Agenda Item D.1
Attachment 2
June 2022

# Central Subpopulation of Northern Anchovy

# STAR Panel Meeting Report

Online
December 7-10, 2021

**STAR Panel Members:**
André Punt (Chair), Scientific and Statistical Committee (SSC), University of Washington
John Budrick, SSC, California Department of Fish and Wildlife (CDFW)
Marisol García-Reyes, SSC, Farallon Institute
Gary Melvin, Center for Independent Experts (CIE)
Will Satterthwaite, SSC, National Oceanic and Atmospheric Administration (NOAA) / Southwest Fisheries Science Center (SWFSC)
Henrik Sparholt, CIE

**Pacific Fishery Management Council (Council) Representatives:**
Kerry Griffin, Council Staff
Diane Pleschner-Steele, Coastal Pelagic Species Advisory Subpanel (CPSAS) Advisor to STAR Panel
Greg Krutzikowsky, Coastal Pelagic Species Management Team (CPSMT) Advisor to STAR Panel

**CSNA Stock Assessment Team:**
Peter Kuriyama, NOAA / SWFSC
Kevin Hill, NOAA / SWFSC
Steve Teo, NOAA / SWFSC
Juan Zwolinski, University of California at Santa Cruz, affiliated to NOAA / SWFSC

## 1) Overview

The Stock Assessment and Review (STAR) Panel (Panel) met online December 7-10, 2021 to review a draft assessment by the Stock Assessment Team (STAT) for the central subpopulation of northern anchovy (CSNA). 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, and throughout the meeting (Appendix 2).

Peter Kuriyama introduced the assessment and provided information about the alternative indices of abundance, Juan Zwolinski provided an overview of the Acoustic Trawl (AT) Method survey, and Emmanis Dorval and Brad Erisman summarized how the age-reading error matrices and maturity ogives were estimated. Kirk Lynn summarized the results of recent aerial surveys for the CSNA, and John Field presented the Rockfish Recruitment and Ecosystem Assessment Survey (RREAS).

The proposed base model in the draft assessment provided to the Panel was based on the Stock Synthesis Assessment Tool v3.30.17. It aimed to estimate current age-1+ biomass using the data source the STAT considered most reliable, the AT survey. Consequently, the assessment started in 2015, the first year for which estimates of biomass for the CSNA are deemed suitable by the survey analysts. In addition to fitting to the biomass index and age-composition data from the AT survey, the assessment also fitted to age-composition data from two aggregated fisheries (MexCal_S1 and MexCal_S2). The fisheries consist of landings made in widely geographically separated areas (Monterey, Southern California and Mexico), each with different targeting practices, broken into two unequal (7 and 5 month) periods. The assessment used empirical estimates of weight-at-age rather than estimating weight-at-age using a parametric growth curve, and allowed for time-variation in selectivity.

It was noted that the Pacific Fishery Management Council (PFMC) has adopted a new management framework (see Council Operating Procedure 9, schedule 3), which requires a "long-term" average estimate of age-1+ biomass for the most recent ten years and an estimate of the exploitation rate on age-1+ biomass corresponding to maximum sustainable yield MSY (i.e., $E_{\mathrm{MSY}}$). In contrast, the STAT developed its assessment with a focus on estimating current age-1+ biomass based on the data available for the last seven years. Panel discussion included an evaluation of whether an assessment that involved a longer time period would be feasible (the STAT included model runs in the draft assessment report based on a longer time period when examining the alternative indices).

Panel discussion also focused on 1) specification of survey catchability (Q), which was set to 1 for the AT survey with no correction for inshore abundance in the draft assessment, which is counter to previous to previous direction given at various reviews of the AT survey, 2), selectivity-at-age (which varied considerably from one year to the next), 3) whether the very high fishing mortality rates for some fisheries and seasons were plausible (given the estimated age-specific selectivity patterns), 4) ageing and specification of age-reading matrices, and 5) whether the results of 2015 AT survey (which appear to be lower than expected given the subsequent surveys) should be included in the assessment. The Panel made numerous requests of the STAT (see below).

A preliminary estimate of biomass from the Summer 2021 AT survey was made available to the STAT (no age data are currently available) but not included in the models contained in the draft report. This estimate was included in some of the model runs during the meeting, but the Summer

2021 biomass estimate will only be finalized in 2022. The sensitivity of the results of the final base model to the fully vetted estimate of the 2021 biomass should be examined before the assessment is endorsed by the SSC in June 2022. It was also agreed that this sensitivity analysis should include an inshore correction to the spring 2016 estimate based on extrapolation (rather than the aerial survey) if available, and that the final summer 2021 estimate should include a correction for nearshore biomass based on either nearshore acoustics (the STAT preferred option) or the results of the aerial survey.

The final base model differed from the base model in the draft assessment report by including the Summer 2021 AT survey estimate of biomass, reducing the plus-group from age-4+ to age-3+, updating the age-reading error matrices, adjusting the AT survey estimates of biomass and the survey Q values given the area not covered by the AT surveys, and modifying how time-varying selectivity is modelled.

The final base model also included adjustments to the biomass estimates and survey Q to reflect biomass inshore of the area sampled by the AT survey. The effect of these adjustments was minor but reflect implementation of the recommendation of the 2018 AT Methodology Review that the corrections be made to AT estimates to reflect inshore areas (albeit preference was given to extrapolation of AT densities over use of aerial survey estimates of abundance). This decision was noted by some as inconsistent with conclusions reached at the joint meeting on issues related to management of CSNA (Agenda Item D.4, Attachment 1, November 2019) to use direct observations.

The STAR Panel thanked the STAT, and particularly the STAT lead, for their hard work and willingness to respond to the many Panel requests. The Panel also recognized the hard work and contributions of the other scientists to the assessment through the provision of, for example, abundance indices, age-reading error matrices, age-composition data, and basic biological information. The Panel also appreciated the very collaborative nature of the team that led to the draft assessment and the final base model.

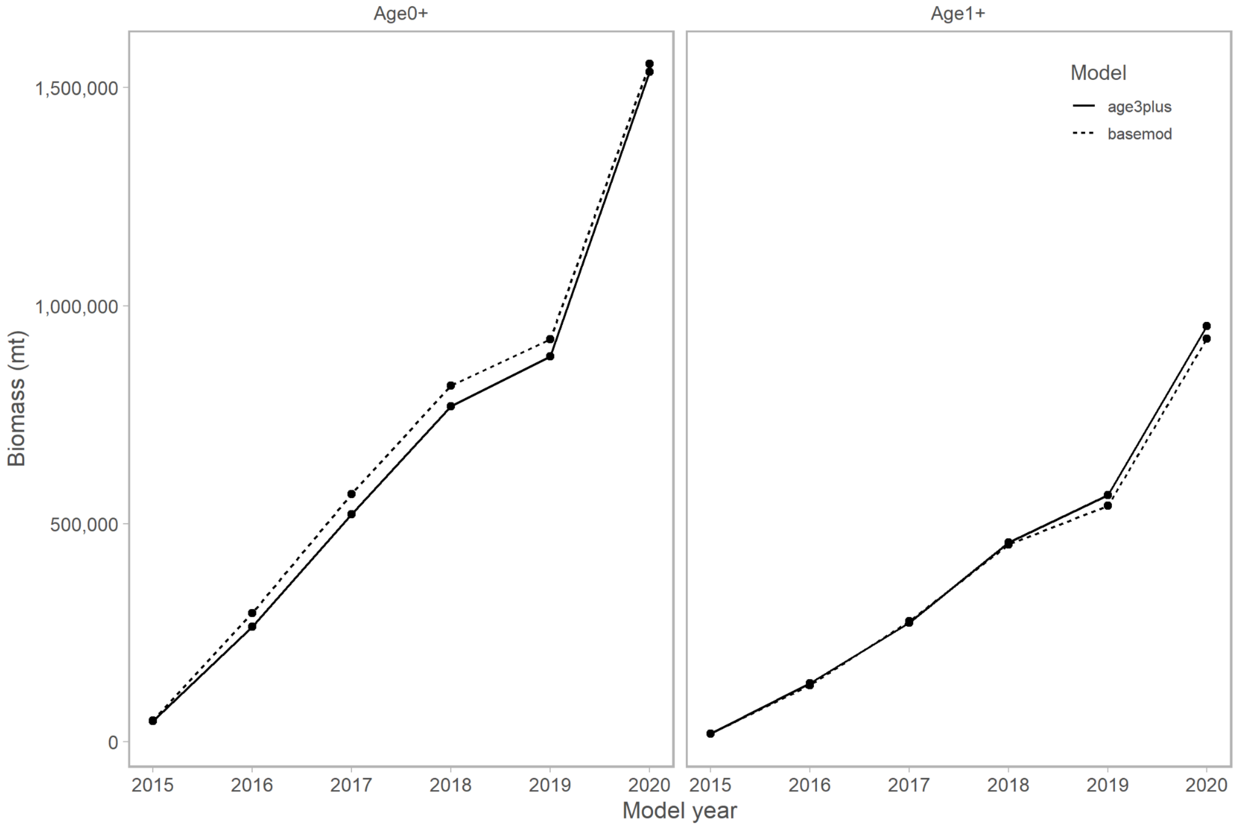
## 2) <u>Requests made to the STAT during the meeting</u>

*Day 1 requests made to the STAT during the meeting – Tuesday, December 7*

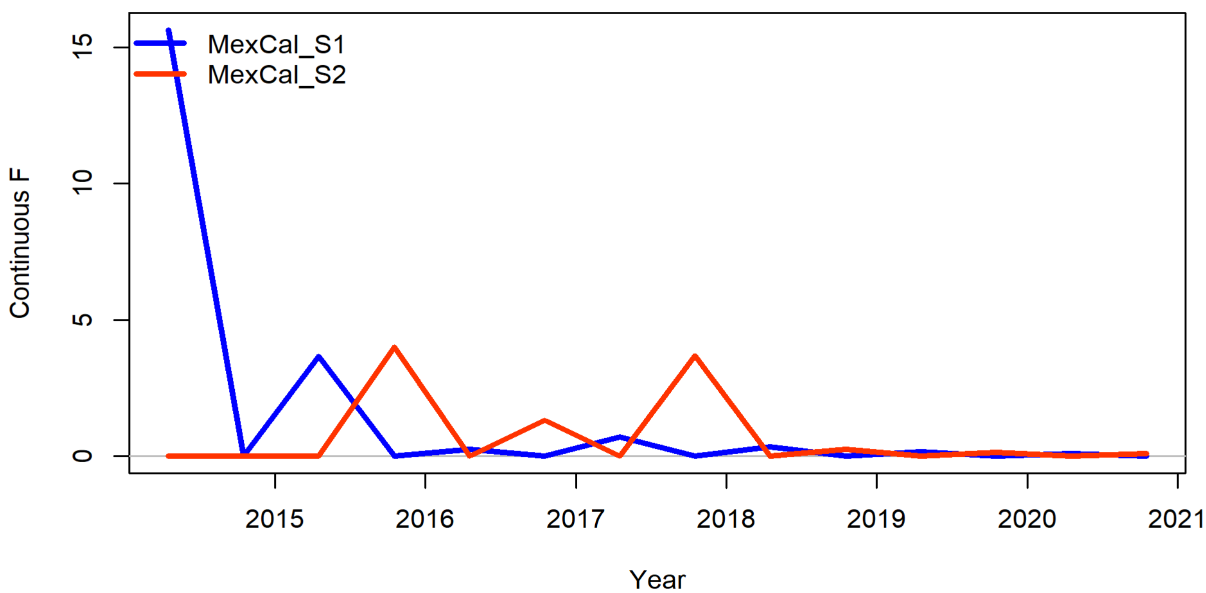
**Request 1**: Provide a figure or table displaying the timeline of important events both as modelled and how they occur in reality, including: model semesters, model years, calendar years, fishing seasons, spawning, ageing up/birthdays, model censuses, and surveys.
**Rationale**: There are multiple timelines (calendar years, model years, fishing seasons) and multiple biological processes that occur over a range of dates, but are assumed to take place at a single point in time or have discrete boundaries in the models. A graphical display would help readers understand and reconcile the different timelines.
**Response**: (note that the labelled dates for Catch reflect the midpoints of the respective seasons).

| Calendar year (example) | Model year (example) | Calendar month | Model semester | Model month | Biology events | Surveys | Catch | Reported values |
|---|---|---|---|---|---|---|---|---|
| 2015 | 2015 | June | 1 | 1 | Recruitment, age+1 | RREAS_YOY; CalCOFI | | Age-0+ and age-1+ biomass |
| 2015 | 2015 | July | 1 | 2 | | AT_summer | | |
| 2015 | 2015 | August | 1 | 3 | | Aerial | | |
| 2015 | 2015 | September | 1 | 4 | | Aerial | MexCal_S1 | |
| 2015 | 2015 | October | 1 | 5 | | | | |
| 2015 | 2015 | November | 1 | 6 | | | | |
| 2015 | 2015 | December | 1 | 7 | | | | |
| 2016 | 2015 | January of next year | 2 | 8 | Spawning | | | Spawning Stock Biomass; Recruits |
| 2016 | 2015 | February of next year | 2 | 9 | | | | |
| 2016 | 2015 | March of next year | 2 | 10 | | AT_spring, Aerial | MexCal_S2 | |
| 2016 | 2015 | April of next year | 2 | 11 | | Aerial | | |
| 2016 | 2015 | May of next year | 2 | 12 | | | | |

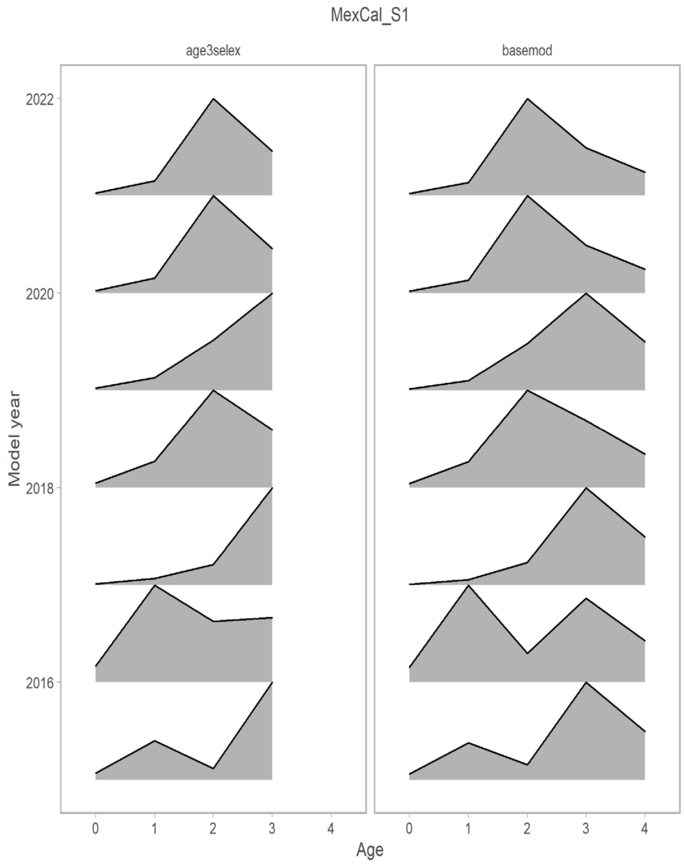
**Request 2**: As a sensitivity analysis, show the results of starting the plus group at age-3 rather than age-4.
**Rationale**: There may be little biological difference (e.g., expected length) between age-3 and age-4 fish, ageing errors are greater at the older ages, and age-4 fish appear to be rare.
**Response**: In the weight-at-age file, the weights-at-age for age-3 and age-4+ fish were combined as a weighted average based on the age-3 and age 4+ values in the age compositions for each fleet. In the age compositions, the age-3 and age-4+ values were summed to one age-3+ value for each year and fleet. The last column of ageing error values was commented out in the dat file and the age-4+ selectivity parameters were removed. The time series comparing age-0+ and age-1+ biomass, selectivity and fully-selected fishing mortality for the two models is shown below.

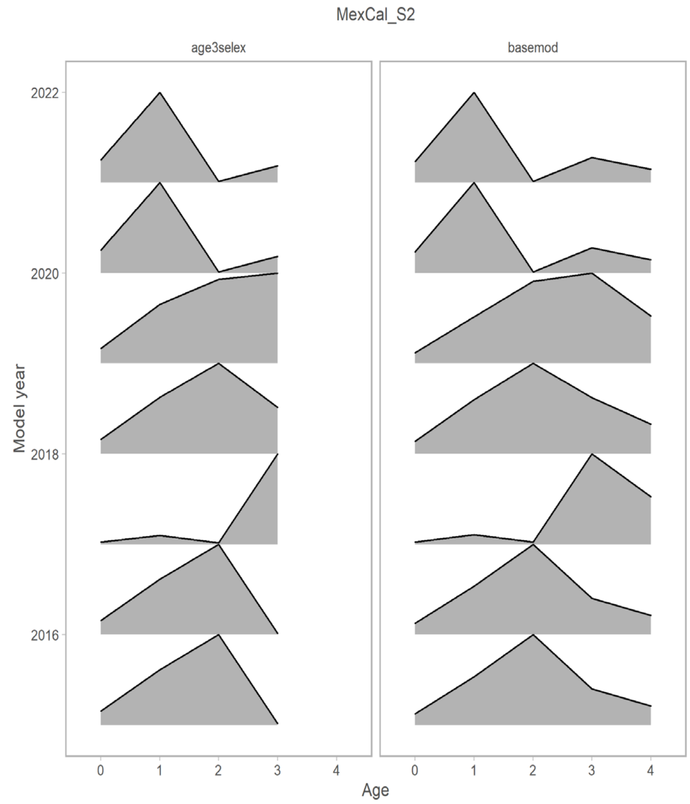


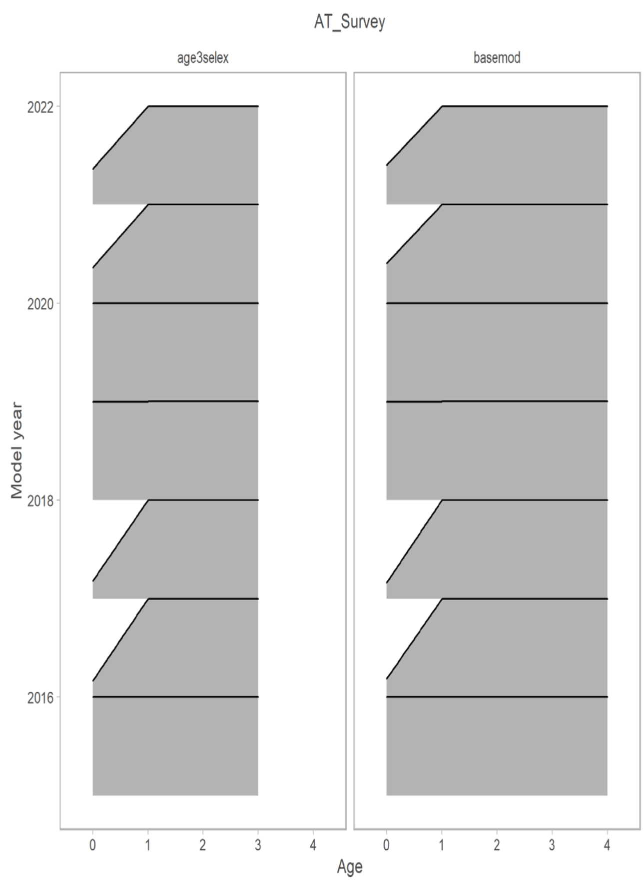
Age0+
Age1+
Model
age3plus
basemod
1,500,000
1,000,000
500,000
0
Biomass (mt)
2015
2016
2017
2018
2019
2020
Model year

MexCal_S1
MexCal_S2
15
10
5
0
Continuous F
2015
2016
2017
2018
2019
2020
2021
Year

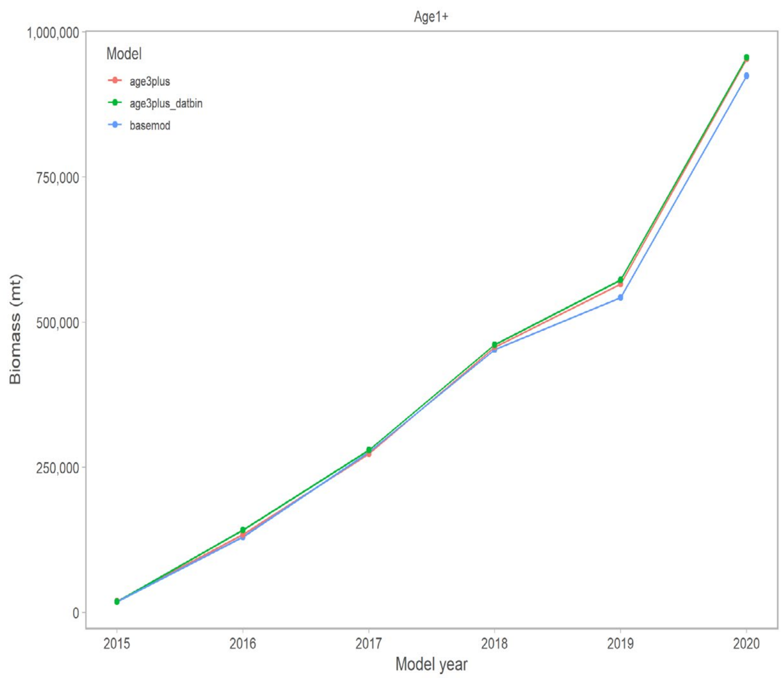

MexCal_S1
age3selex
basemod
Model year
2016
2018
2020
2022
0
1
2
3
4
Age

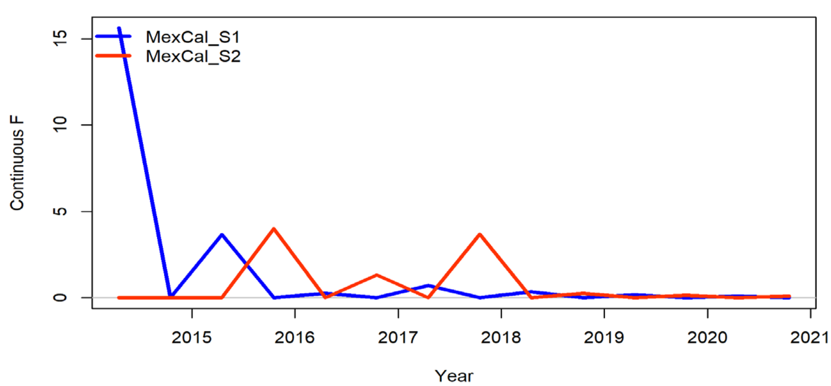

MexCal_S2
age3selex
basemod
Model year
2016
2018
2020
2022
0
1
2
3
4
Age


AT_Survey
age3selex
basemod
Model year
2016
2018
2020
2022
0
1
2
3
4
Age

The Panel noted that the results are insensitive to changing the plus-group age, in particular, pooling age-3 and age-4+ did not result in fewer and less marked time-trajectories of the fully-selected fishing mortality. The STAT agreed to move to a model based on a plus-group at age 3+.

