Pacific Sardine Stock Assessment Review Panel Meeting Report

NOAA / Southwest Fisheries Science Center
La Jolla, California
February 24-27, 2020

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Kerry Griffin, Council Staff
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Pacific Sardine Stock Assessment Team:
Peter Kuriyama, NOAA / SWFSC
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Paul Crone, NOAA / SWFSC
Juan Zwolinski, Univ. California Santa Cruz, affiliated to NOAA/ SWFSC

1) Overview

The Pacific Sardine Stock Assessment and Review (STAR) Panel (Panel) met at the Southwest Fisheries Science Center (SWFSC), La Jolla, CA from February 24-27, 2020 to review a draft assessment by the Stock Assessment Team (STAT) for the northern subpopulation of Pacific Sardine. Introductions were made (see list of attendees, Appendix 1), and the agenda was adopted. A draft assessment document and background materials were provided to the Panel in advance of the meeting on a Council FTP site.

Drs Peter Kuriyama, Paul Crone, Kevin Hill, and Juan Zwolinski presented the assessment methodology. Peter Kuriyama outlined the assessment philosophy, which in common with the 2017 assessment, focused on selecting an approach that made use of the data source considered by the STAT to be the most objective, i.e. the Acoustic Trawl (AT) Method survey.

Juan Zwolinski described the acoustic-trawl survey-based method for estimating biomass and its associated age-structure, highlighting changes in the methodology (updated target strength for Pacific herring and a revised approach for constructing the age-structure of the survey). Kirk Lynn (CDFW) summarized the results of the 2017 and 2019 California Coastal Pelagic Species Survey (CCPSS).

The proposed base model in the draft assessment provided to the Panel was based on the Stock Synthesis Assessment Tool v3.30.14[1]. It differed from the model on which the 2019 update assessment was based by including priors on natural mortality (*M*) and catchability (*Q*), by using updated catches for the Ensenada fishery, and by using updated AT survey index values and age data. This proposed base model also allowed for time-varying age-based fishery selectivity for the three fisheries and time-varying age-0 selectivity for the AT survey. Steepness was pre-specified at 0.27, based on earlier model runs that estimated steepness, rather than being estimated. The major difference in biomass estimates from the 2019 model occurred when the prior for natural mortality was introduced while freely estimating catchability, but this was noted to be a model run that did not converge. In common with the 2017 and subsequent assessments, the proposed base model did not make use of Daily Egg Production Method (DEPM) and Total Egg Production (TEP) indices and did not estimate growth within the model, instead pre-specifying growth based on empirical observations.

The review and subsequent discussions of the model were motivated primarily by the need to more fully understand the basic model inputs (recognizing that this was not a review of the methods on which the acoustic-trawl and aerial survey estimates of biomass were based), how to account for the biomass inshore of the AT survey grid (and the acoustic measurements using sail drone and industry vessels), and the unrealistic estimates for fishing mortality for recent years, including those beyond the end of the years with data from the AT survey.

The STAT considered several approaches related to accounting for the biomass inshore of the AT survey including (a) ignoring it, (b) adding the estimate of biomass from the 2019 CCPSS survey [considered to be more reliable than the 2017 survey because most of the biomass was from schools of sizes included in the point sets used to calibrate observer bias] to the estimate of biomass from the assessment, (c) specifying a change in the acoustic catchability (Q) for recent years using the estimates of AT and aerial survey biomass for 2019, and (d) fully integrating the CCPSS data into the assessment. The first of these options would ignore observed biomass not surveyed acoustically

[1] References in this report to "proposed base model" refer to the model in the document provided to the Panel prior to the review and "final base model" to the model after the changes made by STAT during the Panel review were implemented.

while the second would lead to difficulties when conducting projections for rebuilding analyses. The fourth option is ideal in principle, but there remains considerable uncertainty about how to achieve this given there are only estimates of biomass from the CCPSS for 2017 and 2019 and uncertainty about what selectivity pattern to assume for the CCPSS data were it to be fit as a separate fleet. The final base model therefore specified Q for two periods 2005-2014 and 2015-onwards, with Q for the first period set to 1 and that for second period set to 0.733 to account for an increase in the proportion of sardine biomass inshore of the AT survey since 2015. The Panel considered the final base model, which included specifications to address the inferred high recent fishing mortality, as best available science for use in sardine management for the 2020/21 fishing season.

The Panel acknowledged the efforts made to improve the AT survey, in particular, the increased density of acoustic transects, and the use of alternative survey platforms to provide data for the areas inshore of the R/V *Reuben Lasker*. The collaboration between SWFSC scientists and industry in this regard is noteworthy, and is helping to better characterize the biomass of the northern sub-population of Pacific sardine. The Panel highlights that many uncertainties remain, as noted in the Council reviews of the AT survey, and looks forward to seeing the results of research in response to the recommendations of those reviews.

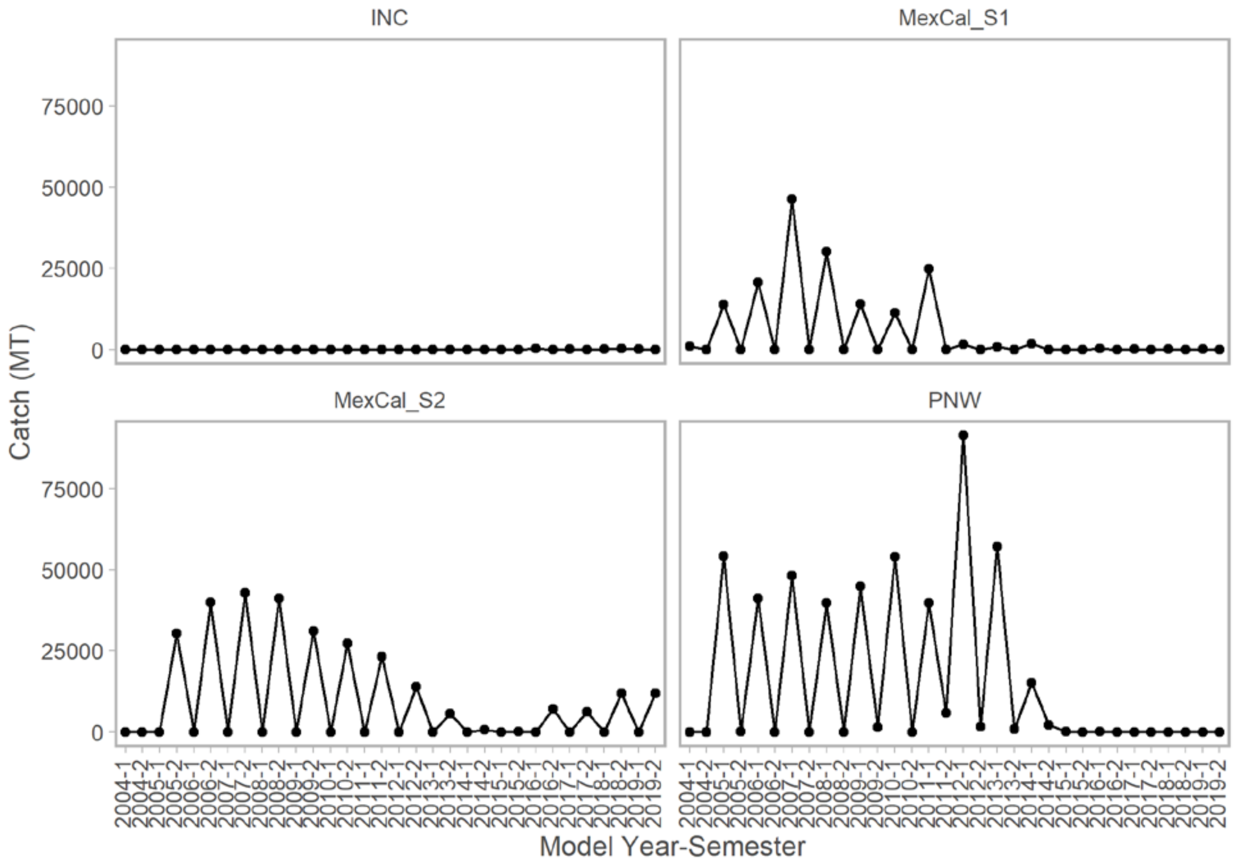
The final base model uses the estimate of 2019 biomass from CCPSS as a way to set a value for Q since 2015, relative to the assumed value of Q=1 prior to 2015. This reflects that there is biomass inshore of the AT survey grid (even after account is taken of the coverage provided by sail drones and industry vessels). However, the utility of these data was not as great as desired because (a) some of the sampling protocols, such as how purse seine catches are used to determine species composition, lead to data that cannot be used in the assessment, (b) most of the sampling for point sets is not synoptic with the aerial survey, and (c) there is a lack of biological data to accurately parameterize selectivity. This led the STAT (endorsed by the Panel) not to include the CCPSS data directly in the model likelihood but rather to include it indirectly by using it as the basis for setting Q (given concerns that including the data would lead to more problems than it would solve).

The Panel recommends that a CDFW scientist be a member of a future sardine STAT to enhance the likelihood of using the CCPSS data to the maximum extent possible. Appendix 2 lists some additional issues with the CCPSS identified by SWFSC and CDFW staff, resolution of which should enhance the value of the CCPSS in assessing sardine.

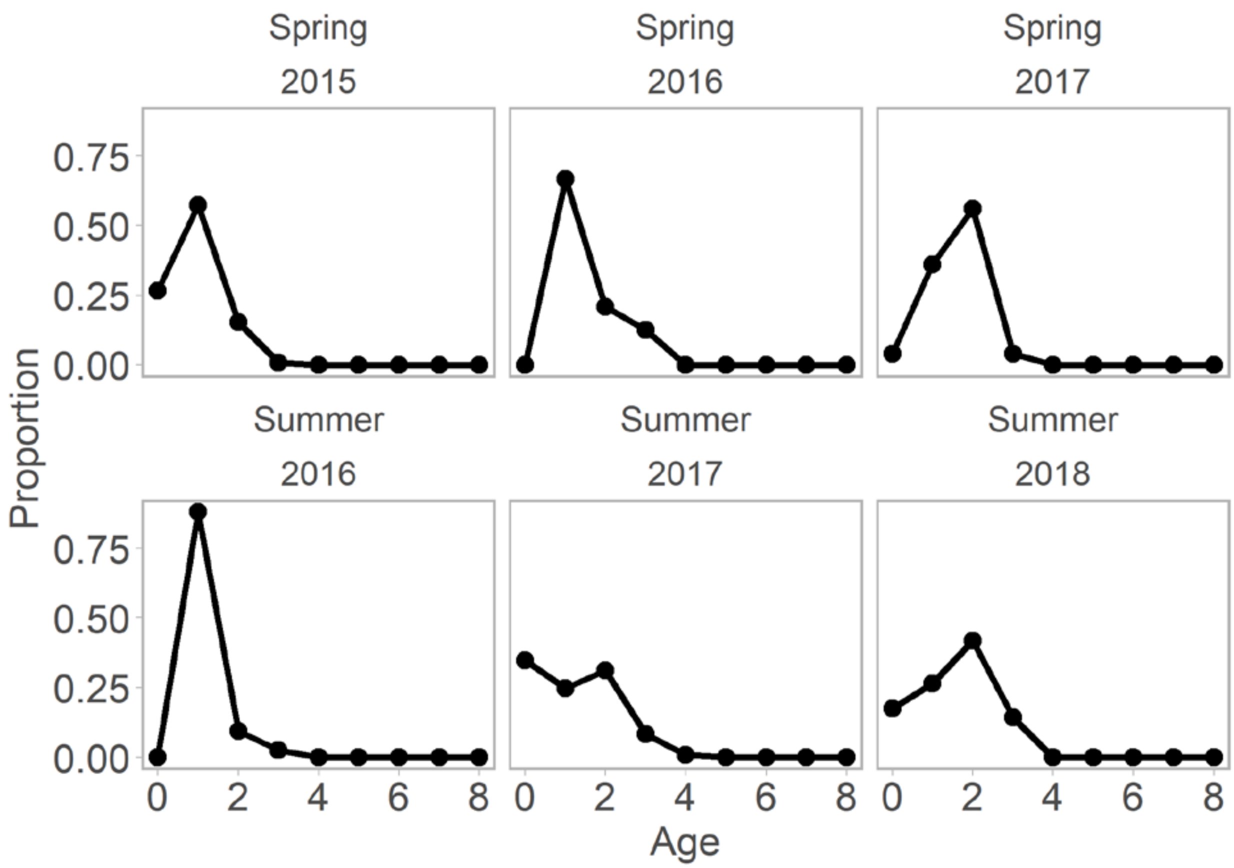
The STAR Panel thanked the STAT for their hard work and willingness to respond to Panel requests, and the staff at the SWFSC La Jolla laboratory for their usual exceptional support and provisioning during the STAR meeting.

2) Day 1 requests made to the STAT during the meeting – Monday, February 24

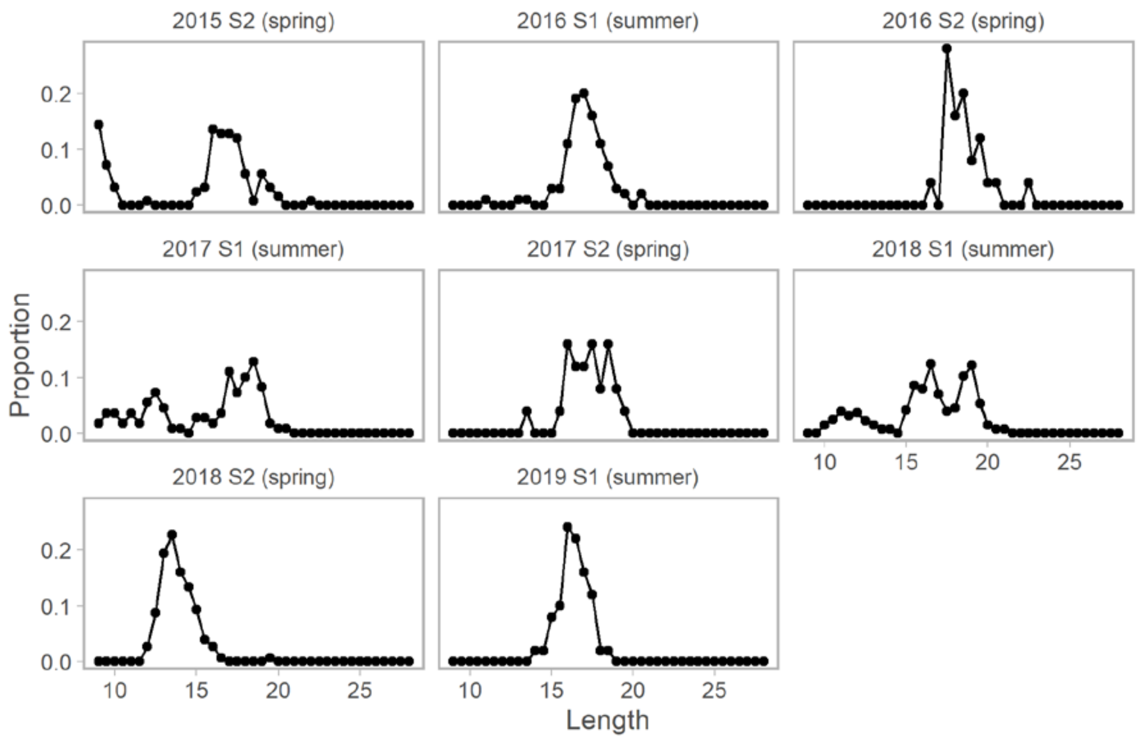
Request 1: Provide a plot of the catches and age- and length-compositions for the non-directed fishery (NDF).
Rationale: These data are included in a model sensitivity run but are not shown in the document.
Response: The STAT provided the requested figures. The following figure shows the 2005 to 2019 catches. The incidental catches (INC) largely come from the MexCal region.



The following figure shows the INC age compositions (note that age-compositions are not available for spring 2018 and summer 2019) [The year refers to the model year (i.e. "Spring 2015" this plot, or 2015s2 next plot refer to January-June of calendar year 2016, and “Summer 2016” this plot, or 2016s1 next plot refer to July-December of calendar year 2016).]:

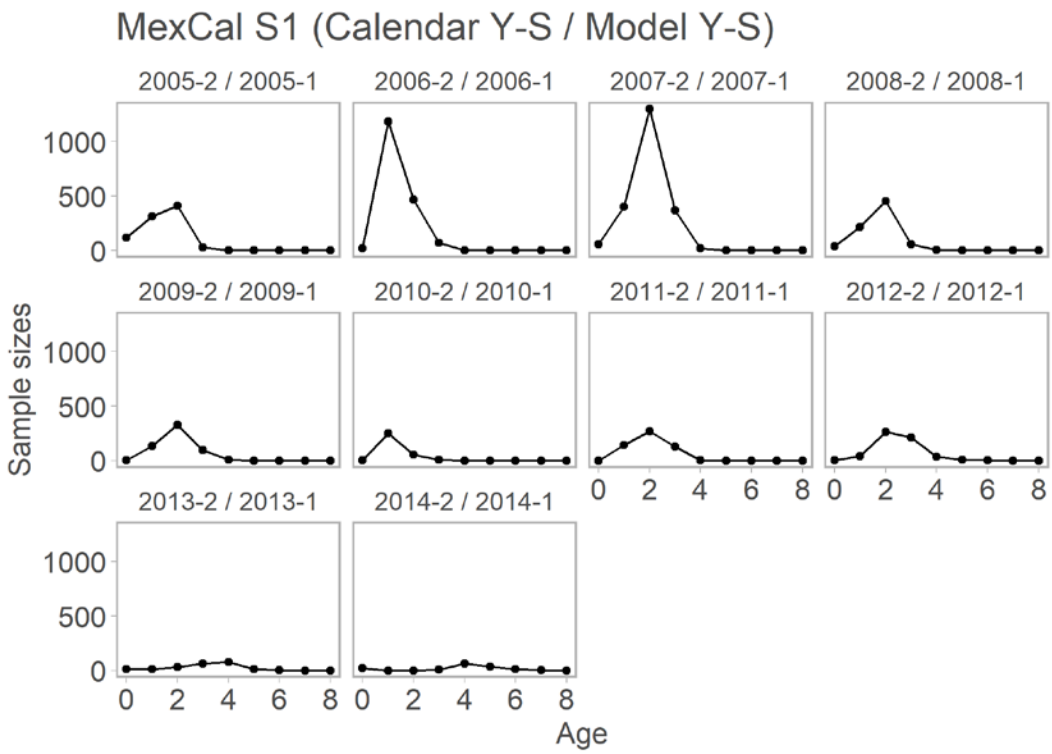


The following figure shows the INC length compositions. The number of model year-semesters with length compositions was greater than the number with age compositions. Not all the incidental length compositions were aged. Note that the length compositions were not used in the assessment model and are shown solely for information.

