survey, as currently implemented, may not provide a completely consistent index of the abundance of Pacific mackerel because the proportion of the stock in the survey area likely varies somewhat among years (primarily because of its distribution south of the US-Mexican border). Although it is unclear exactly how consistent this survey is in its current configuration relative to the stock abundance, the Panel agreed that it did

provide useful information on the relative abundance and composition of Pacific mackerel both in the survey area and, though to a lesser extent, for the stock as a whole.

4) Areas of Disagreement

There were no major areas of disagreement within the Panel.

5) Unresolved Problems and Major Uncertainties

Selection of a base model and the scaling problem

The STAT and STAR panel agreed on the base model ALT_19. This model is 'stable' as shown in jittering analyses and is generally able to fit the data moderately well.

The estimate of the AT survey *q* in this assessment model is 0.67, which practically matches the current Pacific mackerel Harvest Control Rule (HCR) *distribution* parameter of 0.7, implying that 70% of the stock is available in US territorial waters. However, the *distribution* value was determined in 1987. Its provenance is unclear and proportion of the stock in US waters likely changes over time.

Priors are included as penalty functions in SS assessments, which are not fully Bayesian. Transitioning to a fully Bayesian SS assessment model should be explored.

Indices of abundance

The draft assessment for Pacific mackerel included one index of abundance: a survey index of abundance from the summer AT survey. A catch-rate index based on data collected from the CPFV fleet, which was used in the 2015 assessment, was not used in this assessment due to concerns regarding its representativeness and consistency through time, considering that Pacific mackerel is not a target species and the logbook data are self-reported with variable reliability.

The AT index

In principle, an AT survey is an appropriate way to index the abundance of coastal pelagic species such as Pacific mackerel. The Methodology Panels held in 2011 (PFMC, 2011a) and in 2018 (PFMC 2018) concluded that acoustic-trawl surveys, as well as the associated methods of data collection and analysis, are adequate for the provision of advice on (but are not by themselves absolute estimates of) the abundance of Pacific sardine, jack mackerel, and Pacific mackerel, subject to caveats, in particular related to the survey areas and distributions of the stocks at the times of the surveys. While the 2018 review concluded that the AT survey index could be used as a relative index of abundance for stock assessment, it also documented a number of unresolved issues which may cause variability in the catchability associated with the survey across years and/or call into question the prior used on that catchability in the current assessment. These include (but are not limited to):

1. Difference in relative catchability of species by acoustics and trawl net
2. Effect of relative and absolute population sizes across species on behavior and relative trawl catchability by species as well as selectivity

3. CPS in the surface layer not observed by acoustics
4. CPS avoidance of and escape from the trawl net
5. Uncertainty in target strength
6. Uncertainty and bias in ageing methods
7. An unknown and variable fraction of the stock is outside of the survey area, primarily south of the US-Mexico border.

The Panel notes the importance of implementing previous research recommendations related to the AT survey to improve the confidence in the AT survey estimates, including the investigation of potential species selectivity effects by comparing the ratios of catch rates and acoustically-estimated densities in areas where a single species dominates. (PFMC, 2011a, 2018).

The model has trouble fitting either the fishery or derived AT survey age compositions. This issue is explored in Requests 2 and 9-11. Input effective sample sizes for the AT survey age-compositions were based on the number of trawl clusters with Pacific mackerel and are hence smaller than the input effective sample sizes for the fishery age-compositions.

The CPFV index

The concerns with the CPFV index include the fact that the CPFV fleet does not target Pacific mackerel and that the accuracy of the catch reporting may be questionable. Moreover, the targeting practices of the CPFV fleet have changed in response to management actions such as the implementation of the rockfish closures and the reduction in allowable harvests of rockfishes, but the standardization procedure does not account for this change in fleet behavior. Data from this fleet is only consistently collected for U.S. waters and large-scale environmentally-driven changes in the distribution of Pacific mackerel may be mis-interpreted as changes in abundance. The logbook data are also the result of self-reporting, which can be variable for species such as Pacific mackerel that are not typically viewed as a desirable target species.

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

a) CPSMT issues

The Coastal Pelagic Species Management Team (CPSMT) representative commends and thanks the Stock Assessment Team (STAT) for their dedicated effort on the assessment prior to and during the review, and appreciates the in-depth exploration of the issues raised. The representative supports the assessment approach and final model to inform management of the 2019-2020 and 2020-2021 Pacific mackerel fishery.