**Request 3**: Similar to Request 2, but retain a plus-group of age-4+ in the population dynamics model and pool the age-composition data (not weight-at-age data) for age-3 and age-4+ to create a "data plus-group" of age-4+.
**Rationale**: Same as Request 2.
**Response**:

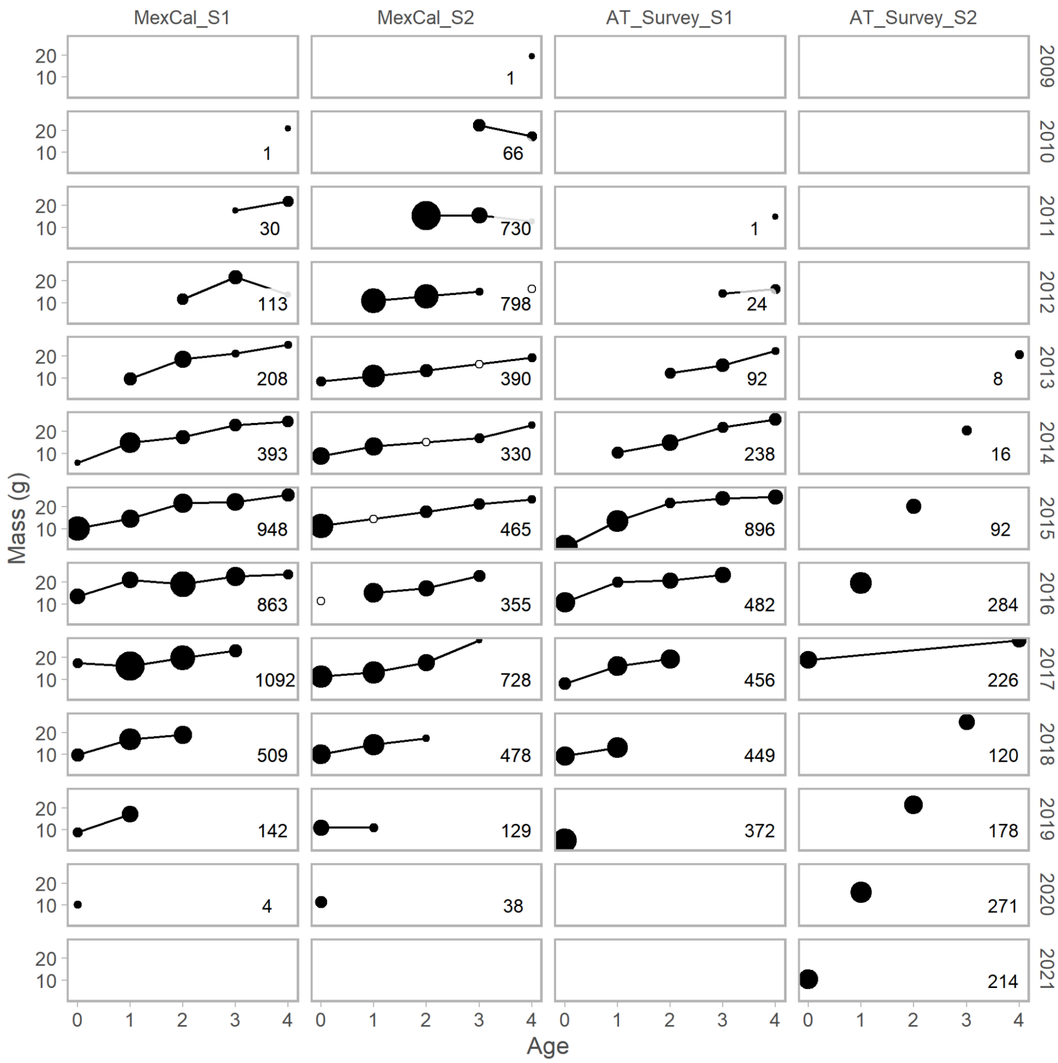



Changing the plus-group age for the data but not the population dynamics model had little impact on the results of the assessment.

**Request 4**: Provide more details on the interpolation method used to reconstruct weight-at-age.
**Rationale**: The interpolation routine was not sufficiently described.

**Response**: The figure in the draft assessment document is shown below. MexCal_S2 had no data for model year 2016. The age-0 weight-at-age (reference cohort year 2016 on the right side of the plot) was calculated based on the average (mean over all years) of other age-0 fish from the MexCal_S2 fleet. The age-4+ value (reference cohort year 2012) was calculated based on the average age-4+ values for the MexCal_S2 fleet. For the cohorts with missing values (e.g., cohort year 2015; age 1), imputed values were calculated as a linear interpolation between age-0 and age-2 for cohort 2015 under the assumption of linear growth.

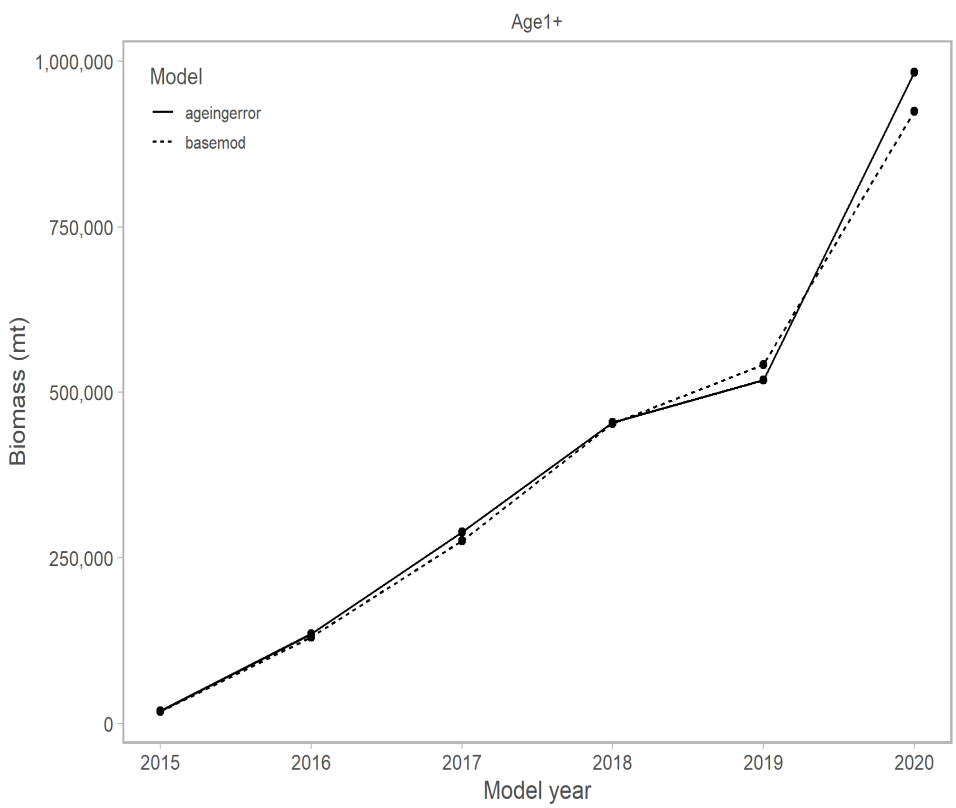



The Panel requested that the final assessment document include the description of how the interpolation was conducted.

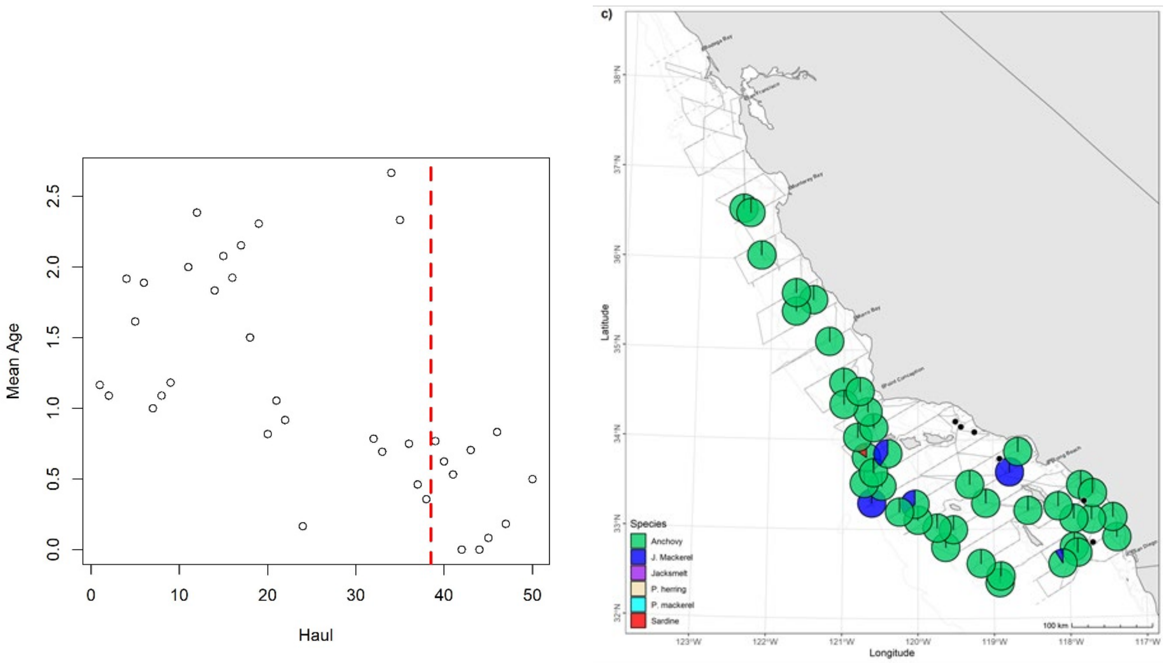
**Request 5**: In the final assessment document, include discussion of the various factors beyond size-dependent vulnerability to gear that may influence the fitted selectivities (e.g., age-dependent movement, fishery targeting behavior, collapsing multiple fisheries into a single modelled fishery, ageing error, unaccounted for spatial structure in sizes, absorbing unmodeled process variation such as changes in *M*, etc.).
**Rationale**: Selectivities for both the survey (on age-0) and fisheries (all ages) were highly variable, and sometimes multimodal in the case of the fisheries, which is contrary to expectation for a well-

specified model of a simple system. Discussing reasons for these divergences would help readers interpret the model outputs.
**Response**: Response deferred until final assessment document.

**Request 6**: Recalculate the age-reading error vectors (for the survey data) to reflect the removal of one reader's outputs from the data included in the assessment, re-run the assessment, and justify the assumption of no bias once that reader is removed.
**Rationale**: If the data generated by that reader were excluded, their ageing performance is not relevant to ageing error in the age data used in the assessment.
**Response**: The STAT updated the age-reading matrices excluding the data for "reader 15" from 2017-2021, which led to much smaller (and more realistic) estimates of age-reading standard deviation. A model run based on the updated age-reading error matrices shows little effect of changing the age-reading error matrices on the time-trajectory of age-1+ biomass. Fits to survey and fishery age data were also similar.

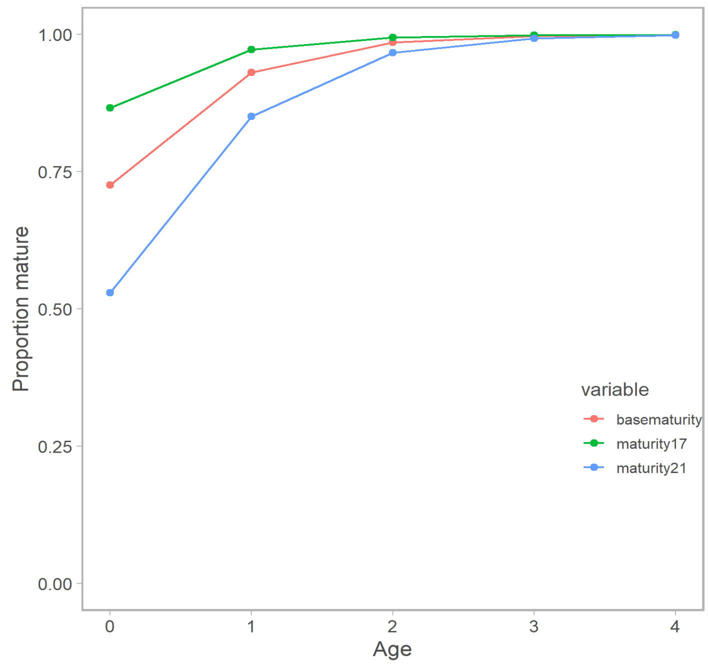


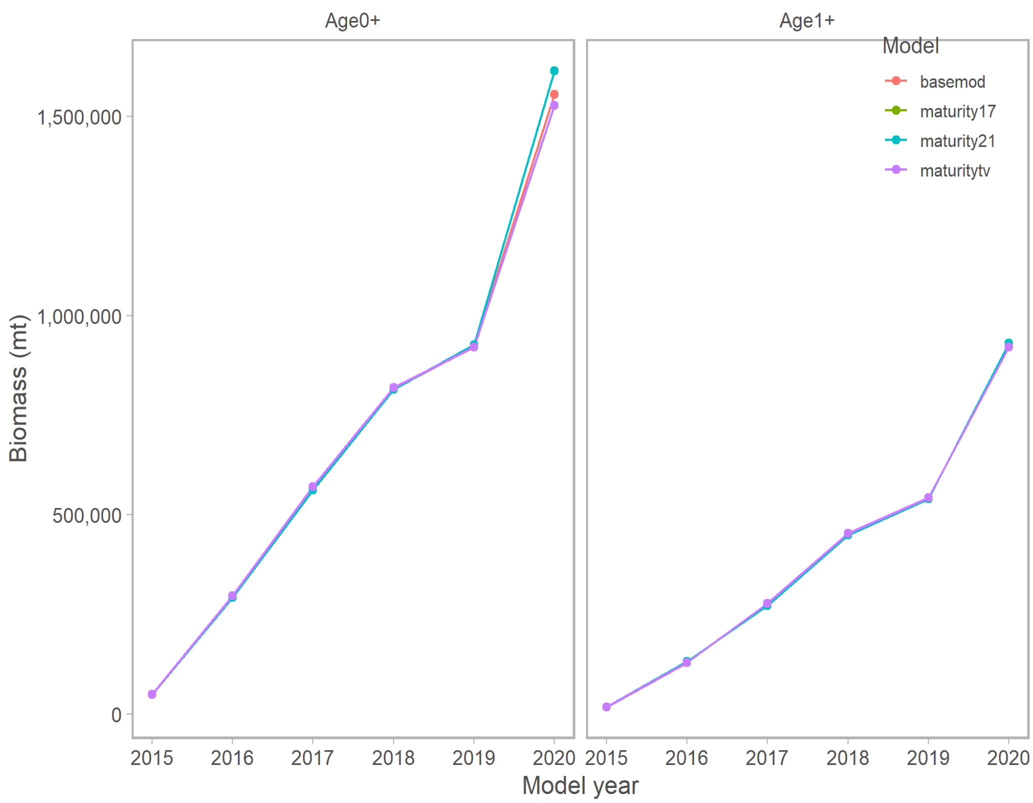

**Request 7**: Plot mean age by trawl for the Spring 2021 AT survey.
**Rationale:** It was noted that there was substantial biomass in the north but spawning primarily appeared to have occurred in the south. This could confound calculations of maturity at age/length if age/length compositions vary across space, to an unknown extent.
**Response**:




(Left) mean age per haul from south to north during the spring 2021 AT survey, and (right) haul location. On the left-hand graph, the points to the left of the vertical line correspond to the trawls south of Point Conception. The Panel agreed that the information provided did not necessitate a change to the assessment model but that continued work on understanding maturity was important.

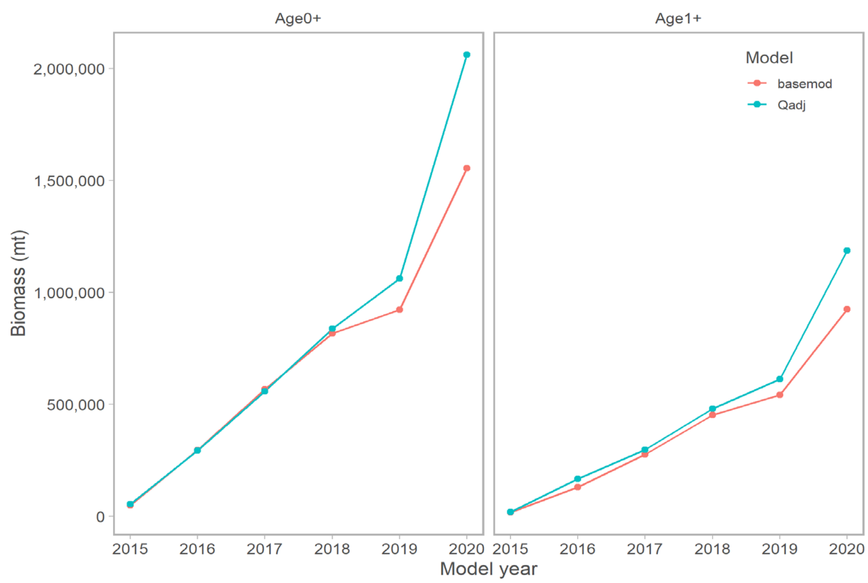
**Request 8**: Perform a sensitivity analysis to assess how much age-1+ biomass changes if the maturation ogive is based on 2017 data alone or 2021 data alone.
**Rationale**: The fitted maturation ogives for 2017 and 2021 are different (possibly reflecting density dependence, but with only two years of data this is necessarily speculative) so it is important to determine how sensitive the relevant assessment outputs are to the uncertain maturation rate of age-0 fish.
**Response**: The figure below shows the maturity curves for only 2017 and only 2021 data compared to that used in the base model and the results of assessment runs using alternative maturity ogives.

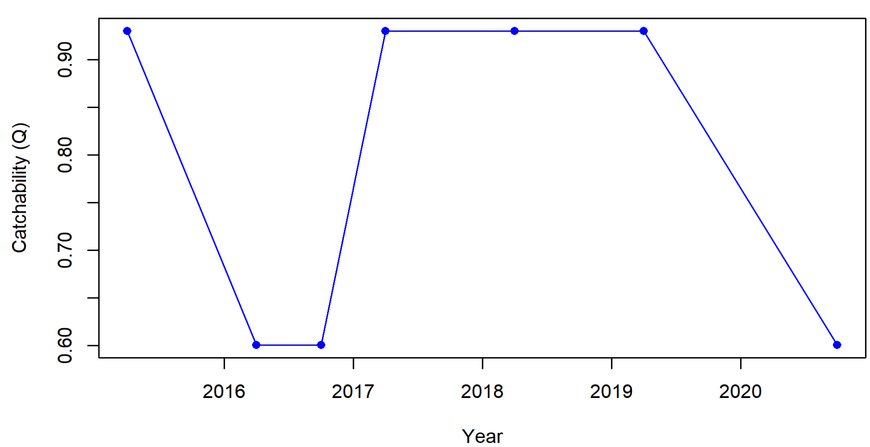



The age-0+ and age-1+ biomass trajectories for each of the models are shown above. The figure also includes results for a model (denoted "maturitytv" above) that included the 2017 maturity values for the years 2015-2019 and the spring 2021 maturity values for 2020 (model year) to include the spring 2021 (calendar year; these are equivalent) maturity. The biomass values differ very little among model runs. The Panel agreed that specifications for maturity had little impact on final model outputs used for management. The estimate of $E_{\mathrm{MSY}}$ will depend to some extent on the assumed maturation ogive and the short-term research recommendations include the need to assess the sensitivity of $E_{\mathrm{MSY}}$ to the assumed maturation ogive (see also request 32).

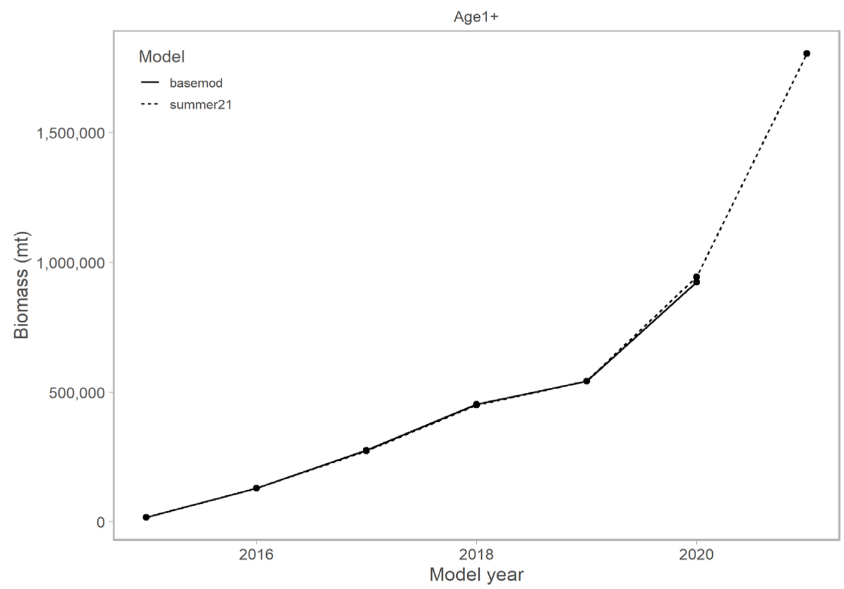
**Request 9:** As a sensitivity analysis, re-run the base model except with catchability Q=0.93 for summer AT surveys and 0.6 for spring AT surveys.
**Rationale**: In 2021, the summer AT survey extended well into Mexico and presumably encompassed the entire range of CSNA, and estimated a biomass of 2,357,317 mt (out of which 168,626 mt or 7% was in Mexico). The spring 2021 AT survey stopped at the US-Mexico border and estimated a biomass of 1,358,587 mt. Assuming no change in total biomass between spring and summer, this suggests that only a fraction (1,358,587/2,357,317 = 0.58) was in US waters in the spring (rounded to 0.6 for the initial request). In the summer 2021 AT survey, 93% of the estimated biomass was in the US.
**Response**: The STAT conducted an initial analysis in which survey Q was 0.93 for summer AT surveys but survey Q for 2016 was 0.6 for both surveys.



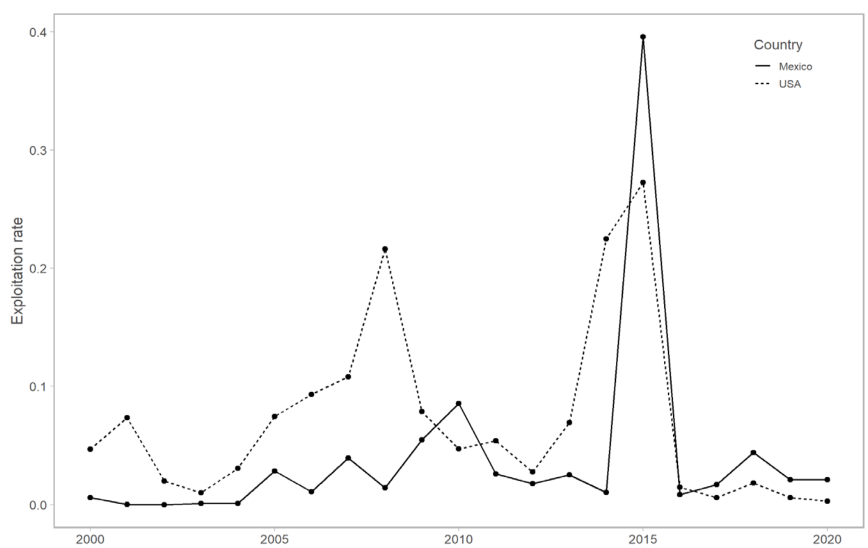




**Request 10:** Same as Request 9, but also include the preliminary results from the summer 2021 AT survey with Q=1.

**Rationale**: Similar to Request 9, plus the summer 2021 AT survey extended into Mexico, implying complete latitudinal coverage.
**Response**: The base model forecasts age-0+ biomass for June 2021 to be 2.26 million mt and 1.59 million mt for age-1+. The preliminary biomass estimate from summer 2021 AT cruise was 2.357 million mt, CV=0.15 (and no age compositions yet). This model has an additional year in the model time period.