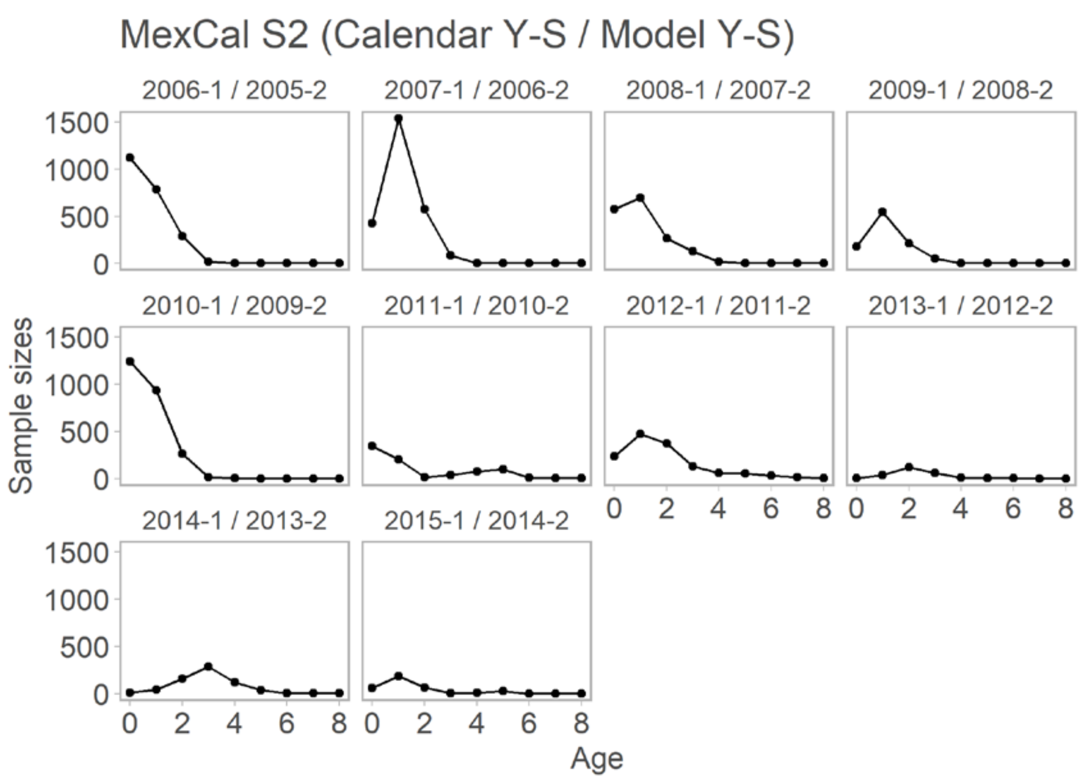


Request 2: Add sample sizes to the weight-at-age plots for all fleets and surveys (or create a table).
Rationale: The weight-at-age by cohort has odd behaviour at older ages in some years; this may be due to small sample sizes.
Response: There are very few samples for ages beyond 4-5 because fish of these ages are not frequently observed (MexCal S1 and S2). The PNW sample sizes are larger at older ages in some, but not all, years. The AT samples have larger sample sizes for older ages (up to about age 7) in some, but not all, years.

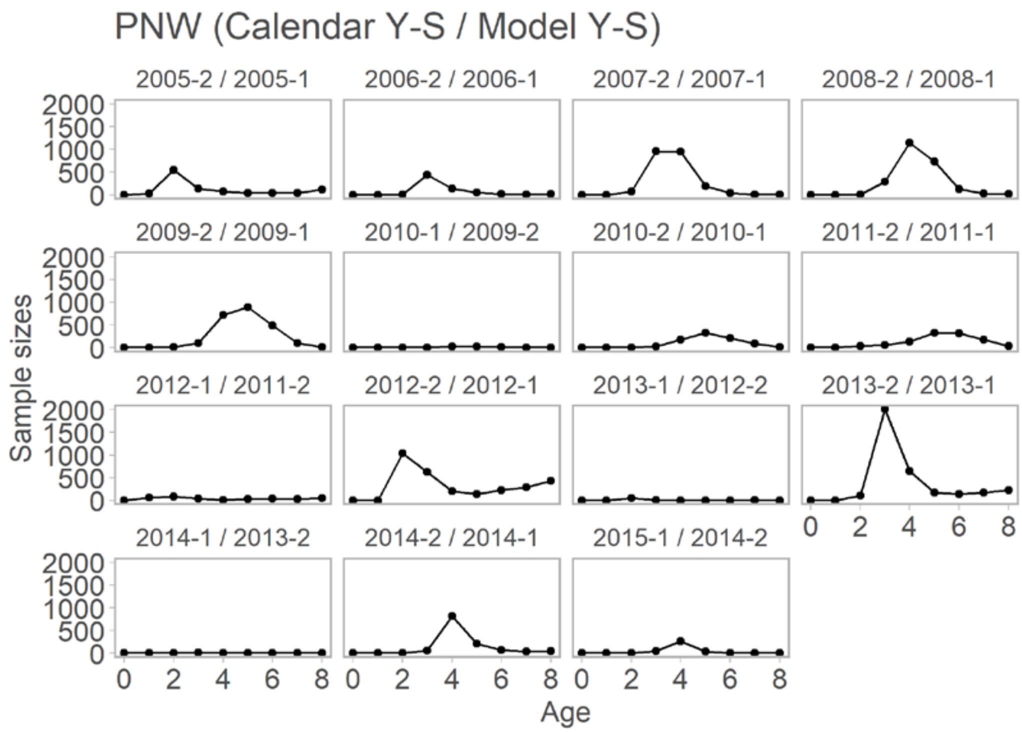
The following figure shows the weight-at-age sample sizes for the MexCal summer fleet.



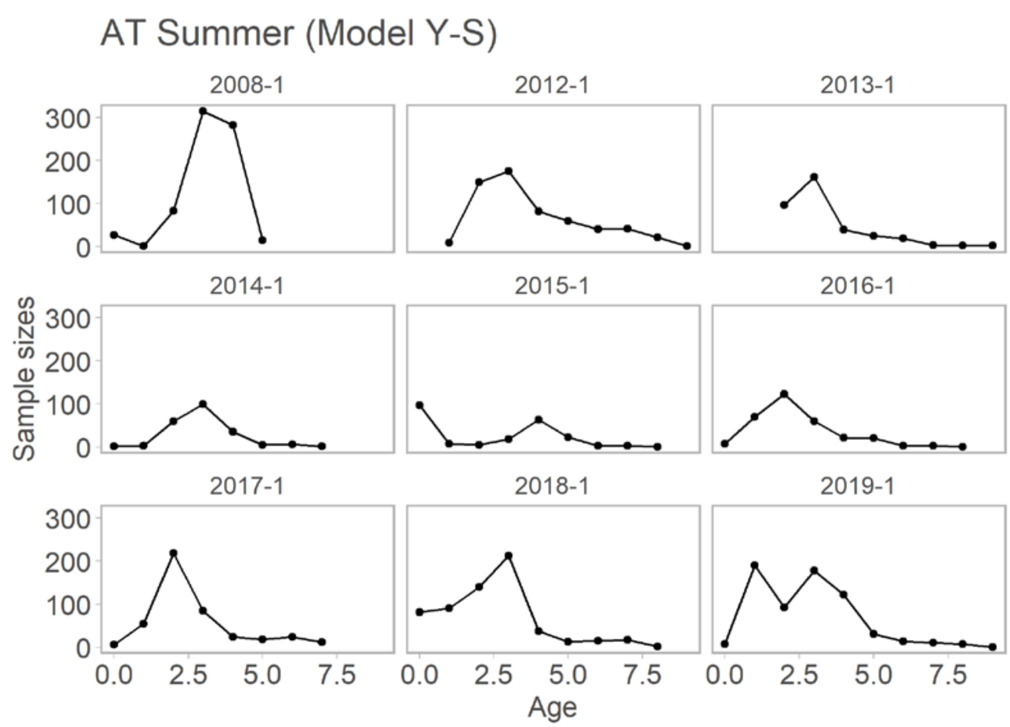
The following figure shows the weight-at-age sample sizes for the MexCal spring fleet

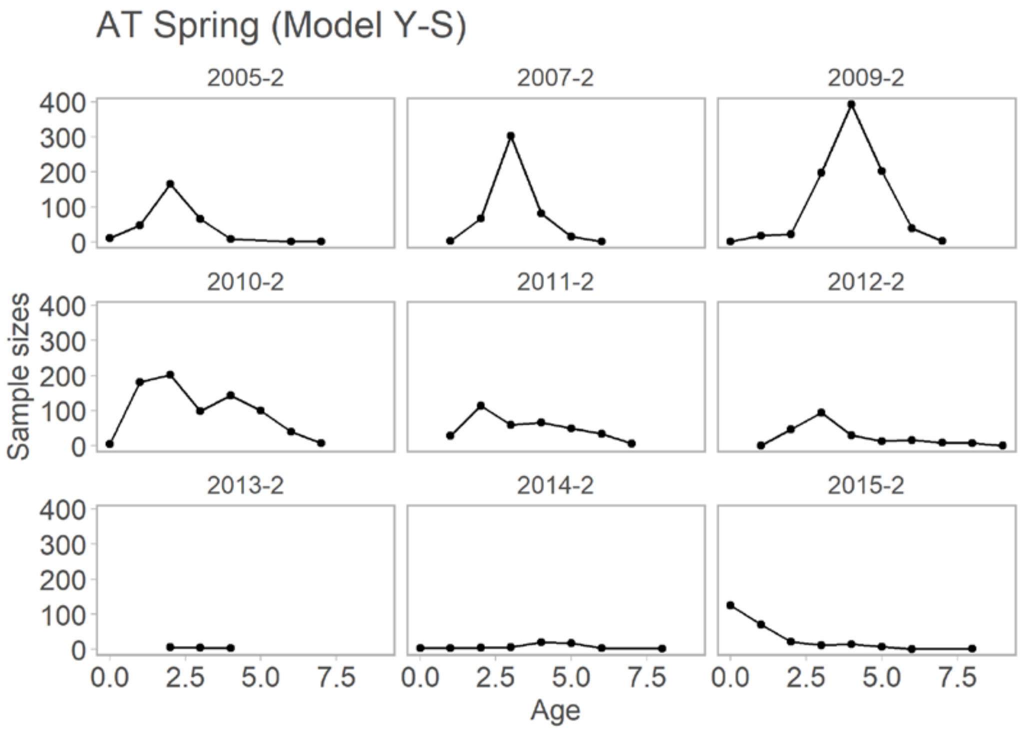


The following figure shows the weight-at-age sample sizes for the PNW fleet.



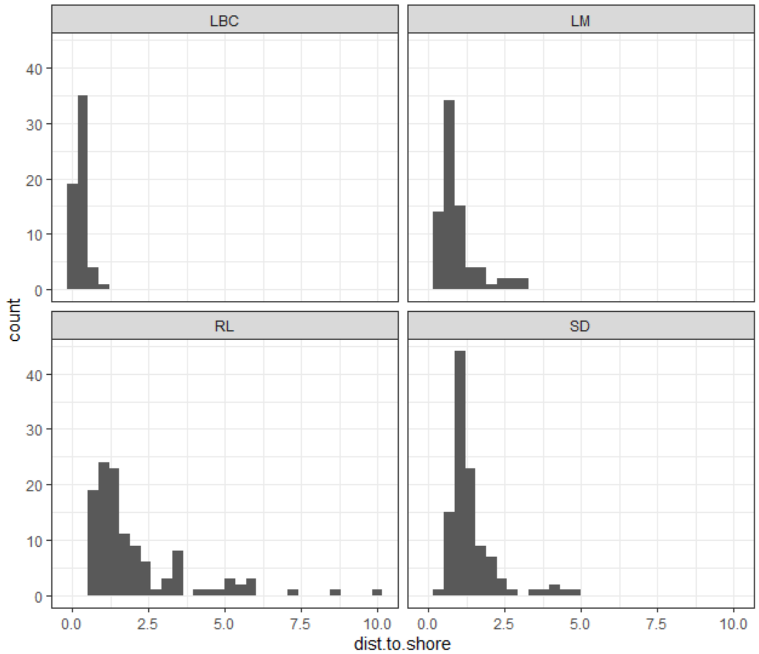
The following figures show the weight-at-age sample sizes for the acoustic trawl survey.





Request 3: Summarize how acoustic backscatter is converted to biomass estimates and how the variance for the estimates of biomass are calculated.
Rationale: The Panel wished to fully understand the current methods, which were previously reviewed by the SSC.
Response: The document titled 'Distribution, biomass, and demography of coastal pelagic fishes in CCE during summer 2019 based on acoustic trawl sampling', page 25 was provided. The discussion noted that the greatest driver of variability is spatial variation in the acoustic backscatter by transect, and that variance may still be underestimated owing to not accounting for uncertainty due to the locations of the trawls, but likely not by much.

Request 4: Provide a table that shows the nearshore extent of each survey method (acoustic trawl, sail drone, commercial vessel, and aerial survey).
Rationale: The Panel wished to better understand each survey region and the extent to which the area covered by each survey type overlaps.
Response: The following figure of the count of point set distances from the coast was provided (LBC=*Long Beach Carnage*, LM=*Lisa Marie*, RL=*Reuben Lasker*, SD=sail drone) for 2019. It was noted that the LBC (nearshore acoustic survey using the fishing vessel *Carnage*) and the CCPSS could overlap in southern California. However, the CCPSS data in this assessment were collected from north of Point Conception. The question of whether the sail drone and CCPSS overlap spatially was raised, but it was concluded that any overlap was minimal because most sardine observations are in the most nearshore band of the CCPSS.



Request 5: Document the methods used to model the age-length keys. Show residual plots from the model fits (observed – expected) or metrics of goodness of fit.
Rationale: Modelling methods have changed from using a multinomial to using a cumulative logistic. It is difficult to evaluate how well the model fits the data given the plots included in the draft report.
Response: The STAT provided a summary of the method and residual plots (Appendix 3). It was concluded that there are no obvious residual patterns

Request 6: Provide a table that summarizes changes in ageing methods and staff (by fleet). Also, provide a summary of ageing protocols by lab, which labs provide ages for which fleet, and any analyses of between-lab age reading comparisons.
Rationale: The history of changes in ageing methods (readers and techniques) and which lab provides ages for which fleet is not clear. Ages are important in the model because the assessment pre-specifies weight-at-age.
Response: The following summary tables were provided. It was noted that systematic sardine ageing started in 2005, and that double reads between the CDFW and the SWFSC are used to estimate ageing error between labs. Ageing error is computed by lab, as is commonly done, and not by age reader. It was also noted that reader 2 has the most experience in ageing sardine and that this reader has been involved in ageing sardine in most years. The method used to estimate age-reading error matrices assumes one reader is unbiased – this is taken to be reader 2 as this reader is the most experienced one. It is common to have ages show ± one year difference due to difficulties in determining the first marginal increment. The Pacific Biological Station (PBS) is not providing ages for the assessment and is included in the table for completeness.

The Panel noted that different labs are using different methods, Mexico in particular. The other labs use more similar methods. Data from Mexico are not used in the assessment, and the model makes the assumption that the age data from California are representative of the Mexican catch (see request 10, which is a follow-up on this issue).

Ageing Laboratory	Fleet/Survey	Collection Year	Reader_ID	# Readers
CICIMAR	Mexican (Mex)	2005-2006	13	1
CDFW	California (Cal)	2005	1,2,3	3
		2007	2,4,5,6	4
		2008-2009	2,4,5.6,7	5
		2010-2011	2,5,6	3
		2012-2015	2,5,15	3
		2016	2,5	2
		2017-2019	2	1
WDFG	PNW	2009-2019	8,9	2
PBS	BC	2007-2013?	10,11, CA*	2
CDFW-SWFSC	SWFSC (DEPM)	2004-2006	1,12	2
		2005-2015	2,12	2
SWFSC	SWFSC (ATM)	2016	12	1
		2017	UA**	1
CDFW-SWFSC	SWFSC (ATM)	2017-2019	2,14, CA*	3

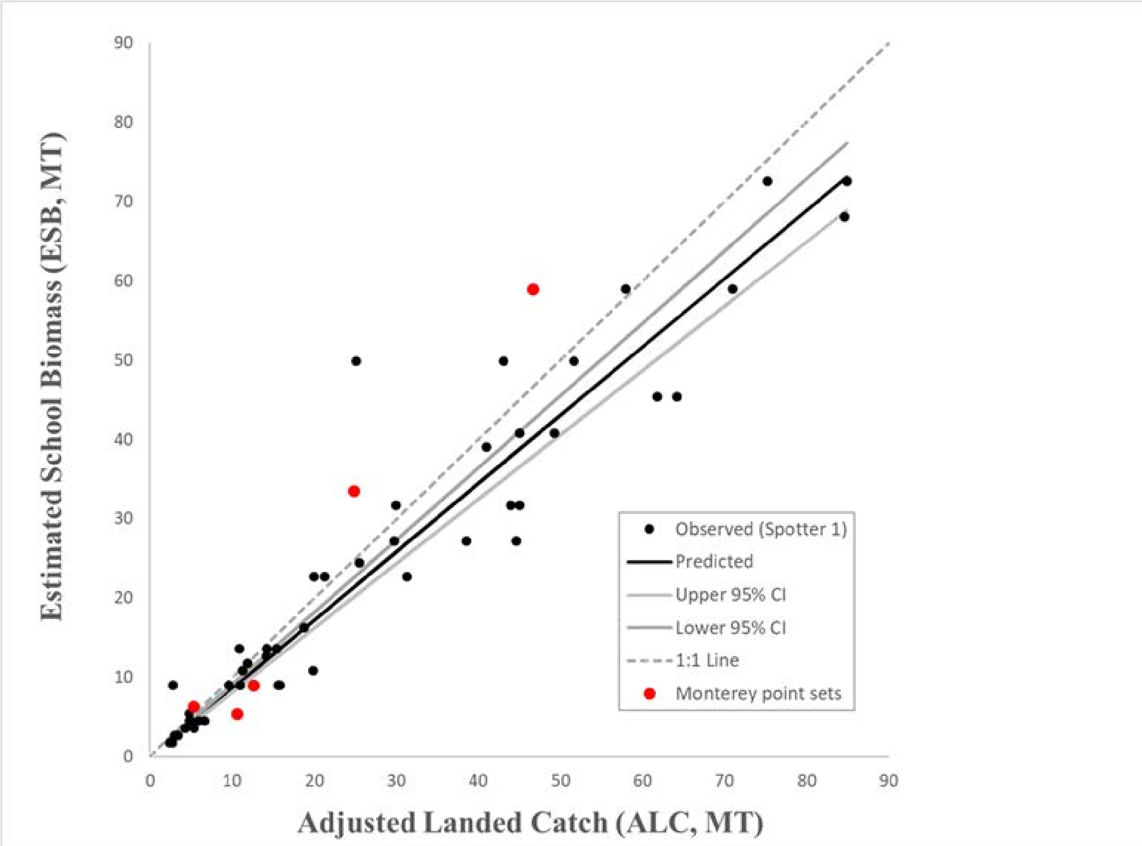
*CA: Corroborated age reading
**UA: Ages were not used in assessment and will be removed from database

Ageing Laboratory	Ageing Method	Light microscope resolution	Assummed Birth date	Final Age assignment
CICIMAR INAPESCA/CICIMAR ?	Whole otolith embedded in synthetic resin Cytoseal	24X on inner increment 40X on marginal increment	No	Based on number of annuli
CDFW	Whole otolith immersed in water	24X	July 1	Based on number of annuli, capture date and the type of marginal increment
WDFG	Whole otolith immersed in full strength alcohol	24X	July 1	
PBS	Whole otolith immersed in water	50X	January 1	
CDFW-SWFSC	Whole otolith immersed in water	24X	July 1	

Request 7: Plot the point set data for the aerial survey showing the observer estimates and landed catches.

