Agenda Item C.3
Supplemental Attachment 3
Electronic Only
April 2018

Center for Independent Experts Independent Peer Review of the Acoustic Trawl Methodology (ATM)

A REPORT BY THE REVIEWER DR. PAUL G. FERNANDES

27 MARCH 2018
ABERDEEN, SCOTLAND, UK

Declaration: The opinions expressed in this report are entirely the author's own. They are based on: his own experience with acoustic surveys, trawl surveys, and stock assessments; the relevant literature; examination of material provided for the review; and discussions with the administrators, scientists and industry representatives present at the San Diego meeting. Some of the report is taken from the Panel's report which the author co-authored.

Front cover: *An image of La Jolla Shores, San Diego, taken on 31 January 2018 showing the pier at Scripps Institute of Oceanography, viewed from the South West Fisheries Science Centre where the review took place*

Contents

Executive summary

1. The Acoustic Trawl Method (ATM) consists of surveys of multiple Costal Pelagic fish Species (CPS) carried out along the US west coast by the South West Fisheries Science Center (SWFSC). Two surveys are conducted annually which produce biomass estimates for Pacific sardine (*Sardinops sagax*) stock assessments. The surveys also provide biomass estimates of northern anchovy (*Engraulis mordax*), jack mackerel (*Trachurus symmetricus*) and Pacific mackerel (*Scomber japonicas*).
2. A review of the ATM took place from 29 January to 2 February 2018 at a meeting at the SWFSC, with administrators, scientists and representatives of industry. The purpose was to: review survey documentation; consider the target strengths (TS) used; examine survey design; examine the trawl survey design; consider the use of the EK80 echosounder; consider effects of vessel avoidance; consider unsampled areas; and ultimately, to determine how the results from the survey should be used.
3. The documentation provided was inadequate to address the TOR. The ATM Team were, however, very forthcoming and diligent in providing further information: a more comprehensive document is in preparation. There is clearly a lot of good practice, particularly in the technical detail associated with the operation of the acoustic instruments. The team are exceptionally well qualified and well equipped to carry out effective surveys. The summer surveys, in particular, seem to contain most of the stocks pretty well. However, survey precision is generally poor (CV's > 20%) and is not [inversely] proportional to the effort applied (as it should). The former may be related to the very challenging problem of species identification, which despite significant progress in signal processing, has been difficult to advance from the expert-based methods of the 1970's (Mais 1974).
4. The application of target strength to length relationships of other species from other parts of the world is one of the factors which inhibits the estimates of biomass for the ATM surveys being used as absolute values. Specific TS/L relationships should be determined for each stock, and these should be depth dependent where appropriate.
5. The survey sampling frame should be set with reference to the habitat model and results from former surveys, and surveyed in full. Adaptive sampling should not prejudice completing the survey design. Enhanced precision should not be sought at the cost of potentially significant bias, notwithstanding the problems highlighted of poor precision: it is better to be vaguely right than exactly wrong.
6. The time delay between acoustic detection and verification of species composition and size by trawling introduces several significant uncertainties. Chief amongst these is the differential selectivity given the different sizes of the animals concerned; but differential vertical distribution by species or by size may also have an effect. Such a delay is not standard practice, and in most cases, trawling to determine or verify species and size composition takes place as soon as significant echotraces are detected. In conjunction with efforts to improve species identification, methods to improve the biological sampling are needed.
7. The new Simrad EK80 broadband echosounder has several interesting features which may enhance the identification of CPS. The Team is well equipped and very well versed in broadband technology. Efforts to develop the system are encouraged.
8. Due to the epi-pelagic nature of the ATM target species, avoidance of the survey vessel is possible during the day and likely at night during trawling. Various approaches to investigating avoidance have been adopted throughout the world and the Team have all the necessary equipment and expertise to try one or more of these. They need to

demonstrate that avoidance is not a source of bias if their estimates are to be considered absolute.

9. There are fish in the inshore areas that are not surveyed by the ATM. There are legitimate concerns from the fishing industry, who fish extensively in these areas, that these fish are not accounted for. However, evidence points to the bias (as per the area) being small. This could be examined retrospectively by extrapolation, but in future, additional efforts should be made to survey inshore areas.
10. It is recommended that ATM survey estimates of sardine, Pacific mackerel, Jack mackerel, the Northern sub-population of northern anchovy, and the Central sub-population of northern anchovy be used in an integrated stock assessment as indices of relative abundance. The use of the ATM biomass estimates as absolute estimates of biomass in assessments is not recommended. This is chiefly due to the aforementioned uncertainties related to target strength, target species identification, unsampled areas (inshore & south of the survey area) and potential avoidance. Many of these uncertainties can be addressed with research which the Team is eminently qualified and well equipped to tackle. Improvements in age reading are essential to improve the quality of the estimates at age.