In this assessment, the STAT expresses their support for a survey-based approach rather than a model-based approach to estimate Pacific mackerel biomass. The CPSMT has previously supported the use of the acoustic trawl (AT) survey (fishery independent) in a model-based assessment and agrees the use of the AT survey in this assessment provides a better index of abundance than the previously used CPFV index (fishery dependent). However, there remain concerns with using the AT survey estimates of biomass directly to inform management (which also apply to a model-based approach described below). These include some general to the AT method and some specific to Pacific mackerel in relation to the survey, e.g., survey coverage

(nearshore, ocean waters off Baja California, surface waters), species specific target strength, and consistent recognition of recruitment (age 0 signal).

Incorporating the AT survey in the model is not without its own challenges. It is apparent from the review discussion that representing recruitment and how to capture that in the model is very challenging, given that the fishery can routinely capture age 0 fish but the signal is less consistently observed in the AT survey. This mismatch may be in part due to the inability of the AT survey to cover nearshore areas or other areas where young fish reside and that are commonly accessed by the commercial fishery. From the discussion, it is also clear that age data strongly influence model outputs and the assessment would benefit by addressing two needs identified by the STAT and independent reviewers. The first need is to achieve full utilization of the age data collected by the AT survey. These data were excluded from the assessment due to concerns over aging error, whereas fishery age data processed by California Department of fish and Wildlife (CDFW) were deemed reliable. The process (transformation and use of a multi-year fishery based age/length key) to incorporate AT data adds uncertainty. Thus, the CPSMT representative encourages the Southwest Fishery Science Center (SWFSC) to explore options such as having CDFW age the fish or pursue other avenues (e.g., meetings, training, exchanges) to improve age reading expertise. This would also help to address another comment made by the STAT that collecting Pacific mackerel biological samples from the Pacific Northwest would elucidate whether there are older and larger fish found in the northern extent of their range. Given the lack of CPS directed fishing and consequent limited amount of fishery data from the Pacific Northwest, the STAT sees value in having additional (i.e., non-CPS fishery) age composition data to inform the assessment. The CPSMT representative understands the SWFSC has coordinated with the Northwest Fishery Science Center on the collection of biological data including otoliths from incidentally caught Pacific mackerel in the Pacific whiting fishery. These samples have not been prioritized for aging due to reduced age reading capacity and expertise for Pacific mackerel. Discussion relative to the workload associated aging and the benefit this information would provide to the assessment is encouraged.

Noting the uncertainty arising from varying and potentially substantial Pacific mackerel biomass off Baja California, the CPSMT representative reiterates the CPSMTs support for continued efforts to improve relations with fishery institutions from Mexico to expand or collaborate on survey operations and work to acquire timely fishery data from Mexico.

As noted above, the STAT expresses a strong preference to move to a survey-based assessment approach, and with that, a change to the fishing start date to reduce the time over which biomass must be projected. Under the current management structure, this time lag is currently a year and would be reduced to six months (or less) with a January 1 instead of July 1 start date for Pacific mackerel. However, the CPSMT representative would point out that the start date for the Pacific sardine fishery year was changed from January 1 to July 1 to accommodate summer surveys that had difficulty providing final data products to meet the necessary schedule for Pacific Fishery Management Council adoption of the assessment, biomass estimate, and harvest management specifications at the November meeting. The CPSMT representative agrees with the STAT's alternative suggestion for pursuing a concurrent AT survey and modeling path.

b) CPSAS issues

The CPSAS representative thanks the Stock Assessment Team (STAT) for their work, and shares the frustration of STAR panel members regarding the continuing uncertainties inherent in this Pacific mackerel stock assessment, which largely mirror problems experienced at the 2011 and 2015 Pacific mackerel STAR panel meetings as well as the 2018 Acoustic Trawl (AT) methods review.

From an industry perspective, this STAR panel review seems to have jumped from the proverbial frying pan into the fire. The 2015 benchmark assessment attempted to assess the Pacific mackerel population with a model based primarily on CPFV surveys that did not report much of the mackerel caught. Including AT surveys in the 2015 model scaled biomass downward, but provided little information on biomass. Thus, the AT survey was dropped from the 2015 assessment.