Rationale: The Panel wished to better understand how visual estimates from observers compare to captured biomass. What proportion of the visually estimated biomass is covered by the catch data?

Response: The following figure of adjusted landed catch and estimated school biomass was provided. The plot confirms good estimation of school size biomass up to about 100 mt.



Additional information on the proportion of the visually estimated biomass that is covered by the catch data is provided below (request 11).

Request 8: Provide the methods for estimating biomass and variance by stratum for the CCPSS. Provide the sum of the biomass estimated from each CCPSS stratum, along with the variance. Calculate the annual CV using the sum of variances rather than the sum of CVs.
Rationale: The Panel wished to understand how the aerial survey estimates of inshore biomass were determined and to correct the CVs used in the draft document.
Response: The Nearshore Cooperative Survey (NCS) was the experimental phase of what is now the CCPSS. This survey design had multiple flights in a day over the same transect and concluded that spatial variation can act as proxy for temporal variation. It was noted that when the number of schools are high, the observer provides only a combined estimate of biomass because fish are moving. Two observers were used in the NCS. The implementation phase of the survey is the CCPSS, which has one observer. Methods for analyzing the data from this survey are given in Appendix 4.

Request 9: Provide a table on apportionment of southern and northern stock catches for the past few years.
Rationale: The Panel wished to better understand the consequences of the change to the method used to assign catches to the two subpopulations.
Response: The STAT provided tables of catches comparing the catches by the MexCal fleet and off Ensenada. The Mexican catches are more uncertain than those in the US. The Panel discussed the uncertainty in the proportion of the stock caught in Ensenada and how to obtain an upper and lower bound on Mexican catches, particularly for the years that influence the forecast (2019 and 2020).

(a) MexCal catches assigned to the northern sub-population in the 2019 and 2020 assessments.

Calendar Yr-Sem	2019	2020
2017-1	9,364.6	7,080.5
2017-2	170.4	170.4
2018-1	11,439.7	6,229.4
2018-2	35.3	35.3
2019-1	---	11,819.4
2019-2	---	130.9

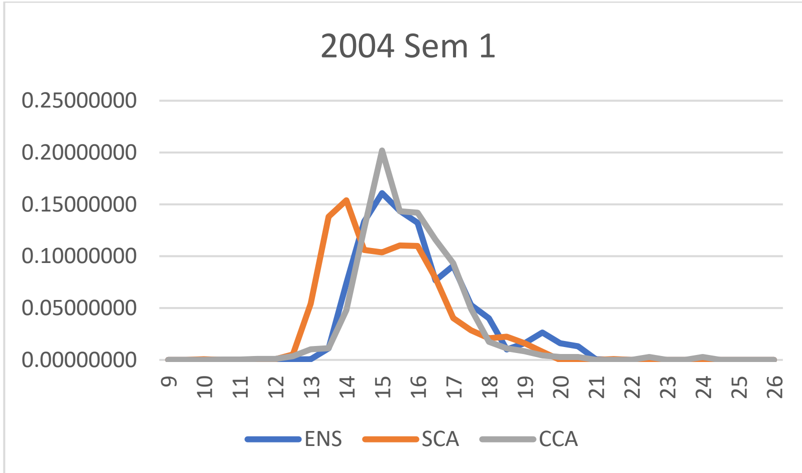
(b) Ensenada catches assigned to the northern sub-population in the 2019 and 2020 assessments, total catch off Ensenada, and the change in the catch assigned to the northern sub-population between the 2019 and 2020 assessments.

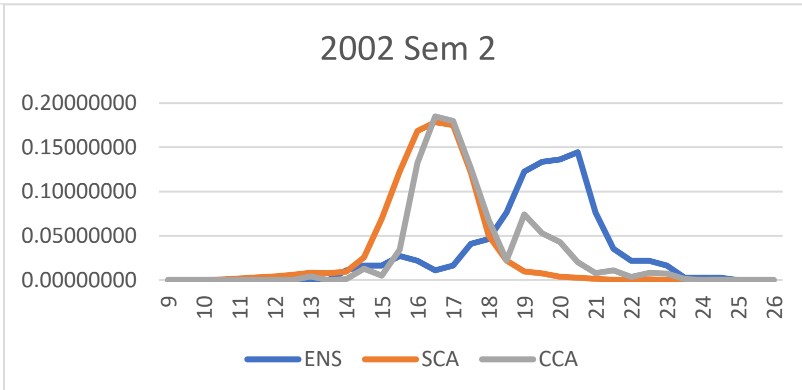
Calendar Yr-Sem	ENS_NSP (2019)	ENS NSP (2020)	ENS Total (2020)	Decrease (2020-2019) (mt)
2017-1	9,219.9	6,935.8	28,211.9	2,284.1
2017-2	0.0	0.0	99,966.6	
2018-1	11,241.9	6,031.7	24,534.0	5,210.3
2018-2	0.0	0.0	43,369.8	
2019-1	*13,255.2*[1]	11,210.0	32,168.5	2,045.2
2019-2	0.0	0.0	46,943.0	

1: Provisional value

Day 2 requests made to the STAT during the meeting – Tuesday, February 25

Request 10: This request follows from Request 5. Verify that ages are similar for Mexico and California by showing the length frequencies for each fleet.
Rationale: This is important because there are no Mexican age data and this comparison serves as a test of the assumption that California ages are representative of Mexico.
Response: Data show that Ensenada lengths are typically similar or larger than those from California. However, the data are variable, rather than being systematically different. It was noted that it would be beneficial to get age data from Mexico in the future, which would require coordination of methods between ageing labs. Example comparisons of the proportion of the catch by region in each 0.5cm length class are provided below.





Request: 11: This request follows from request 8. Provide the sum of the biomasses for each CCPSS band. Compute the variance as documented in Appendix 4.
Rationale: Correct the data.
Response: The following table was provided. The Panel discussed the need for multiple flights over the same band if this survey is to continue, as it is clear that there are differences in the distribution of fish between bands.

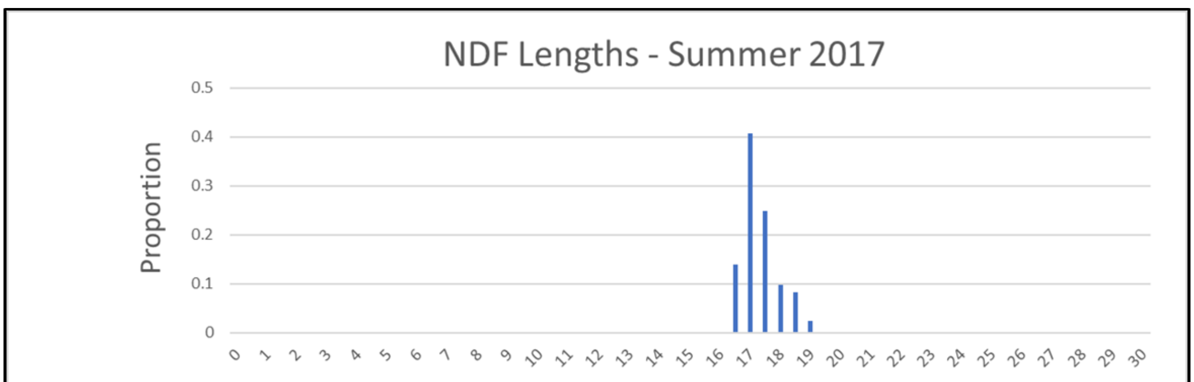
Survey Date	Band	Survey Area	Band Biomass* $B_{j,A}$	Daily Total Biomass B_{tot}	Daily Mean Biomass $\bar{B}_A$	Daily Biomass Variance $V(\bar{B}_A)$	Seasonal Variance	SD	Seasonal Total Biomass	CV
8/3/2017	1 2	Carmel to Half Moon Bay	4,807 69	4,876	2,438	11,224,322				
8/4/2017	1 2	Half Moon Bay to Point Arena	16,089 0	16,089	8,045	129,427,961	562,622,252	23,720	21,046	1.13
8/10/2017	1 2	Carmel to Morro Bay	81 0	81	41	3,281				
8/6/2019	1 2	Stewart's Point to Cape Mendocino	0 9	9	5	41				
8/7/2019	1 2	Manresa Beach to Drake's Bay	11,851 242	12,093	6,047	67,384,441	269,549,476	16,418	12,279	1.34
8/8/2019	1 2	Monterey to Limekiln SP (Kirk Creek)	51 127	178	89	2,888				

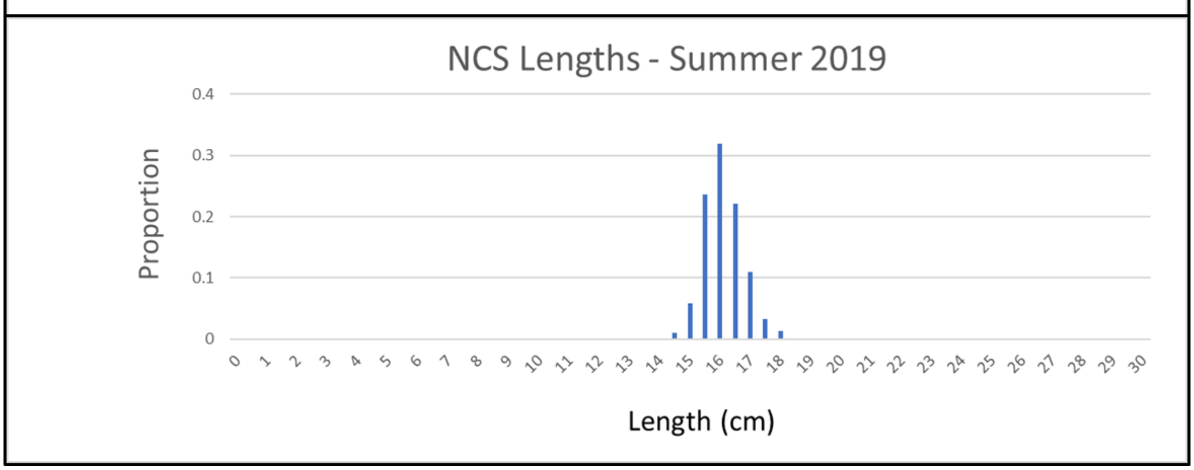
*Bias-corrected biomass based on calibration curve

CCPSS observed school sizes were also presented (following on request 7, day1)

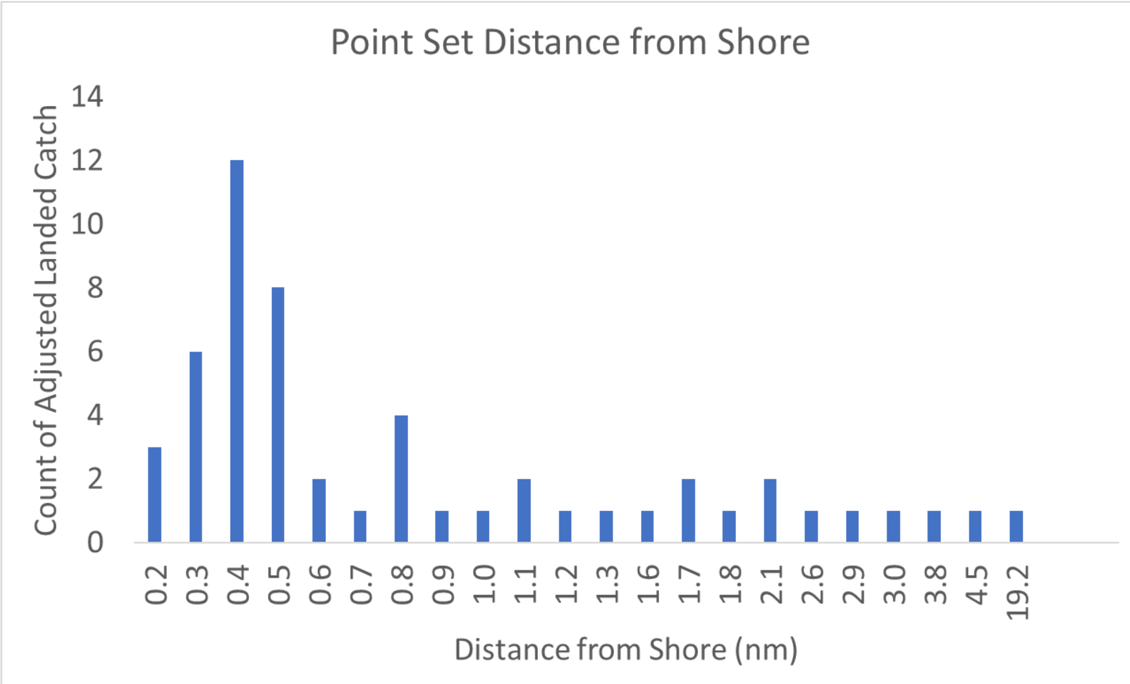
2017					1	2	3
num schools			field estimates (mt)		bias-corrected (mt)	no bias correction for > 100 mt	remove >100 mt
<100 mt	39	23.1%	3,140	17.3%	3,647	3,647	
>100mt	130	76.9%	14,980	82.7%	17,398	14,980	
					21,045	18,627	3,647
Avg	125						
2019					**1**	**2**	**3**
num schools			field estimates (mt)		bias-corrected (mt)	no bias correction for > 100 mt	remove >100 mt
<100 mt	269	96.4%	8,748	82.7%	10,160	10,160	
>100mt	10	3.6%	1,825	17.3%	2,120	1,825	
					12,280	11,985	10,160
Avg	44						

CCPSS length compositions were provided for summer 2017 and 2019 based on the non-directed fishery (NDF) and the Nearshore Cooperative Survey (NCS).





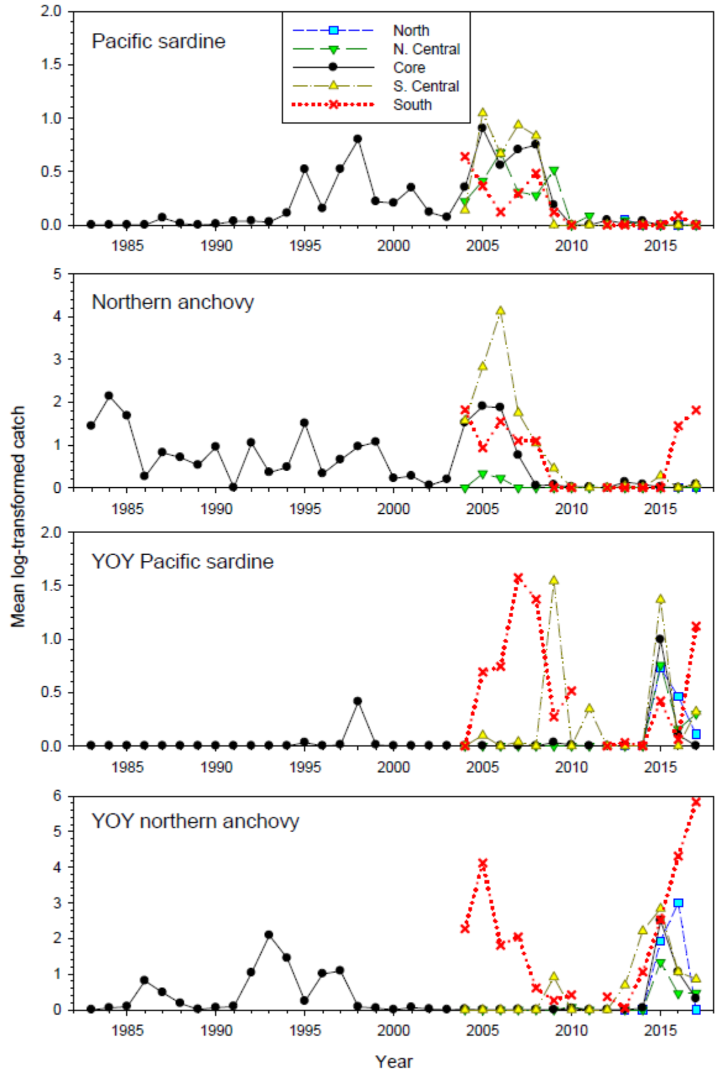
Point set distance from shore were provided.



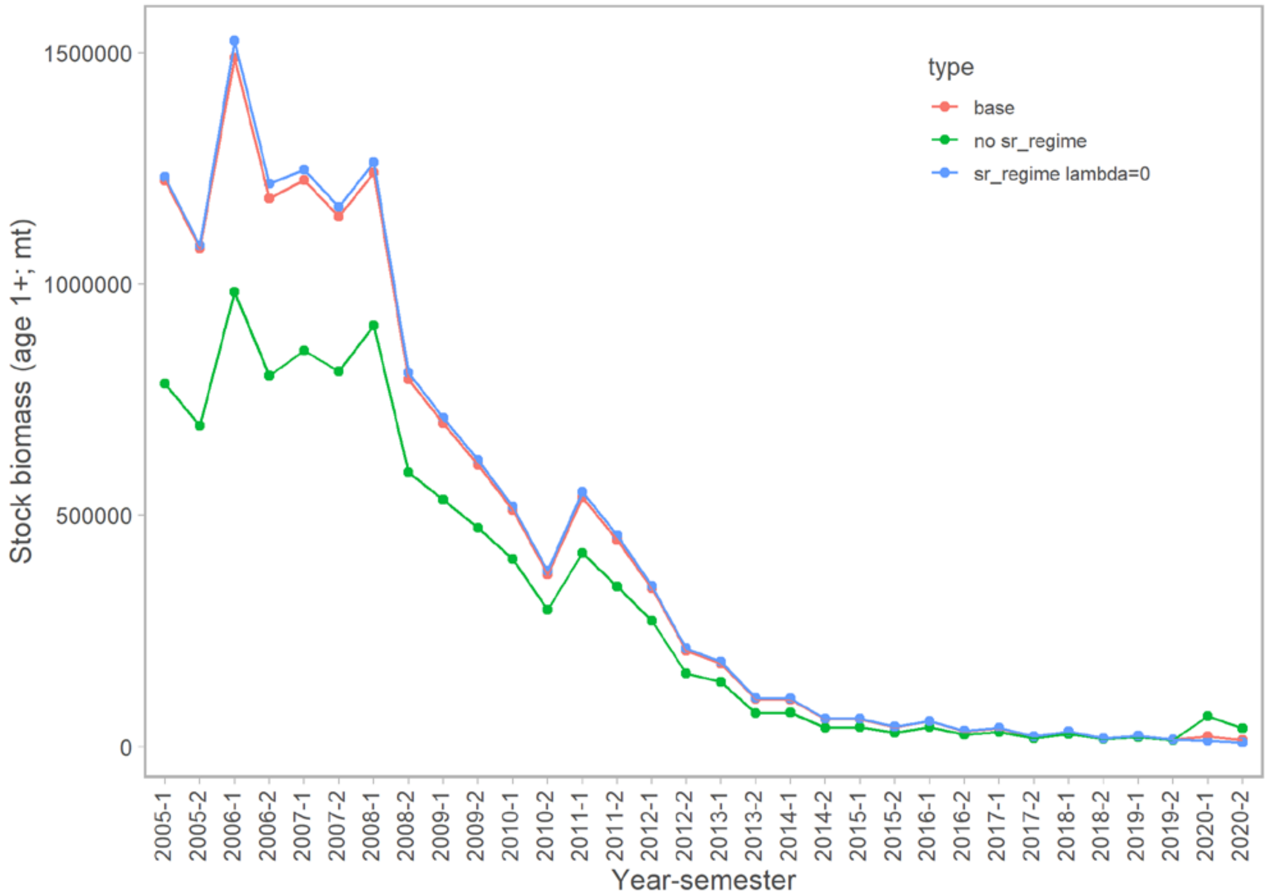
The Panel noted that the school sizes for the 2019 CCPSS were more in the range covered by the point sets.