1 Background

The Acoustic Trawl Method (ATM) is the name given to the survey of multiple Costal Pelagic fish Species (CPS) carried out along the Californian coast by the South West Fisheries Science Center (SWFSC) of the United States National Marine Fisheries Service (NMFS). The survey is currently used annually, to produce biomass estimates for Pacific sardine (*Sardinops sagax*) stock assessments, which in turn are used to provide advice on the management of the stock. The survey also provides estimates of the biomass of three other species: northern anchovy (*Engraulis mordax,* of which there are two sub-stocks), jack mackerel (*Trachurus symmetricus*) and Pacific mackerel (*Scomber japonicas*). NMFS works with the Pacific Fishery Management Council (PFMC) to improve the advice associated with management of these stocks and to this end, they commissioned an independent peer review to determine the usefulness of the ATM for all of these stocks. Pacific herring (*Clupea pallasii*) also occur in the area, although the species is predominantly distributed further north, so this species was not included in the review's terms of reference (TOR).

The ATM review took place from 29 January to 2 February 2018. The independent review was conducted by the Center for Independent Experts (CIE) and examined 8 TOR. This report details the individual views of one of the four reviewers, Dr. Paul G. Fernandes (see Appendix 3 for contact details, and for details of the other three reviewers). The report, as stipulated in the statement of work (Appendix 2), includes a description of the reviewer's role, a summary of findings for each TOR, and conclusions and recommendations in accordance with the TOR. A full list of references, including those provided as background material, and those cited in this report appears in Appendix 1 and was posted in ftp://ftp.pcouncil.org/pub/

2 Description of the Individual Reviewer's Role in the Review Activities

The reviewer, Dr Paul G Fernandes, is a fisheries scientist at the University of Aberdeen in Scotland UK. Dr Fernandes has a BSc in Marine Biology and a PhD in Marine Ecology from Liverpool University's Port Erin Marine Laboratory. He worked overseas in Bolivia on the artisanal fisheries of Lake Titicaca and in the Republic of Ireland, before embarking on a 17-year stint at the Marine Laboratory in Aberdeen, Scotland (now Marine Scotland Science). Initially, he worked on fisheries surveys (acoustics and trawl), then on fish stock assessment, and latterly he managed over 20 scientists in the Sea Fisheries group; this group was responsible for the assessment of Scotland's internationally managed fish stocks. He took up his current position as reader in Fisheries Science at the University of Aberdeen in July 2011 partly funded by the Marine Alliance for Science and Technology Scotland (MASTS). He has a small (8) research group, FEAST (Fisheries Ecosystems and Advanced Survey Technologies), working on topics such as ecosystem modelling, acoustic surveys (active and passive), trawl surveys, visual surveys and stock assessments. He also convenes the MASTS Fisheries Forum, which pools all of Scotland's expertise in marine fisheries across academic, government and industry sectors.

Dr Fernandes role in the review activities was specified according to matching experience and expertise in: (1) the design and application of fisheries underwater acoustic technology to estimate fish abundance for stock assessments; (2) the design and execution of fishery-independent surveys for use in stock assessments, preferably with coastal pelagic fishes; (3) expertise in the application of fish stock assessment methods, particularly, length/age-structured modeling approaches, e.g., 'forward-simulation' models (such as Stock Synthesis, SS) and how fishery-independent surveys can be incorporated into such models; (4) expertise in the life history strategies and population dynamics of coastal pelagic fishes. This reviewer does not have experience in the design and application of aerial surveys to estimate fish abundance for stock assessments.

3 Summary of Findings for each TOR

3.1 TOR 1. ATM survey documentation.

Document the ATM survey design, protocols (sampling, data filtering, etc.), and estimation methods, including the following: a) delineate the survey area (sampling frame); b) specify the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification); c) specify the rule for stopping a transect (offshore boundary by species); d) specify the rules for conducting trawls to determine species composition; e) specify the rules for adaptive sampling (including the stopping rule); and f) specify the rules for post-stratification, and in particular how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account densities should be considered (PFMC 2017). g) Describe how echogram backscatter is analyzed to exclude non-CPS backscatter.

A document entitled Acoustic-Trawl Methods for Surveying Coastal Pelagic Fishes in the California Current Ecosystem (Demer et al. 2018) was provided. This document describes the sampling domain, sampling process, survey time series and, briefly, highlights measurement bias. It makes reference to a number of peer-reviewed articles, which were provided for the review, along with survey and assessment reports (see bibliography in Appendix 1). The document fell short on detail and failed to describe many of the essential processes, notably the identification of CPS backscatter, the specific target strength to length relationships used, the limits to the survey design, details of the trawl, the trawling strategy, and how the trawl clusters are determined. These points were described during the course of the meeting and a more comprehensive document describing the survey methods is being prepared.