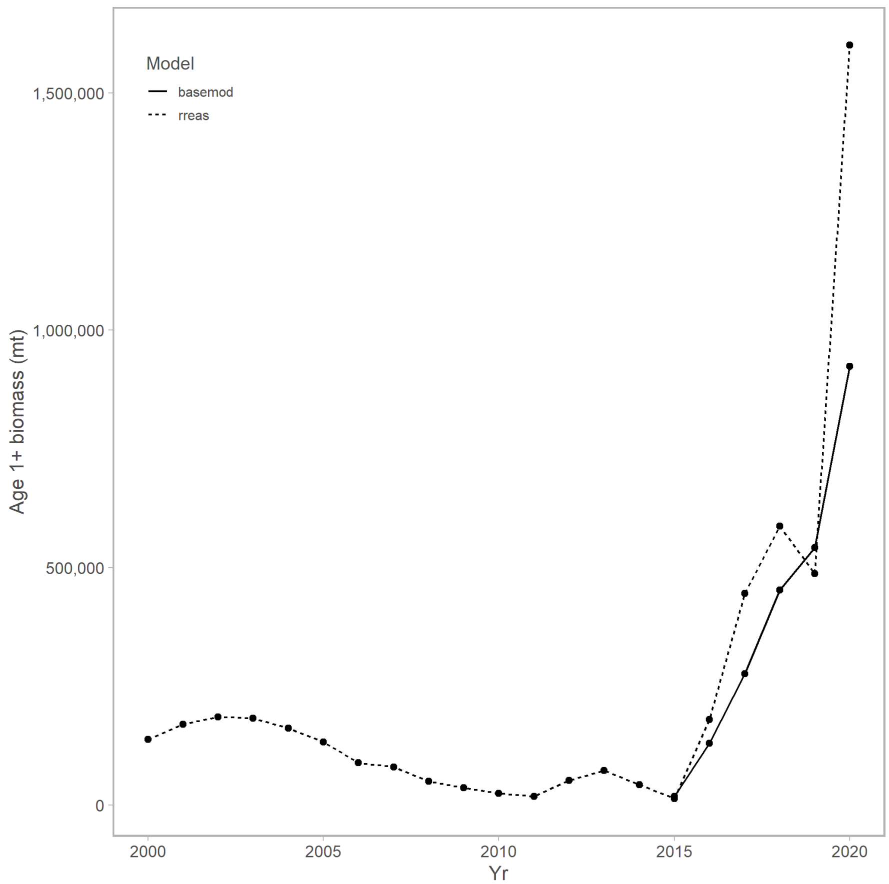

**Request 11**: Convert plots of F through time to exploitation rate for the extended RREAS model, similar to Figures 34 versus 35 of the draft assessment document.
**Rationale**: Some "unreasonably high" F values may reflect very low modelled selectivity on the age classes predominantly available to the fishery in a particular year, and the base model included some similarly high (or higher) F estimates.
**Response**:



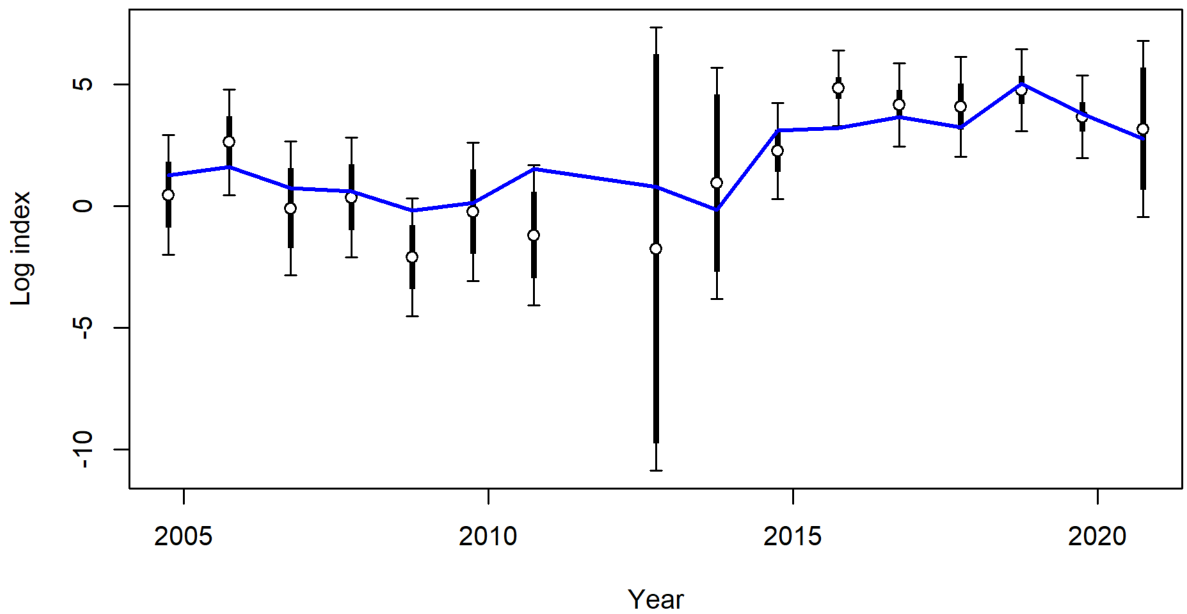

The Panel noted that the exploitation rates were generally low (< 5% for most years and fleets) with the notable exception of 2015, which had similarly high exploitation rates in the base model, and appears to be a year of rapid biomass increase that may not be well reflected by using June 1 biomass as the denominator in the exploitation rate calculation.

**Request 12**: Provide r4SS outputs for the draft base model and for the extended RREAS model to investigate patterns in F, exploitation rate, selectivity, and how well the modelled recruitments fit the RREAS recruitment index.
**Rationale**: The Panel wished to better understand the changes in fit when the RREAS YOY index is included and the model timeline is extended.
**Response**: The plots were provided and the Panel continued to use r4ss to examine model fits, outcomes and parameter values.

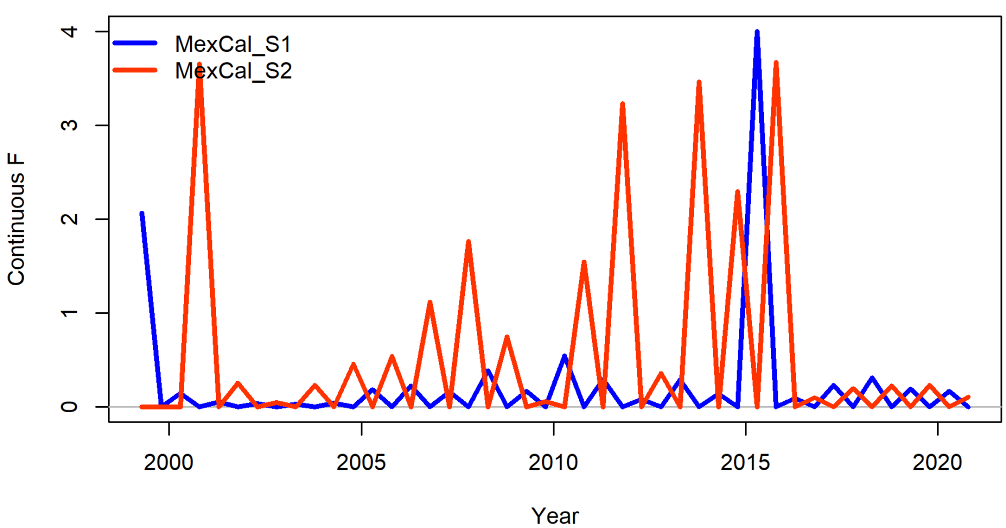
Age 1+ biomass comparison



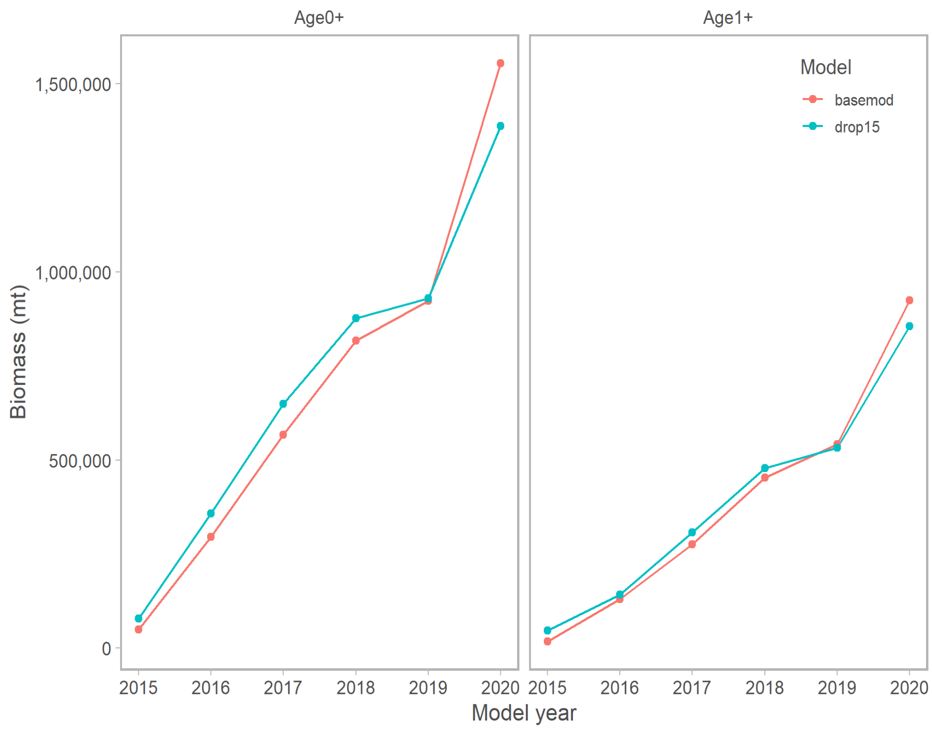
Fit to RREAS index



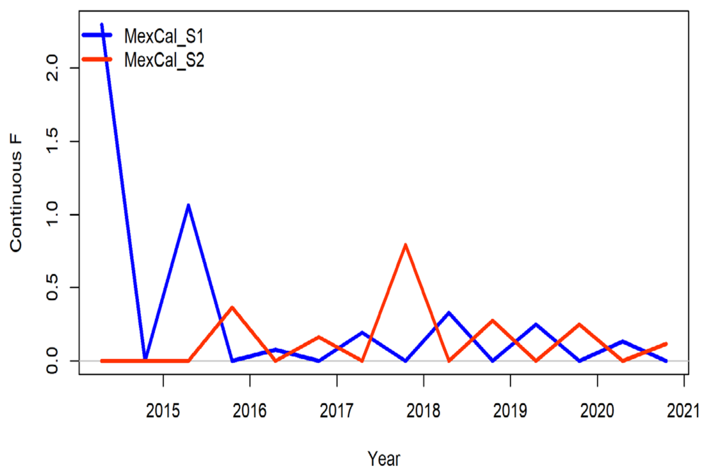

F values from RREAS model



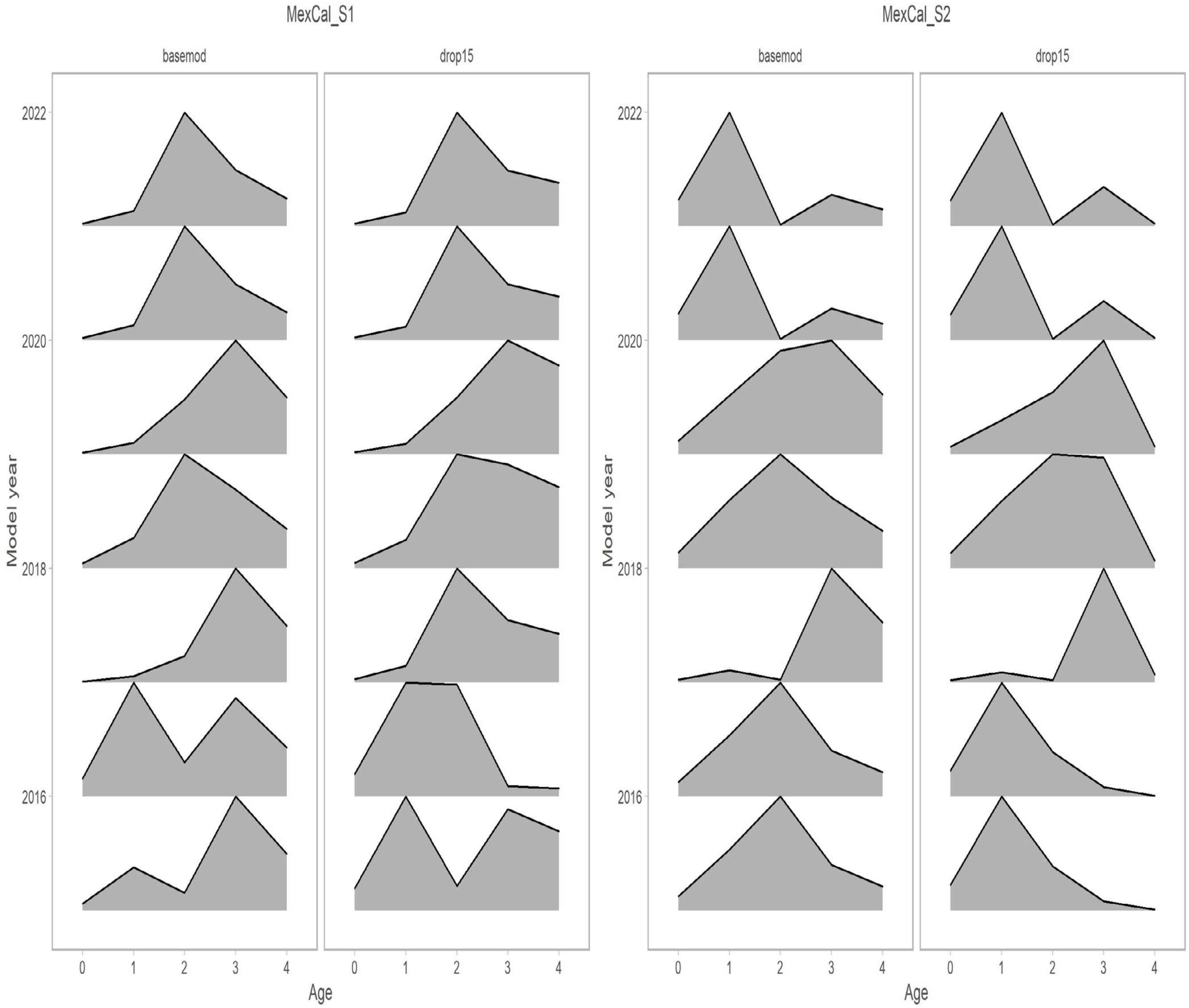

**Request 13:** As a sensitivity analysis, re-run the base model excluding the 2015 AT survey.
**Rationale**: The 2015 AT survey may be less reliable than more recent AT surveys for the purpose of estimating CSNA biomass.
**Response**:



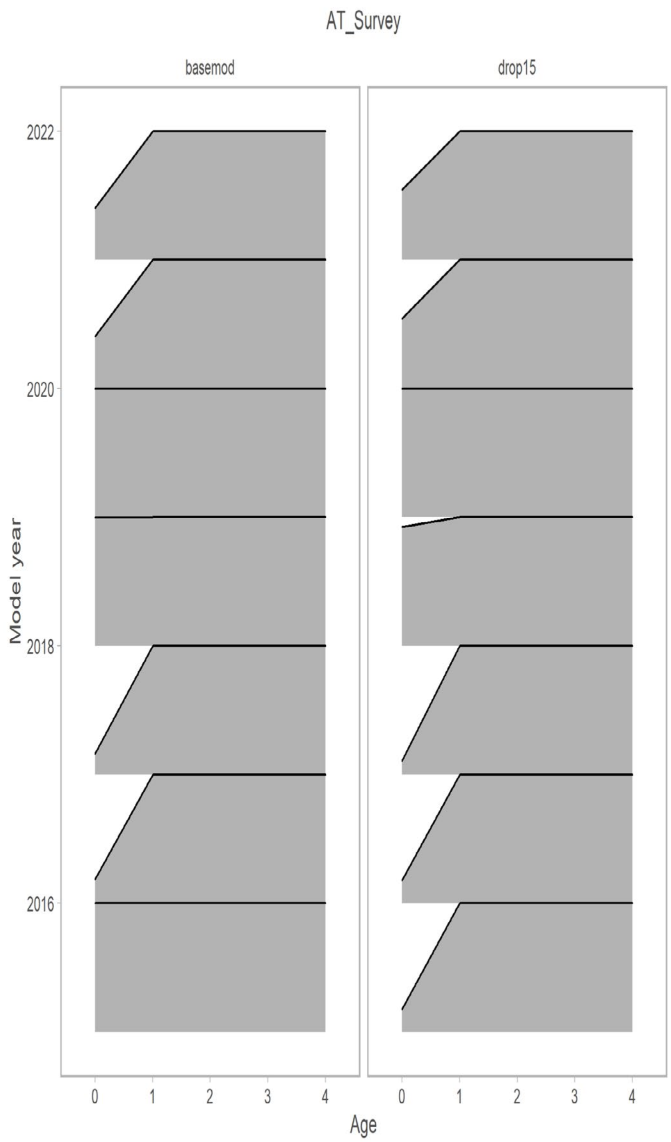
Age0+
Age1+
Model
basemod
drop15
1,500,000
1,000,000
500,000
0
Biomass (mt)
2015
2016
2017
2018
2019
2020
Model year

MexCal_S1
MexCal_S2
Continuous F
0.0
0.5
1.0
1.5
2.0
2015
2016
2017
2018
2019
2020
2021
Year



MexCal_S1
MexCal_S2
basemod
drop15
basemod
drop15
2022
2020
2018
2016
Model year
0 1 2 3 4
Age




The results of the run with no 2015 survey (index or age-composition) were qualitatively nearly identical to those for the original base model.

**Request 14**: Explain the parameterization of the selectivity function used (Pattern 17 in SS).
**Rationale:** It is not clear how the parameters map onto the emergent selectivity curves, and there seem to be values for years not included in the model.
**Response**: The parameter values, which can be both positive and negative, in the parameter section of the report file do not directly represent selectivity-at-age. From the SS manual:

### Pattern 17 (age) - Random Walk

This selectivity pattern provides for a random walk in ln(selectivity). For each age $a \geq A_{\text{min}}$, where $A_{\text{min}}$ is the minimum age for which selectivity is allowed to be non-zero, there is a selectivity parameter, $p_a$, controlling the changing selectivity from age $a-1$ to age $a$.

The selectivity at age $a$ is computed as

$$S_a = \exp(S'_a - S'_{\text{max}}), \tag{24}$$

where

$$S'_a = \sum_{i=a_{\text{min}}}^{A} p_i \tag{25}$$

and

$$S'_{\text{max}} = \max\{S'_a\}. \tag{26}$$

Selectivity is fixed at $S_a = 0$ for $a < A_{\text{min}}$.

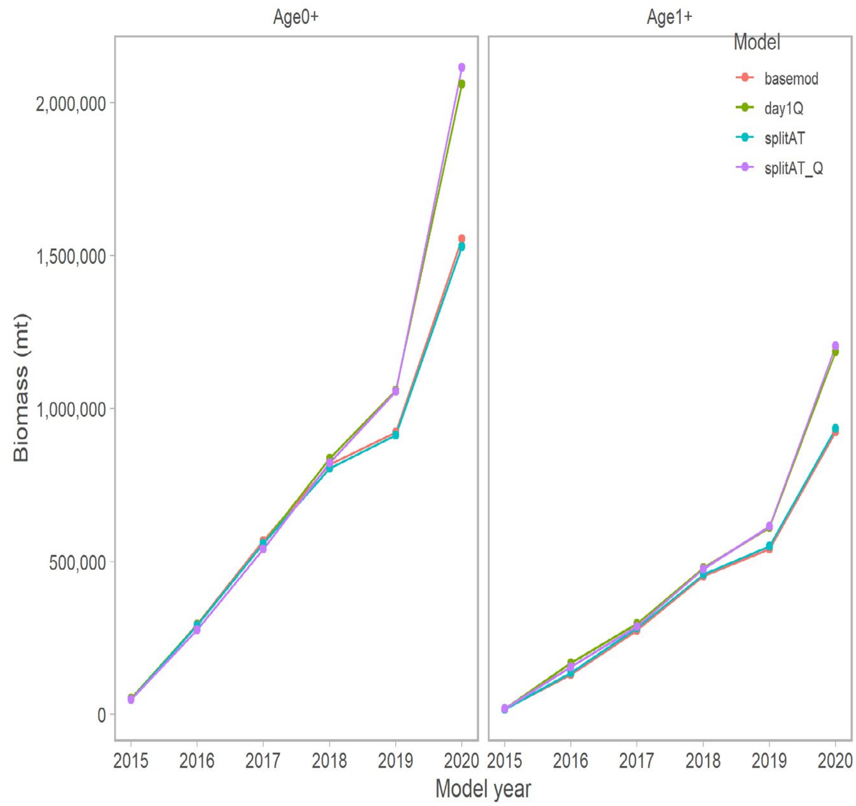
The 2012 selectivities are the average selectivities from 2015-2020 that are used for benchmark calculations. The Panel noted that the current parameterization implies that the ratio of selectivity between age-0 and age-1, as well as between age-3 and age-4+ are time-invariant, which led to a new request (Request 26) to examine a more flexible (but at the same time constrained) selectivity pattern.

*Day 2 requests made to the STAT during the meeting – Wednesday, December 8*

**Request 9a:** Similar to Request 9, but use separate Qs for the AT spring versus summer surveys in 2016. This can be done by treating the spring and summer AT surveys as separate fleets.

**Rationale:** Same as Request 9, noting that it is more time consuming to set up a model that allows for different Qs for the spring versus summer AT surveys in the same year and so this was not done in the initial response to Request 9.

**Response:** The plot below shows the biomass values with the AT survey treated as two separate fleets, each with their own Q values. The "splitAT" scenario is the base model with two AT fleets.




**Request 15 (STAT-initiated):** Re-run the extended RREAS model with a fix to the timing assigned to the AT survey in the model, with and without the 2020 index, and using a larger upper bound on $M$ (1.5yr$^{-1}$).

**Rationale**: It was noted that the timing was incorrect in previous versions of the model with the RREAS index. The STAT also suggested dropping the 2020 RREAS index value because of very limited spatial coverage. The surveys occur in May, generally after the spring AT survey and before summer AT survey. Consequently, for example, the May 2015 RREAS should be input as a recruitment index input to the model at June 1 during model year 2016. The RREAS base model is “realigned_rreas_no2020” in the figure below.