Request: 12: Provide methods and or justification for the Q prior in the proposed base model.
Rationale: The Panel would like a better justification for how the Q prior was obtained.
Response: Catchability is estimated based on a normally distributed prior with a mean of 0 and a standard deviation of 0.1 in the proposed base model (catchability is estimated in log space). The decision to assume a relatively small standard deviation (0.1) was made to prioritize model stability. In the development of the proposed base model, sensitivities run with a standard deviation of 0.2 resulted in high estimates of catchability (~0.5; 1.5 in arithmetic space) and low estimates of natural mortality (~ 0.4yr^{-1}). The estimate of log-catchability in the proposed base model is 0.08 (1.08 in arithmetic space), which is consistent with values used / estimated in previous benchmark assessments. The 2014 benchmark assessment fixed log-catchability at 0 (1 in arithmetic space), and the 2017 benchmark assessment estimated log-catchability to be 0.11 (1.12 in arithmetic space).

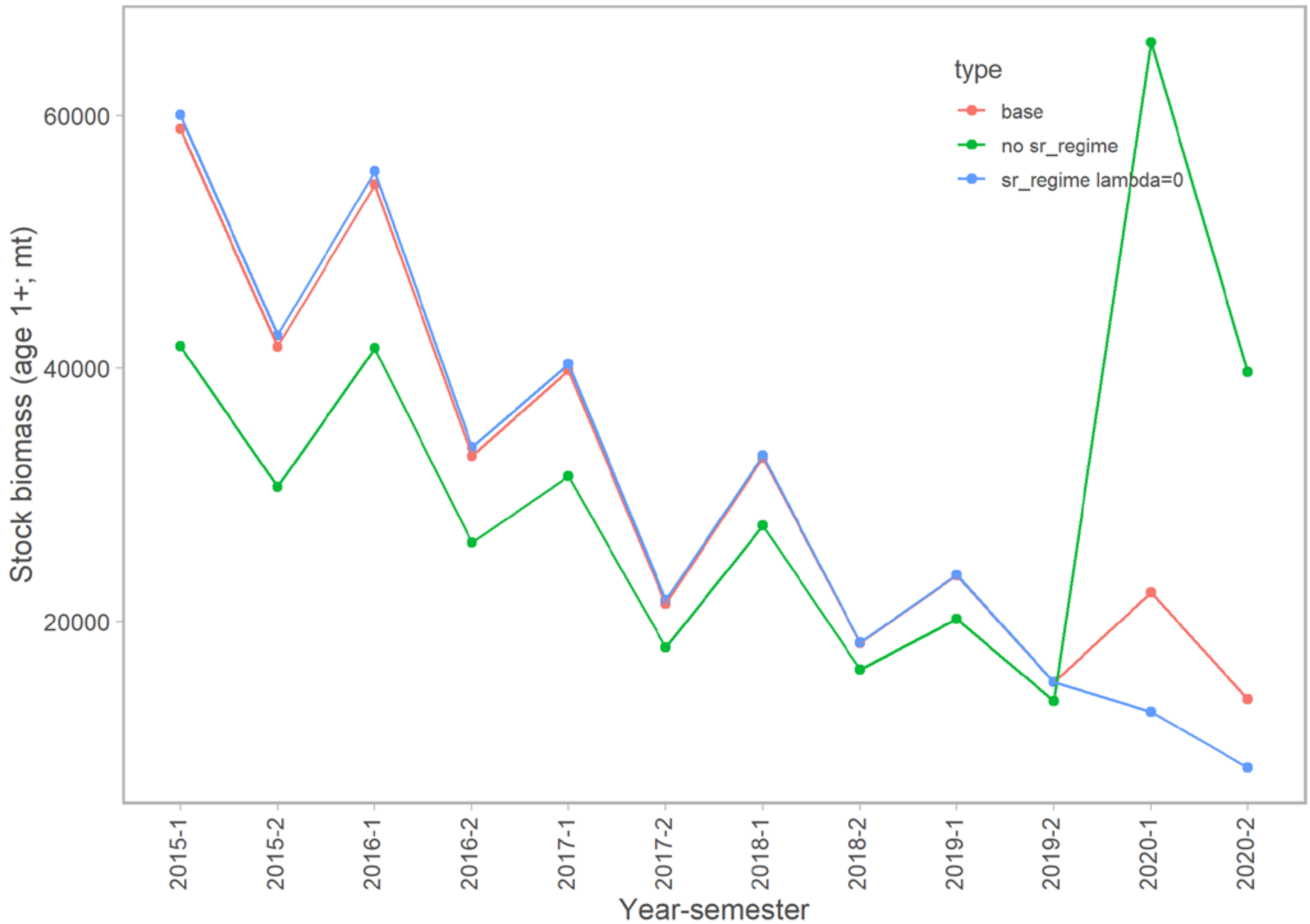
Request 13: Get and plot sardine data for the juvenile rockfish survey, including the index and composition data (if available).
Rationale: The juvenile rockfish survey may provide information in recruitment not currently in the model.
Response: The following figure from the 2017 cruise report shows that there was a spike in 2015 in young of year (YOY – age 0) Pacific sardine but not adult (age 1+) Pacific sardine. See also the response to Request 16, which shows positive recruitment deviations in 2016 and 2017, suggesting that the data from the juvenile rockfish survey may be capable of detecting recent recruitment events. This survey could not be included in the assessment because it has not been subject to a methodology review.



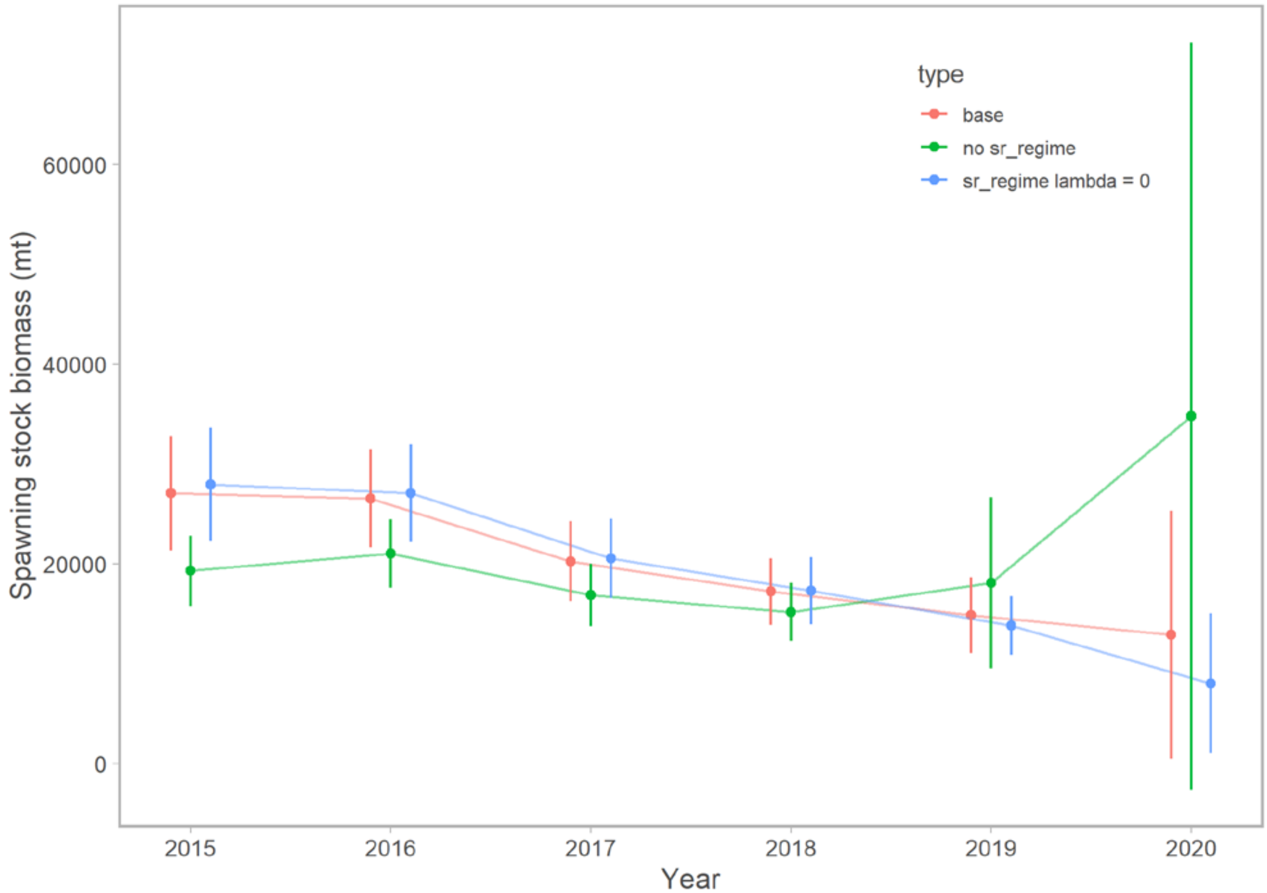
Request 14: Run a model without the R1 offset and with the R1 offset estimated but with no penalty on this parameter.
Rationale: The Q profile has a likelihood component for the R1 offset (aka the "SR regime parameter"), but it was never the intention to impose a penalty / prior on this parameter – the STAT and Panel were unclear how this penalty was defined.
Response: The 2005-2020 stock biomass is shown below. The three lines are the 2020 proposed base model ("base"), a model does not estimate the SR regime block parameter ("no sr_regime"), and a model with the SR regime parameter assigned a lambda of 0 in the likelihood ("sr_regime lambda=0"). It was agreed that setting the lambda for the R1 offset to 0 is the best approach because it best matches the intent of how this parameter was to be treated in the 2017-2019 assessments.



Below is a plot of the previous figure zoomed in to focus on values from 2015-2020.



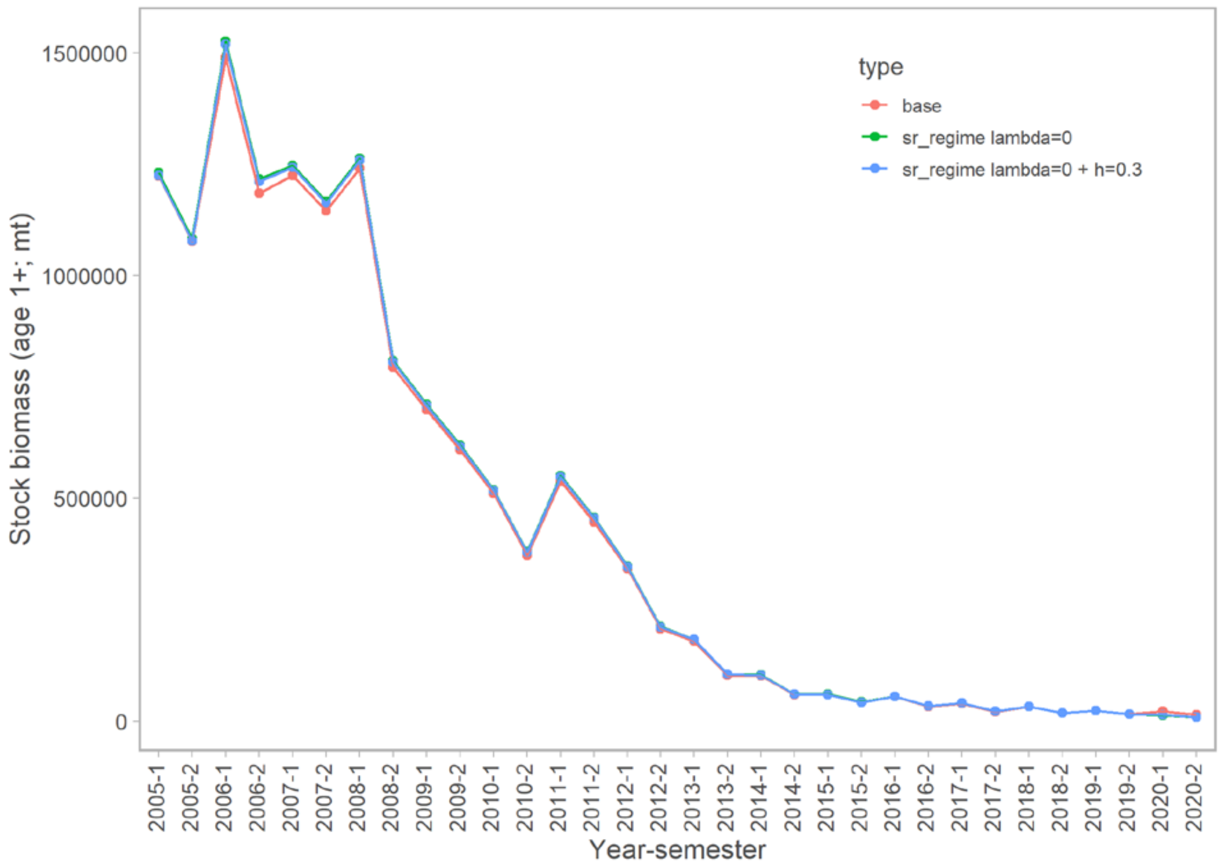
The figure below is zoomed in to focus on spawning stock biomass values from 2015-2020. The bars indicate the uncertainties (mean +/- standard deviation) associated with the point estimates of spawning stock biomass.

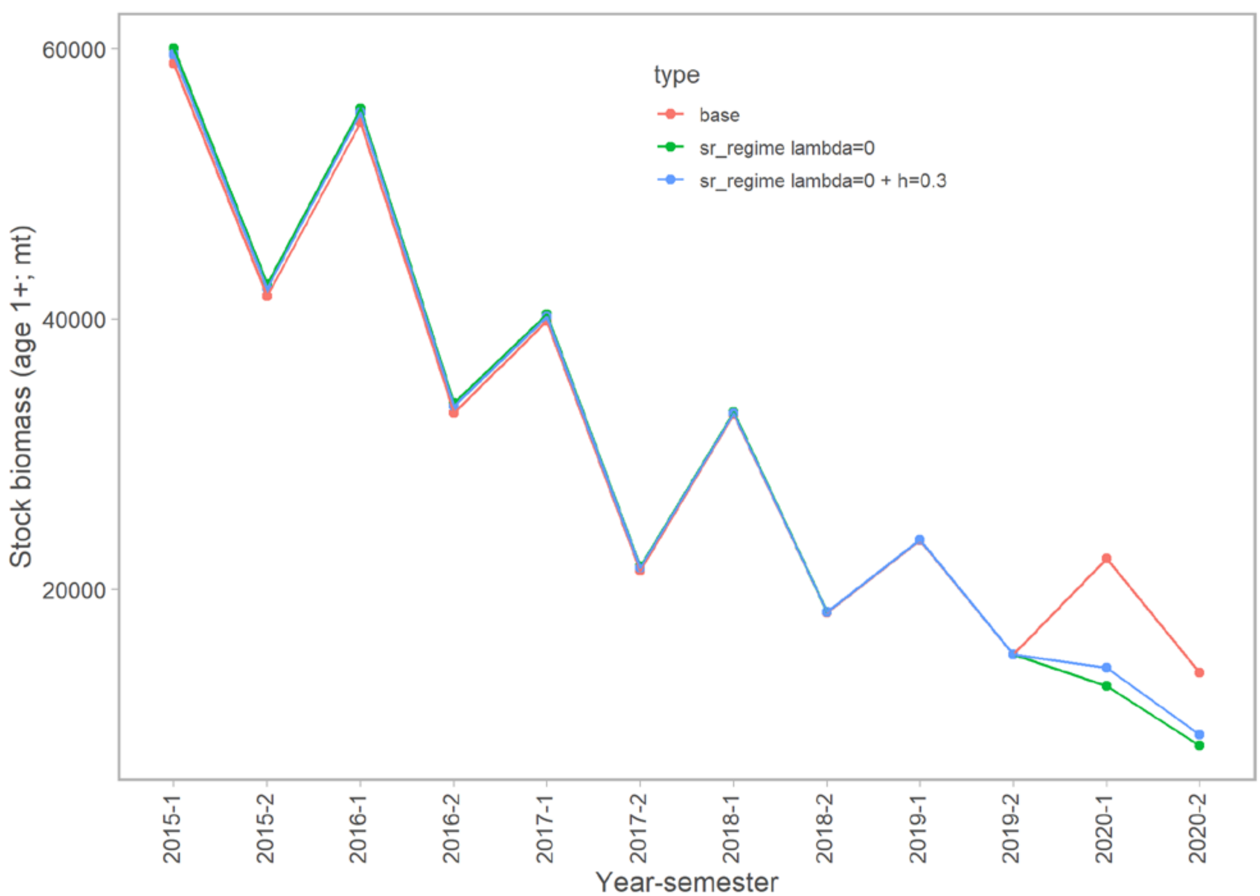


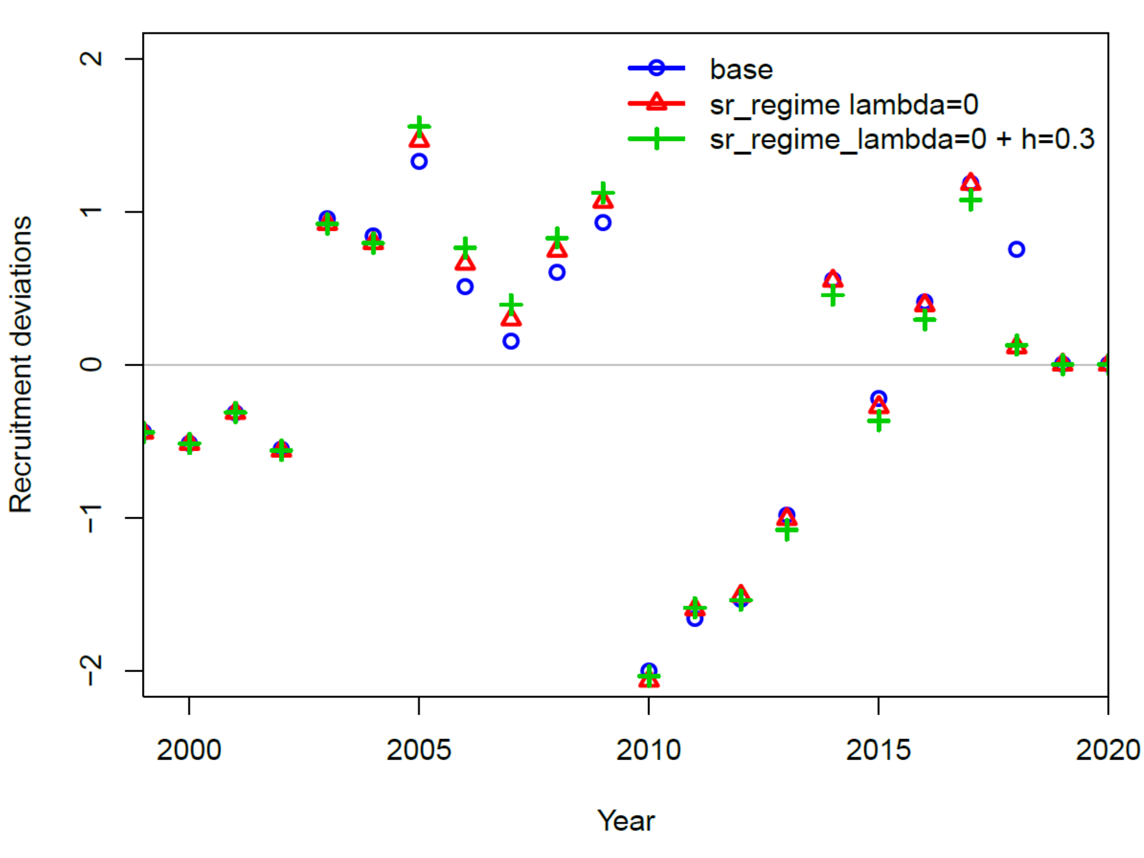
parameter	base	no sr_regime	sr_regime lambda=0
InitF_seas_1_flt_1MexCal_S1	1.41	1.82	1.46
LnQ_base_AT_Survey(4)	0.08	0.3	0.07
NatM_p_1_Fem_GP_1	0.56	0.47	0.56
SR_LN(R0)	14.7	16.28	14.5
SR_regime_BLK1repl_2004	2.09	NA	2.34