This 2019 benchmark now attempts to assess biomass with a new Model ALT that is based mainly on the AT survey. However, although the STAT strongly advocates for a survey-based assessment, the AT methods review recommended that AT estimates of relative abundance could be used directly for management only after a Management Strategy Evaluation. Further, the 2018 AT survey: apparently didn't 'see' the substantial biomass of Pacific mackerel that fishermen have seen in the Pacific Northwest over the past two years. So, unfortunately, the core issues remain:

- AT surveys cover only a portion of the Pacific mackerel range, excluding Mexico and an unquantified but likely substantial portion of the stock.
- Further, the summer AT survey makes only one pass along the west coast at a predetermined time and without replication, irrespective of oceanic cycles and the dynamic behavior of CPS such as mackerel.
- There is still the issue of fish missed in the 10-meter depth-to-surface acoustic 'dead zone', and the probability that the AT survey missed the reportedly 'vast' schools of one- and two-pound Pacific mackerel that albacore fishermen have observed breezing near the surface in the past couple of years from 30-to 75-miles offshore in the Pacific Northwest.
- Issues identified at the AT methods review also remain: questions about target strength, the assumption that CPS do not occur below 70 meters depth, and the use of a time-invariant conditional age-at-length (CAAL) key, rather than physically aging fish.
- There is also the issue that biological composition data, specifically age, are only available from California. Incidental catch data from the whiting fishery are available, but those fish have not been aged, hence age data from the Pacific Northwest beyond the AT survey's CAAL data do not inform the model.

The final straw: there was not sufficient time during this STAR panel meeting to fully explore and resolve the conflict in Model Alt between fishery age data, particularly age zeros collected in California (but sometimes also in AT surveys), with the time-invariant CAAL key used to assigned age to relatively small sample size of fish captured in AT surveys. This review grappled with how to down-weight the increase in recruitment of age 0s observed in 2018 in light of model sensitivity, and how to fit Model ALT (to the degree possible) to the AT survey.

The final outcome reduced the estimated Pacific mackerel biomass substantially from recent years, with a resultant sharp cut in harvest guideline. Although fishery catches have been relatively low in recent years in California, it should be noted that Pacific mackerel are characterized by sharp spikes in abundance, particularly when anchovy are as abundant as they are now. Industry is very

concerned that the reduced harvest limits prescribed in this STAR panel review may be in effect for another four years, and could preclude harvest opportunity if the Pacific mackerel population spikes in the interim. Pacific mackerel are a key alternative fishery in southern California when sardine and market squid are unavailable. The sardine fishery is now closed, and this is an El Niño year, so maintaining a viable wetfish industry, especially in southern California, will be a major challenge.

Recommendations:

- Data collection programs need to be substantially expanded to include ageing Pacific mackerel captured incidentally in the whiting fishery, as well as Pacific mackerel captured in the Pacific Northwest fishery. This information should be included in the next update assessment.
- AT survey methodology should be improved as recommended in the AT methods review.
- Also, AT surveys should increase the spatial boundaries of the survey grid, ideally into Mexico either independently or cooperatively, as well as adding side-looking sonar acoustics to capture fish in the upper water column. Sample size in AT surveys also should be substantially increased.
- Likewise, efforts should be continued to encourage collaborative Tri-national research and data exchanges, and to collaborate with the fishing industry toward improving the knowledge of Pacific mackerel.
- Finally, increased collaboration with industry, both in expanding surveys and acknowledging fishermen's observations of CPS stock presence / abundance on the fishing grounds, and focusing surveys accordingly, would improve the accuracy of future stock assessments.

The CPSAS representative notes that most of these concerns have been expressed in some form in the Research and Data Needs section of the Pacific Mackerel Stock Assessment Report in prior years as well as in 2019.

One further recommendation that the CPSAS representative believes is critical, in light of recognized 'spikes' in Pacific mackerel abundance in favorable conditions, is to allow the Council flexibility to adjust update reviews and management measures as needed between scheduled benchmark assessments. It is important to point out that with the closure of the sardine fishery, and the potential decline in squid abundance due to the current El Niño cycle, effort could increase on Pacific mackerel in 2019, if pure mackerel schools are available (the 20-percent bycatch rate now required for incidental catch of sardine will likely preclude fishing on mixed-fish schools).

If the Pacific mackerel fishery expands, either in California, the Pacific Northwest or both places at once, the potential for premature fishery closure exists at the low harvest limit proposed in this stock assessment. This is another compelling reason to develop a systematic aging program that includes mackerel from the full range of the stock.