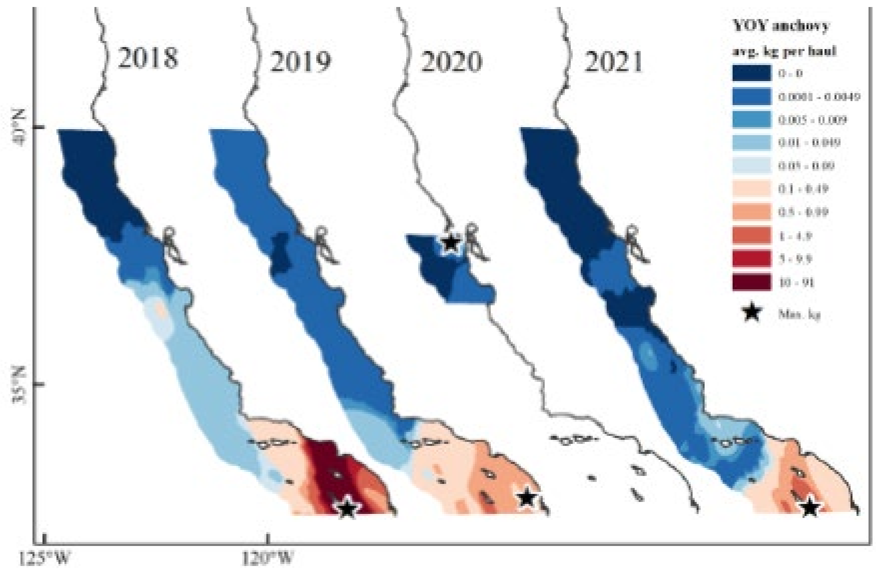
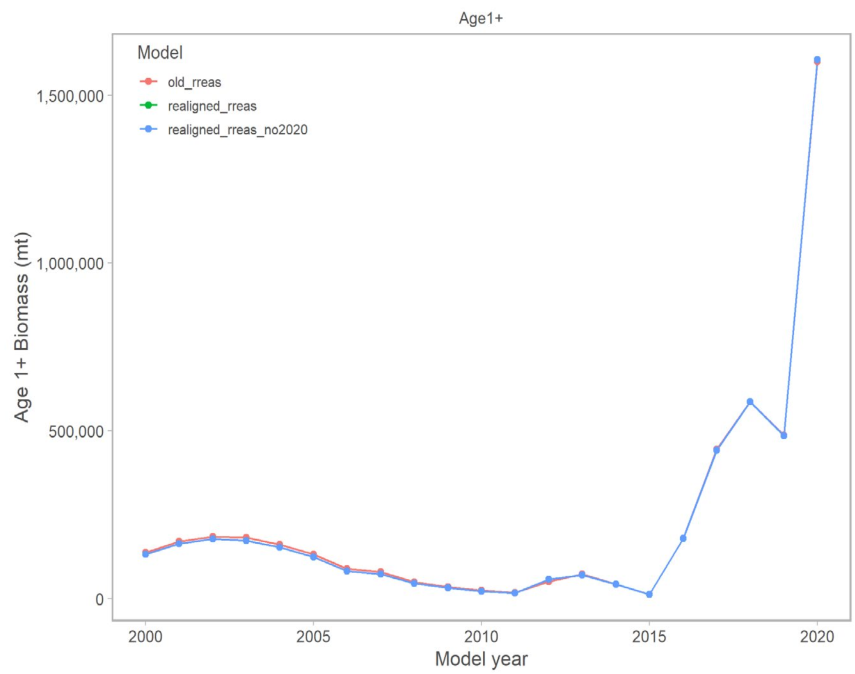



Figure 5: Spatial distribution of young-of-the-year (YOY) anchovy catches, 2004-2021

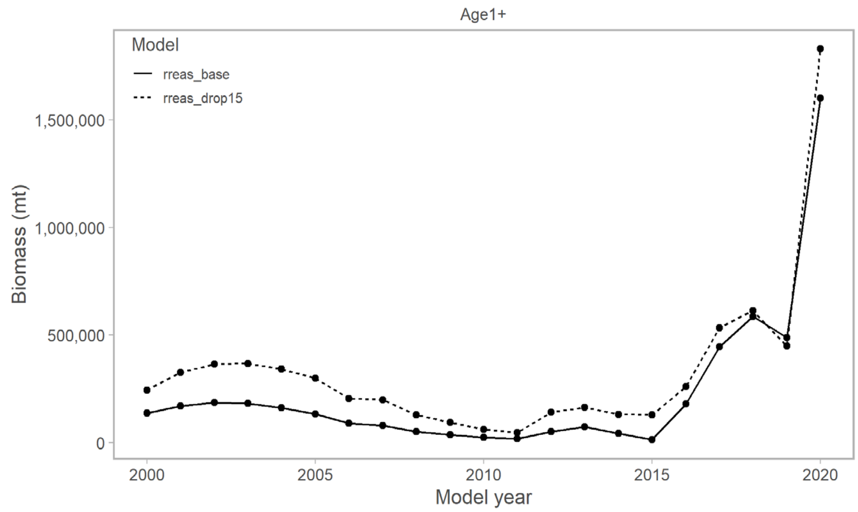



The Panel agreed that dropping the 2020 (as well as 2011, which also had low spatial coverage and was dropped from all runs under consideration) estimate from the index was appropriate.

**Request 16**: Provide information relevant to the reliability of estimates of weight-at-age for age-0 fish from the AT survey when applied to the modelled population as a whole.
**Rationale**: Age-0 fish make a large contribution to total biomass and there was considerable inter-annual variation in the estimated weight-at-age for age-0 fish from the surveys.
**Response**: This will be addressed as a future research issue.

**Request 17**: Provide a run of the extended model including the RREAS, but excluding the 2015 AT survey.

**Rationale**: The 2015 AT survey may be less reliable than later AT surveys for the purpose of estimating CSNA biomass.
**Response**:




The revised model showed that excluding the 2015 AT survey increased biomass (as expected). It was noted that the estimate of *M* hit its upper bound (initially set to 1.0 yr$^{-1}$), which led to request 27. In a re-run of this model that increased the *M* boundary to 1.5 yr$^{-1}$, *M* was estimated as 1.06 yr$^{-1}$.

**Request 18:** Provide a table of temporal overlap in aerial surveys and the corresponding biological sampling.
**Rationale**: If the aerial survey and biological sampling of a particular area are disjunct in time, the biological samples may not be representative of what was observed from the airplane.
**Response**:
This table summarizes aerial survey dates (including # of anchovy observations) and sampling dates by source for same-region samples collected within 30 days of aerial survey observations. Note: maps for these samples and surveys are in the CCPSS report, Figures 6-16.

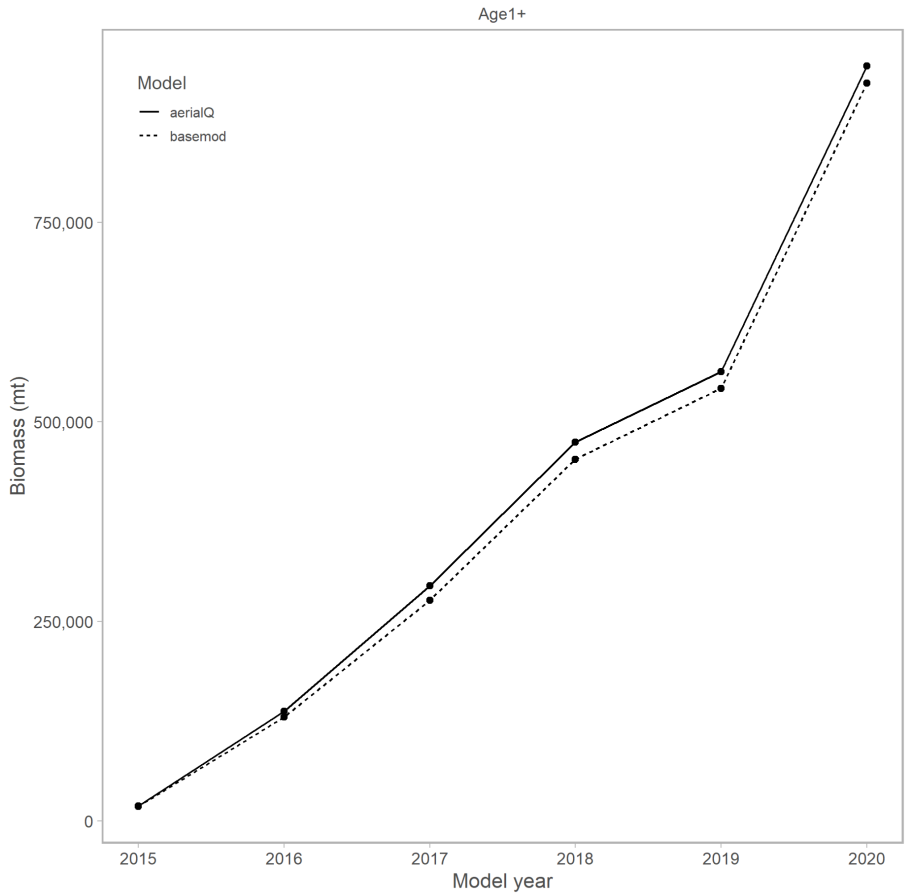
| Aerial Season | Year | Region | Data Source | # of Samples | Sample Collection Dates | Aerial Obs Dates (#NA Obs) |
|---|---|---|---|---|---|---|
| 4/16-4/26 | 2016 | SCA | Fishery | 12 | 3/16 (3), 3/29, 4/6, 4/13 (2), 4/27, 5/3, 5/4, 5/5 (2) | 4/16 (9), 4/17 (22), 4/26 (19) |
| 5/23-6/23 | 2016 | SCA | Fishery | 5 | 4/27, 5/3, 5/4, 5/5 (2) | 5/23 (15), 6/22 (27), 6/23 (2) |
| 8/11-8/29 | 2016 | SCA | None | 0 | NA | 8/11 (9), 8/29 (6) |
| 3/28-3/30 | 2017 | SCA | None | 0 | NA | 3/28 (6), 3/30 (4) |
| 8/3-8/10 | 2017 | NCA | Fishery | 6 | 8/18 (2), 8/24, 8/25, 9/5 (2) | 8/3 (18), 8/4 (17), 8/10 (11) |
| 4/24-4/27 | 2018 | SCA | None | 0 | NA | 4/24 (3), 4/26 (8), 4/27 (3) |
| 5/4 | 2018 | SCA | None | 0 | NA | 5/4 (20) |
| 9/10-9/13 | 2018 | SCA | None | 0 | NA | 9/10 (8), 9/13 (32) |
| 10/13 | 2018 | NCA | Fishery | 24 | 9/13, 9/18, 9/19, 9/20, 9/21, 9/24, 9/26, 9/27, 9/28, 10/2, 10/5, 10/9, 10/12, 10/15, 10/16, 10/18, 10/22, 10/24, 10/25, 10/26, 11/2, 11/5, 11/7, 11/9 | 10/13 (18) |
| 5/29-6/28 | 2019 | SCA | None | 0 | NA | 5/29 (3), 6/8 (13), 6/14 (2), 6/28 (5) |
| 8/6-8/8 | 2019 | NCA | Fishery | 5 | 8/5, 8/21, 8/22, 8/28, 8/30 | 8/6 (1), 8/7 (30), 8/8 (5) |
| | | | NCS Point Set | 3 | 8/13, 8/14, 8/15 | |
| 8/27-8/29 | 2019 | SCA | None | 0 | NA | 8/27 (26), 8/28 (9), 8/29 (1) |
| 9/5-9/16 | 2020 | NCA | Fishery | 5 | 8/27, 9/16, 9/17, 10/7, 10/8 | 9/5, (7), 9/6 (2), 9/7 (3), 9/14 (2), 9/15 (43), 9/16 (2) |
| | | | LBC | 6 | 9/9 (2), 9/10 (3), 9/12 | |
| | | | NCS Point Set | 1 | 10/12 | |
| 9/18-9/20 | 2020 | SCA | LBC | 7 | 9/17, 9/18, 9/20, 9/21 (3), 9/22 | 9/18 (27), 9/19 (69), 9/20 (10) |
| 3/22-4/2 | 2021 | SCA | LBC | 7 | 3/21, 3/22 (2), 3/27, 3/28 (2), 3/31 | 3/22 (70), 3/24 (46), 4/1 (67), 4/2 (71) |
| 8/6-8/11 | 2021 | NCA | Fishery | 3 | 9/7, 9/9, 9/10 | 8/6 (11), 8/10 (29), 8/11 (32) |
| | | | LBC | 7 | 8/12, 8/13, 8/14, 8/15, 8/19, 8/20 (2) | |
| 9/12-9/17 | 2021 | SCA | LBC | 6 | 9/13 (2), 9/15 (2), 9/17, 9/18 | 9/12 (68), 9/14 (57), 9/16 (61), 9/17 (67) |

**Request 19**: Provide a table of the spatial and temporal overlap of the AT survey and the inshore (aerial and/or small vessel acoustic) surveys each year during 2015-2019.
**Rationale**: The inshore surveys could be informative on biomass missed by the AT survey, but anchovy dynamics and movement may limit the utility of comparisons across surveys separated in time and space.
**Response**: This table shows daily aerial survey flights for seasons that were coordinated with the AT surveys. Acoustic survey dates that covered the corresponding areas are listed, with the difference in days from the aerial flight date, and the aerial survey anchovy biomass (mt) for that flight date. Maps displaying A-RL overlap are on slides 13-15, 36-38 in the CCPSS presentation file. There was very little A-RL inshore-offshore spatial overlap in the nearshore portion of the AT survey and western boundary of the aerial survey (the nearshore portion of the RL surveyed area rarely extended into the aerial survey area).

| Aerial Season | | | Survey Dates | | | Difference in Days | | Aerial B (mt) |
|---|---|---|---|---|---|---|---|---|
| Year | Season | Region | Aerial | RL | LBC | A-RL | A-LBC | |
| 2017 | Sum | NCA | 8/3 | 8/6, 8/7, 8/8 | - | 3-5 | - | 35,651 |
| 2017 | Sum | NCA | 8/4 | 8/3-8/6 | - | 1-2 | - | 32,039 |
| 2017 | Sum | NCA | 8/10 | 8/8, 8/9, 8/10 | - | 0-2 | - | 7,648 |
| 2019 | Sum | NCA | 8/6 | 7/21-7/25, 7/31, 8/1, 8/2, 8/7 | - | 1-16[1] | - | 0 |
| 2019 | Sum | NCA | 8/7 | 8/3-8/10 | - | 3-4 | - | 47,102 |
| 2019 | Sum | NCA | 8/8 | 8/9-8/12 | - | 1-4 | - | 1,520 |
| 2019 | Sum | SCA | 8/27 | 8/25-8/29 | 8/27 | 0-2 | 0 | 9,744 |
| 2019 | Sum | SCA | 8/28 | 8/30-9/2 | 8/29, 9/3 | 2-5 | 1-6 | 33 |
| 2019 | Sum | SCA | 8/29 | 8/29, 8/30 | 8/26 | 0-1 | 3 | 6 |
| 2021 | Spr | SCA | 3/22 | 3/21, 3/22 | 3/21, 3/22 | 0-1 | 0-1 | 577 |
| 2021 | Spr | SCA | 3/24 | 3/23, 3/24 | 3/23 | 0-1 | 1 | 45 |
| 2021 | Spr | SCA | 4/1 | 3/29, 3/30, 3/31 | 3/29, 3/30 | 1-3 | 1-2 | 5,043 |
| 2021 | Spr | SCA | 4/2 | 3/23, 3/30 | 3/28, 3/31 | 3-10[2] | 2-5 | 2,499 |
| 2021 | Sum | NCA | 8/6 | 8/8, 8/9 | Not Surveyed | 2-3 | NA | 16 |
| 2021 | Sum | NCA | 8/10 | 8/10, 8/11 | 8/12, 8/14 | 0-1 | 2-4 | 50 |
| 2021 | Sum | NCA | 8/11 | 8/11 | 8/14, 8/15 | 0 | 3-4 | 11,800 |
| 2021 | Sum | SCA | 9/12 | 9/10, 9/11 | 9/12 | 1-2 | 0 | 80 |
| 2021 | Sum | SCA | 9/14 | 9/11, 9/12, 9/13 | 9/14, 9/15 | 1-3 | 0-1 | 11,399 |
| 2021 | Sum | SCA | 9/16 | 9/14, 9/15, 9/16, 9/18, 9/19 | 9/17, 9/18 | 2-3 | 1-2 | 2 |
| 2021 | Sum | SCA | 9/17 | 9/17-9/21 | 9/18, 9/19 | 0-4 | 1-2 | 130 |

[1]No anchovy observed. Survey flight date covered large area from Cape Mendicino to ~ 50 miles S of Pt. Arena. (Slide 37)
[2]The 10-day difference was stratum S4 where no anchovy were observed. Anchovy were observed in strata S1 and S1E, which the RL surveyed 3/30 and LBC surveyed 3/28. (Slide 13)

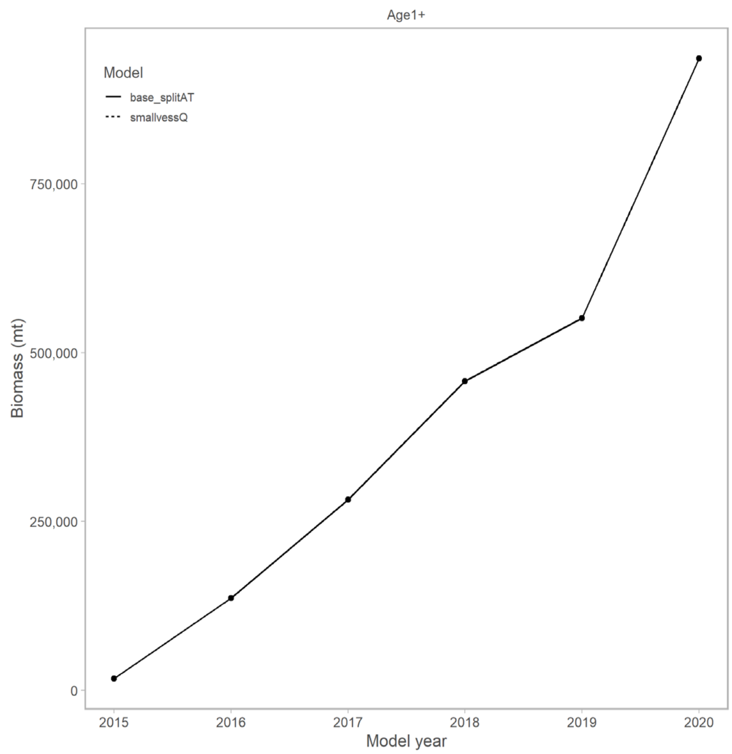
**Request 20**: Conduct a sensitivity analysis using alternative values for the AT survey catchability Q informed by the estimates of the proportion of biomass observed by the aerial survey inshore of the AT survey.
**Rationale**: The AT survey is constrained by the draft of the vessel preventing access to the most nearshore waters where CSNA are commonly observed, resulting in their omission from the survey estimates. This analysis is intended to use aerial survey data to inform catchability, accounting for the proportion of the abundance unaccounted for in the area shoreward of the AT survey.
**Response**:



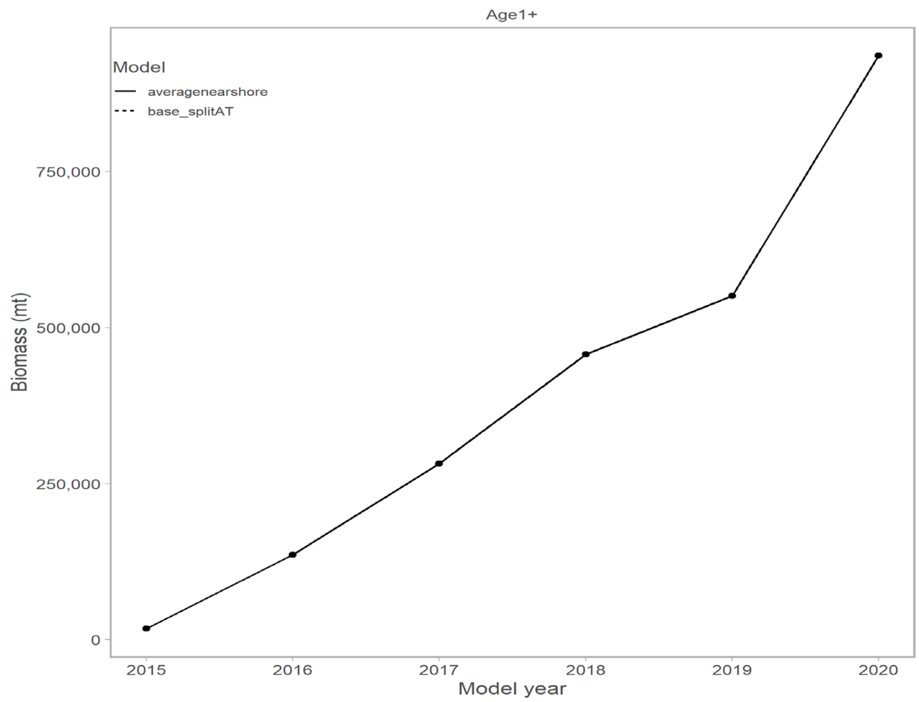

As expected, there was little impact on estimates of age-1+ biomass by accounting for inshore corrections.

**Request 21**: Conduct a sensitivity analysis using alternative values for the AT survey catchability Q informed by the estimates of the proportion of biomass observed by small vessel acoustic surveys inshore of the AT survey.
**Rationale**: The AT survey is constrained by the draft of the vessel, preventing access to the most nearshore waters where CSNA are commonly observed, resulting in their omission from the survey estimates. This analysis is intended to use small vessel acoustic survey data to inform catchability, accounting for the proportion of the abundance unaccounted for in the area shoreward of the AT survey.
**Response**: A table was created with the fraction of the biomass estimated nearshore, and used to inform Q, producing the following biomass trajectory. Surveys are coded as YYMM, i.e. 1507 corresponds to summer (July) 2015.

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | Survey | Core estimate | Extrapolation | extrapolation fraction | Small vessel | Small vessell fraction | Aerial | Aerial fraction |
| 2 | 1507 | 10528 | 7000 | 0.399361022 | NA | NA | 0 | 0 |
| 3 | 1607 | 150907 | 0 | 0 | NA | NA | 29 | 0.000192134 |
| 4 | 1704 | 173973 | 45,055 | 0.205704294 | NA | NA | 294 | 0.001687066 |
| 5 | 1707 | 153460 | 45,446 | 0.228479784 | NA | NA | 75338 | 0.329277354 |
| 6 | 1807 | 723,826 | 4110 | 0.005646101 | NA | NA | 32 | 4.42076E-05 |
| 7 | 1907 | 769,154 | NA | NA | 41,480 | 0.0512 | 58406 | 0.070576152 |
| 8 | 2104 | 1,358,587 | NA | NA | 13047 | 0.0095 | 8092 | 0.005920922 |




**Request 22**: Conduct a sensitivity analysis using alternative values for the AT survey catchability Q informed by estimates of the proportion of biomass inshore of the AT survey based on the average of the aerial and nearshore acoustic surveys.
**Rationale**: This analysis is intended to use small vessel acoustic survey and aerial survey data to inform catchability, accounting for the proportion of the abundance unaccounted for in the area shoreward of the AT survey.
**Response**: There were only two cruises with overlap in both small vessel and aerial nearshore observations (Summer 2019 [1907] and Spring 2021 [2104]).