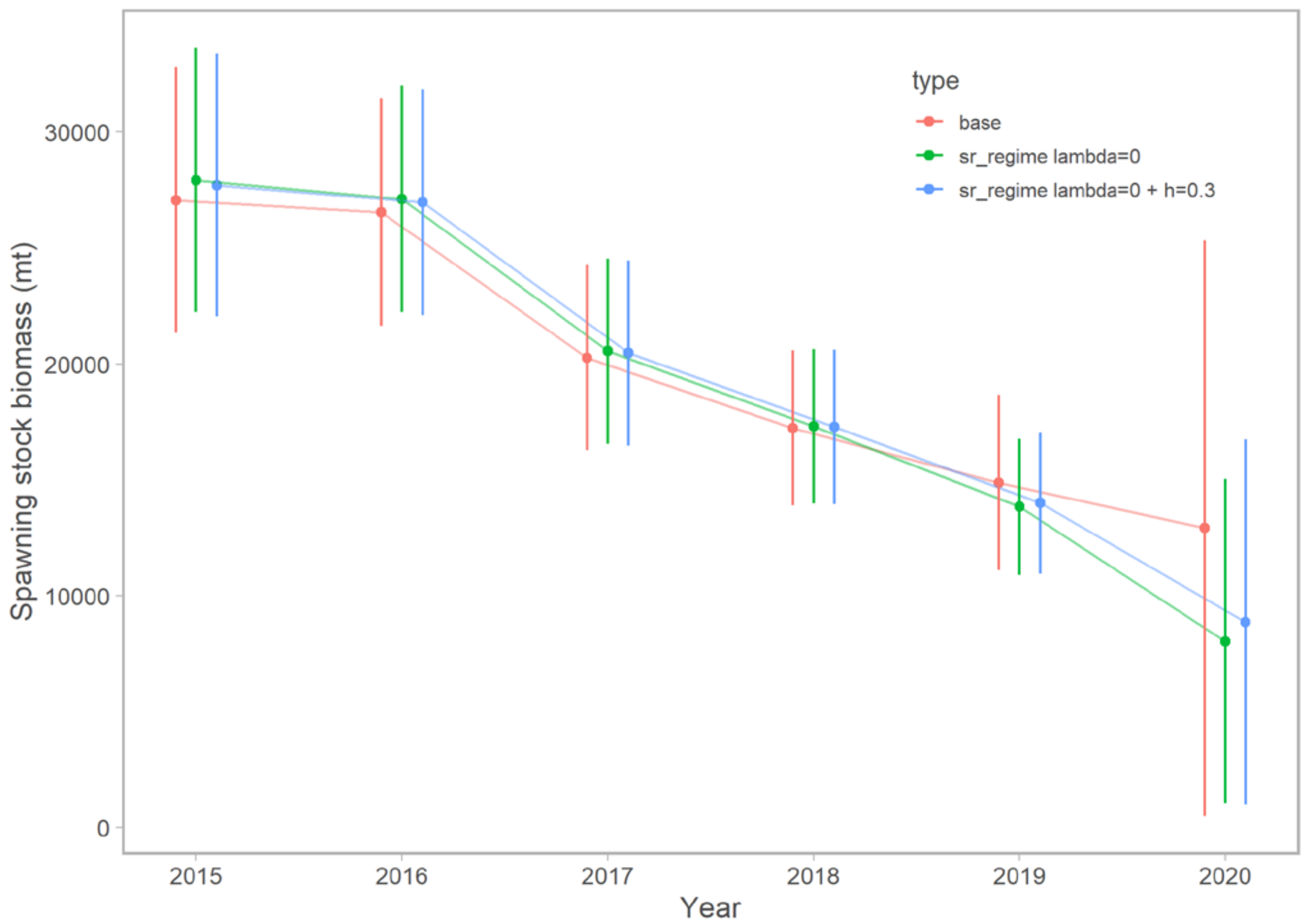
Request 15: Provide a model run with corrected CCPSS data included into the model.
Rationale: These data are incorrect in the proposed base model sensitivity.
Response: This will now be addressed within the day 3 requests.

Request 16: Evaluate whether the model without the R1 offset (see Request 14) can estimate steepness. If not, conduct a model run with steepness fixed at 0.3.
Rationale: It is not clear which data are informing the estimate of steepness; the current base model appears to depend much on the R1 offset.
Response: Steepness was not estimable, and the STAT proposed to set steepness at 0.3 (a value consistent with previous estimates). The three figures below show the 1+ biomass time series for 2005-2020 and 2015-2020, and the recruitment deviations. The STAT and Panel agreed that steepness would be fixed at 0.3 in the final base model.


type
base
sr_regime lambda=0
sr_regime lambda=0 + h=0.3
Stock biomass (age 1+; mt)
Year-semester

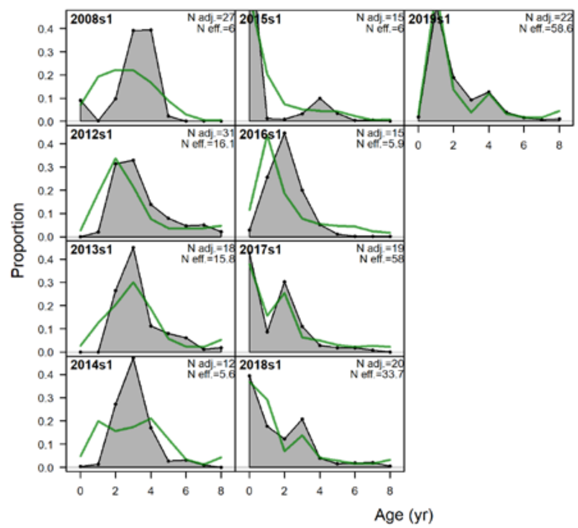

type
base
sr_regime lambda=0
sr_regime lambda=0 + h=0.3
Stock biomass (age 1+; mt)
Year-semester

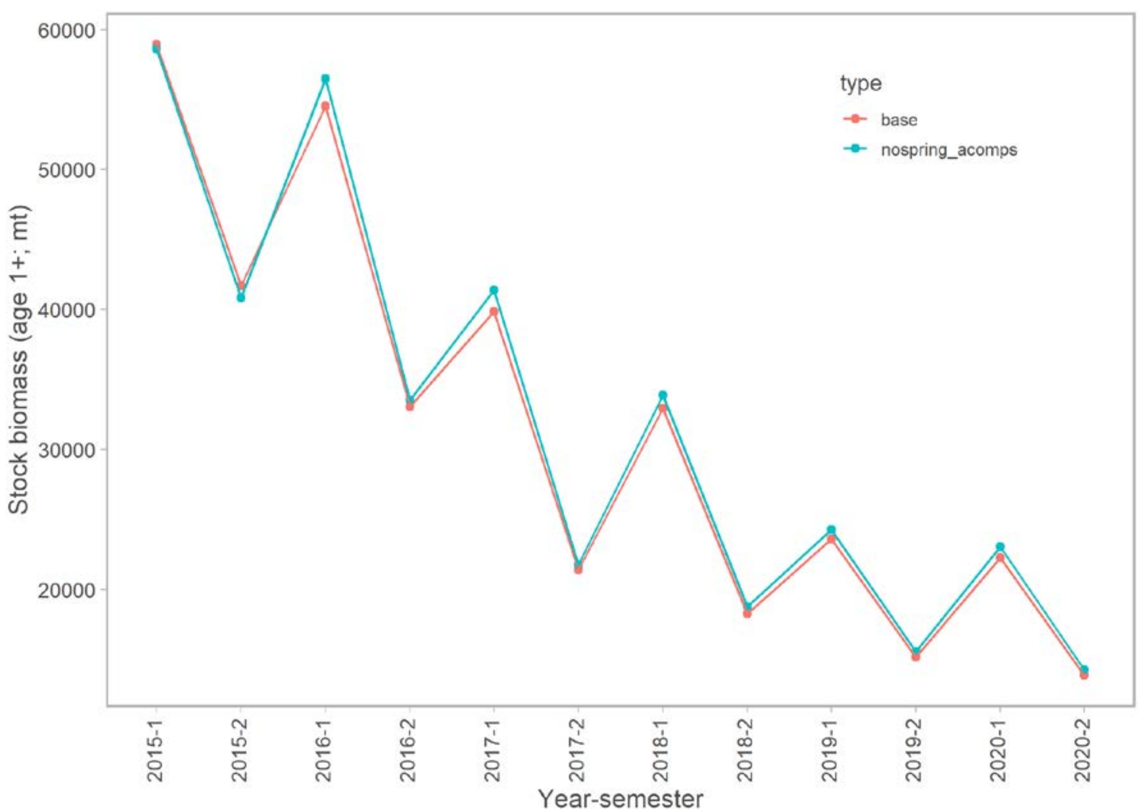

Recruitment deviations
2
1
0
−1
−2
2000
2005
2010
2015
2020
Year
base
sr_regime lambda=0
sr_regime_lambda=0 + h=0.3

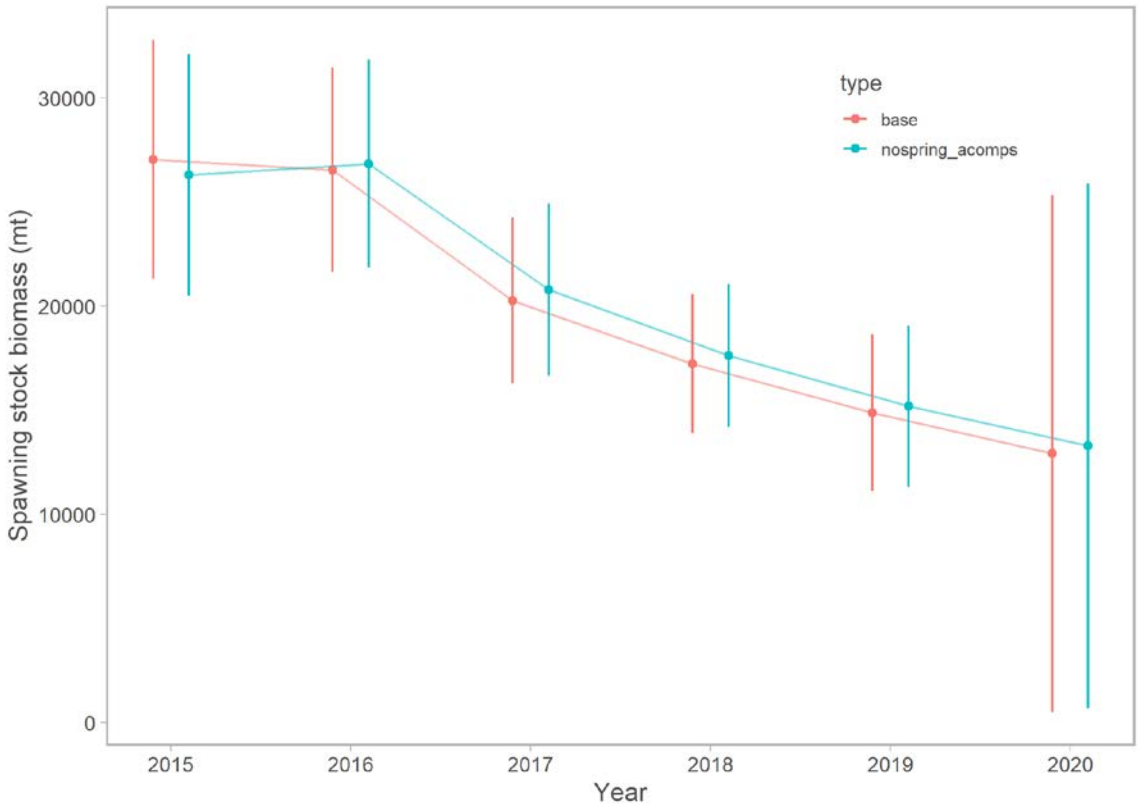

Spawning stock biomass (mt)
30000
20000
10000
0
2015
2016
2017
2018
2019
2020
Year
type
base
sr_regime lambda=0
sr_regime lambda=0 + h=0.3

The figure above shows the recent time series of spawning stock biomass and the values +/- the standard deviations.

Request 17: Examine the sensitivity to removing the spring AT age data.
Rationale: The spring AT age data are based on a pooled age-length key, which is not appropriate because the estimates of age-frequency will be biased as no account is taken of varying cohort strengths.
Response: The fits to age compositions in which fish were re-aged (2017 and 2018) and 2019 were relatively good. The STAT and Panel agreed that the spring AT age data would be excluded from the final base model.







<u>Day 3 requests made to the STAT during the meeting – Wednesday, February 26</u>

Request 18: Run a model with all day 2 changes, i.e.: (1) turn off the likelihood component for the R1 offset parameter by setting the 'lambda' to zero, (2) fix steepness to 0.3, and (3) remove the spring AT age data.
Rationale: These model changes were agreed based on the day 2 requests.
Response: The estimate of the fishing mortality rate for 2020 is unrealistically high and is related to pre-specifying the catches (particularly for MexCal S2) from the 2019-2 model year onwards.

Request 19: Remove earlier years of AT age-composition data and/or include these compositions as a separate fleet because they do not appear to be representative of the biomass observed by the acoustics.
Rationale: The early AT age compositions were not well sampled (based on few clusters) and likely not representative of the population surveyed using the acoustics.
Response: The fits to the data are better, but still have fishing mortality rates that are unrealistically high for 2020-2. This led to the suggestion to use the forecast F option in the forecast for 2020 rather than setting catches after the 2019-1 model year to the observed catches for the 2018-2 and 2019-1 model years. This suggestion formed part of the final base model.

Request 20: Conduct a model run that allows for a time change in AT Q in 2015 (Q=1 before 2015 and Q equal to the ratio of the AT estimate of biomass for 2019 [33,632t] to the sum of the CCPSS estimate of biomass for 2019 [12,280] and the AT estimate of biomass for 2019 [33,632t].
Rationale: There is evidence that the proportion of the stock shoreward of the acoustic trawl survey area has increased since at least 2015 onwards.

Response: The results of this run look reasonable. This addresses the nearshore region not surveyed by the acoustic trawl survey.

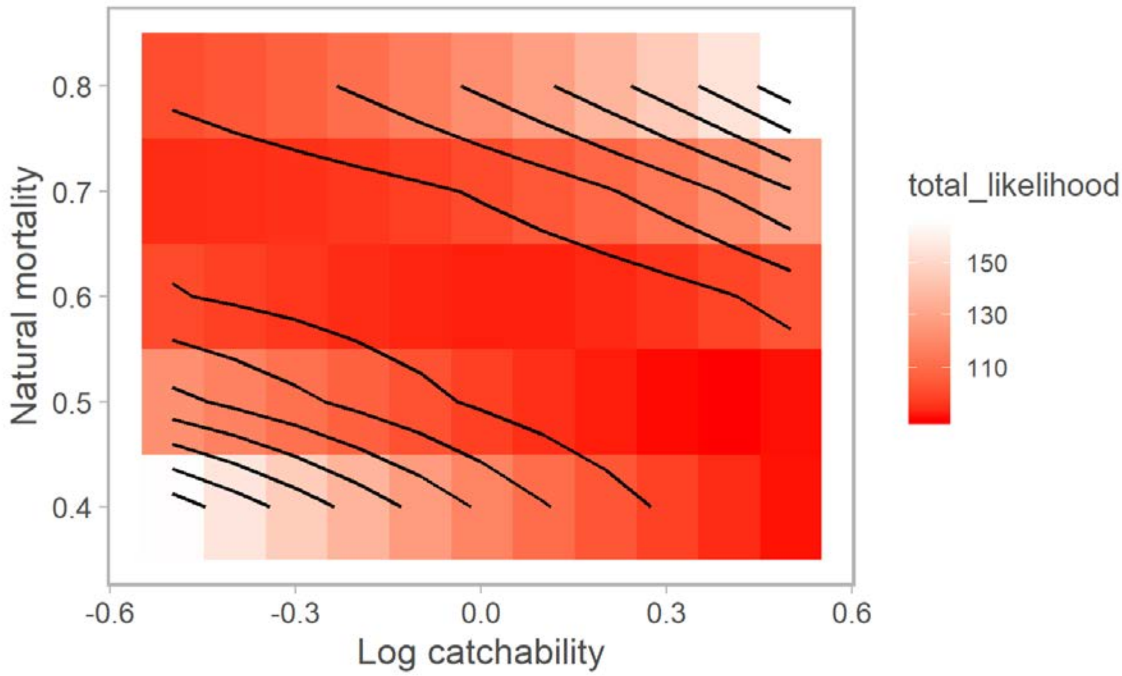
Request 21: Run a model with all agreed changes to the proposed base model : (a) the changes in request 18, (b) the changes to acoustic Q from request 20, (c) basing removals off Mexico from the 2020-1 model year on the estimates of fishing for the 2018-2 and 2019-1 model years (i.e. the catches for model years 2020-1 and 2020-2 are based on the F's estimated for model years 2019-1 and 2018-2) [the catch for model year 2019-2 is unchanged from that in the proposed base model, but see the research recommendations for an alternative approach] , and (d) use the selectivity pattern for the AT survey from the proposed base model
Rationale: This was a possible new base model.
Response: The 2020 catches are now based on F's, and match the F estimated for the 2018-2 and 2019-1 model years. Time series of derived outputs for the model are largely the same as previous model runs. The Panel investigated the impact of the near zero acoustic trawl survey selectivity on the estimated biomass, finding that the near-zero selectivity still amounted to a large enough biomass of age 0 fish in the acoustic estimate, so that the acoustic biomass estimate is quite a bit different than expected from the model 1+ biomass estimate.