7) Other issues

1. The STAT, CPSAS and Panel agreed that conducting an annual update of the AT model each year to be reviewed by the SSCCPS in the years intervening full assessments would be advantageous to account for recent patterns in recruitment. The current process would have a catch-based projection be conducted in 2021. While this would account for removals in the intervening years since the full assessment, it would not provide additional information on recruitment. Given that the fishery is primarily fishing on age 0 and age 1 biomass, knowledge of recent recruitment is critical to informing appropriate harvest levels. The additional effort on the part of the STAT must be weighed against other demands on the limited assessment

resources of the SWFSC. A compromise be may be to conduct a complete update in lieu of the catch-based projection in 2021. In any case, the Panel agrees that the Council may want to consider more frequent complete updates between full assessments.

2. If the acoustics during the day and the fishing operations using a net during the night have different selectivities in terms of the observation and relative target strength of different sized fish in the acoustics and the capture of fish of different sizes/ages and/or species in the net, it is important to account for this and understand how this might affect biomass estimates and model parameters. The ability to explore differing selectivities between the fish sampling and the index would be useful.

3. The log of observed abundance with age from the AT survey decreases with a linear fit implying an instantaneous total mortality rate of 1.12. This puts the instantaneous total mortality rate (Z) in the range of 1.4 (estimated M) to 1.8 (prior median M) times estimates of M, suggesting that fishing mortality is substantial but likely in the sustainable range. The rate of decline in observed abundance increases after age 4. This is thought to be due to dome-shaped selectivity, rather than a higher total mortality rate for older Pacific mackerel as it is known that larger fish may escape the net if the trawl speed is less than 5 knots.

8) 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 comparable surveys within Mexican waters because such information could be used to develop a nearly comprehensive index of the abundance of the transboundary stock of Pacific mackerel. Alternatively, collaborative research extending the AT survey into Mexican waters would also achieve the goal of encompassing the full range of Pacific Mackerel.

2. Continue to refine the indices of abundance. The Panel considers an AT survey to be an appropriate way to index the abundance of CPS such as Pacific mackerel. The PFMC conducted 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). However, most of the recommendations, even those from the 2011 review, have yet to be addressed. 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 composition 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.

3. Standard data processing procedures should be developed for CPS, similar to those developed for groundfish species, and a 'data document' developed that provides, in considerable detail, how the basic data sources (e.g., catches, CPFV indices, etc.) are constructed. Much of this information has been published in the past, but a single (and 'living') document describing the basic data will assist assessment authors and future review panels.

4. 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.

5. 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.

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.

c. Ageing of survey collections for the survey age production laboratory at SWFSC needs increased collaboration to increase precision in reads. Reading of otoliths from the AT survey should be prioritized to alleviate the need for using age length keys to convert lengths to ages with greater potential for bias and imprecision. Production ageing of otoliths from the AT survey needs validation and verification of age reads between observers or laboratories should be conducted to provide reads consistent with those currently provided by CDFW for commercial landings, relying on experienced age readers as the basis for comparison between laboratories.

d. Cross reads should be conducted between laboratories or, preferably, reads simply done by CDFW staff to provide greater consistency and precision. Ageing bias can be identified using cross-reads of the same otoliths among laboratories.

6. Revisit the harvest control rules and reference points for Pacific mackerel. The basis for the current harvest cutoff are 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 as reflected in the ALT_19 assessment model, it is likely time to revise the scientific basis for these reference points.

Medium Priority

1. Examine whether parameters such as growth rate and asymptotic size have changed over time.

2. Conduct a study to update the information used to determine maturity-at-length (and maturity-at-age).

Low Priority

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

References

Crone, P.R., Hill, K.T. 2015. Pacific mackerel (*Scomber japonicus*) stock assessment for USA management in the 2015-16 fishing year. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR, 97220. 131 p

Crone, P.R., Hill, K.T. 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, OR, 97220. 13 p

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

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

PFMC. 2011b. Scientific and Statistical Committee Report on Coastal Pelagic Species (CPS) Survey Methodology Review. Agenda Item C.3.b. Supplemental SSC Report, April. 2011.

PFMC. 2018b. 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.

Stock Assessment Review (STAR). 2015. Pacific mackerel STAR panel meeting report. A. Punt (chair) and members W. Satterthwaite, V. Haist, and D. Checkley. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, OR, 97220. OR. 27 p.

Zwolinski, J. and D. Demer. 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.