3.1.1 The survey area (sampling frame).

The survey area is defined according to the expected distribution of the target species. The area is seasonally dynamic in terms of its oceanography (Figure 1), and the CPS distribution is similarly seasonal. In summer and fall, sardine feed in the productive coastal upwelling areas north of Oregon, whereas in winter and spring they migrate south off central and southern California. Mackerel follow a similar latitudinal pattern but are located further offshore. Anchovy are divided into a northern stock off Washington and Oregon and a central stock off California.

The spring survey takes place in spring (March to May), and it lasts ~30 days. The given design covers an area from about 32°N to 42°N with systematic transects orientated perpendicular to the coast extending about 80 nautical miles, although the offshore extent is adaptively set according to the CPS distribution at the time (up to 200 n.mi). Survey bounds are set to include sardine potential habitat at the beginning of the survey, although it is not clear how this varies and is planned in terms of actual survey design according to Demer et al. (2018). The individual survey reports indicate that this design is rarely achieved in spring and that potential habitat extends beyond the realm of the survey (e.g. Figure 2), in both a latitudinal and offshore extent (particularly in 2016).

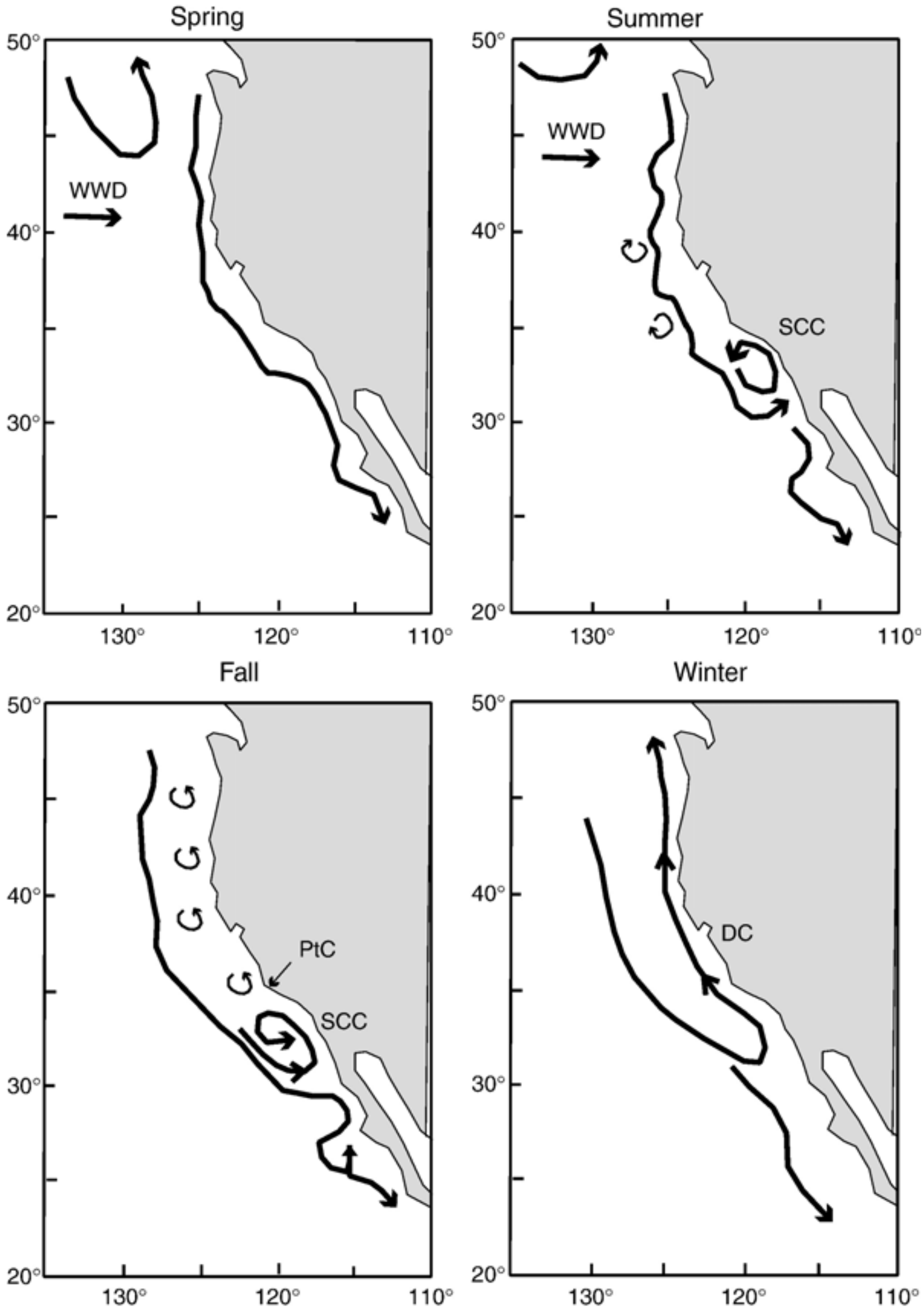

Figure 1. Maps of the western seaboard of the United States of America showing the seasonal circulation of the California current, reproduced from Barron and Bukry (2007). WWD = West Wind Drift; SCC = Southern California Countercurrent; PtC = Pt. Conception; DC = Davidson Current.

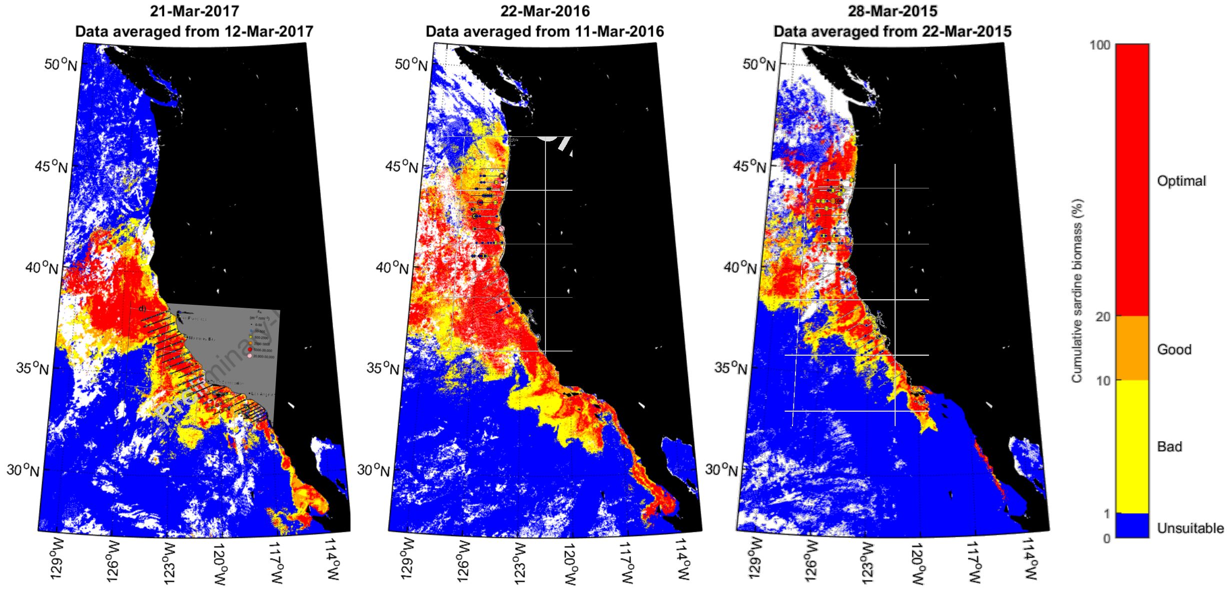

Figure 2. Maps of western North America with suitable coastal pelagic species (CPS) habitat for the spring ATM surveys of 2017, 2016 and 2015, with the final survey design superimposed and acoustic backscatter attributed to CPS.