Request 22: Run the following sensitivities:

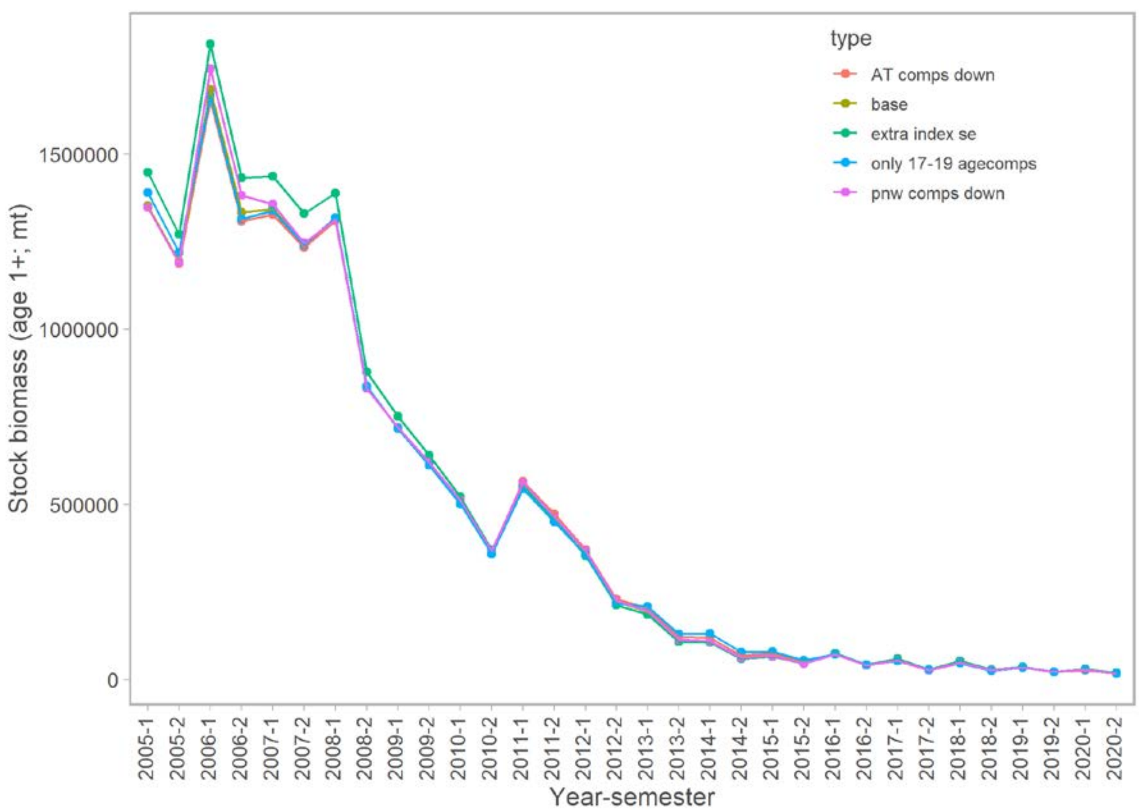
- consider a time-invariant dome-shaped selectivity pattern for the AT age data (treated as a separate fleet);
- consider a dome-shaped selectivity pattern for the AT age data (treated as a separate fleet) with the ascending limb time-varying;
- set the 2019 and 2020 Mexican catches to the average of the those for 2016-2018; and
- change the year in which the time change in Q for the AT survey occurs.

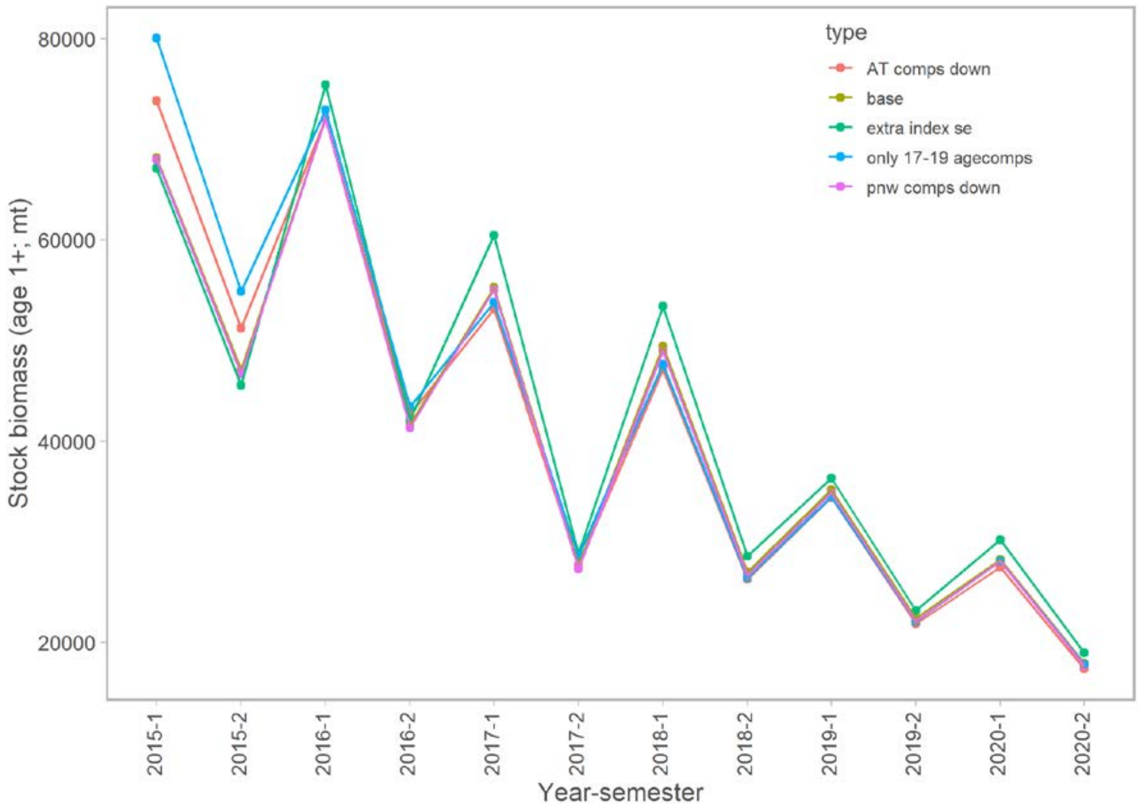
Rationale: These sensitivity analyses reflect some of the major sources of unresolved uncertainty.
Response: Changing the AT selectivity pattern did not improve the fits to the age compositions. A more complex selectivity pattern is needed to fit these data. Changing the year in which Q changes results in a very similar model to the base model. Using the average catches from MexCal S2 from 2016-2018 (8,376 mt) as input catches for 2019 and 2020 resulted in similar outcomes to the base model. The forecast stock biomass was 32,292 mt compared to 28,275 from the base model. Model results were not sensitive to changing the year in which Q changes.

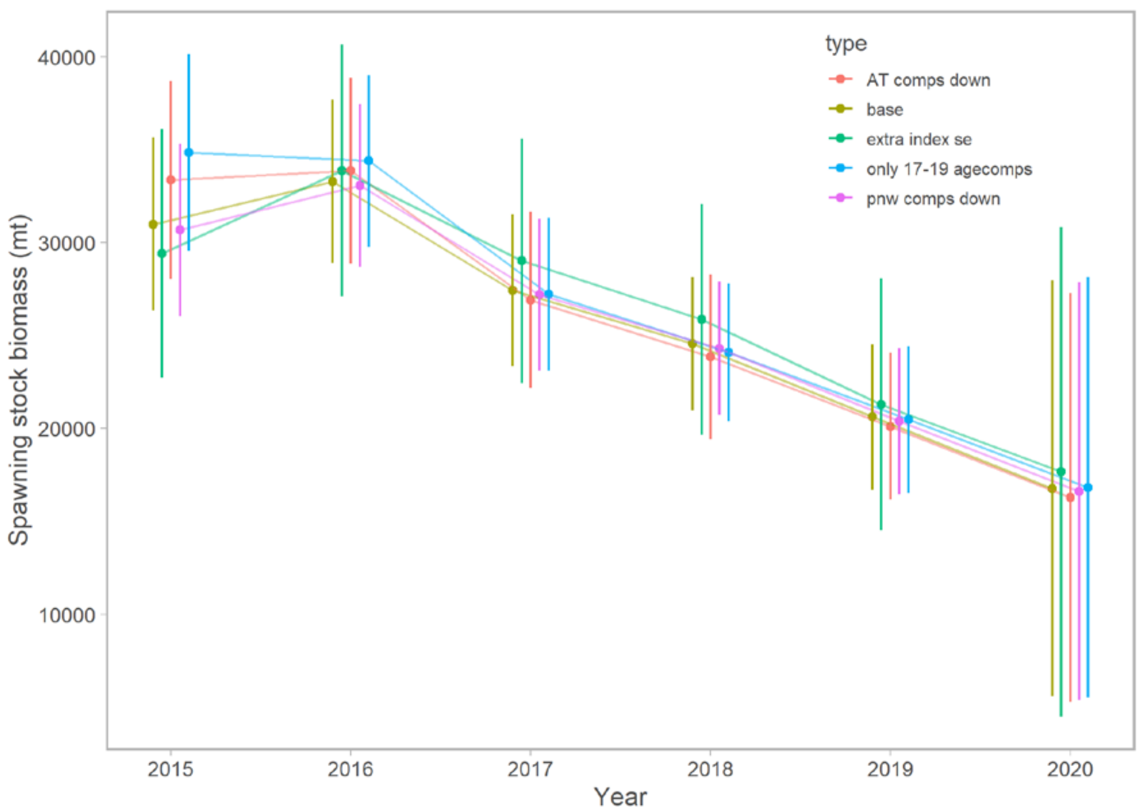
Request 23: Provide a joint likelihood profile across *M* and Q. Add standard profiles on *M*, steepness and Q. Also show how derived parameters change across the likelihood surface, e.g. 2020 season 1 biomass and stock depletion, where appropriate.
Rationale: *M* and Q are likely influencing the poor fits, a joint likelihood profile across *M* and Q would be helpful.
Response: Likelihood profiles for steepness show that recruitment drives the steepness profile. Likelihood profiles for *M* show that the data are informative and with little conflict between data sources. Likelihood profiles on *M* for only the age data sources showed that the PNW fleet wants a lower *M*, while the AT survey age data want a higher *M*. The likelihood profile for Q, using a single fixed Q, looks fine. The Q profile shows that the acoustic trawl survey wants a high Q value. The joint profile on *M* and Q, using a single fixed parameter for Q, showed the correlation between these two parameters. The Panel requests the STAT use a contour plot for this profile in the final document and a profile for Q that accounts for the change in Q in 2015.



Request 24: Conduct additional sensitivity tests in which (a) the AT age data are down-weighted by 50%, (b) the PNW age data are down-weighted by 50%, (c) the AT age data are restricted to 2017 onwards, and (d) an additional variance parameter is estimated for the AT survey.
Rationale: The Panel wished to explore the sensitivity of the results of the weighting of the data.
Response: The time-trajectories of biomass (both long-term and recently) are robust to these changes. The estimate additional variance for the AT survey is 0.22.




type
AT comps down
base
extra index se
only 17-19 agecomps
pnw comps down
Stock biomass (age 1+; mt)
80000
60000
40000
20000
2015-1
2015-2
2016-1
2016-2
2017-1
2017-2
2018-1
2018-2
2019-1
2019-2
2020-1
2020-2
Year-semester


type
AT comps down
base
extra index se
only 17-19 agecomps
pnw comps down
Spawning stock biomass (mt)
40000
30000
20000
10000
2015
2016
2017
2018
2019
2020
Year

3) Technical Merits and/or Deficiencies of the Assessment

The Panel had several concerns with the model in the document provided to the Panel (i.e. the proposed base model): (a) it did not make use of the data from the CCPSS, and hence ignored biomass inshore of the AT grid, (b) the estimates of fishing mortality were unrealistically high for the last years of the modelled period and for the 2020 projection year (>3yr^{-1} for the MexCal S2 fleet), given the catches for the 2019-2, 2020-1, and 2020-2 model years were assumed to be the same as for 2018-2 and 2019-1 model years, implying major increases in fishing intensity/effort, and (c) there was a penalty on the initial "R1" deviation that was not part of the model on which the 2017-2019 assessments was based.

The STAT revised the model in the document provided to the Panel to address these concerns by: (a) setting the Q for the acoustic survey (and the extensions inshore using sail drones and industry vessels) to 1 for 2005-2014 and to the ratio of the 2019 AT survey estimate (33,632) to the sum of the AT survey and CCPSS estimates (33,632+12,280) [i.e. 0.733], (b) replacing the pre-specified catches for the 2019-2 to 2020-2 model years by the estimates of the fishing mortality rates for the 2018-2 and 2019-1 model years (this assumes that fishing intensity has been constant, particularly in Mexico, since 2019), and (c) the penalty on the initial "R1" deviation was dropped. Other changes to the proposed base model were that stock-recruitment steepness was fixed at 0.3, and the spring AT age-frequency data were dropped. Stock-recruitment steepness was pre-specified because it could not be estimated after the penalty on the initial "R1" deviation was removed and because steepness was estimated it to be ~0.3 in earlier assessments that could estimate this parameter. The spring AT age-frequency data were dropped because they were based on year-pooled age-length keys that would lead to biased estimates of age-frequency, and additionally because the model was unable to fit these data. The Q for the AT survey was pre-specified rather than estimated because model runs provided to the Panel suggested that the ability to estimate 'scale' without a prior was limited, suggesting that the results would depend on how the Q prior was specified (e.g., central tendency and precision). Setting Q to 1 rather than estimating Q reflects that the AT covered most, if not all, 1+ animals during the period of high sardine biomass (i.e. before 2015), and that there is no evidence for bias in the AT survey estimates of biomass (but see the research recommendations). The lower value for Q for recent years reflects the estimates of biomass from the CCPSS for 2019 and anecdotal evidence that while sardine have always been in nearshore waters, the proportion of the total biomass there appears to have increased since about 2015.

The final base model incorporates the following specifications:

- sexes were combined; ages 0-10+;
- two fisheries (MexCal and PacNW fleets), with an annual selectivity pattern for the PNW fleet and seasonal selectivity patterns (S1 and S2) for the MexCal fleet;
  - MexCal fleets: age-based selectivity (time-varying and non-parametric [option 17 in Stock Synthesis]);
  - PNW fleet: asymptotic age-based selectivity (time-varying for the inflection point);
  - age-compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=1 (internally);
- Beverton-Holt stock-recruitment relationship with "steepness" set to 0.3;
- initial equilibrium ("SR regime" parameter) estimated with the 'lambda' for this parameter set to zero;
- *M* estimated with a prior;
- recruitment deviations estimated from 2005-2020;
- virgin recruitment estimated, and σ_R fixed at 1.2;

- initial *F* estimated for the MexCal S1 fleet and assumed to be 0 for the other fleets;
- fishing mortality for the 2020-1 to 2020-2 model years set to those for the 2018-2 and 2019-1 model years.
- AT survey biomass 2006-2019, partitioned into two (spring and summer) surveys, with Q set to 1 for 2005-2014 and 0.733 for 2015-2019;
  - age-compositions with effective sample sizes set to 1 per cluster (externally);
  - age-compositions for the spring AT survey ignored;
  - selectivity is assumed to be uniform (fully-selected) above age 1 and estimated annually for age-0.

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

Several sources of variation in the CCPSS need to be considered. There is error in the aerial estimates of a school size that has been examined using point set purse seine sampling. A possibly larger source of uncertainty involves the detection probability of a school. This may be time (i.e. sea state, etc.) and location dependent, and seems currently to be poorly understood. Nonetheless, the schools detected in a particular band seem likely to be a subset of the total number of schools available; therefore, biomass estimates based on observed schools provide a stochastic lower bound on the total biomass in a band, with stochasticity arising from the measurement error and bias involved in aerial estimates of school biomass. This should be somehow clarified when final biomass estimates and confidence intervals are stated.

Repeat sampling may partially address the variability of school size detection, but in repeat sampling fish movement between bands will be an additional source of variation that will be confounded with the variability due to incomplete detection of schools. Repeat sampling may result in over-estimation of the latter source of variation.

The AT survey age-composition data are poorly fitted by the model, even though the AT survey is considered the best source of information on the biomass of the northern subpopulation of Pacific sardine. Attempts to obtain better fits by treating the AT age data as a separate fleet and estimating a selection pattern for that fleet led to somewhat better fits, but to an unrealistic selectivity pattern. The Panel notes the many previous research recommendations related to the AT survey and highlights that those related to trawling should be a focus because the poor fits are likely linked in some way to how the trawl samples relate to the actual underlying age and length structure of the sardine population.

The biomass is projected to decline from July 1, 2019 to July 1, 2020, but this decline is driven in large part by the assumed catches for Mexico. The approach of fixing fishing mortality for the projection year reduced this effect, but not completely.

The assessment (in common with many previous assessments of the northern subpopulation Pacific sardine) was unable to estimate scale. The final base model addresses this issue by fixing Q. However, Q is clearly neither known nor a constant.

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

a) CPSMT issues

The CPSMT (MT) representative greatly appreciates the substantial efforts by the STAT and the constructive Panel discussion, and offers the following comments.

The methodology review panel of the AT survey (PFMC 2018) identified many recommendations for future research and data collection. The MT representative does not see that many of these have been addressed and continues to encourage the AT team to perform experimental work to improve the results and further evaluate the catchability of various species with the trawl gear. The only noticeable improvement since the review is the use of commercial fishing vessels and saildrones to survey the nearshore, which has considerably increased the coverage area of the AT survey. Further investigations should be done using these methods if at all possible, and some experiments to evaluate the performance of acoustic tools in shallow water should also be performed. Also, documentation of the AT methods, as recommended by the panel in 2018, would be helpful.

The STAR Panel has identified research recommendations that could help inform future stock assessments. The MT representative concurs with most of these and highlights a few notable recommendations. The potential inclusion of information from the SWFSC juvenile rockfish survey, via a methodology review, should be listed among high priority items. The attribution of catch and biomass between the northern and southern subpopulations appears to incorporate large imprecisions, and further development of the methods and potential methods of separation of these two subpopulations, including a potential methodology review would likely be beneficial.