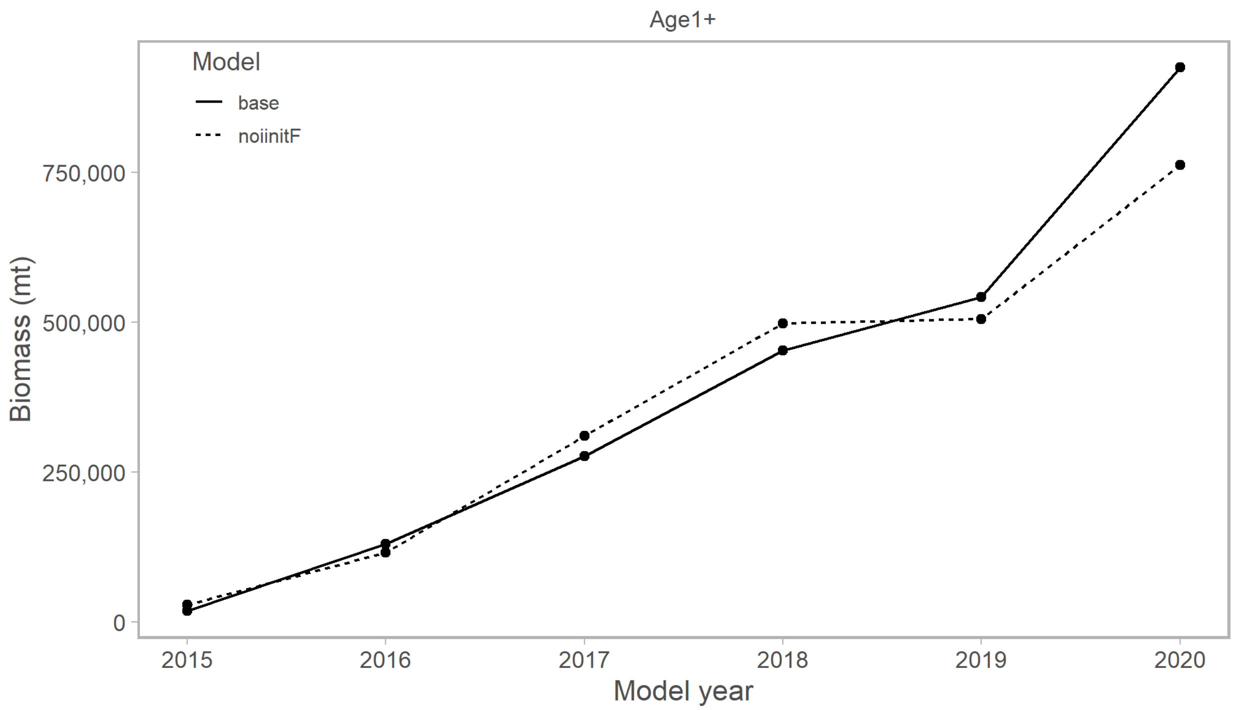

A table was created with the fraction of the biomass estimated nearshore.

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | Survey | Core estimate | Extrapolation | extrapolation fraction | Small vessel | Small vessell fraction | Aerial | Aerial fraction |
| 2 | 1507 | 10528 | 7000 | 0.399361022 | NA | NA | 0 | 0 |
| 3 | 1607 | 150907 | 0 | 0 | NA | NA | 29 | 0.000192134 |
| 4 | 1704 | 173973 | 45,055 | 0.205704294 | NA | NA | 294 | 0.001687066 |
| 5 | 1707 | 153460 | 45,446 | 0.228479784 | NA | NA | 75338 | 0.329277354 |
| 6 | 1807 | 723,826 | 4110 | 0.005646101 | NA | NA | 32 | 4.42076E-05 |
| 7 | 1907 | 769,154 | NA | NA | 41,480 | 0.0512 | 58406 | 0.070576152 |
| 8 | 2104 | 1,358,587 | NA | NA | 13047 | 0.0095 | 8092 | 0.005920922 |

**Request 23**: Conduct a sensitivity analysis using alternative values for the AT survey catchability Q informed by the proportion of habitat south of the AT survey (i.e., Request 9) and inshore of the AT survey as estimated by the inshore surveys (using the average of the aerial and nearshore acoustic surveys, or otherwise as deemed appropriate).
**Rationale**: The AT survey is constrained by the draft of the vessel preventing access to the most nearshore waters and sampling is not consistently undertaken south of the survey area in Mexican waters where northern anchovy are commonly observed, resulting in their omission from the survey estimates. This analysis is intended to use aerial survey and small vessel acoustic survey data to inform catchability accounting for the proportion of the abundance unaccounted for in the area shoreward of the AT survey and the proportion of the biomass in Mexico south of the AT survey as evaluated under the previous request.
**Response**: This request could not be completed as described during the review meeting, although multiple model runs, including the adopted base, adjusted Q to account for geographic coverage and accounted for inshore biomass using year-specific approaches.

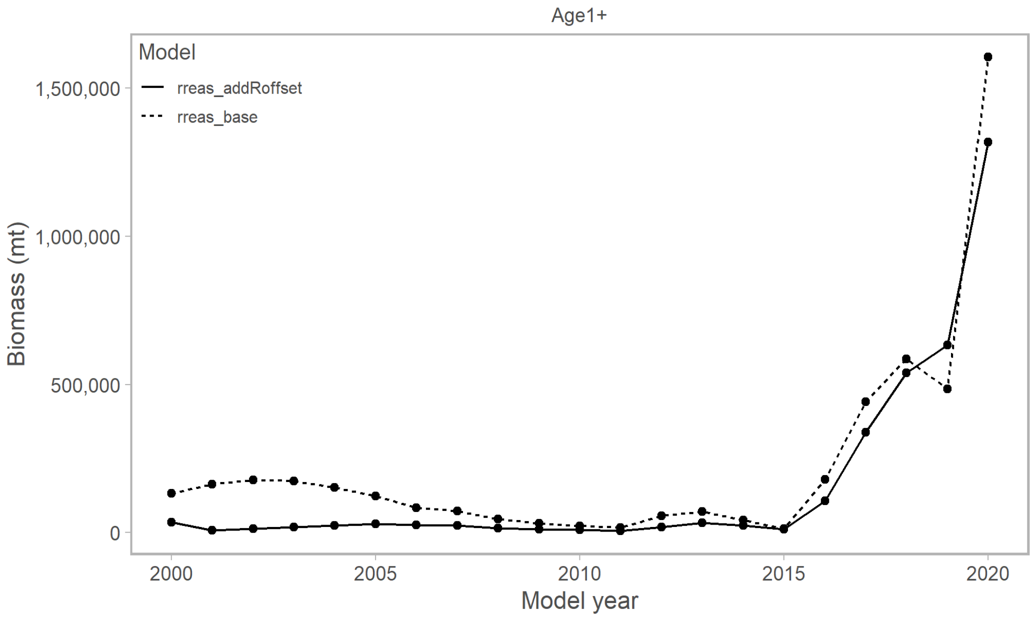
**Request 24**: Perform a run of the base model that does not estimate initial F.

**Rationale**: It was hypothesized that initial F and the $R_0$ offset parameters were to some extent redundant, and the initial F estimate from the base model seemed suspect.
**Response**:



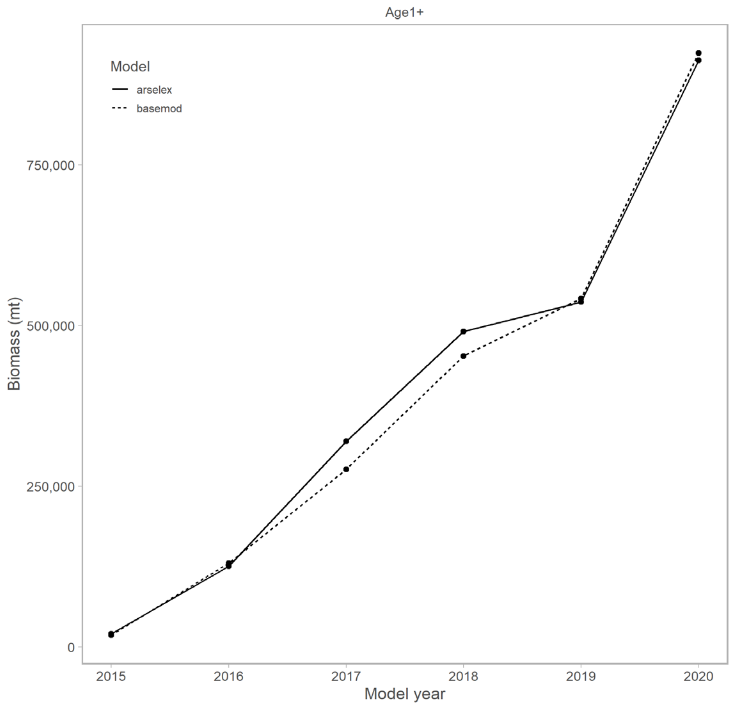

The fit of the model (as indicated by the change in negative log-likelihood) got appreciably poorer (7 log-likelihood units), supporting continued estimation of all three parameters ($R_0$, $R_0$ offset, and initial F).

**Request 25**: Perform a run of the extended RREAS model that does not estimate initial F but does estimate offset in $R_0$.
**Rationale**: It was hypothesized that the two parameters were redundant.
**Response**:



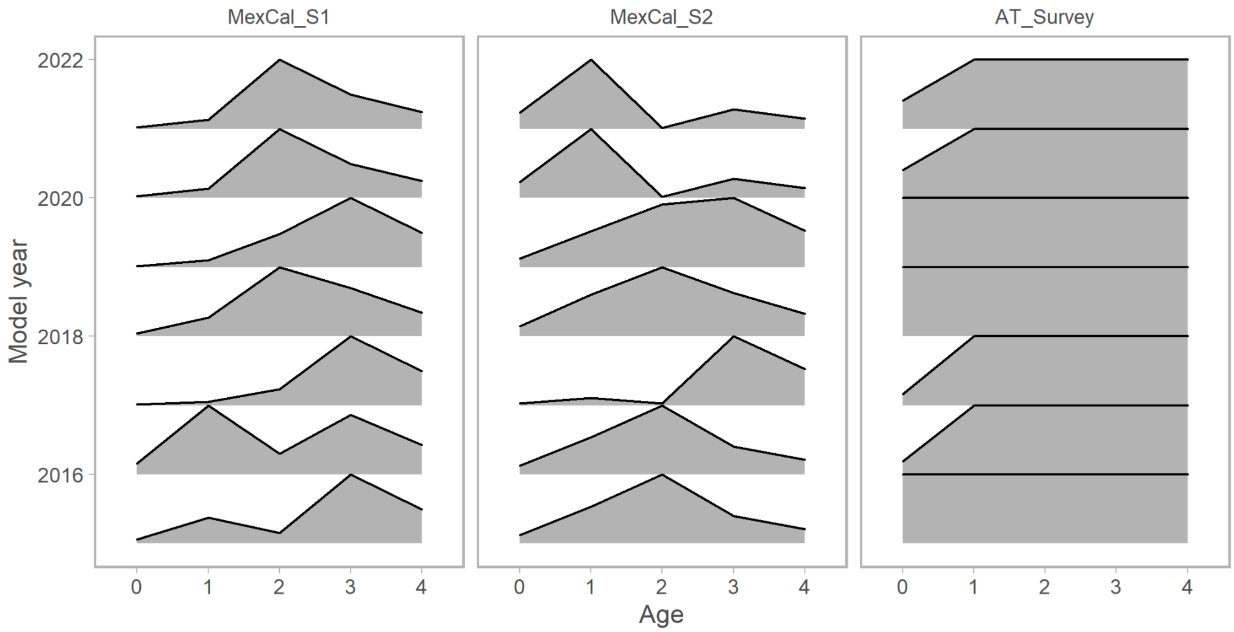

The model results in high fishing mortality rates, odd selectivities that change substantially among years, a similar fit to indices, and a very low *M* (~$0.25 yr^{-1}$). The STAT and Panel agreed that all three parameters determining the initial size should be estimated.

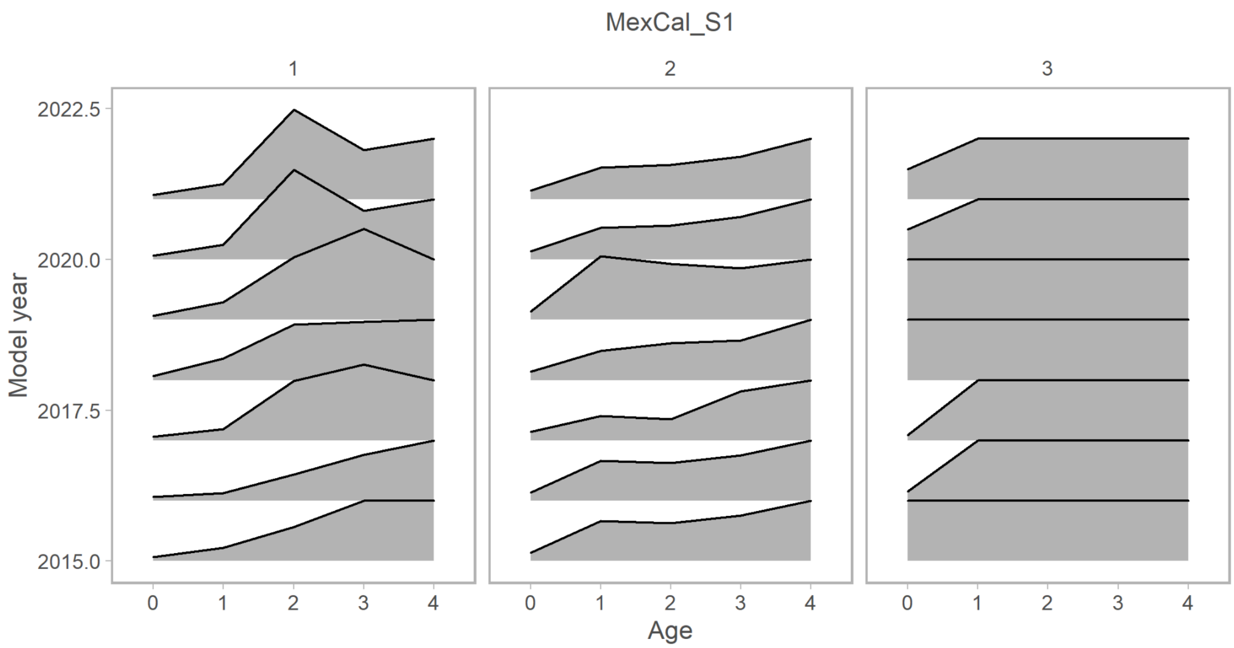
**Request 26**: Explore selectivity parameterizations where the ratio of selectivity for age-0 vs age-1 is not fixed (consider the 2dAR option in SS, which combines flexibility with a penalty for too much deviation). Consider combining this change to the model specifications with changing the data plus group to ages 3+.
**Rationale**: It did not seem reasonable to expect a fixed ratio between selectivity for age-0 and age-1 to apply in all years, although allowing complete flexibility may result in model instability.
**Response**: The analysis suggests that a penalized selectivity pattern leads to what the STAT and Panel considered more realistic selectivity patterns, but with little impact on the overall results (similar biomass trajectories and similar, but possibly slightly improved, fits to data).



Age1+
Model
arselex
basemod
750,000
500,000
250,000
0
Biomass (mt)
2015
2016
2017
2018
2019
2020
Model year

Base model selectivities




AR selectivities

| Yr | fleetname | age0 | age1 | ratio |
|---|---|---|---|---|
| 2015 | MexCal_S1 | 0.066447 | 0.217814 | 0.305062 |
| 2016 | MexCal_S1 | 0.066447 | 0.129674 | 0.512413 |
| 2017 | MexCal_S1 | 0.066447 | 0.193546 | 0.343312 |
| 2018 | MexCal_S1 | 0.066447 | 0.356816 | 0.186221 |
| 2019 | MexCal_S1 | 0.066447 | 0.293518 | 0.22638 |
| 2020 | MexCal_S1 | 0.066447 | 0.248863 | 0.267001 |

| | | | | |
|---|---|---|---|---|
| 2021 | MexCal_S1 | 0.066447 | 0.248863 | 0.267001 |
| 2015 | MexCal_S2 | 0.139911 | 0.661765 | 0.211421 |
| 2016 | MexCal_S2 | 0.139911 | 0.661765 | 0.211421 |
| 2017 | MexCal_S2 | 0.139911 | 0.402683 | 0.347447 |
| 2018 | MexCal_S2 | 0.139911 | 0.484346 | 0.288866 |
| 2019 | MexCal_S2 | 0.139911 | 1.0579 | 0.132254 |
| 2020 | MexCal_S2 | 0.139911 | 0.521404 | 0.268335 |
| 2021 | MexCal_S2 | 0.139911 | 0.521404 | 0.268335 |

**Request 27**: Raise the upper bound on *M* for future model runs. An upper bound of at least 1.5 yr-1 seems plausible.
**Rationale**: Anchovy likely have high natural mortality and past estimates of *M* have exceeded 1.0 yr-1.
**Response**: This was done for the Request 17 run of the RREAS model where *M* previously hit the bound. The revised model run estimated *M* as 1.06$yr^{-1}$ and was otherwise similar to the previous run. *M* did not seem to approach the initial 1.0$yr^{-1}$ boundary in all base model runs.

*Day 3 requests made to the STAT during the meeting – Thursday, December 9*
**Request 28**: The final assessment document should explain and justify years/seasons for which surveys were available but not used (e.g., early AT surveys, any individual years excluded from the AT survey or the RREAS if it is included in the final model).
**Rationale**: Some survey estimates could have been available but were not used.
**Response**: This information will be included in the final report.

**Request 29**: Provide a vector of average weight by year for young of year (YOY) anchovy in the RREAS.
**Rationale**: Weight in the AT survey may not match that in the RREAS.
**Response**: The weights in the RREAS were provided by John Field (SWFSC) and included the model runs in request 30.

**Request 30:** Run a set of models as described below, implementing the "agreed changes" listed below in all runs. For each row/model number, both a short and a long variant are requested. Model length "S" means a model starting in 2015 and using the AT survey but not the RREAS. Model length "L" means a model starting in 2004 and using both the AT survey and the RREAS.

- Plus-group 3+
- Catch series: extend the model so that the first projection year is part of the historical period
- Estimate $R_0$, $R_0$ offset and initial F
- Split AT formulation (will be inconsequential if Q is the same for all AT surveys)
- Include new age-reading error matrices
- Long model
    - RREAS: Exclude 2011 & 2020; include 2021
    - Start in 2004
    - Correct timing of survey
    - Use weight-at-age provided by John Field for the RREAS

| | Model Length | Selex* | Q (summ/spr) | Q (nearshore adjustment?) | 2015 AT Survey |
|---|---|---|---|---|---|
| Model 1 | S/L | Option 17 | 1/1 | N | Y |
| Model 2 | S/L | 2dAR (σ=1) | 1/1 | N | Y |
| Model 3 | S/L | 2dAR (σ=1) | 0.93/0.58 | Y | Y |
| Model 4 | S/L | 2dAR (σ=0.5) | 1/1 | N | Y |
| Model 5 | S/L | 2dAR (σ=2) | 1/1 | N | Y |
| Model 6 | S/L | 2dAR (σ=1) | 1/1 | N | N |

*For all instances of selectivity 2dAR, implement time blocking of age-0 selectivity.

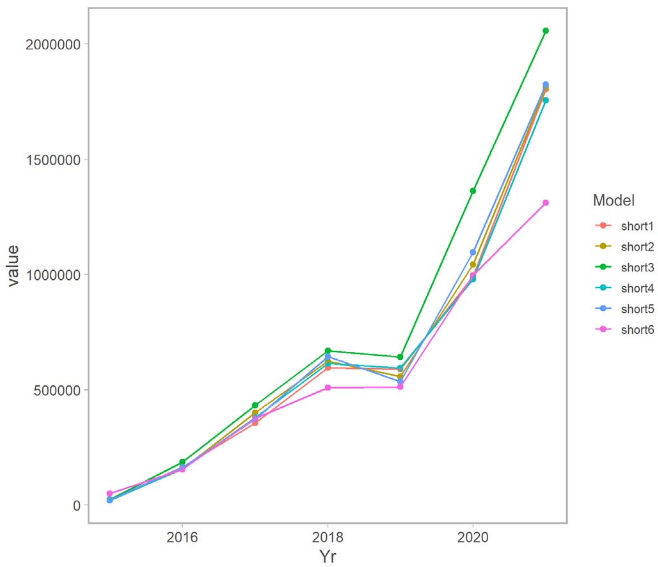
For each run, report the following: (a) -LnL (total), -Lnl (Survey), -Lnl (Ages), *M*, Current age-1+ biomass (quota year); list of parameters near bounds, (b) age-1+ biomass trajectory (all on one plot), and (c) selectivity patterns.

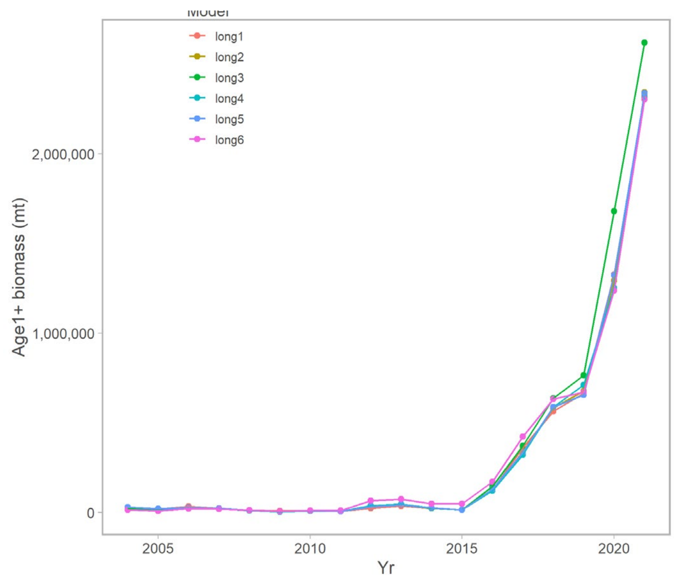
**Rationale:** The "agreed changes" are those for which there is consensus among the Panel and STAT that they are improvements relative to the initial base model, based on the responses to requests so far. Model 1 (short version) reflects the base model in the draft assessment report incorporating these changes. Model 2 (short version) reflects a potential alternative starting point for further exploration that incorporates a change to selectivities that was broadly agreed to maintain or improve fits to data relative to the base model, while appealing on grounds of parsimony and theoretical support. Models 3 through 6 each represent a single axis of change away from model 2 to explore the effects independently. Each model formulation is then repeated across short formulations without the RREAS and long formulations including the RREAS, to explore effects of including the RREAS and analyzing a longer time period.

**Response:** A detailed response to this request follows over the next several pages. In summary, the STAT and Panel agreed that for the "short" model formulations, model 1 could be ruled out from further consideration because the 2dAR selectivity models performed in ways that were superior (equal or better fit and plausibility of parameter estimates) to the Option 17 selectivity and was better supported on grounds of theory and parsimony, model 4 could be ruled out due to a poor fit to the age data, and model 5 could be ruled out due to poor likelihood and convergence issues. The STAT and Panel further agreed that for the "long" model formulations, models 1, 4, and 5 could be ruled out for the same reasons and also because the model 5 Hessian was not positive definite. Further discussion also led to proposal of a tentative new base model, to be further analysed as described in Request 31.