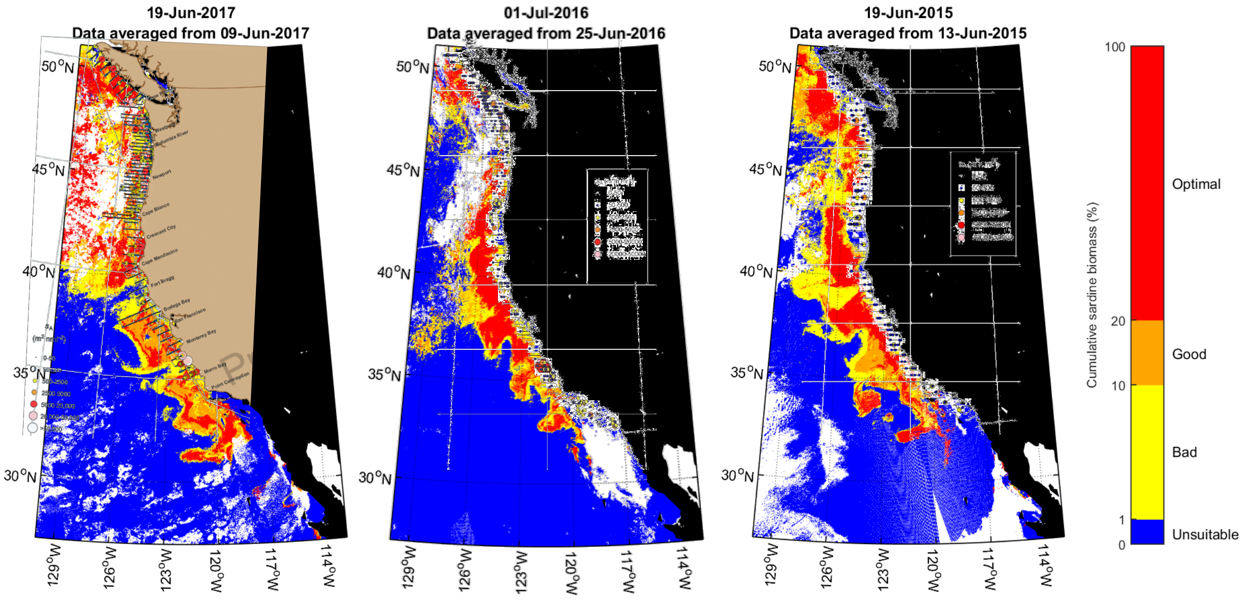

Figure 3. Maps of western North America with suitable coastal pelagic species (CPS) habitat for the summer ATM surveys of 2017, 2016 and 2015, with the final survey design superimposed and acoustic backscatter attributed to CPS.

In 2017 & 2016 the area surveyed in spring was small relative to the potential habitat (see Fig. 2) and CPS were detected at the offshore end of transects indicating a potential bias as fish may have been missed. It is apparent that due to the adaptive nature of the acoustic sampling, the sampling frame may not be completely covered as time runs out. This prioritizes precision over bias and should be avoided.