The CCPSS has contributed substantially to this stock assessment, including informing an adjustment of the Q value used for the AT survey results from 2015 forward in the assessment model. The CCPSS only covered a fraction of the coastline where sardines may be found, yet the results were not able to be extrapolated; therefore, the portion of the biomass inshore of the AT survey for the rest of the coast still has not been included within this stock assessment. There are additional unsurveyed areas between the inshore extent of the AT survey and offshore extent of the CCPSS. The evidence provided by the CCPSS data make it clear that there was substantial biomass of sardine in the area within 1.2 km of the shore in the portion of the coast that it provided data for the assessment during the recent summer AT surveys in California. Yet, these data are only available for a very small portion of the coast and it is unclear how large a portion of the sardine biomass may be unavailable to the AT survey or how sensitive the assessment model results are to the assumptions made regarding the adjustment to Q that were incorporated. The information provided during the STAR panel meeting are further evidence that sardine utilize these areas more extensively at lower population levels than were evident during the inception of the AT method, and therefore the AT survey may be negatively biased at the present. Further investigations in how to utilize these data more extensively or more effectively should be conducted.

b) CPSAS issues

The CPSAS representative compliments the Chair and members of the sardine STAR Panel, Acoustic Trawl (AT) team and Stock Assessment scientists (STAT) for their extensive body of work throughout the 2020 'northern' sardine stock assessment review. Industry members present extend special thanks to the Chair and members of the Panel for recognizing that a significant biomass of sardines (and anchovy) reside in nearshore waters in California inshore of current Acoustic Trawl (AT) surveys. Fishermen also appreciate the efforts made by the AT team and STAT to figure out a way to use the 2019 aerial survey abundance data provided by the California Department of Fish and Wildlife (CDFW). The roughly 12,280 mt of sardine that the aerial survey estimated nearshore along a relatively small stretch of the central California coast in 2019 (the survey was limited due to weather constraints) represented more than 30% of the 33,632 mt of sardine estimated coastwide by the AT survey. Adding the 2019 nearshore to offshore biomass estimates to develop a nearshore correction factor (the interim solution suggested by the STAT and approved by the STAR Panel) resulted in reducing Q for the AT survey from 1+ to 0.733, acknowledging that the AT survey does not 'see' all the fish. Although the projection for the 'northern' stock far underestimates the abundance fishermen have been reporting since 2015, this new method to account for nearshore sardines by utilizing nearshore abundance as a correction factor sets a precedent in the model that can be utilized in update assessments until nearshore data gathering is more robust and complete enough to include directly in the model.

A massive effort is planned for 2020, including spring AT and DEPM and coastwide summer AT surveys mounted by the SWFSC, coupled with spring and summer aerial surveys by CDFW, supported by EFP work, and a near coastwide collaborative nearshore acoustic survey conducted by industry vessels in the PNW and California, using EK 60 arrays loaned by the SWFSC. If the stars align, the 2021 sardine update assessment should come closer to reflecting the abundance that fishermen have been seeing, and CWPA's EFP work, CDFW aerial surveys and fishermen have been documenting.

While this effort offers potential good news for the future, the industry is still hamstrung by the present methods and assumptions employed in the AT survey, now the primary basis for the model that drives the stock assessment. This includes but is not limited to the assumption that "northern" stock sardines occur only in water below 16.7^0 C (about 62^0 F).

Based on the observations of numerous fishermen, in addition to CDFW's aerial surveys, if sardine biomass estimates were accurate, the sardine fishery would not be declared 'overfished.' Even the ATM abundance data show a strong increase from 2017-2019, yet the assessment model predicts a sharp decline – a clear inconsistency that was not explored during the STAR Panel.

Reading the draft stock assessment, this CPSAS representative was dismayed to find that most of the recommendations from the 2011 AT methods review, the 2014 and 2017 sardine STAR Panel reviews and the 2018 AT Methods reviews have not been addressed nor resolved – a key rationale: those issues require a Management Strategy Evaluation (or Methods Review) that has not occurred.

Listed here are several core issues that continue to plague sardine stock assessments (in our opinion). These issues are discussed in detail in the Appendix 5.

- *Need for the 2020 assessment to review the basis for the habitat model and refine estimates of both the catch and biomass attributable to the NSP and SSP. (first recommendation of the SSC CPS Subcommittee, in Italic comments related to the 2020 benchmark assessment)*
    - *Assigning 16.7 deg. C as the knife-edge boundary of the 'northern' stock has resulted in eliminating most California sardines from the 'northern' stock assessment*
- *AT estimates should be considered RELATIVE indices of abundance for all CPS, as recommended in the 2018 AT Methods review, but AT estimates are generally used as absolute here*
- *Target strength is an issue still unresolved (the achilles heel of acoustic surveys)*
- *Species composition attributed to backscatter is a serious question – samples are collected at night (on the surface in the vessel's wheel water) while backscatter is collected during*

daylight, omitting the top 7-9 meters of the water column (another criticism highlighted in the 2018 Methods Review)

- *Age composition data from the fishery were not included in the model, despite the SSC recommendation to include them*
- *Scale is still a BIG problem -- the model cannot estimate scale*

Another key point: the draft assessment report states that recruitment has not been observed. However, recruitment has been apparent in live bait pens, and in fishermen's observations, since 2015. Sardines must have spawned to produce all the 3-inch fish that fishermen have been seeing, both in Monterey and in Southern California. An index of recruitment could be developed via systematic surveys and biological sampling of live bait catches. The Juvenile Rockfish Survey is another informative source of recruitment, but it could not be considered until a Methods Review is conducted. We highlight this need as a high priority.

The current situation is déjà vu all over again for those of us who were around when sardines returned to abundance in the early 1990s. The conflict now, as then, is between what fishermen say is out there, based on what they see, versus what biologists say is out there, based on insufficient science.

Industry in both the PNW and California are committed to improve the science, and we encourage and welcome increased collaboration with the SWFSC and state agencies to improve the accuracy of stock assessments.

Our strong recommendation continues to be to consider and utilize multiple indices at various times of year in future stock assessments, not just one summer Acoustic Trawl survey with no replication.

If the 'northern' vs. 'southern' stock assumption persists, the AT survey should begin in CA in water temperaures below 16.7^0C, and survey the PNW later in summer, when sardines are more likely to be present.

High Priority Recommendations:

- Conduct a methods review of the habitat model
- Conduct a methods review of Juvenile Rockfish Survey so it can be used to predict recruitment
- Conduct an MSE to evaluate use of AT surveys as recommended in 2018 AT Methods Review
- Re-evaluate model assumptions to learn why the assessment model predicts a sharp decline in age 1+ biomass when AT survey abundance data show a strong increase

7) Research Recommendations

The draft assessment document does not include a detailed summary of the basic data (and data gaps), such as plots of the locations of the catches, and how the catches vary seasonally, temporally and spatially, which would have allowed questions related to how much of the catch is taken in nearshore to be investigated in detail. The availability of more of the raw data from the aerial survey would have allowed a more thorough review of ways to include these data in the assessment. The Panel recommends that updated Terms of Reference for Stock Assessments include a requirement that the more basic data summaries are included.

High priority

A. The final base model relies on the 2019 CCPSS estimate of biomass as the basis for recent Q. However, the ideal is to integrate these data into the assessment. Increased collaboration between SWFSC and CDFW scientists (and ideally inclusion of a CDFW scientist on the next STAT) is needed to achieve this goal.
B. Purse seine nets used in nearshore areas should utilize a mesh size that can catch anchovy effectively without leading to biased estimates of species composition.
C. The approach to estimating the variance of the CCPSS based on between-band variance will be flawed if the steep gradient in biomass from band 1 and 2 is confirmed by future surveys. Consideration should be given to estimating variance by temporal replication.
D. More biological samples should be collected during the CCPSS to allow length and age compositions to be estimated and these data included in a future assessment. It is more desirable that the CCPSS and AT results be combined to provide a more spatially complete index of total stock abundance at length and/or age.
E. Examine information on the attribution of catch and biomass between the northern and southern subpopulations based on the habitat model. It will be necessary to conduct a Methodology Review if this leads to a substantial change to the methodology used to conduct this split.
F. The approach of basing OFLs, ABCs and HGs for the current year on the previous year's biomass estimate from the AT survey should be examined using MSE so the anticipated effects of larger CVs and a possible time-lag between when the survey was conducted and when catch limits are implemented on risk, catch and catch variation statistics can be quantified. The survey projection method proposed during the 2017 assessment should be developed further.
G. Investigate alternative approaches for dealing with highly uncertain estimates of recruitment that have an impact on the most recent estimate of age-1+ biomass given its importance for management.
H. Modify Stock Synthesis so that the standard errors of the logarithms of age-1+ biomass can be reported. These biomasses are used when computing OFLs, ABCs and HGs, but the CV used when applying the ABC control rule is currently that associated with spawning biomass and not age-1+ biomass.
I. The assessment would benefit not only from data from Mexico and Canada, but also from joint assessment activities, which would include assessment team members from both countries during assessment development.
J. Reduce ageing error and bias by coordinating and standardizing ageing techniques and performing an ageing exchange (double blind reading) to validate ageing and estimate error. Standardization might include establishing a standard "birth month" and criteria for establishing the presence of an outer annuli. If this has already been established, identify labs, years, or sample lots where there is deviation from the criteria. The outcome of comparative studies should be provided with every assessment.
K. Add a bycatch fleet for MexCal S2 that has zero catch for all but the last two years, where catch is a function of the fishing mortality rate in the last year with data so that the 2019 fishing mortality rate is a function of the data.
L. Evaluate the model sensitivity to the input weight-at-age, and/or to have a deeper think on how uncertainty in the input weight-at-age could/should be characterized because these data are from the AT trawl samples.

Medium priority

A. Further investigate the catch data from Ensenada to (a) quantify uncertainty in the estimates of northern subpopulation catches, (b) examine how sensitive the estimates of northern subpopulation catch are to how the habitat model is applied.
B. Obtain ageing data for northern subpopulation fish from the Ensenada fishery to allow testing of the hypothesis that the age-structure of the Ensenada catch matches that of the catches off California. Care should be taken to ensure that a common ageing protocol is followed for ageing of fish off Ensenada and California.
C. Continue to explore possible additional fishery-independent data sources such as the SWFSC juvenile rockfish survey. Inclusion of a substantial new data source would likely require review, which would not be easily accomplished during a standard STAR Panel meeting and would likely need to be reviewed during a Council-sponsored Methodology Review.
D. Consider spatial models for Pacific sardine that can be used to explore the implications of regional recruitment patterns and region-specific biological parameters. These models could be used to identify critical biological data gaps as well as better represent the latitudinal variation in size-at-age; this should include an analysis of age-structure on the mean distribution of sardine in terms of inshore-offshore (especially if industry partner-derived data were available).
E. Consider a model that has separate fleets for Mexico, California, Oregon-Washington and Canada.
F. Compare the annual length-composition data for the Oregon-Washington catches with those from the British Columbia fishery to evaluate the assumption that the age-structure of the historical catches of British Columbia matches those off Washington. This is particularly important if a future age data/age-based selectivity model scenario is further developed and presented for review.

Low priority

A. A single length-weight relationship is used for all years and seasons. The data on length and weight should be analysed to assess whether this relationship varies between seasons and over time
B. Consider a model that explicitly models the sex-structure of the population and the catch.
C. Develop a relationship between egg production and fish age that accounts for the duration of spawning, batch fecundity, etc. by age. Using this information in the assessment would require that the stock-recruitment relationship in Stock Synthesis be modified appropriately.

Appendix 1
Attendance List – Pacific Sardine STAR Panel February 2020

Name	**Affiliation**
Stock Assessment Review Panel	
André Punt	SSC/University of Washington, Chair
Noel Cadigan	CIE
Melissa Haltuch	SSC/NWFSC
José De Oliveira	CIE
Marisol García-Reyes	SSC/Farallon Institute
Advisers	
Diane Pleschner-Steele	CPSAS
Alan Sarich	CPSMT
Stock Assessment Team	
Peter Kuriyama	SWFSC
Juan Zwolinski	UC Santa Cruz / SWFSC
Kevin Hill	SWFSC
Paul Crone	SWFSC
Other attendees	
Dale Sweetnam	SWFSC
Kirk Lynn	CPSMT/CDFW
Kerry Griffin	PFMC
Lynn Massey	NMFS WCR
Josh Lindsay	NMFS WCR
Kelsey James	SWFSC
Brittany Schwartzkopf	SWFSC
John Budrick	CDFW
Trung Nguyen	CDFW
Briana Brady	CDFW
James Gardner	Oceanside Bait Company
Vince Torre	Trimarine
Corbin Hansen	F/V Cape Blanco
Nick Jurlin	F/V Eileen
Steve Crooke	CPSAS
Kristen Koch	SWFSC
James Hilger	SWFSC
Kristin Roll	SWFSC
Dianna Porzio	CDFW
Bev Macewicz	SWFSC
Emmanis Dorval	SWFSC
Anthony Russo	F/V King Philip
Tom Brinton	F/V Long Beach Carnage

Jamie Ashley	Long Beach Bait Company
Mike Conroy	West Coast Fisheries Consultants
Peter Ciaranitaro	Triton Fishing
Jason Dunn	Everingham Bait Company
Kevin Piner	SWFSC
Alayna Siddall	Sportfishing Association of California
Don Hansen	PFMC
David Haworth	
Gwendal Le Fol	
Huihua Lee	SWFSC
Annie Yau	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 WCR = National Marine Fisheries Service West Coast Region
NWFSC = Northwest Fisheries Science Center
PFMC = Pacific Fishery Management Council
SSC = Scientific and Statistical Committee
SWFSC = Southwest Fisheries Science Center

Appendix 2

Additional research recommendations for the CCPSS identified by SWFSC and CDFW staff

A meeting between STAT and CCPSS reps was held to address STAT concerns about reproducibility, quality control and sustainability of the aerial survey method of using observer estimations for sardine biomass – see **STAT desired information required for reproducibility and quality control of aerial biomass estimates** below. The STAT requested photogrammetric analyses of aerial observations using school area and bottom depth with packing density to corroborate aerial observer estimates, especially for schools > 100 mt that cannot be validated by point sets. These analyses can also be applied with point set validations to develop a relationship between school area from photographs and school biomass as a check on visual estimates. The rationale for these efforts is to validate aerial survey biomass and as an alternative method for surveying that can be automated and not rely on a few observers. CCPSS staff responded that CDFW has already been working towards this goal and has the data needed to conduct a preliminary analysis.
Additional work is needed to look into potential automation methods, including machine learning that may be able to distinguish species and calculate biomass. LIDAR and vessel SONAR are possible tools for determining the vertical extent of fish schools to use packing density to calculate biomass from photographs. However, in shallow water where most schools have been observed, the difference between bottom depth and vertical school extent may be negligible. Both current aerial survey and nearshore acoustics surveys can be compared with potential automated methods to determine the most efficient and reliable survey method for nearshore areas. Research and development of automated survey methods will be a longer-term project.

The STAT also requested future aerial surveys to conduct temporal replicates for every band. For point sets, the STAT also would like randomized point sets for survey locations, species and size compositions, and attempts made to conduct point sets on mixed schools. The CCPSS responded that future survey designs will include replicates (within strata), and that species and size compositions are part of the current point set protocols. Attempts to conduct point sets on mixed schools have not occurred because they have not been encountered to date, but are a priority. Randomized point sets that are representative of survey observations will be attempted, but logistical constraints over vessel range and proximity to fish schools, as well as school availability and detectability will limit the ability do these.

STAT desired information required for reproducibility and quality control of aerial biomass estimates

For every school counted as sardine or mixed with sardine, provide:

- Proportion of the school considered sardine
- Photographs or video images
- Time-stamp
- Geolocation
- Plane altitude

- Surface area estimated photogrammetrically
- Pilot-estimated biomass
- Point set biomass, when available
- Measured bottom depth, if possible, or best depth from existing benthic survey data

For future surveys attempt to:

- Conduct temporal replicates for every band
- Obtain randomize point sets for the same locations where the biomass will be estimated
- Species and size composition from the point sets.
- Conduct experimental point sets to validate pilot accuracy in estimating mixed school proportions

STAT Research Request	Rationale	CDFW Response
Photogrammetric analysis of CCPSS observations - use school area and bottom depth with packing density to corroborate aerial estimates, especially for schools > 100 mt	Validate aerial survey biomass and development of automated survey methods	Data are available to conduct analysis, CDFW already working towards this goal
Examine use of alternate survey tools such as LIDAR, SONAR	Determine vertical extent of fish schools to calculate biomass from photographs	These will be explored as part of CDFW task group assignment
Temporal replicates for every band	Acquire data from replicates to compute variance	Temporal replicates included in 2020 CCPSS design
Random point sets at locations of observations	Obtain representative bias correction factor and biological information by region	These can be attempted, but logistical constraints over vessel range and proximity to fish schools, as well as school availability and detectability will limit the ability to do these
Biological and species comp information for point sets	Inform age structure of observed fish	These data have been collected and can be provided
Point sets on mixed schools	Validate species ID and tonnage estimates for mixed schools	Mixed school point sets are a priority, but have not been encountered

Appendix 3
Calculation of abundance-at-age and weight-at-age from ATM surveys

Juan Zwolinski, UC Santa Cruz / SWFSC

Two of the outputs of the ATM survey are abundance-at-length and biomass-at-length (Zwolinski et al., 2019). The calculations of abundance-at-age, biomass-at-age, and weight-at-age required for the current sardine assessment rely on the constructions of age-length keys (Hill et al., 2017). An age-length key (ALK) is a model that describes the probability of a fish of a known length belonging to an age-class (Stari et al., 2010). ALKs are used often to calculate abundance and catch-at-age from fisheries-dependent and -independent sources (e.g., Kimura, 1977; Clark, 1981; Hoenig and Heisey, 1987; Robotham et al., 2008). Their use is common when only a subsample of all the fish sampled for lengths are aged, a practice that reduces the time and costs of sampling and analysis. The use of an ALK relies on the assumption that the conditional distribution of ages given length in the subsample is representative of that in the population (Kimura, 1977; Westrheim and Ricker, 1978).

The sampling scheme to build an ALK necessary requires a sufficient number of individuals to estimate the conditional age-distribution over a set of fixed length intervals. For Pacific sardine, ALKs were based on individuals from a two-stage sampling procedure. The first level sampling was used to obtain a length-frequency distribution for the population, and a subsample of those individuals was used to derive the distribution of ages-at length (Clark, 1981).

When the number of individuals sampled for age is large, an empirical age-length key can be built by computing the proportion of individuals of all ages across all discrete length classes (Ailloud and Hoenig, 2019). However, when sample size is small and there is ageing error, empirical age-length keys might be dominated by error (Stari et al., 2010). In these cases creating a smooth ALK relying on some sound underlying process is preferable (e.g., Martin and Cook, 1990; Berg and Kristensen, 2012).