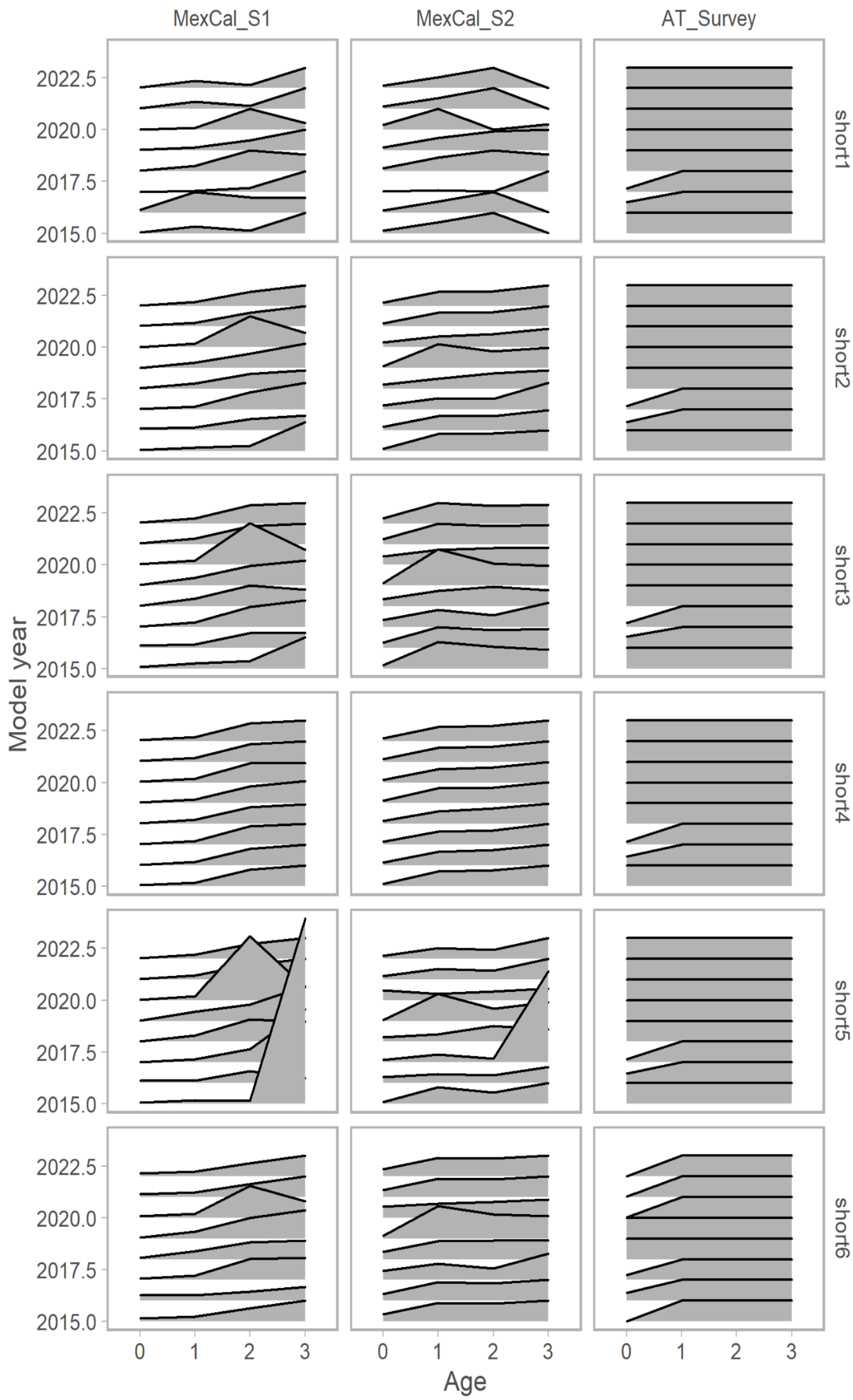
With steepness fixed at 0.6, it is difficult to decide which parameters to estimate. Looking at the likelihoods would support estimating initF and the $R_0$ offset or estimating the $R_0$ offset and not initF. However, these models with low likelihood also have *M* estimates that do not line up with previous studies.

The negative log-likelihoods (NLLs) should not be compared between the long and short models because they differ substantially in the amount of data included, and NLLs should not be compared directly between model 6 and the other models without considering that model 6 is fit to fewer data - one less survey index and one fewer year of age data from the AT survey, which would be expected to improve total likelihoods (reduce the NLL) as well as likelihoods for the survey and age composition components.

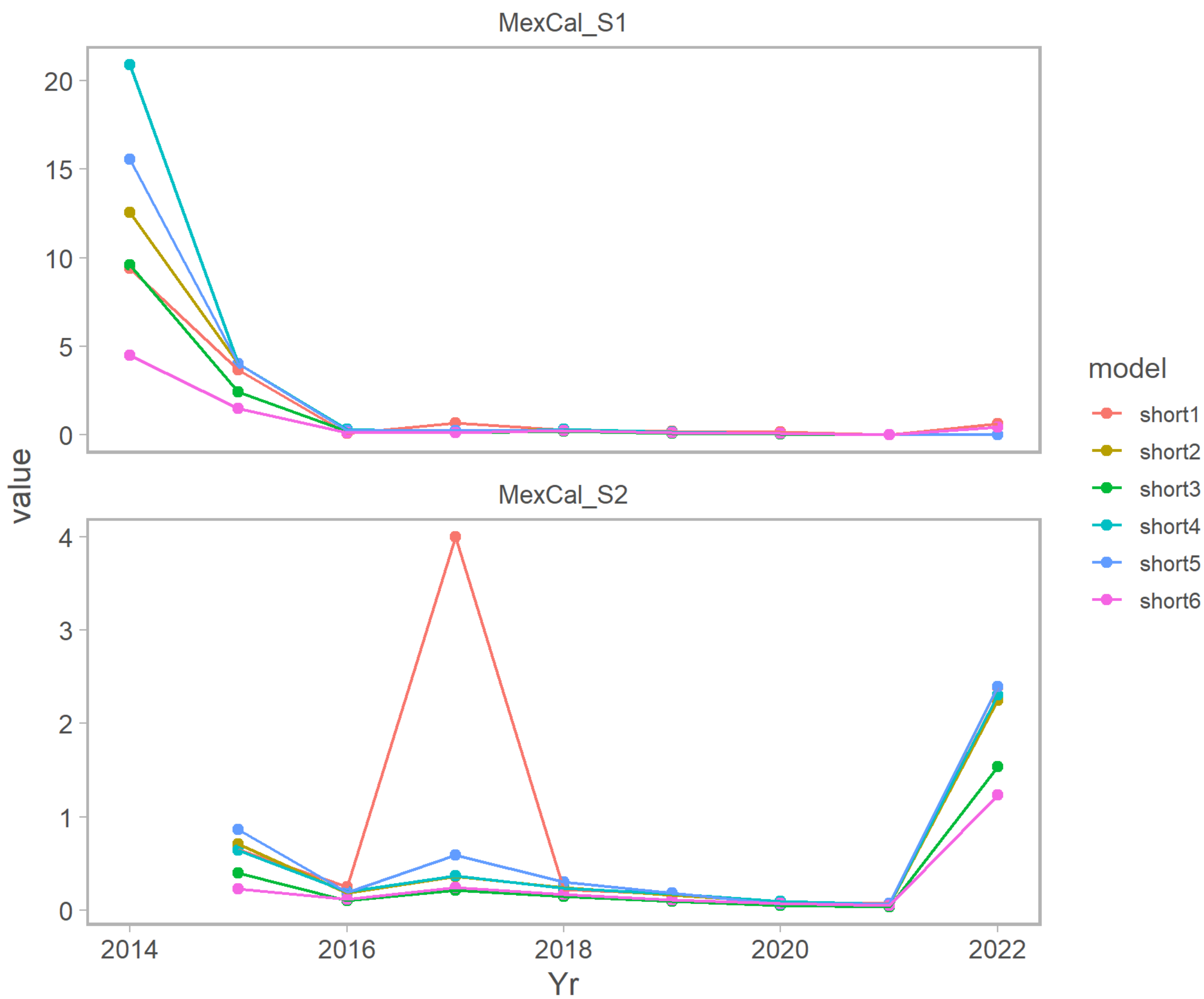


Short model selectivities



Short model Fs



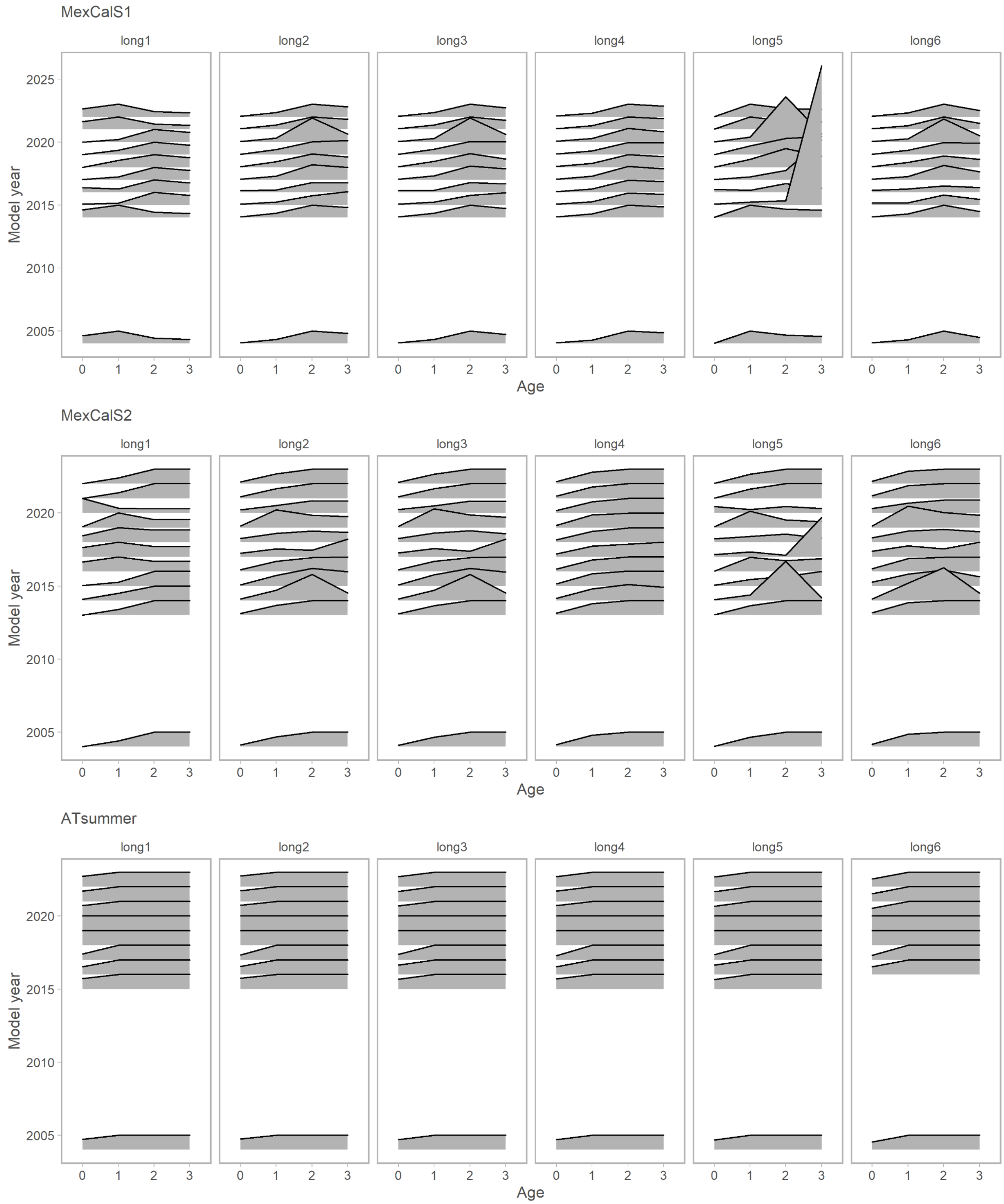

Short model numerical diagnostics

| short1 | short2 | short3 | short4 | short5 | short6 | Label |
|---|---|---|---|---|---|---|
| **19.1894** | **61.5541** | **63.0224** | **35.8** | **88.8626** | **42.1555** | **TOTAL** |
| **-5.4963** | **-5.3608** | **-4.1457** | **-5.625** | **-5.9826** | **-6.7888** | **Survey** |
| **22.344** | **17.5064** | **17.3232** | **27.734** | **14.2025** | **11.3481** | **Age_comp** |
| 0.68739 | 0.70009 | 0.56489 | 0.7096 | 0.68108 | 0.53728 | NatM_uniform_Fem_GP_1 |
| 19.183 | 19.2036 | 19.2203 | 19.236 | 19.1356 | 18.7695 | SR_LN(R0) |
| -2.0648 | -2.122 | -2.1137 | -2.1332 | -2.0417 | -2.0165 | SR_regime_BLK1repl_2014 |
| 9.40991 | 12.5589 | 9.58993 | 20.91 | 15.576 | 4.46647 | InitF_seas_1_flt_1MexCal_S1 |

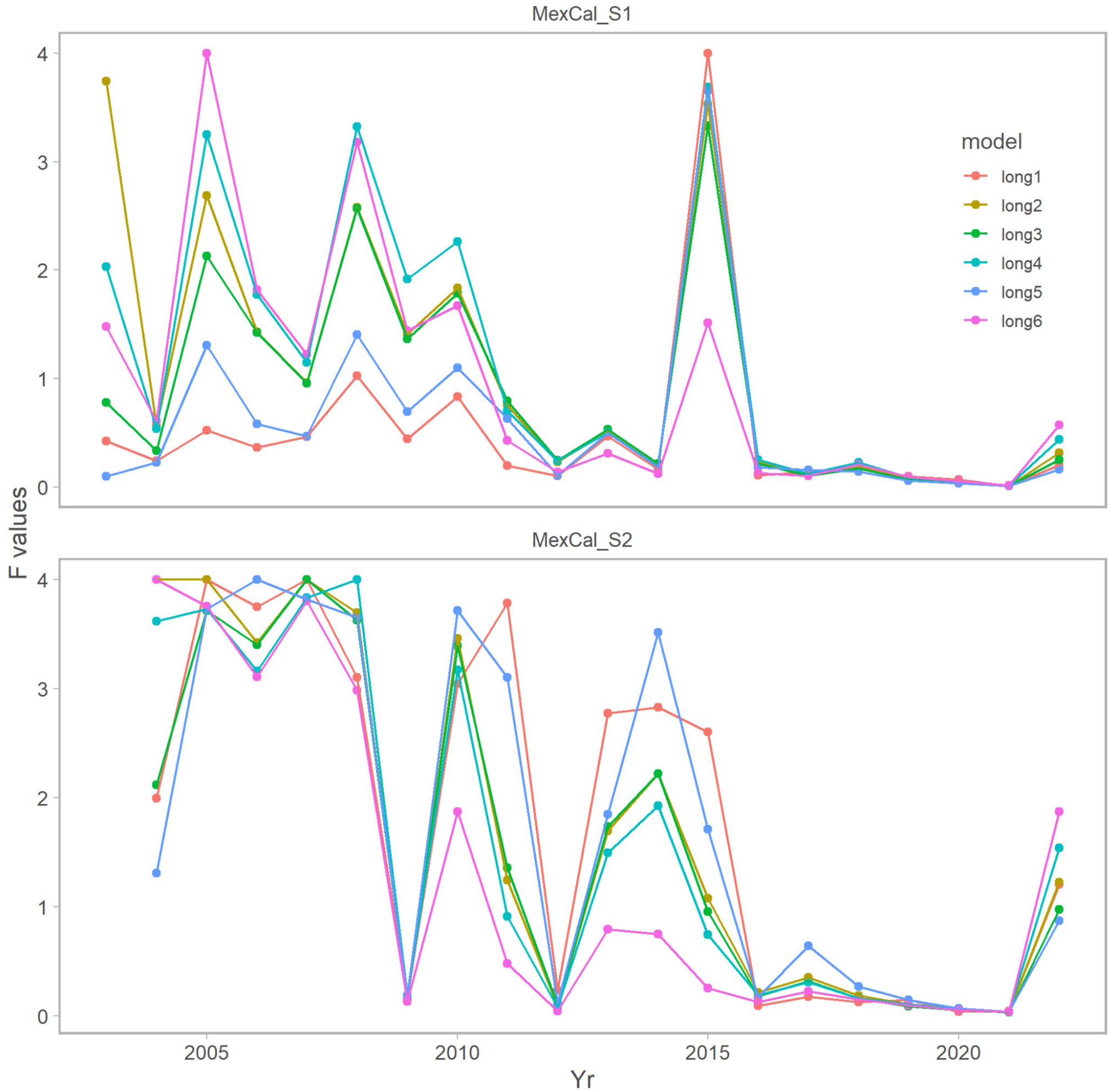
Short model parameters near bounds

| model | Label |
|---|---|
| short1 | AgeSel_P2_AT_summer(3) |
| short1 | AgeSel_P2_AT_summer(3)_BLK3repl_2018 |
| short1 | AgeSel_P2_AT_summer(3)_BLK3repl_2019 |
| short2 | AgeSel_P2_AT_summer(3) |
| short2 | AgeSel_P2_AT_summer(3)_BLK3repl_2018 |
| short2 | AgeSel_P2_AT_summer(3)_BLK3repl_2019 |
| short3 | AgeSel_P2_AT_summer(3) |
| short3 | AgeSel_P2_AT_summer(3)_BLK3repl_2018 |
| short3 | AgeSel_P2_AT_summer(3)_BLK3repl_2019 |
| short4 | AgeSel_P2_AT_summer(3) |
| short4 | AgeSel_P2_AT_summer(3)_BLK3repl_2018 |
| short4 | AgeSel_P2_AT_summer(3)_BLK3repl_2019 |
| short5 | AgeSel_P2_AT_summer(3) |
| short5 | AgeSel_P2_AT_summer(3)_BLK3repl_2018 |
| short5 | AgeSel_P2_AT_summer(3)_BLK3repl_2019 |
| short6 | AgeSel_P2_AT_Summer(3)_BLK3repl_2018 |
| short6 | AgeSel_P2_AT_Summer(3)_BLK3repl_2019 |

# Long model selectivities



Long model Fs




Long model numerical diagnostics (note that model 5 did not converge)

| long1 | long2 | long3 | long4 | long5 | long6 | Label |
|---|---|---|---|---|---|---|
| 42.6279 | 99.0055 | 98.5432 | 70.7106 | 125.728 | 84.0664 | TOTAL |
| 11.4593 | 11.3006 | 11.6985 | 10.8344 | 10.8798 | 5.96431 | Survey |
| 24.6253 | 29.2449 | 28.1623 | 39.4547 | 21.8125 | 18.8887 | Age_comp |
| 0.349381 | 0.366676 | 0.323506 | 0.417157 | 0.325311 | 0.47853 | NatM_uniform_Fem_GP_1 |
| 18.0802 | 18.0616 | 18.4829 | 18.0529 | 18.1977 | 17.6596 | SR_LN(R0) |
| -4.26245 | -3.91793 | -4.80357 | -4.0907 | -4.63537 | -3.82466 | SR_regime_BLK1repl_2003 |
| 0.423403 | 3.74617 | 0.780251 | 2.03337 | 0.0945 | 1.47719 | InitF_seas_1_flt_1MexCal_S1 |

Long model parameters near bounds

| model | nbounded | ll |
|---|---|---|
| long1 | 2 | AgeSel_P2_AT_summer(3)_BLK3repl_2018 ; AgeSel_P2_AT_summer(3)_BLK3repl_2019 |
| long2 | 2 | AgeSel_P2_AT_summer(3)_BLK3repl_2018 ; AgeSel_P2_AT_summer(3)_BLK3repl_2019 |
| long3 | 2 | AgeSel_P2_AT_summer(3)_BLK3repl_2018 ; AgeSel_P2_AT_summer(3)_BLK3repl_2019 |
| long4 | 2 | AgeSel_P2_AT_summer(3)_BLK3repl_2018 ; AgeSel_P2_AT_summer(3)_BLK3repl_2019 |
| long5 | 3 | InitF_seas_1_flt_1MexCal_S1 ; AgeSel_P2_AT_summer(3)_BLK3repl_2018 ; AgeSel_P2_AT_summer(3)_BLK3repl_2019 |
| long6 | 2 | AgeSel_P2_AT_summer(3)_BLK3repl_2018 ; AgeSel_P2_AT_summer(3)_BLK3repl_2019 |

*Day 4 requests made to the STAT during the meeting – Friday, December 10*

**Request 31**: Propose and run a tentative base model (structure as described in the Response below) and report:

- Likelihood profile across *M* with steepness fixed at 0.6
- Age-1+ biomass trajectories across *M* with steepness fixed at 0.6
- Likelihood profile (and corresponding *M* estimates) across steepness
- Age-1+ biomass trajectories across steepness
- Jittering/convergence checks before final submission

Additional sensitivity analyses were requested to show the effects of not including inshore biomass estimates, a run in which the highest possible (out of aerial surveys, small vessel surveys, or extrapolations) inshore estimates were used for each survey, the lowest possible inshore adjustments were used for each survey, exploring the effects of Francis weighting for all fleets at once, and fixing age-0 selectivity for the 2015 AT survey at 0.5.

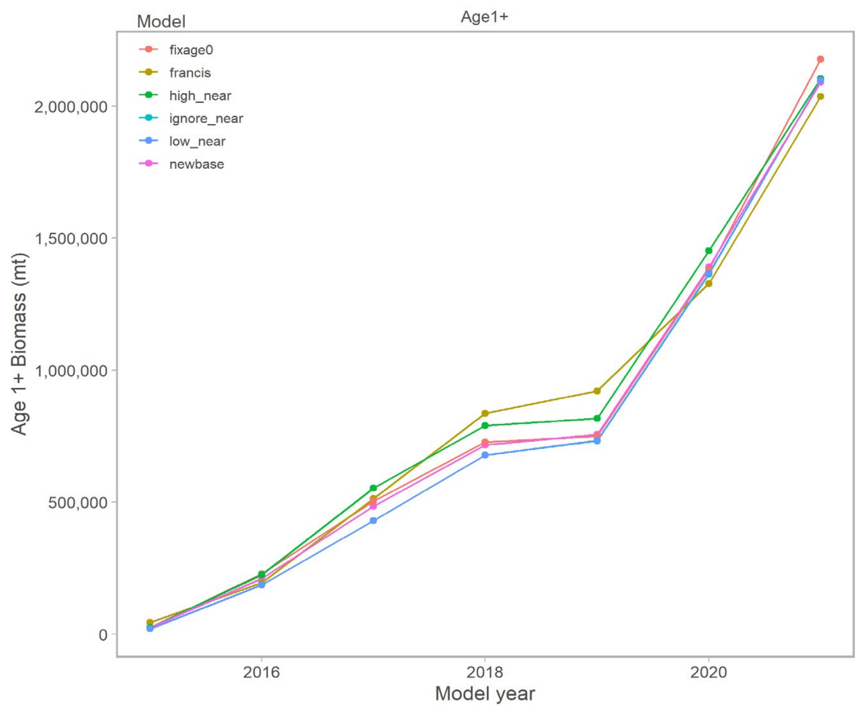
**Rationale**: The outputs and diagnostics requested are standard ways of evaluating a proposed base model, and sensitivity to Francis weighting is routinely evaluated. The remaining sensitivity runs reflect concerns about the treatment of nearshore biomass and the uncertainty surrounding the 2015 AT survey and a perception that the high age-0 selectivity estimated for that survey may not be correct.