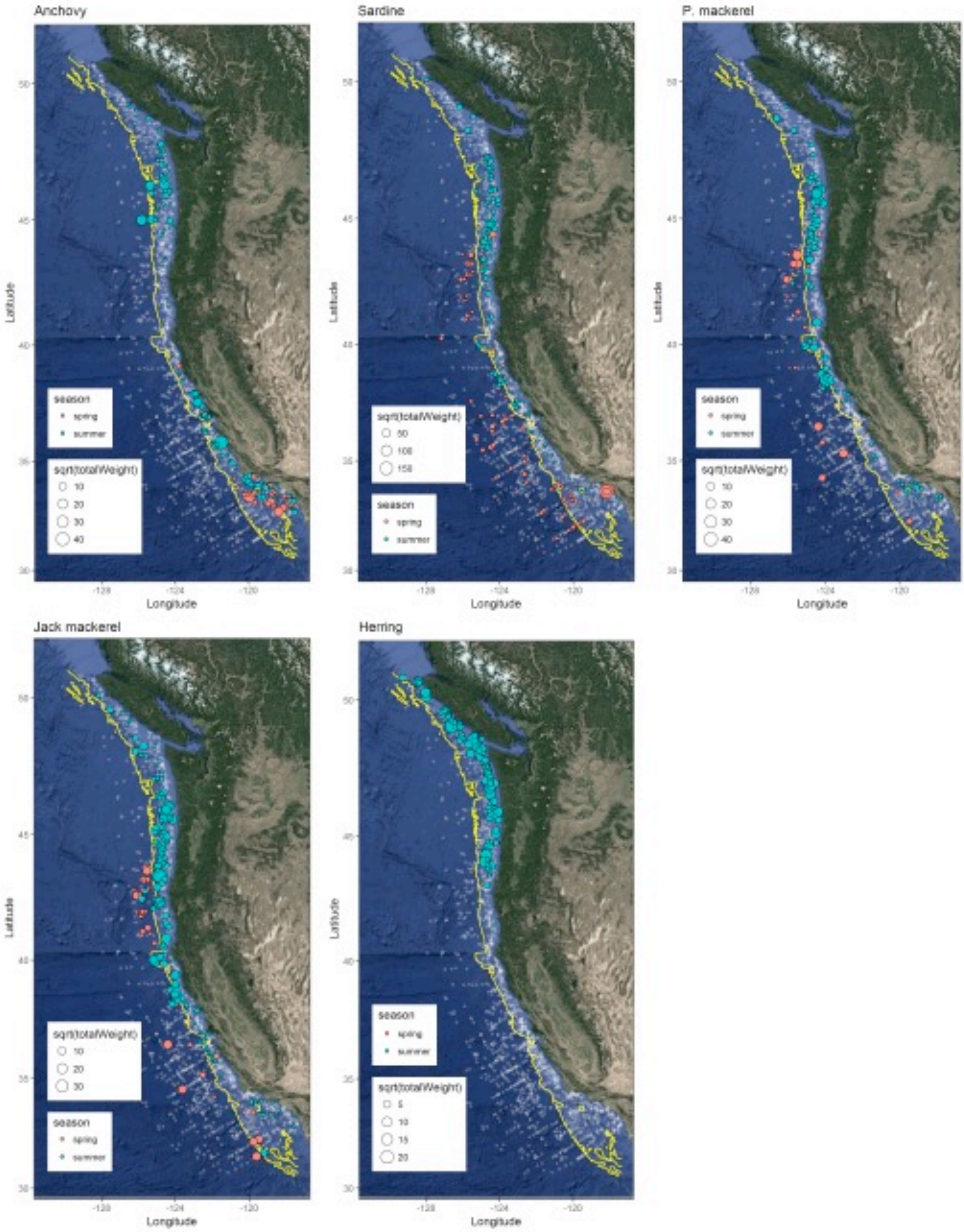

Figure 4. Maps of the west coast of North America showing the locations (circles) of all trawl catches of coastal pelagic species (labelled at the top of each panel) during all of the ATM surveys conducted since 2006. The circles are sized according to the square root of the total catch (kg) and colored by survey (red = spring, blue = summer). The yellow line is the 500 fathom bathymetric contour, which, in summer (blue circles), contains most of the distributions of each species.

The summer surveys are much more extensive in terms of the latitude covered (Fig. 3): in fact, they often cover the entire seaboard of the western USA and include parts of Canadian coastline. The offshore extent of these surveys is much less than that of the spring surveys, but results indicate that the sardine are contained closer to the coast in summer. In fact, the summer surveys seem to contain all of the main species considered by this review (Fig. 4).

It was clear that the survey sampling frame may change due to different survey objectives (target species). Table 1 provides a summary of the surveys to date with the essential elements, such as survey objectives, biomass estimates, precision, length of transects and survey area.

There are two observations of note from this table. Firstly, the values and range of coefficients of variation (CV) are quite high for acoustic surveys (Fig. 5). Rose et al. (2000) reported CVs for cod and redfish between 7 and 13% (once recalculated as the reported standard error divided by the mean, as their reported values make no sense); Demer (2004) estimated a total CV of 10-11% for Antarctic krill surveys; Simmonds et al. (2009) CVs in Peruvian anchoveta surveys were mostly between 5-25% (although one was 149% for a very low stock size); and Woillez et al. (2009) CVs for herring were between 5 and 17%. Many of these are estimates of the total error but all (with the exception of Simmonds) indicate that the sampling variance of the acoustic measurements dominate. A more interesting observation from Table 1 is the lack of relationship between the precision (CV), and the degree of coverage (DOC) (Aglen 1989), which is the effort relative to area (specifically, the total length of transect divided by the square root of the survey area). One would expect the CV to decline with an increase in DOC (see, for example, Aglen's Figure 8) as this is equivalent to increasing sample intensity [size, accounting for area]. Notwithstanding the DOC measure, precision generally increases with sample size (Cochran 1977), which in the case of an acoustic survey is usually dominated by the acoustic data (Demer 2004, Woillez et al. 2009). In the case of ATM, however, if the figures in Table 1 are correct, then the precision is invariant with increased sampling intensity (Fig. 5). This points to a source of error not related to survey effort, such as for example species allocation, which typically is the larger source of error (up to 50%), particularly when there are species mixtures (Simmonds and MacLennan 2005).