Figures

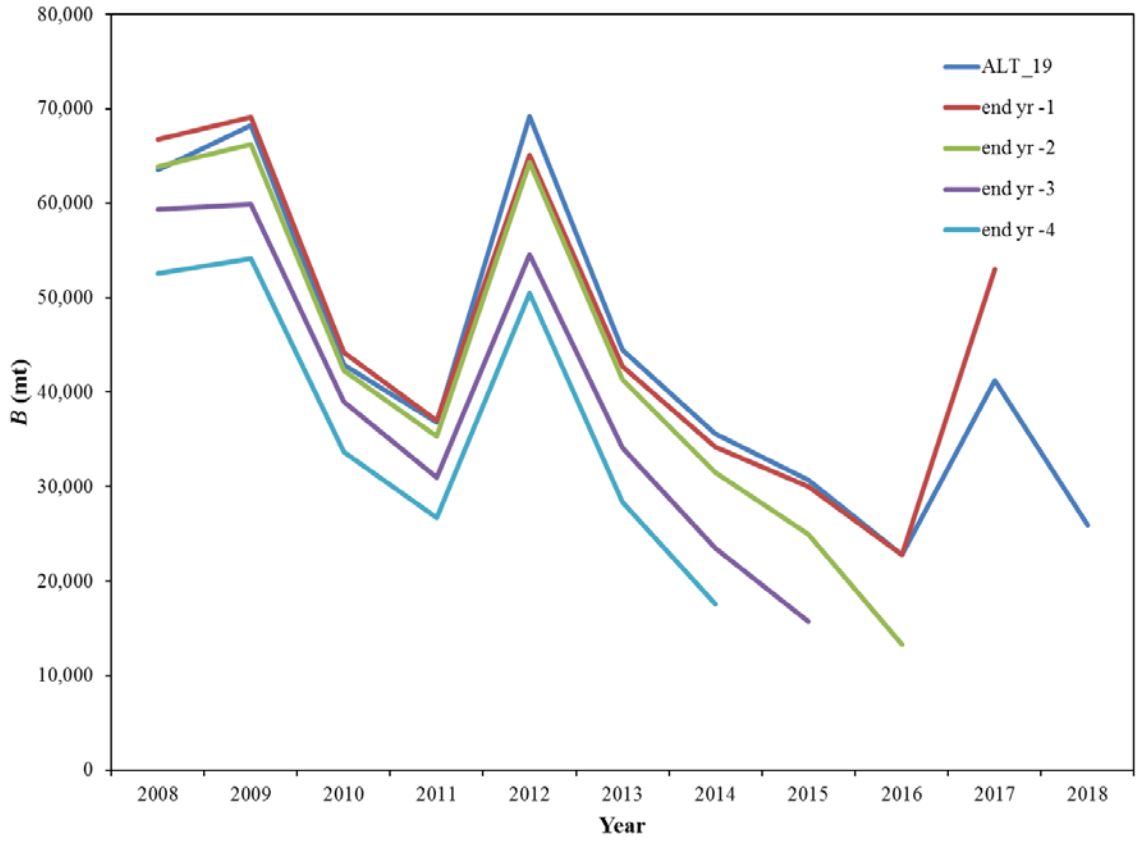

Figure 1. Estimated stock biomass (*B,* age 1+ fish, mt) time series associated with retrospective analysis (2014-18) for final base model ALT_19.