**Response**: The STAT proposed a base model structured as follows:

- Use the shorter model time period, excluding the RREAS because of model instability in the longer formulation, and because estimation of *M* was especially challenging for the long model.
- Keep 2015 AT data because after extensive discussion, it was decided that the data for this survey should not be discarded simply because 2015 seemed biologically anomalous since there was nothing so unusual about the execution of the 2015 AT survey compared to later years to exclude it on methodological grounds, and it is expected that some data points will have large residuals, that are not sufficient reason to exclude it (see Appendix 2, AT survey NOAA Tech Memos).
- Use 2dAR selectivity with $\sigma$=1 for the two fisheries, with 2d selectivity estimation starting in the second year of available age composition data (the first age composition defines the reference curve), because the 2dAR selectivity with $\sigma$=1 led to the best performance (Request 30).
- Add ageing bias for reader 14, based on the outcomes of Requests 6 and 30.
- Account for biomass shoreward of the AT core survey area: Add nearshore AT biomass (preferably from surveys, otherwise from extrapolation and do not adjust Q to account for inshore coverage when these additions are made) or apply Q ratio calculations based on

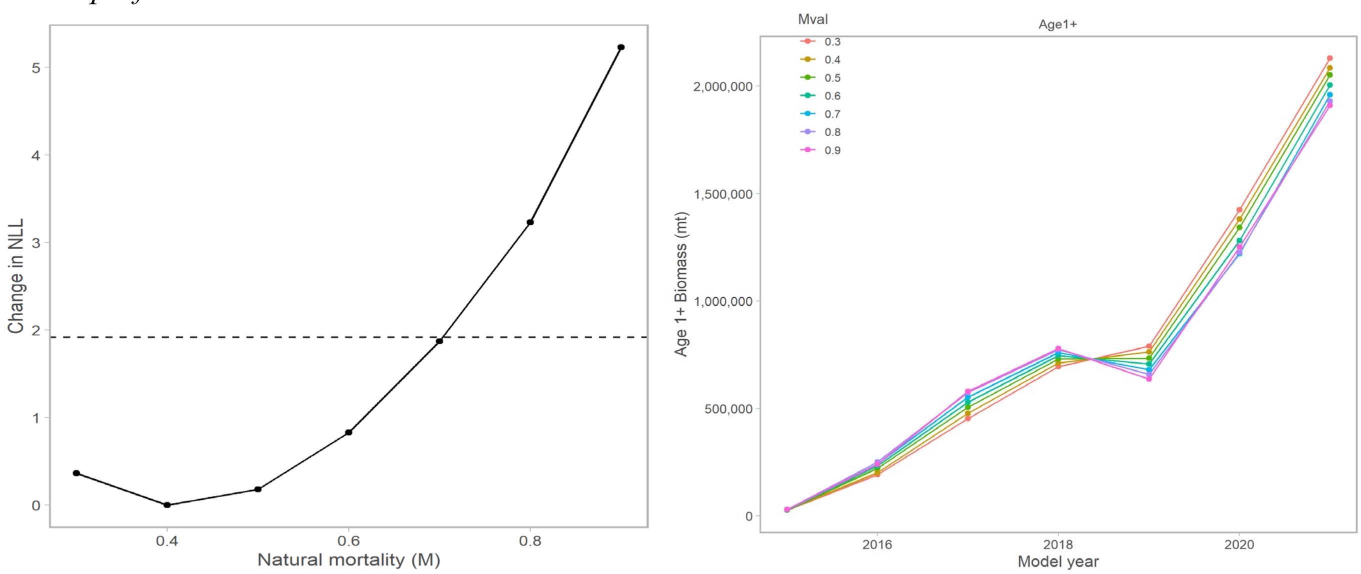
aerial surveys as in Request 20. This was based on STAT preference to add observed or extrapolated biomass to the core AT survey rather than adjust Q when possible.

- Adjust AT Q in all years to account for geographic coverage (spring Q=0.58, summer Q=0.93) based on the estimated proportion of biomass in Mexico as described in Request 9 (spring Q is 0.58 rather than 0.6 due to performing the final calculation to a higher precision).

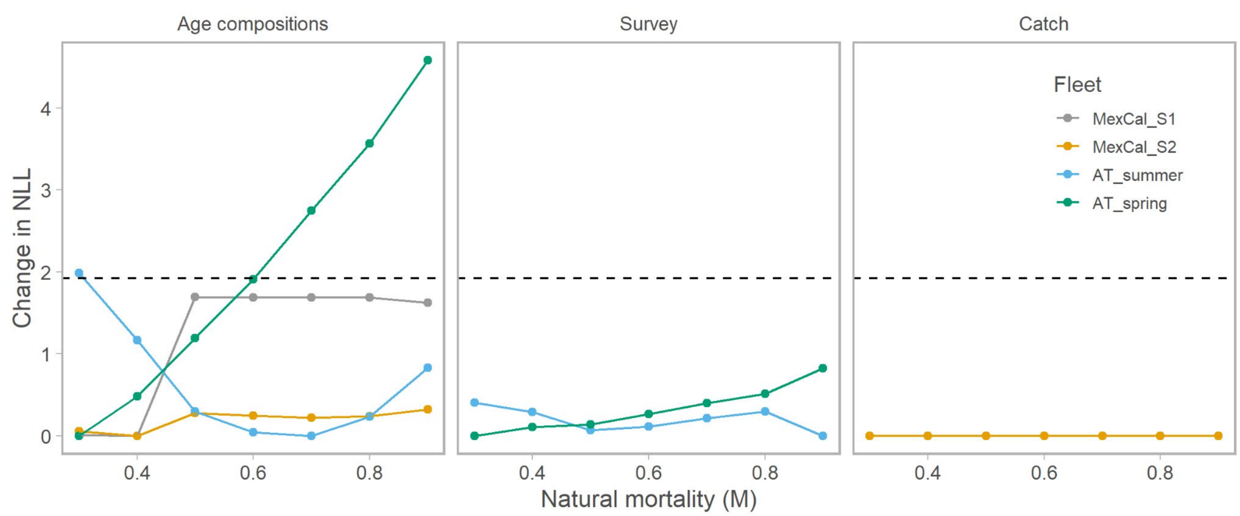



The figure above shows the age-1+ biomass trajectories for the model period of 2015-2021. The models shown are the base model ("newbase"; pink), a model that ignores nearshore biomass estimates ("ignore_near"; light blue), a model with Francis reweighted age composition for all fleets ("francis"; yellow), a model that assumed the highest nearshore biomass values ("high_near"; green) and a model that assumed the lowest nearshore biomass values ("low_near"; purple).

*M profile*



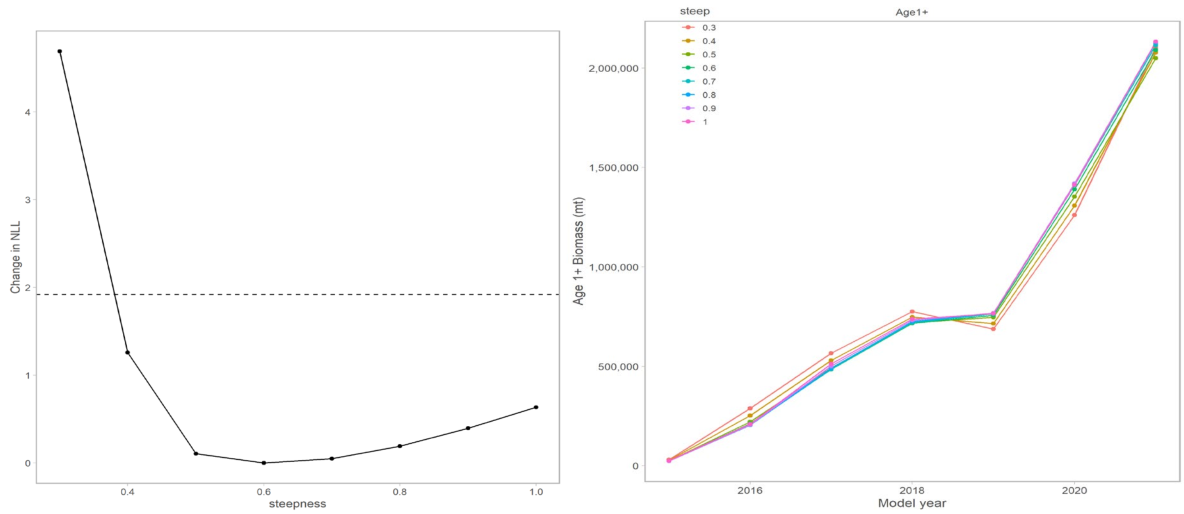

*M* profile (age-1+ biomass trajectories) with steepness fixed at steep 0.6 (left) and the biomass trajectories for the alternative values of *M* (right).



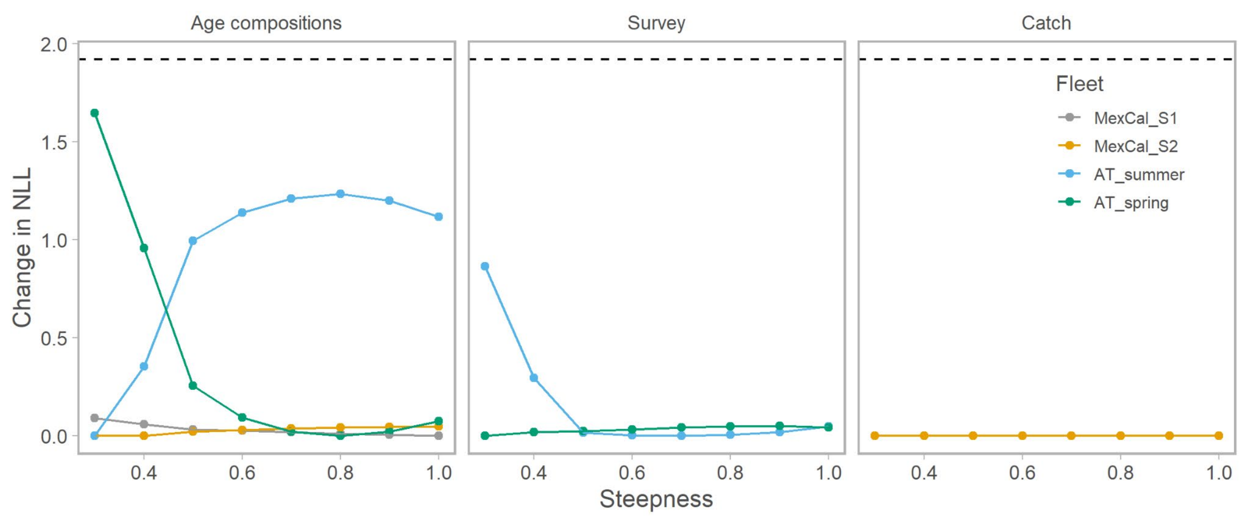

Likelihood profiles for *M* by component. Note the conflicting profiles for *M* for the spring vs summer AT surveys. Not many sources favour high *M* from a likelihood perspective and the profiles for the indices are quite flat.

| **M value** | **0.3** | **0.4** | **0.5** | **0.6** | **0.7** | **0.8** | **0.9** |
|---|---|---|---|---|---|---|---|
| **SR_LN(R0)** | **20.622** | **19.514** | **19.249** | **19.2** | **19.216** | **19.273** | **19.372** |
| **SR_BH_steep** | **0.6** | **0.6** | **0.6** | **0.6** | **0.6** | **0.6** | **0.6** |
| **InitF_seas_1_flt_1MexCal_S1** | **4.711** | **5.469** | **16.627** | **17.99** | **19.38** | **23.147** | **25** |
| **LnQ_base_AT_summer(3)** | **-0.073** | **-0.073** | **-0.073** | **-0.073** | **-0.073** | **-0.073** | **-0.073** |
| **LnQ_base_AT_spring(7)** | **-0.547** | **-0.547** | **-0.547** | **-0.547** | **-0.547** | **-0.547** | **-0.547** |
| **LnQ_base_AT_spring(7)_BLK6repl_2020** | **-0.545** | **-0.545** | **-0.545** | **-0.545** | **-0.545** | **-0.545** | **-0.545** |
| 2020 Age1+ biomass | 1,424,810 | 1,381,660 | 1,342,610 | 1,280,570 | 1,219,700 | 1,225,010 | 1,251,260 |
| 2021 Age1+ biomass | 2,129,470 | 2,085,390 | 2,051,320 | 2,005,500 | 1,960,330 | 1,929,790 | 1,909,800 |
| TOTAL Likelihood | 54.8152 | 54.4552 | 54.6344 | 55.2824 | 56.3254 | 57.6864 | 59.6854 |

*Steepness profile*




Steepness profile (1+ biomass trajectories) and the biomass trajectories for the alternative values of steepness (right).




| h value | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 |
|---|---|---|---|---|---|---|---|---|
| **NatM_uniform_Fem_GP_1** | **0.65** | **0.556** | **0.442** | **0.414** | **0.402** | **0.4** | **0.405** | **0.417** |
| **SR_LN(R0)** | **29.999** | **29.998** | **29.963** | **19.413** | **18.795** | **18.471** | **18.267** | **18.136** |
| **SR_regime_BLK1repl_2014** | **-12.422** | **-12.638** | **-12.836** | **-2.349** | **-1.763** | **-1.448** | **-1.236** | **-1.078** |
| **InitF_seas_1_flt_1MexCal_S1** | **19.646** | **17.87** | **15.878** | **15.464** | **15.265** | **15.194** | **15.25** | **15.415** |
| **LnQ_base_AT_summer(3)** | **-0.073** | **-0.073** | **-0.073** | **-0.073** | **-0.073** | **-0.073** | **-0.073** | **-0.073** |
| **LnQ_base_AT_spring(7)** | **-0.547** | **-0.547** | **-0.547** | **-0.547** | **-0.547** | **-0.547** | **-0.547** | **-0.547** |
| **LnQ_base_AT_spring(7)_BLK6repl_2020** | **-0.545** | **-0.545** | **-0.545** | **-0.545** | **-0.545** | **-0.545** | **-0.545** | **-0.545** |
| 2020 Age1+ biomass | 1,260,740 | 1,308,100 | 1,353,810 | 1,389,990 | 1,410,930 | 1,420,330 | 1,420,350 | 1,413,070 |
| 2021 Age1+ biomass | 2,104,340 | 2,079,150 | 2,049,410 | 2,090,640 | 2,115,270 | 2,127,880 | 2,132,660 | 2,132,780 |
| TOTAL | 59.1349 | 55.7023 | 54.5494 | 54.4445 | 54.4937 | 54.637 | 54.8408 | 55.0797 |

There is little information on steepness beyond ruling out very low values. As steepness goes up, $M$ goes down; but $M$ is less than or equal to 0.65 $yr^{-1}$ over the range explored

Although jittering will be completed after the Panel, an initial 50 jitter runs with 5% jitter, resulted in no jitter runs with lower likelihood than base model (NLL=54.445). While 62% of runs had the same NLL, 36% had a NLL of 54.454 and 2% had 55.522.

**Request 32**: Calculate $E_{\mathrm{MSY}}$ for the base model, and as sensitivities calculate $E_{\mathrm{MSY}}$ using maturity ogives based on just 2017 or just 2021 data.
**Rationale**: $E_{\mathrm{MSY}}$ from the base model is needed to inform management. $E_{\mathrm{MSY}}$ may be sensitive to maturation schedules, and maturity ogives were estimated from only two years' worth of data with some differences between the two years.
**Response**: This will need to take place after the Panel is complete because Stock Synthesis does not report MSY divided by age-1+ biomass.

**Request 33**: Calculate a 10-year mean of age-1+ biomass using all available years (2015-2021) from the base assessment model and each of three options for setting age-1+ biomass for years before 2015: (a) zero, the estimate of age-1+ biomass for 2015, and 1.5x the estimate of age-1+ biomass for 2015.
**Rationale**: The management framework adopted for CSNA requires a 10-year mean biomass to inform specification of the Overfishing Level (OFL) and Acceptable Biological Catch (ABC) default, but the base model does not estimate biomasses for a full 10 years. It was noted that due to the large increase in biomass over the modelled years, a 10-year mean would likely be insensitive to the values assumed for pre-model years. Averaging over a shorter time period is also an option, though it would not account for years likely to be low abundance relative to the included years.
**Response**: The three mean biomasses are: 567,554 mt, 574,997 mt, and 578,719 mt respectively.

**3) Technical Merits and/or Deficiencies of the Assessment**
This is the first assessment of the CSNA for over 25 years. The STAT formulated the assessment giving considerable emphasis to the data source it considered most reliable, i.e., the AT survey. The resulting assessment leads to biomass trajectories that mimic the biomass estimates from the AT survey well, with the exception of the 2015 estimate. The 2015 AT survey estimate is lower than expected from the model but there is no *a priori* reason (e.g., based on survey performance) to exclude the 2015 survey data from the assessment. The fits to the age-composition data from the AT survey are quite poor even though age-reading error is taken into account. The assessment recognizes that the fishery age-composition data are informative about the age-structure of the removals, but given changes in the timing and location of fishing over time may not be informative about recruitment strength, and the assessment consequently allowed for time-varying selectivity by fishery. Weight-at-age was set to empirical values.

The STAT attempted to obtain a model that captured a longer set of years than 2015+. Models explored during the Panel included an index of young-of-year and catches prior to 2015 (along with a 2014 fishery age-composition). Indices were also available from California Cooperative Oceanographic and Fisheries Investigations survey (CalCOFI) eggs and larvae and age-1+ animals from the RREAS, but were not included in any of the models considered during the Panel. The resulting "long" models were found to have poor convergence (high gradients and non-positive-definite Hessian matrices). Estimates of *M* were at the upper bound and there were similar stability issues with estimating initial F, equilibrium recruitment ($R_0$), and the recruitment offset.

Three key parameters of the population dynamics model are poorly estimated by the available data (steepness, survey Q and natural mortality). The STAT decided to set survey Q to 1 for the core survey area and explored the implications of correcting the estimates of biomass for the latitudinal coverage of the stock, i.e., Mexican waters, and the proportion of the stock that is inshore of the core sampling area. The likelihood profiles for steepness and *M* are quite flat, indicating that the available data provided little information on these parameters.

The models lead to very high fishing mortalities for some ages in 2015. The final base model has fewer high fishing mortalities than the model in the draft assessment, owing to the change in the way selectivity is modelled. The exploitation rate on age-1+ biomass is much lower than the fishing mortality rate on single age-classes, and this exploitation rate is higher than if the exploitation rate was based on age-0+ biomass as some of the catch is of age-0 animals.

The approaches used to add inshore biomass or modify survey Q are based on limited data and the uncertainty of extrapolations into the inshore area is not quantified. The effect of the latter is likely small for this assessment but could have been consequential had biomass not been substantial recently.

The final base model incorporates the following specifications:

- Sexes were combined; age-0 to age-3+
- Two fisheries (MexCal S1 and MexCal S2), which combine the fisheries off Mexico and California and allow for seasonal selectivity patterns (the penalty on the deviations in selectivity about expected recruitment is based on a variance of 1).
- Beverton-Holt stock-recruitment relationship with steepness set to 0.6 and $\sigma_R$ to 1.
- Initial fished equilibrium with a "SR regime" parameter and an "initial F" parameter.
- *M* and virgin recruitment estimated
- Recruitment deviations estimated for 2015 to 2020 and initial age-structure (age-1 to age-3+).
- Biomass estimates for the AT survey that reflect corrections for inshore biomass or survey Q for unsurveyed areas (see Table below). Note, that when available, observations from AT nearshore surveys from small vessels or extrapolation from the more easterly side of the AT survey core area surveyed by the *Lasker* to the area shoreward of the AT core area were added to the AT survey observation from the core area. For spring 2016 (model year), the Q value was adjusted based on the temporally aligned aerial observation.
- Age-composition for the AT survey weighted by the number of positive clusters (calculated during AT survey data processing), with selectivity assumed to be uniform (fully-selected) above age-1 and estimated annually for age-0.
- The age data are weighted with effective sample sizes set to 1 per cluster.
- Empirical weight-at-age (fisheries and the AT survey).

| | AT Values<br>Model year | AT Core | AT Nearshore | AT total | | | |
|---|---|---|---|---|---|---|---|
| S1 (summer) | 2015 | 10,528 | 7,180 * | 17,708 | | | |
| | 2016 | 150,907 | 274 * | 151,181 | | | |
| | 2017 | 153,460 | 45,446 * | 198,906 | | | |
| | 2018 | 723,826 | 4,110 & | 727,936 | | | |
| | 2019 | 769,154 | 41,480 & | 810,634 | | | |
| | 2021 | 2,357,000 | Not yet processed+ | 2,357,000 | | | |
| | | | | | Aerial | Q ratio | Q adj (0.5798) |
| S2 (spring) | 2016 | 173,973 | -- | -- | 294 | 0.9983 | 0.5780 |
| | 2021 | 1,358,587 | 13,047 & | 1,371,634 | | | |

& based on nearshore acoustics; * based on extrapolation; + so no inshore correction applied

**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**

***Ability to estimate the 10-year biomass estimate informing $E_{MSY}$***

The STAT preferred the short-term model based on the period of greatest data availability for the AT survey from 2015 to 2021, and the fact that the longer-term model was less stable. A ten-year time series of biomass estimates is required under the anchovy management framework adopted in COP 9, schedule 3 for determination of the average biomass component of the OFL. The biomass estimates resulting from the shorter-term revised base model provide fewer years for estimating the average biomass (see Request 33). Surveys for short-term biomass are better informed given data availability in the recent past, and more years of data can be added to update the OFL and ABC with a longer-term average biomass from a longer time series. The management quantities can be informed with the current short-term assessment model but could be revisited when additional data are available from 2015 to 2025, and assessment considerations are addressed. Final recommendations will come from the SSC.

***Uncertainty in the estimate of the $E_{MSY}$***

Selectivity, maturity, $h$ and $M$ have implications for the estimates of $E_{MSY}$. However, the data are largely uninformative about $M$ and $h$ (Request 31). Differences in the maturity ogive derived from 2017 and 2021 data compared to 2017 data alone leads to additional uncertainty in the estimate of $E_{\mathrm{MSY}}$. The maturity-at-age may be biased by the geographic distribution of sampling, given the cline in the age-at-length observed in the spring 2021 survey data. The extent of any bias is difficult to determine, making this an outstanding uncertainty.

***Discrete vs. continuous time periods for key parameters***

The model is based on discrete time (and assumes spawning in only one semester), but the population dynamics are continuous (recruitment and growth). The timing of spawning and rates of growth relative to the discrete time break between the first and second semester of each year may contribute to the variability in selectivity of the AT survey and impact parameter estimates and estimates of exploitation rates. A monthly model might better approximate these continuous processes than a semester-based model.

***Stock structure***
The assessment assumes a discontinuous distribution of the northern and central sub-populations with a gap between them in the vicinity of Point Reyes to Cape Mendocino, California identified in DiNardo and Sweetnam (2018), which is not supported by previous studies (Vrooman and Smith 1979; Vrooman 1981). The boundaries of the northern and central sub-populations are potentially subject to seasonal shifts, and previous studies have provided differing perspectives on the geographic distribution of sub-populations and the extent of geographic separation of sub-populations. The geographic distribution of sub-populations is an uncertainty relative to (a) growth rate given patterns of latitudinal variation in weight-at-age, (b) catchability considerations regarding the spatial extent of the AT survey (if the boundaries are wrong, more or less of the stock in unsampled areas is missed), and (c) geographical extent expansion of survey estimates for each sub-population (if the boundaries are wrong, expansions will be to an inappropriate parcel of water or some part of the stock will be left unsampled preventing expansion and estimates to the appropriate range of the stock).

***Selectivity***
The factors contributing to variability in selectivity of age-0 and age-1+ fish was the subject of Request 5. Variability in the timing of peak spawning and growth rates between years relative to the timing of the AT survey can affect the selectivity of the survey for age-0 fish necessitating time-varying selectivity. Time-varying age-0 selectivity with a time block, was successfully implemented in Stock Synthesis. The 2016 and 2017 age-0 selectivities were consistently 1 among model options, but the estimated selectivity of 1 in 2015 may contribute to the apparent underestimates when the biomass estimates for the 2015 survey are back calculated from the 2016 results. Thus, a sensitivity analysis with an age-0 selectivity in 2015 fixed at 0.5 was conducted to evaluate uncertainty, though results were not wholly inconsistent, indicating that the biomass estimates were robust to the assumed value (Request 31).

Understanding the reasons for the time-varying selectivity is important given the high interannual variance in the fishery data and the reduction in information from the age composition since true variability is subsumed by invoking variable selectivity. Discussions with the CPSAS representative indicated that variability in fishery age data may be market-driven, since fish below a given size may not be marketable. That said, the fisheries in the Los Angeles and Monterey areas were represented in the 2015-2018 fishery data, and most of the data are from Monterey during 2019-2021, potentially affecting selectivity over time. No age data from Mexico are included, and the selectivity from Monterey may not be representative of Los Angeles and Mexico. Length and age data from Mexico are needed to inform selectivity for the entire fishery. Combining data from three fisheries with potentially different availability and selectivity, and representing them as a single fleet, may contribute to uncertainty in the assessment.