There are numerous analytical approaches to build smooth or model-based ALK (e.g., references above; Stari et al., 2010; and references therein). Here, we postulated that for ages a (in years) such that $a \in \{0,1,\dots,9+\}$, the probability distribution conditioned on length l, $P_a(l) = \{p_0(l), p_1(l), \dots, p_{9+}(l)\}$, follows an ordered categorical distribution. $P_a(l)$ was modeled using the *gam* function in the *mgcv* package (Wood et al., 2016) for *R*, with distribution *ocat.* Detailed information about the ordered categorical regression used can be found in the supplementary information of Wood et al. (2016). Below is brief explanation of the model fitting in R.

For a data set with a variable *age.ordinal* – coded by natural numbers from 1 to 10, corresponding to ages 0, 1, 2, … 9+ years, and *standard.length* – coded as a continuous variable in mm, the *gam* model can be fitted by

```
R = 10 # number of age categories
model <-   gam(age.ordinal ~ s(standard.length) , data  =  data  , family= ocat(R= R)) # the ordinal model
    as smooth function of length
```

and the resulting ALK can be created by

```
prob.matrix <- predict( model , newdata = data.frame(standard.length = seq(40,300, by =10)), type =
    "response")
```

which results in a 27x10 matrix in which each row is the estimated vector of probabilities $P_a(l)$ of a fish of length l (in cm) with $l \in \{4,5,\dots,30\}$ belonging to an age group a, with $a \in \{0,1,\dots,9+\}$. Considering a vector of abundances at length $N_l = n_4, n_5, \dots, n_{30}$, the elements of vector of abundances at age N_a are calculated by $n_a = \sum_{l=4}^{30} P_a(l) n_l$. Similarly, the elements of biomass at age B_a are given by $b_a = \sum_{l=4}^{30} P_a(l) n_l w_l$, where $w_l$is the average weight of sardine in the l-th length class. Finally, mean weight-at-age is obtained by dividing B_a by N_a.

A diagnostic of the model for age-length keys involves visually comparing the empirical distribution of numbers-at-age in the subsample (Fig. A.3.1a), to those of the reconstructed distribution (Fig. A.3.1c) using the smooth ALK (Fig. A.3.1b) as described above. Additionally, the residuals of the ALK, calculated as

$$r_{la} = \frac{n_{la} - P_a(l) n_l}{\sqrt{n_l P_a(l)(1 - P_a(l))}}$$

were inspected for signs of structure (Fig 1d).

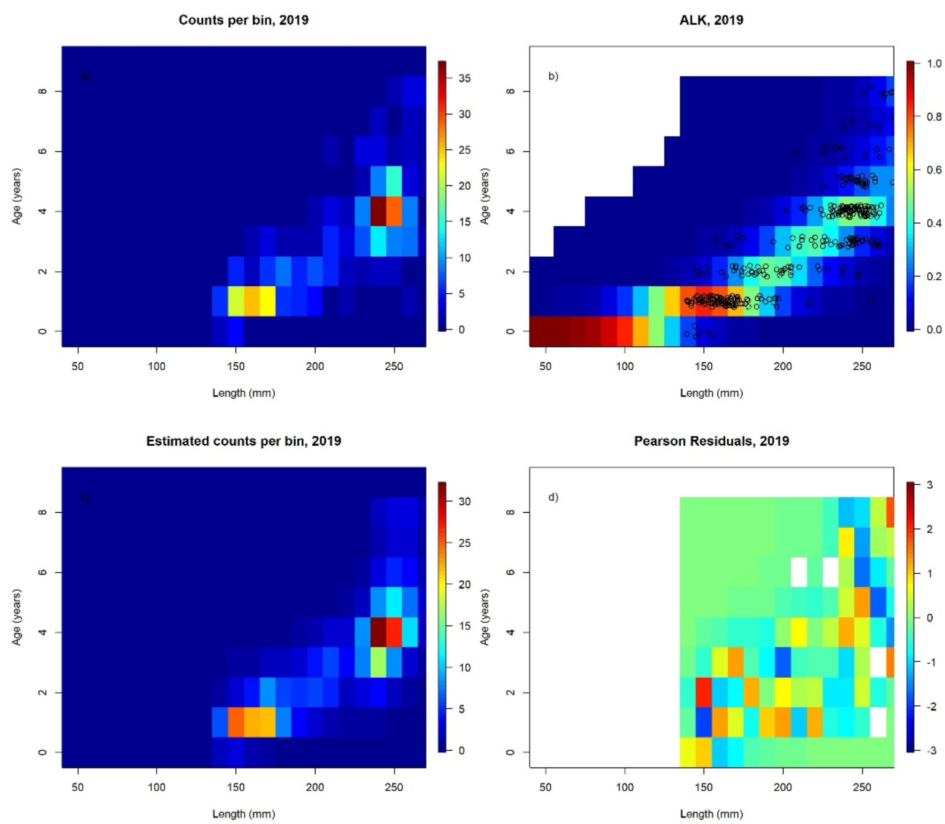


Figure A.3.1 – Example of the fit of an age-length key to the 2019 survey data. a) Empirical distribution of numbers-at-age and length; b) ALK generated by the *gam* model with ordered categorical distribution and with the pairs of observations overlaid (jittered black circles); c) reconstructed distribution of numbers-at-age and length; d) residuals-at-age and length.

References

Ailloud, L. E., and Hoenig, J. M. 2019. A general theory of age-length keys: combining the forward and inverse keys to estimate age composition from incomplete data. Ices Journal of Marine Science, 76: 1515-1523.

Berg, C. W., and Kristensen, K. 2012. Spatial age-length key modelling using continuation ratio logits. Fisheries Research, 129: 119-126.

Clark, W. G. 1981. Restricted Least-Squares Estimates of Age Composition from Length Composition. Canadian Journal of Fisheries and Aquatic Sciences, 38: 297-307.

Hill, K., Crone, P., and Zwolinski, J. P. 2017. Assessment of the Pacific Sardine resource in 2017 for U.S. management in 2017-18. US Department of Commerce. NOAA Technical Memorandum NMFS-SWFSC-576. 262 pp.

Hoenig, J. M., and Heisey, D. M. 1987. Use of a Log-Linear Model with the Em Algorithm to Correct Estimates of Stock Composition and to Convert Length to Age. Transactions of the American Fisheries Society, 116: 232-243.

Kimura, D. K. 1977. Statistical Assessment of Age-Length Key. Journal of the Fisheries Research Board of Canada, 34: 317-324.

Martin, I., and Cook, R. M. 1990. Combined Analysis of Length and Age-at-Length Data. Journal Du Conseil, 46: 178-186.

Robotham, H., Young, Z. I., and Saavedra-Nievas, J. C. 2008. Jackknife method for estimating the variance of the age composition using two-phase sampling with an application to commercial catches of swordfish (Xiphias gladius). Fisheries Research, 93: 135-139.

Stari, T., Preedy, K. F., McKenzie, E., Gurney, W. S. C., Heath, M. R., Kunzlik, P. A., and Speirs, D. C. 2010. Smooth age length keys: Observations and implications for data collection on North Sea haddock. Fisheries Research, 105: 2-12.

Westrheim, S. J., and Ricker, W. E. 1978. Bias in Using an Age-Length Key to Estimate Age-Frequency Distributions. Journal of the Fisheries Research Board of Canada, 35: 184-189.

Wood, S. N., Pya, N., and Safken, B. 2016. Smoothing Parameter and Model Selection for General Smooth Models. Journal of the American Statistical Association, 111: 1548-1563.

Zwolinski, J. P., Stierhoff, K. L., and Demer, D. A. 2019. Distribution, biomass, and demography of coastal pelagic fishes in the California Current Ecosystem during summer 2017 based on acoustic-trawl sampling. NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-610: 74.

Appendix 4
Methods for calculating biomass and variance for CCPSS Survey:

- Two bands, each 1200m width, were flown on the same day one time;
- Biomass estimated on each band was assumed independent;
- When few schools were observed, spotter was able to estimate the biomass of each schools;
- When too many schools were observed on a given transect for the spotter to be able to estimate single school biomass, he instead provided an aggregated biomass estimate;
- Hence, it was not possible to develop a method to consistently estimate a variance for all individual bands;
- Therefore, only total biomass was estimated for each band in the analysis as follows:

$$B_{j,A} = \sum_{i=1}^{n(j)} b_{i,j,A}$$

  where $b_{i,j,A}$, is the biomass estimated for each single (or aggregated) school i (total number of schools = $n(j)$) on band j in area A;
- An estimated of number of schools was provided for each band;
- The estimate in inshore biomass in area A is then

$$B_A^{tot} = \sum_{j=1}^{2} B_{j,A}$$

- For daily biomass observed in a given area, the mean of total biomass across the two bands, can be estimated as follows:

$$\bar{B}_A = \frac{1}{2}\sum_{j=1}^{2} B_{j,A}$$

- And the variance of each daily biomass ($\bar{B}_A$) is estimated as follows:

$$V(\bar{B}_A) = \frac{1}{(2-1)}\sum_{j=1}^{2}(B_{j,A} - \bar{B}_A)^2$$

Variance of a given season where x areas were surveyed is computed as:

$$\sum_{A=1}^{x} 4 \times V(\bar{B}_A)$$

Appendix 5
Additional CPSAS issues

As noted in our summary, the CPSAS representative thanks the Chair and members of the sardine STAR Panel, Acoustic Trawl (AT) team and Stock Assessment scientists (STAT) for their work throughout the 2020 ‘northern’ sardine stock assessment review. We, as well as fishermen present at the meeting, also thank the Chair and STAR Panel for urging the STAT to figure out a way to use CDFW’s 2019 aerial survey abundance in the stock assessment, and we thank the STAT for finding a way to utilize these data. It is notable that the roughly 12,280 mt of sardine that the aerial survey estimated near shore along a relatively small stretch of the central California coast in 2019 represented more than 30% of the 33,632 mt of sardine estimated coastwide by the AT survey. Adding the 2019 nearshore to offshore biomass estimates to develop a nearshore correction factor resulted in reducing Q for the AT survey from 1+ to 0.733, acknowledging that the AT survey does not ‘see’ all the fish. Albeit possibly an ‘inelegant’ and interim solution, this new method to account for nearshore sardines sets a precedent that can be utilized in update assessments until nearshore data gathering is more robust and complete enough to include in the model itself.

However, the industry is still hamstrung by the present methods and assumptions employed in the AT survey, now the primary basis for the model that drives the stock assessment. As noted in the CPSAS statement, if sardine biomass estimates were accurate, the sardine fishery would not be declared ‘overfished.’ This comment is based both on fishermen’s observations and our collaborative CDFW/CWPA EFP and aerial work. Even the ATM abundance data indicate a strong increase from 2017-2019, yet the assessment model predicts a sharp decline. This clear inconsistency was not explored during the STAR Panel, and thus is included here as a high priority recommendation.
The draft stock assessment acknowledges that most of the recommendations from the 2011 AT methods review, the 2014 and 2017 sardine STAR Panel reviews and the 2018 AT Methods reviews have not been addressed nor resolved, ostensibly because those issues require a Management Strategy Evaluation (or Methods Review) that has not occurred. The lack of progress in addressing these issues results in using survey data that jeopardizes the livelihoods of fishermen and processors who rely on the sardine fishery. In California, the sardine fishery is the foundation of a historic wetfish industry that until recent years, comprised 80% or more of total commercial fishery landings state-wide.
Numerous issues repeatedly identified in earlier STAR Panel and Methods Reviews continue to plague sardine stock assessments. I will elaborate on these issues below.

- *Need for the 2020 assessment to review the basis for the habitat model and refine estimates of both the catch and biomass attributable to the NSP and SSP. (first recommendation of the SSC CPS Subcommittee, in Italic comments related to the 2020 benchmark assessment)*
   - *Assigning 16.7 deg. C as the knife-edge boundary of the ‘northern’ stock has resulted in eliminating most CA sardines from the ‘northern’ sardine stock assessment*

This recommendation topped the list of issues to address at the 2020 STAR Panel review identified by the SSC CPS Subcommittee, and endorsed by the full SSC. However, this issue was not discussed because no background information was provided. But as noted above, in recent years the assumption that the ‘northern’ stock exists only in water temperatures below 16.7^0 C (62.06^0. F), has resulted in scrubbing most of the sardines in CA from the ‘northern’ stock assessment. In 2018, the summer AT survey estimated 35,000 tons of sardines offshore (in addition to the tens – perhaps hundreds – of thousands of tons of sardine observed by fishermen nearshore) in southern California. but because the water temperature was above 16.7^0 C, those fish were subtracted from the stock assessment on the assumption that they were 'southern' sardines. Had those fish been included, sardines would not have been declared "overfished."

Fishermen have reported an abundance of sardines yearlong for several years; CWPA aerial surveys and point sets conducted in spring 2019 (in water temperatures. below 62^0 F) documented tens of thousands of tons – 6,000 tons in one small area off Seal Beach, April 1, 2019 in 60 feet of water, water temp. 61^0 F.

According to best available science, there is no genetic difference between 'northern' and 'southern' stock sardines. Moreover, although potential mixing of stocks is acknowledged, no studies have been done to test the assumption that southern and northern stock movement is synchronous.

Because the primary index informing the 'northern' sardine stock assessment is now largely truncated to summer AT surveys, which for the past several years have begun in June in the PNW and concluded in August / September in southern California., this has resulted in most CA sardines being removed from the 'northern' biomass estimate. But all landings in southern California are subtracted from the 'northern' sardine harvest allowance, and fishermen must follow management policies set for 'northern' stock sardine, regardless of stock origin.

Since 2015, the directed fishery has been closed, and only incidental catch of sardines is allowed (exceptions: live bait and artisanal 1-ton landings). Until last year the incidental allowance was 40% by weight in other CPS fisheries. Last year, when the biomass estimate fell below 50,000 mt, and sardines were declared 'overfished,' the incidental catch limit automatically dropped to 20% by weight. That reduction has had a major impact on other CPS fisheries, precluding catches of mackerel, anchovy and even squid if the bycatch rate is higher than 20 percent -- and it often is.

Therefore, it is critically important to re-evaluate the temperature assumption used to separate northern and southern sardines. And fishermen should not be penalized for catching 'southern' stock sardines, which are not declared overfished – in fact, according to a recent assessment conducted by Mexican scientists, the 2018 'temperate' (southern) stock biomass was 872,745 t, allowing a 2019 harvest guideline for Mexico of 140,570 tons. The same stock assessment estimated that an average (1989-2018) of 12%of this stock has been caught in southern California (likely underestimated because the U.S. sardine fishery has been closed since 2015.) California fishermen are being penalized by the current stock / temperature assumptions.

- *AT estimates should be considered RELATIVE indices of abundance for all CPS, as recommended in the 2018 AT Methods review, but AT estimates are generally used as absolute for sardine assessments*

According to the draft stock assessment report, addressing this issue requires a Management Strategy Evaluation, which was first recommended in the 2018 AT Methods Review. This MSE should be conducted as a high priority, as recommended below.

- *Target strength is an issue still unresolved (the achilles heel of acoustic surveys)*

We supported the STAT high-priority recommendation in the 2017 STAR Panel review to address: "*technical issues related to echosounder deployment and associated signal interpretation (e.g., uncertainty surrounding species-specific target strength [TS], sonar bias related to backscatter uncertainty, and areas of the upper water column that potentially are not capable of being surveyed*)."

The AT team noted at that time that TS is currently based on "similar" fish, not CPS found in the California Current. The 2017 Panel acknowledged that incorrect TS could result in both over or **under-estimate** of biomass. We encourage the SWFSC to pursue this high priority recommendation identified in the 2017 STAR Panel review and repeated in the 2018 AT Methods Review.

- *Species composition attributed to backscatter is a serious question – samples are collected at night (on the surface in the vessel's wheel water) while backscatter is collected during daylight, omitting the top 7-9 meters of the water column (another criticism highlighted in the 2018 Methods Review)*

The AT team acknowledged that the biggest difference between SWFSC AT surveys and other acoustic surveys is that they collect backscatter during daylight hours and go back to the general area where fish were observed and conduct trawling at night, and use the samples to apportion the backscatter. This process was criticized by CIE acoustic experts during the 2018 AT Methods Review. It was also strongly criticized by fishermen who attended this STAR Panel review and who intend to submit a public comment with their explicit objections. To summarize, fishermen pointed out that the trawl net is deployed at the surface, towed behind the vessel in the wheel water, and the net extends only from the surface to 15m underwater. However, the echosounder is deployed at minimum 7m depth underwater, and in rough weather dropped to 9m. So the backscatter misses a 'dead zone' from the surface to at least 7m deep (22-30 feet below the surface), but this dead zone area constitutes a majority of the samples collected in the trawl. Two issues emerge: first, species composition may change between day and night. Second, because fish have tails and move around actively, the samples probably do not represent the same fish ensonified hours earlier, but the samples are used to apportion the biomass. Another problem is that the AT surveys avoid the use of sidescan sonar, and there is controversy over the issue of vessel avoidance. According to veteran fishermen, an average tow speed of 4 knots used by the AT survey vessel is not fast enough to catch fast-swimming sardines and mackerel, who also tend to avoid the net by moving to the side when the vessel approaches, and thus are not recorded in the backscatter.

- *Age compositions from the fishery were not included in the model, despite the SSC recommendation*

The STAR Panel discussed the conflict between fishery age comps and AT age comps, and the STAT ran a sensitivity considering both together to explore trade-offs. While the fishery age comps. tended to fit well in the model, the AT age comps fit poorly. The Panel also noted the uncertainty due to lack of nearshore biomass, and remarked that the assumption that AT weight at age is representative of population weight at age is a problem. But the issue was not resolved during the time allotted for the STAR Panel review. More attention is needed to incorporate biological data from all sources, including the live bait fishery and incidental catches from other fisheries, as recommended by the SSC.

- *Scale is still a BIG problem -- the model cannot estimate scale*

This is an obvious problem that needs to be addressed.

As noted in the CPSAS summary: the draft assessment report states that recruitment has not been observed. However, recruitment has been apparent in live bait pens, and in fishermen's observations, since 2015. Sardines must have spawned to produce all the 3-inch fish that fishermen have been seeing, both in Monterey and in Southern California. An index of recruitment could be developed via systematic surveys and biological sampling of live bait catches. The

Juvenile Rockfish Survey also provides helpful information on recruitment that should be considered in the sardine stock assessment.

Our strong recommendation continues to be to consider and utilize multiple indices at various times of year, not just one summer Acoustic Trawl survey, in future stock assessments.

If the ‘northern’ vs. ‘southern’ stock assumption persists, the AT survey should begin in CA in water temps. below 16.7^0 C, and survey the PNW later in summer, when sardines are more likely to be present.

High Priority Recommendations:
- Conduct a methods review of the habitat model.
- Conduct a methods review of Juvenile Rockfish Survey so it can be used to predict recruitment.
- Conduct an MSE to evaluate use of AT surveys as recommended in 2018 AT Methods Review.
- Re-evaluate model assumptions to learn why the assessment model predicts a sharp decline in age 1+ biomass when AT survey abundance data show a strong increase.