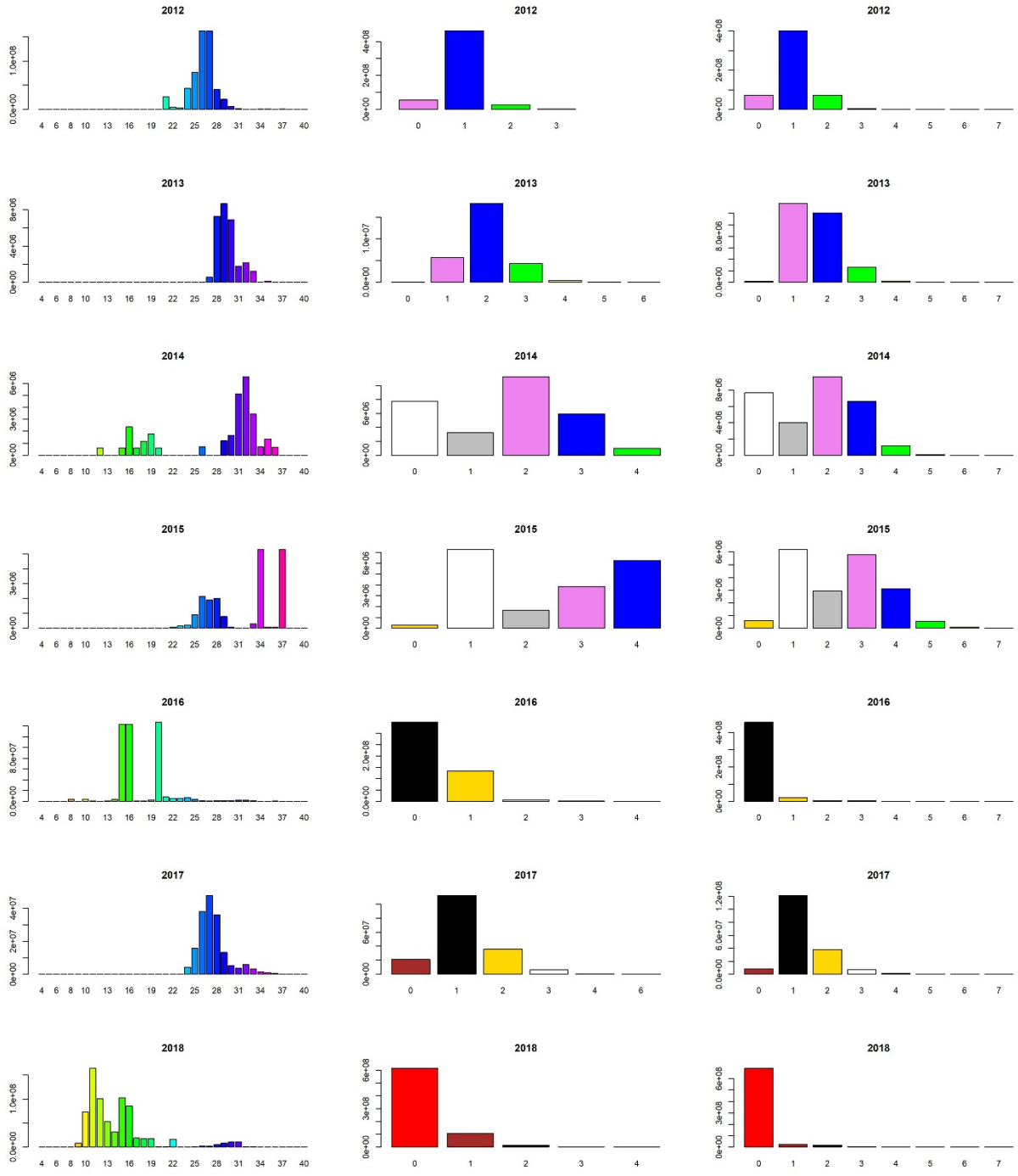

Figure 2. AT Survey length composition data (left column) and derived age composition using year-specific length-to-age transition matrices (keys) (center column) or single combined-year length-to-age transition matrix (key) (right column).