***Ageing error***
While one age reader's observations from 2017-2021 were removed from analysis due to severe divergence in results compared to the other readers, ageing error among remaining readers was still greater than anticipated for a short-lived species. While ageing error for older individuals is expected, there was considerable error in reads for age-1 fish, which was a source of greater concern. Implementation of an age-3+ age bin instead of age-4+ in the base model to address the high ageing error for the few age-4 fish available did not resolve the high $F$ values in the base model. Implementing the auto-regressive selectivity model resulted in improved fits to the age-composition data. While ageing bias is accounted for in the proposed base model, addressing

ageing error in laboratory methods to increase consistency between readers in the future is essential to reduce the error among readers. That said, it should be acknowledged that some of the inconsistency in age reads may be due to the inability to standardize by being in the same room to calibrate reads among readers due to limitations on travel and laboratory access resulting from the COVID-19 pandemic. Age validation studies may also provide a way to provide an objective basis for standardizing reads rather than basing reference reads on the most experienced reader, which are still subject to potential error.

***Natural mortality estimation and high fishing mortality rates***

The ability of the model to estimate $M$ is limited given the availability of data and the lack of its constancy in reality. The precision of the $M$ estimates depends on the model, but a range from 0.2 to 0.8yr$^{-1}$ seems reasonable given the confidence interval estimates. The long model did not provide additional information on $M$ relative to the short model, and would make the assumption of time-invariant $M$ even less tenable. No prior on $M$ was implemented, and it could be hard to justify an informative prior given the limited available data.

Natural mortality rates below 0.6 yr$^{-1}$ were subject to scrutiny given studies conducted by MacCall (1973) that resulted in an estimate of $M$ of 1.06 yr$^{-1}$ for periods when predator populations were much lower than present. The value of $M$ may depend on age and otherwise vary over time based on environmental conditions including predator abundance, but is currently assumed constant and independent of age. Multi-species models could help examine the effects of predation by sealions and whales etc. on $M$ over time. Exploration of these and other variables in association with a time-varying $M$ may be an additional area of future research.

Structural assumptions can change the estimate of $M$ including the initial $F$, $R_0$, and offsets between sexes, which could be examined in future assessments. There are fewer extreme $F$ values in the final base model than in the pre-STAR base model, but the estimate of $F$ in 2015 in the final base model is still very high for age 3+, and reasons for this remain unclear. While low selectivity on younger ages means overall exploitation rates are lower than the F values might initially imply, the age-3+ fish are fully selected, and so the high F in 2015 remains problematic..

**Catchability (Q)**

The Q in the base model of the draft assessment was assumed equal to 1, indicating that all biomass was accounted for by surveying in the core area sampled by the NOAA Ship *Reuben Lasker* (*Lasker*). Alternative models accounting for biomass outside the core sampling area through concomitant nearshore sampling by the aerial survey, AT small boat sampling or extrapolation from the offshore areas sampled by the *Lasker* to the shoreward areas were explored. The preference of the STAT was to prioritize direct observations by the AT small boat sampling, followed by extrapolations shoreward from offshore sampling by the *Lasker*, and lastly estimates from the aerial survey.

This may not be fully consistent with the guidance provided by a joint meeting of the members of the SSC, CPSMT, and CPSAS (https://www.pcouncil.org/documents/2019/10/agenda-item-d-4-attachment-1-report-of-the-joint-meeting-of-representatives-of-the-ssc-cps-subcommittee-the-cpsmt-and-the-cpsas.pdf/) to use direct observations in preference to extrapolation, although no method was proposed to directly add aerial estimates to core AT biomass (as was done with small vessel acoustics or extrapolated biomass). The SSC's report on this issue (https://www.pcouncil.org/documents/2019/11/agenda-item-d-4-a-supplemental-ssc-report-

1.pdf/) noted that "acoustic sampling conducted by industry vessels is most comparable to ATM surveys" and "any of the four approaches described in the report are acceptable, including extrapolation", concluding that "Assessment analysts should determine the most appropriate approach in their particular case, so long as the caveats and limitations of different approaches are considered."

Along with concerns about large variances, the lack of validation on large schools, and the lack of a method for adding aerial survey biomass estimates to the core AT biomass estimate directly, the STAT noted the lack of complete coverage of the entire coastline as justification for prioritizing extrapolation. That said, the aerial survey estimate in the summer of 2017 was nearly twice that of the extrapolated value despite having only sampled a fraction of the coastline, indicating the underestimate from extrapolation may be more extreme than reflected in the limited sampling inshore by the aerial survey (although the aerial estimate is fairly imprecise). Concern has been expressed in previous reviews noted above and was reiterated by panel members about extrapolating from waters seaward of the AT survey eastern boundary to waters shoreward given the potential for differing densities of fish with distance from shore, especially when the stock is at low abundance and expected to be distributed closer to shore (MacCall 1990), resulting in the potential for underestimation from extrapolation. While adjustment of Q to account for biomass inshore of the AT survey may not result in a substantial difference in the biomass estimates at present, it is possible that a substantial proportion may be nearshore at low abundance, which could make the choice of method to account for nearshore biomass more consequential in the future

In addition, surveys including AT sampling into Mexican waters in the summer of 2021 provided information on the proportion of biomass in Mexican waters to inform catchability of previous surveys conducted only in US waters. The adjustments to AT catchability for spring surveys and in other years of the assessment period assume the total biomass has not changed over time (whereas it appears biomass is currently increasing, meaning this method will yield a Q value that is too small), and Q will potentially be biased depending on the distribution of the biomass in the period in question compared to summer 2021.

Sensitivity analyses were conducted to catchability assumptions that ranged from ignoring the biomass inshore and assuming a Q = 1, to the alternatives using data from the aerial survey resulting in the lowest estimates of Q to bracket uncertainty, and resulted in a relatively narrow range of biomass estimates. This was consistent with expectations given that the stock is at high abundance, and most of the biomass is distributed offshore. Accounting for biomass inshore of the AT survey when the stock is at low abundance becomes more critical, as a higher proportion of the stock is expected to be distributed closer to shore (MacCall, 1990) and omitted by the AT survey in the core area offshore. In the future, and as noted by previous reviews, additional research to account for the biomass between the surface and the transducer mounted at the bottom of the hull of the *Lasker*, potentially missed if the fish move laterally rather than under the vessel is an area for further research. The upper water column is also missed to some extent by small vessels conducting acoustic surveys nearshore. The surface area nearshore is observed by the aerial survey. This is an area for further research to provide a more complete understanding of the survey catchability in the core and nearshore areas in acoustic surveys.

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

*a) CPSMT issues*

The CPSMT representative greatly appreciates the substantial efforts by the STAT and the constructive STAR Panel discussion and requests. Both the STAT and others from the SWFSC who did the ageing and maturity work were very responsive to the numerous requests made by the STAR Panel.

The original base model used for the assessment initially provided to the STAR panel only encompassed AT survey data from 2015 forward as an index of abundance. Other data sources with longer time series were considered but not utilized. The CPSMT representative raised the issue early on that the STAT's stated goal in the draft assessment reviewed by the STAR panel (lines 552-526), "to estimate terminal year stock biomass, and for a short-lived species like CSNA, a model with a longer time frame would likely not enhance achievement of this goal", should be reconsidered. The management of CSNA is based on the long-term MSY rather than setting harvest specifications based on the terminal year biomass estimate (e.g., Pacific sardine). A management framework for CSNA was recently adopted by the Council and added to the revised COP 9 Schedule 3 after extensive review and revision dating back to 2018. That management framework calls for a 10-year biomass estimate for the stock and $E_{\mathrm{MSY}}$ value that come directly from an assessment. From a management perspective it would be ideal for the assessment to provide those two key parameter values needed to implement the adopted framework for CSNA if possible.

Using another index of abundance such as the RREAS, which was examined during the STAR panel, may have provided those values for management since it provides a longer time series using standardized sampling that includes the Southern California Bight going back to 2004. However, the STAT preferred to utilize only the AT survey index of abundance from 2015 forward in the final base model. The model proposed by the STAT for this assessment does not strictly meet the Terms of Reference which states, "Stock assessments are conducted to assess the abundance and trends of fish stocks and provide the fundamental basis for management decisions regarding appropriate harvest levels." Thus, the Council and its advisory bodies will need to consider the results from sensitivities to average biomass estimates done in request 33 when making management decisions for this stock and setting any new harvest specifications when it meets to consider this assessment in June 2022. These sensitivities should provide the additional information for 10-year average biomass needed for management purposes, but they will need to be examined by the full SSC in June for that determination. There is also still work needed to modify the Stock Synthesis software to provide the required $E_{\mathrm{MSY}}$ value that is needed (see request 32), but that is anticipated to be completed for inclusion in the assessment provided to the Council in June. Depending on the management outcomes related to the assessment presented in June, the CPSMT may need to consider if it should recommend another assessment of this stock occur as soon as enough AT survey data are available to directly provide the key parameter values from the assessment model itself rather than from sensitivity analyses when it provides the Council with its Stock Assessment Prioritization report at the November 2022 meeting.

The STAR Panel discussed the technical merits and/or deficiencies of the assessment in section 3 and the unresolved problems and major uncertainties for this assessment in section 4. The CPSMT representative generally agrees with the STAR Panel on these issues. A couple of key points along these lines are noted here. The estimated value for natural mortality $M$ seems quite problematic in this assessment as it is particularly low given previous work on this issue. The issues raised by the

STAR Panel related to the uncertainty in being able to accurately estimate $E_{\text{MSY}}$ is concerning from a management perspective, especially since this is a key parameter value for managing the fishery. While it is certainly easier to model the stock in discrete time periods, the biology of anchovy does not fit that method very well given that CSNA can spawn throughout the year. The combining of the three very distinct fishing fleets widely geographically separated and their differing targeting strategies, timing, and degree of effort fishing for this stock of anchovy in Monterey, southern California, and Mexico also seems problematic. Also, the work on how best to adjust AT survey results to deal with the nearshore correction factor is still a work in progress for stock assessments of CPS. This assessment used methods for nearshore correction that were prioritized by the STAT which followed some of the recommendations made by the SSC in 2019. The CPSMT representative notes that the methods utilized in this assessment differ from those used in the 2020 benchmark assessment for sardine and that there may be benefits in developing and utilizing consistent methods for nearshore correction.

In the end the STAT proposed a base model that they are comfortable defending as representing the best information scientifically available for this stock. The CPSMT representative thanks the STAT for its hard work modelling this stock and thinks that the Council will be provided with an assessment in June that will be useful for managing the fishery.

*b) CPSAS issues*

The CPSAS representative notes that this STAR Panel review is the first attempt to assess the CSNA in more than 25 years. However, it is important to understand this in context. Following sharply declining landings beginning in the early 1980s, CSNA (i.e., California's anchovy fishery) was categorized as a "monitored" stock in 2000, when the Northern Anchovy FMP was expanded to include all coastal pelagic species (CPS). One purpose of the monitored designation was to focus time and resources on fisheries requiring active management. The monitored category established a precautionary default management policy, reducing the OFL by 75% and setting an Annual Catch Limit (ACL) of 25,000 mt., with annual review and potential management action if landings approached the limit. In fact, California's anchovy fishery has landed less than 10,000 mt annually, on average, for the past three-plus decades, except for 2015, when a perfect storm of conditions – including a dearth of squid to catch and an abundance of anchovy near port in Monterey – increased landings to about 17,100 mt (17,264.4 mt statewide). This temporary spike triggered concern and urgent requests from some for active management, albeit 2016 landings declined to about 7,000 mt (only around 2,300 mt in Monterey), and have remained low in recent years.

A first impression of this STAR Panel meeting is amazement at the extraordinary amount of time and effort invested by the STAT and Panel to undertake this assessment, in light of the small size of the fishery, although the anchovy fishery is very important to California's wetfish industry, especially in Monterey. The CPSAS representative appreciates acknowledgement during the meeting, "We knew going in this assessment would be challenging." We also express thanks to the STAT, and particularly the STAT lead, for their hard work and willingness to respond to the many Panel requests. We recognize the extensive work and contributions of the other scientists who contributed to this assessment.

Our second impression is concern over the dearth of biological data needed to develop a model that can accurately inform the anchovy management framework recently adopted by the PFMC, including a 10-year average biomass estimate, natural mortality ($M$) and $E_{\text{MSY}}$. Essentially, fishery sampling stopped after landings declined in the 1980s and did not resume until 2014, making it virtually impossible to construct a model appropriately reflecting long-term biomass trends. This anchovy assessment is a painful example of why it is critically important to maintain a time series of fishery sampling even if the fishery declines (or is closed, as is the current case with Pacific sardine.)

We appreciate the STAT's and STAR Panel's efforts to develop the best assessment they could notwithstanding serious data constraints, but our concerns remain nonetheless. Following is a summary list of troublesome issues:

- The draft assessment report began by describing the hypothetical stock structure of CSNA, but misrepresented genetic studies (including Vrooman et al., 1981). In reality, the status of genetic and/or fishery stocks of northern anchovy in the Northeastern Pacific is currently unknown. This has particular relevance for central California.
- The model is based solely on AT surveys from 2015-2021 that reflect wide variability in annual estimates. The 2018 AT Methods Review recommended the use of AT survey data as a relative index, and not appropriate for anchovy absent nearshore correction, preferably a nearshore AT survey. Q needs to be established.
- We agree with the recommendation to develop a model that includes nearshore correction for Q. That may be inconsequential now at a record-high biomass level (based on CalCOFI egg/larval surveys), but nearshore correction will be essential when the biomass naturally declines and the population moves inshore.
- The final base model is insensitive to the natural mortality rate, and the original model was incapable of estimating $M$>1yr $^{-1}$. The small differences in biomass based on fixed natural mortality rates from $M$ = 0.3 to 0.9 yr $^{-1}$ suggest that some model input is interfering with natural mortality. The consistent pattern with biomass being higher with larger $M$ until 2018 and switching to biomass being lower with larger $M$ after 2018 is highly unusual. The model's insensitivity to the natural mortality rate needs further evaluation.
- When $E_{\mathrm{MSY}}$ is estimated for management, analysts will need to consider uncertainty around $M$, steepness, varying weight-at-age etc.
- Age validation has not yet been completed for northern anchovy. There was extensive discussion during the meeting regarding uncertainty in ageing, including ageing errors, weight at age estimates, and the age/length key in AT surveys.
- The 2015 AT survey was a combined sardine/hake survey not targeting anchovy; as such it was not a 'normal' survey. It had reduced geographical coverage (for example, it did not include offshore areas sampled in later surveys) and it had low sampling effort. Even including extrapolation for the nearshore and Baja, the total AT estimate was only 17,708 mt, according to the Table on P. 45 of the STAR Panel Report. The Panel agreed the 2015 AT estimate was an underestimate. In fact, landings in 2015-1 were 35,721 mt. An independent spring 2015 egg-larval production estimate was 178,900 mt, which appears similar to the estimate produced in Request 17 – the only model run that excluded the 2015 AT survey. The extended run including the RREAS, with the 2015 AT survey omitted, increased the 2015 biomass by about an order of magnitude, and it increased the 2020 biomass by about 200,000 mt. Yet the 2015 survey was included in the final model despite these apparent problems.
- The STAR Panel did not examine what happens to the assessment if the short-term model includes other indices, i.e., RREAS, instead of just the AT survey. We recommend that future assessments consider and incorporate multiple indices, including RREAS, CalCOFI and nearshore aerial as well as the acoustic surveys.

We understand that AT surveys including a nearshore small boat component, and nearshore aerial surveys with enhanced sampling, are improving data collection capabilities. These surveys, along with continued biological sampling, offer hope that over the next several years the data deficiencies present in this assessment will also be improved upon. We recommend that the future management and assessment framework provides sufficient flexibility to account for deficiencies present in this assessment. This includes use of additional indices beyond acoustic surveys if they can inform biological parameters needed for management decisions that might be required before the next benchmark assessment.

**7) Research Recommendations (priorities high = H, medium = M, low = L)**

*Natural Mortality*

- (M) Estimate a time-varying natural mortality rate given changes in predator numbers relative to prey abundance over time. The STAT indicated that there is a proposal within SWFSC to investigate this issue.
- (M) Assess whether predator abundance, absolute or relative, and their anchovy consumption can provide a lower bound for anchovy biomass and/or inform $M$.
- (H) Develop a prior for $M$.

*Ageing*

Assessing age presented a challenge for the assessment given the diversity of sources of data and methods.

- (H) Obtain length/age composition for the Mexican anchovy catch and include it in future assessments.
- (H) Improve the accuracy of ageing determination and increase age validation efforts.
- (H) Continue efforts to standardize the ageing process among laboratories, including Mexican laboratories.

*Stock structure*

- (M) Consider genetic and non-genetic methods to determine stock structure.

*Modeling*

- (M) Develop ways to better account for the continuous nature of spawning and growth versus the discrete time steps used in current modelling.
- (H) Examine the sensitivity of estimates of $E_{\mathrm{MSY}}$ to assumptions regarding $M$, maturity, and growth.
- (L) The current available input data for the model covers a period during which the CSNA is increasing. However, CSNA is characterized by rapid increases and declines. Examine the performance, stability and accuracy of the assessment framework under different circumstances such as different trends in CSNA recruitment and biomass. Explore whether other data sources, longer than the AT surveys (for example, CalCOFI egg and larval data, RREAS) might inform on YOY and/or age-1+ biomass.
- (M) Conduct research to understand the reasons behind the (interannual) variability in selectivity, including variability in market demand.

*Data - Aerial Surveys and Small Vessel Inshore Acoustic Surveys*

- (M) Uncertainty prevails in how to use/include the aerial surveys and/or small vessel inshore acoustic surveys as the coverage changes, and the aerial and the acoustic-trawl surveys have not always overlapped in the past. Continue to conduct research to estimate corrections to AT survey Q or adjustments to the AT survey estimates of abundance to account for the components of the stock south and inshore of the core sampling area.
- (M) Aerial survey biomass estimates have only been validated for a limited number of anchovy schools, and only for small schools (typically 100 mt or less) because of challenges in vessel capture of larger schools for sampling, but larger schools contribute most of the estimated inshore biomass in high biomass years. Use of packing densities, aerial photos of school area combined with vessel estimates of school depth is one approach to validating large school estimates from spotter pilots. Validation of biomass estimates for larger schools remains an ongoing challenge but important to increasing confidence in use of aerial survey estimates in high biomass years.
- (M) Compare the proportion of volume of waters shoreward of the AT sampled by the aerial survey vs. the inshore acoustics to better understand how much shoreward habitat each covers. While the nearshore AT penetrates deeper into the water column than the 10 meters typically observed by the aerial survey, the narrow swath of water sampled by the limited cone width of the AT in shallow waters and water not observed between the transducer at the keel and the waterline limit the volume of habitat sampled in the nearshore. Using track lines and the geometry of the coverage of each survey, the total volume of surveyed waters shoreward of the AT survey can be estimated and compared to account for differences in spatial coverage in considering which survey is preferable. This becomes important given the patchy distribution of the species and a minimum target of 30% from basic sampling design considerations, which have implications for the precision of the estimates.
- (M) Age-0 fish make a large contribution to total biomass and there was considerable annual variation in the estimated weight for fish of age-0 from the surveys. Provide information relevant to the reliability of estimates of weight-at-age for age-0 fish from the AT survey when applied to the modelled population as a whole.

*Improvements to Stock Synthesis*

- (H) Add an option to output estimates of uncertainty in age-1+ biomass

## References

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## Appendix 1
## Attendance List

| Name | Affiliation |
|---|---|
| *Stock Assessment Review Panel* | |
| André Punt | SSC/University of Washington, Chair |
| John Budrick | SSC/CDFW |
| Marisol García-Reyes | SSC/Farallon Institute |
| Will Satterthwaite | SSC/SWFSC |
| Gary Melvin | Canada Department of Fisheries and Oceans |
| Henrik Sparholt | Denmark, Independent Scientist |
| | |
| *Advisers* | |
| Diane Pleschner-Steele | CPSAS |
| Greg Krutzikowsky | CPSMT |
| | |
| *Stock Assessment Team* | |
| Peter Kuriyama | SWFSC |
| Juan Zwolinski | UC Santa Cruz / SWFSC |
| Kevin Hill | SWFSC |
| Steve Teo | SWFSC |
| | |
| *Other attendees* | |
| Dale Sweetman | SWFSC |
| Kirk Lynn | CPSMT/CDFW |
| Alan Sarich | CPSMT |
| Angela Forristall | NMFS |
| Brad Erisman | SWFSC |
| Briana Brady | CDFW |
| Brittany Schwartzkopf | SWFSC |
| Chelsea Protasio | CDFW |
| Emmanis Dorval | SWFSC |
| Heather Fitch | Alaska Department of Fish and Game |
| John Field | SWFSC |
| Josh Lindsay | NMFS |
| Julie Thayer | Farallon Institute |
| Kelsey James | SWFSC |
| Lorna Wargo | CPSMT/WDFW |
| Owyn Snodgrass | SWFSC |
| Richard Parrish | Independent Consultant |
| Steve Crooke | CPSAS |
| Kevin Piner | SWFSC |
| Taylor Debevec | NMFS |
| Trung Nguyen | CPSMT/CDFW |
| Alex Jensen | University of Washington |
| Anne Frieire de Carvalho | SWFSC |
| Barb Muhling | SWFSC |
| Ben Enticknap | Oceana |
| Bill Sydeman | Farallon Institute |
| Brian Wells | SWFSC |
| Conception Enciso | INAPESCA |
| Corey Niles | PFMC/WDFW |
| Dana Myers | CDFW |

| | |
|---|---|
| Desiree Tommasi | SWFSC |
| Dianna Porzio | CDFW |
| Ed Weber | SWFSC |
| Erin Satterthwaite | CA Sea Grant |
| Geoff Shester | Oceana |
| Jarrod Santora | SWFSC |
| Jon Walker | SWFSC |
| Josiah Renfree | SWFSC |
| Julia Coates | CDFW |
| Katie Grady | CDFW |
| Kelly Kloos | CDFW |
| Martin Hernandez Rivas | Instituto Politécnico Nacional, Mexico |
| Megan Human | SWFSC |
| Michelle Horecxko | CDFW |
| Mike Cornman | CPSAS/Ocean Gold |
| Mike Okoniewski | CPSAS/Pacific Seafood |
| Noelle Bowlin | SWFSC |
| PY Hernvann | UC Santa Cruz |
| Rebecca Miller | UC Santa Cruz /SWFSC |
| Robert Wildermuth | UC Santa Cruz |
| Sherri Charter | SWFSC |
| Tara Brock | Oceana |
| Theresa Tsou | SSC/WDFW |
| Will Fennie | Moss Landing Marine Labs |
| William Watson | SWFSC |

CDFW = California Department of Fish and Wildlife
CIE = Center of Independent Experts
CPSAS = Coastal Pelagic Species Advisory Subpanel
CPSMT = Coastal Pelagic Species Management Team
NMFS = National Marine Fisheries Service
NWFSC = Northwest Fisheries Science Center
PFMC = Pacific Fishery Management Council
SSC = Scientific and Statistical Committee
SWFSC = Southwest Fisheries Science Center

## Appendix 2
## Documents Considered

**Primary document**

Kuriyama, P.T., Zwolinski J.P., Teo, S.L.H. and K.T. Hill. Assessment of the Northern anchovy (*Engrualis mordax*) central subpopulation in 2021 for U.S. management in 2021-2022.

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Zwolinski J.P., Stierhoff, K.L. and D.A. Demer. 2019. Distribution biomass, and demography of coastal pelagic fishes in the California Current Ecosystem during summer 2017 based on acoustic-trawl sampling. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-610.

**Other documents**

PFMC. 2020. Terms of Reference for the Groundfish and Coastal Pelagic Species Stock Assessment Review Process for 2021-2022. https://www.pcouncil.org/documents/2021/01/terms-of-reference-for-the-coastal-pelagic-species-stock-assessment-review-process-for-2021-2022-december-2020.pdf/