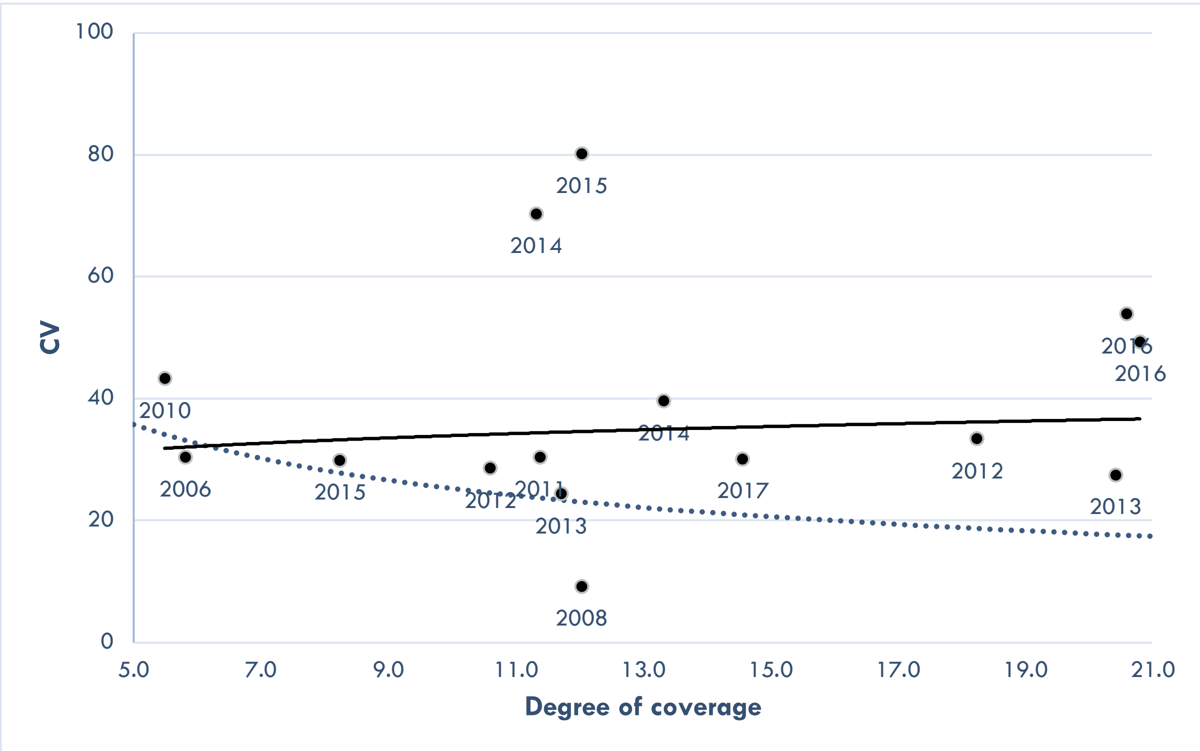

Figure 5. ATM survey precision (CV) against sampling intensity (DOC). Aglen's (1989) Degree of Coverage is N/√A, where N = total transect distance, and A = survey area , both taken from Table 1; CV is the Coefficient of Variation for the ATM surveys. Individual point labels are survey years. The black solid line is the fitted power function of the form CV = 26.6 $DOC^{0.1}$, and the grey dotted line is Aglen's empirical form for contagious fish schools where CV = 0.8 $DOC^{-0.5}$ and therefore represents the expected relationship.

3.1.2 Spatial stratification (if any) and transect spacing within strata planned in advance (true stratification)

The survey design consists of systematic parallel transects orientated perpendicular to the average coastline. There is no mention of a randomized start point which is required to ensure that all elements in the area have an equal probability of being sampled over the time series. The argument given in defense of this omission was that because these are pelagic species, their point of [spatial] reference is not fixed as it is likely to be determined by dynamic oceanographic currents. This, therefore, results in a dynamic positioning of the resource relative to the fixed transect design which in effect is the same as a randomized start point. This may be partly or even wholly true, but there may still be areas with unknown specific effects, close to canyons for example. Given that a random start point is not an onerous logistical requirement, the team should consider implementing it.

Transect spacing is default to 20 n.mi., with 10 n.mi. spacing "…in areas with historically high CPS densities and diversity". These areas (strata) were described as "…off Washington and Oregon during the summer" but not specifically identified in Demer et al. (2018): they should be specified (mapped) in the detailed survey protocol document being prepared. A map of mean abundance and variance over the time series should be prepared to determine the validity of these "…historic high CPS densities…"; see for example, Figures 1 and 2 in Simmonds (1995). This would provide a documented and valid justification of the high density strata.

3.1.3 Rule for stopping a transect (offshore boundary by species)

According to (Demer et al. 2018), transect length is adaptively extended offshore to map CPD based on the CPS echoes, eggs, or CPS in survey and/or commercial catches. This is a rather vague description and an inspection of the data reveals CPS to be present at the end of some transects. A single map of the entire time series of CPS, egg and commercial catch would have been instructive in this regard, although the former were available in the individual survey reports. Information on the location of commercial catches was not available despite a specific request which infers it is not easy to obtain.

3.1.4 Rules for conducting trawls to determine species composition

Trawl sampling is conducted each night by returning to positions where either: i) CPS schools were acoustically observed earlier that day; ii) CUFES samples indicated egg presences; iii) reports on the locations of CPS catches by the industry. The ATM team's initial experiences with attempting to fish during the day has been bad because schooling fish avoid the net during the day. The temporal mismatch may cause problems if there is no spatial pattern in the school's length or age makeup. More detail on this point is provided in Section 4.4.

3.1.5 Rules for adaptive sampling (including the stopping rule)

Adaptive sampling is included in the offshore extent of the individual transects, as well as adding interlaced transects. (Demer et al. 2018) states that "in areas with CPS, a minimum of three interstitial transects are added to the compulsory transects": but no mention is made of what the threshold is which invokes the decision to add transects. There is no evidence of 3.3 n.mi. spacing transects in some of the survey reports where CPS was detected.