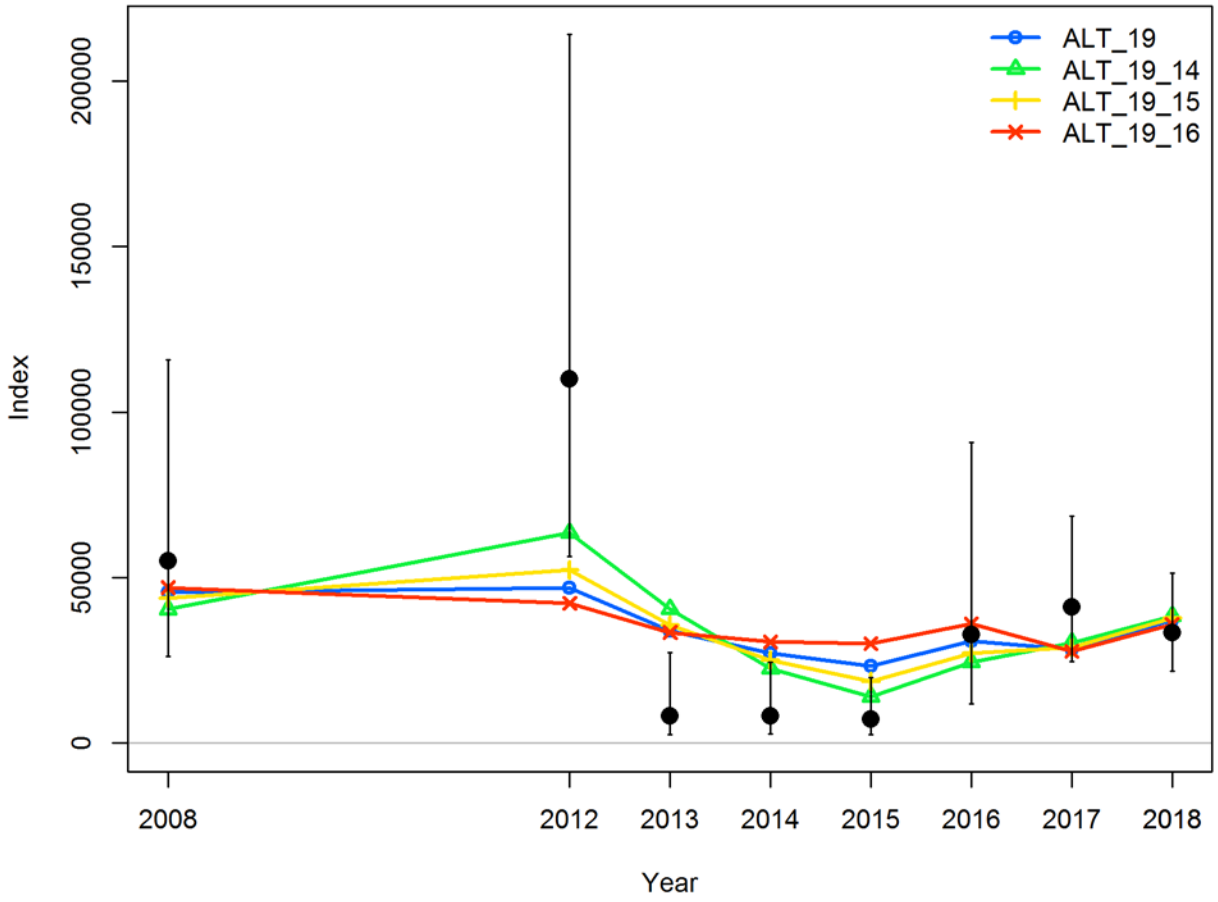

Figure 3. Fits to AT survey index of abundance assoicated with alternative model ALT_19 configurations based on different data weighting (lambda emphasis in SS) assumptions for the fishery age-composition time series, including: lambda=1 (i.e., full weight, **ALT_19_16**); lambda=0.5 (**final base model ALT_19**); lambda=0.25 (**ALT_19_15**); and lambda=0 (i.e., no weight and fishery selectivity fixed at estimated parameters from model ALT_19, **ALT_19_14**).

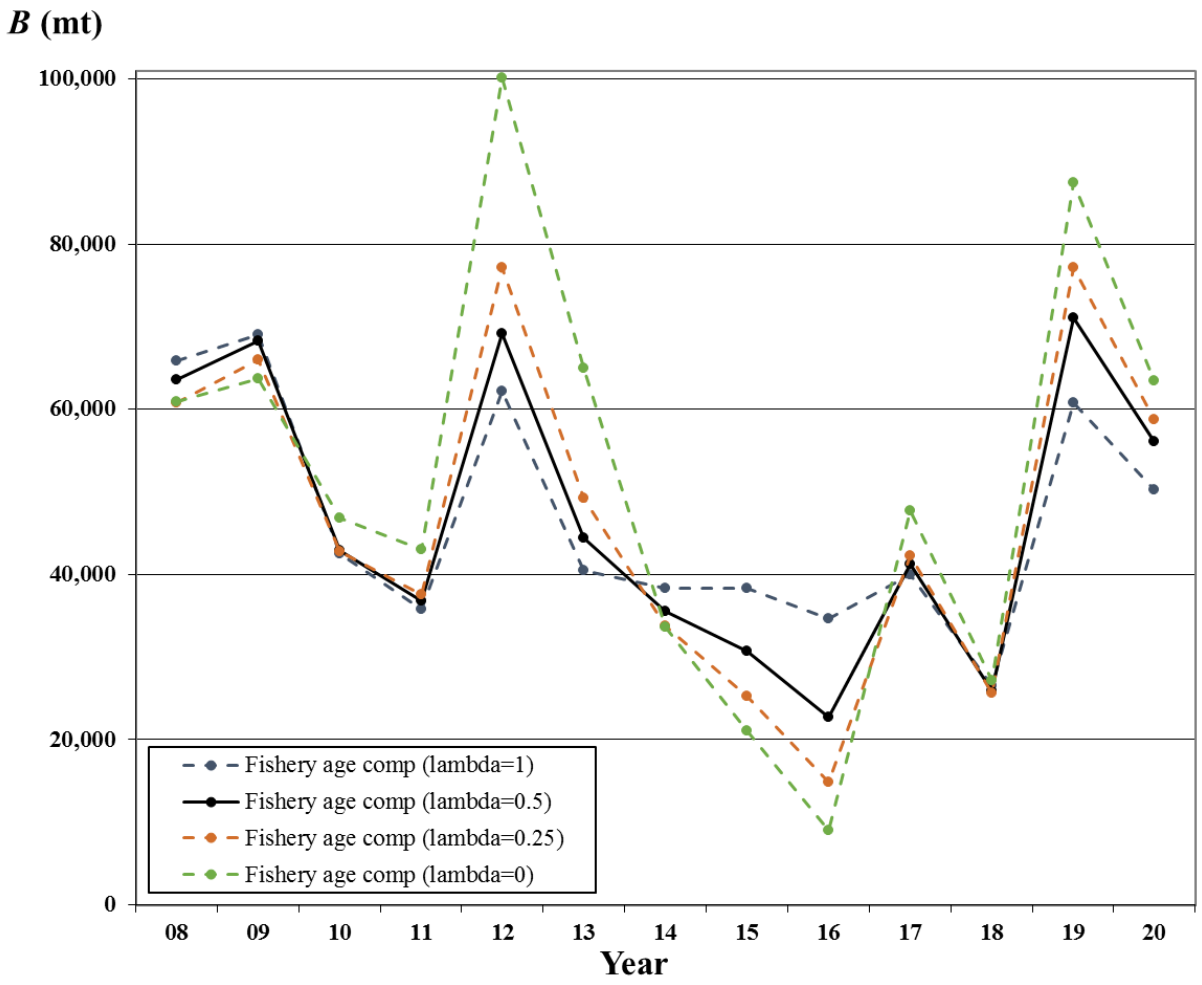

Figure 4. Estimated age 1+ stock biomass (*B*, mt) time series assoicated with alternative model ALT_19 configurations based on different data weighting (lambda emphasis in SS) assumptions for the fishery age-composition time series, including: lambda=1 (i.e., full weight); lambda=0.5 (final base model ALT_19); lambda=0.25; and lambda=0 (i.e., no weight and fishery selectivity fixed at estimated parameters from final base model ALT_19).

Appendix 1
2019 Pacific Mackerel STAR Panel Meeting Attendees

STAR Panel Members:
Owen Hamel (Chair), SSC, NWFSC
John Budrick, SSC, CDFW
Andrew Ole Shelton, SSC, NWFSC
Yan Jiao, CIE / VT

CPSMT/CPSAS Advisors to STAR Panel
Diane Pleschner-Steele, CPSAS
Lorna Wargo, CPSMT

Pacific Sardine Stock Assessment Team:
Paul Crone, SWFSC
Kevin Hill, SWFSC
Juan Zwolinski, UCSC/SWFSC
Michael Kinney, SWFSC

Other Attendees
Briana Brady, CDFW
Emmanis Dorval, CPSMT, SWFSC
Kerry Griffin, PFMC
Peter Kuriyama, SWFSC
Hui-Hua Lee, SWFSC
Josh Lindsay, CPSMT, NMFS WCR
Kirk Lynn, CPSMT, CDFW
Trung Nguyen, CDFW
Kevin Piner, SWFSC
Dale Sweetnam, SWFSC
Annie Yau, SWFSC
Louis Zimm, PFMC

CDFW – California Department of Fish and Wildlife
CPSAS - Coastal Pelagic Species Advisory Subpanel
CIE – Center for Independent Experts
CPSMT - Coastal Pelagic Species Management Team
NMFS – National Marine Fisheries Service (NOAA)
NOAA - National Oceanic and Atmospheric Administration
NWFSC - Northwest Fisheries Science Center (NMFS/NOAA)
PFMC - Pacific Fishery Management Council
SSC - Scientific and Statistical Committee (of the PMFC)
SWFSC - Southwest Fisheries Science Center (NMFS/NOAA)
UCSC – University of California Santa Cruz
VT - Virginia Polytechnic Institute and State University
WCR – West Coast Region (NMFS/NOAA)