Table 1. Summary of the characteristics of the surveys conducted to date. Note that the values reported are preliminary. The Team should be contacted for updates prior to citing these values.

Survey ID	Date start	Date end	Duration (d)*	Target Species	Sardine biomass (10^3 t) [CV]	Anchovy biomass (10^3 mt) [CV]	Number of transects (n)	Length of transects (n.mi.)	Area covered (n.mi.^{2})	Acoustic equipment	Number of trawls (n)	Total number of trawl Clusters (n)	Number of positive trawl cluster (n)
0604OD	4/12/2006	5/8/2006	26	Sardine/CPS	1,947 [30.4]	n.a.	18	2,563	194,543	EK60	40	n.a.	n.a.
0804JD	4/12/2008	4/28/2008	16	Sardine/CPS	751 [9.2]	n.a.	15	3,489	84,095	EK60	30	n.a.	n.a.
0804MF	4/12/2008	4/30/2008	18				18	2,458	106,879	EK60	42	n.a.	n.a.
1004FR	3/30/2010	4/27/2010	28	Sardine/CPS	357 [43.3]	n.a.	9	1,360	61,435	EK60	55	n.a.	n.a.
1004MF	4/3/2010	4/20/2010	17				15	1,780	70,936	EK60	43	n.a.	n.a.
1104FR/ 1104SH	3/25/2011	4/25/2011	31	Sardine/CPS	494 [30.4]	n.a.	21	2,919	65,741	EK60	105	19	16
1204SH/ 1204OS	3/17/2012	4/30/2012	44	Sardine/CPS	470 [28.6]	n.a.	19	3,230	92,823	EK60/ME70	95	35	14
1206SH	6/24/2012	8/30/2012	67	Sardine/hake /CPS	341 [33.4]	n.a.	85	3,509	36,991	EK60/ME70	98	38	31
1304OS/ 1304SH	4/10/2013	5/4/2013	24	Sardine/CPS	305 [24.4]	n.a.	17	2,791	56,804	EK60	70	26	15
1306SH	6/6/2013	8/30/2013	85	Sardine/hake /CPS	314 [27.5]	n.a.	62	4,420	46,865	EK60/ME70	147	56	39
1404SH	4/13/2014	5/7/2014	24	Sardine/CPS	35 [39.6]	n.a.	10	3,890	85,265	EK60/ME70	39	16	8
1406SH	6/24/2014	8/5/2014	42	Sardine/CPS	26 [70.3]	n.a.	22	2,278	40,513	EK60/ME70	85	36	29
1504SH	3/28/2015	5/1/2015	34	Sardine/CPS	29 [29.9]	n.a.	13	1,843	50,038	EK60/ME70	54	22	15
1507SH	6/15/2015	9/10/2015	87	CPS	16 [80.2]	n.a.	32	2,614	47,188	EK60/ME70	160	58	50
1604RL	3/22/2016	4/22/2016	31	Sardine/CPS	83 [49.3]	n.a.	12	3,849	34,223	EK60/EK80/ME7 0/MS70/SX90	43	18	9
1607RL	6/28/2016	9/22/2016	86	CPS	79 [53.9]	152 [41]	54	4,627	50,477	EK60/EK80/ME7 0/MS70/SX90	121	49	40
1706RL	6/21/2017	8/10/2017	50	CPS	37 [30.1]	n.a.	68	3,313	51,743	EK60/EK80/ME7 0/MS70/SX90	86	36	34

*Includes in-port days

3.1.6 Rules for post-stratification, and in particular how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account densities should be considered (PFMC 2017).

The post stratified method applied here was described at length [on request] at the meeting. The aim of the post-stratification process is two-fold: (a) to identify strata for which the assumption of approximate stationarity is valid, and (b) to create strata for which the number of transects per unit area is constant. The aim is to distinguish regions with 'structural zeros' from regions (which may include transects with observed zero acoustic density) for which density is likely non-zero. Juan Zwolinski explored the validity of the approach to post-stratification taken by the Team by computing autocorrelation functions (there was no evidence for significant autocorrelation within the post-stratified strata at any lag when transect means were considered). He also compared the variance estimates when they were computed using the current post-stratification approach and a simpler approach that defined strata without reference to density and found the estimates of variance to be similar, suggesting that the expected negative bias in the variance estimates due to post-stratification is not likely to be substantial. Essentially it purports to follow the methods of Fewster et al. (2009) but the selection of strata is not as indicated in Fewster et al.: they post stratify systematically across the entire survey design, whereas in the ATM the strata are ad hoc selections to isolate largely positive values. It is unknown what the effects of this strategy are but it is irregular. There is almost certainly some autocorrelation in the data which, because the design is systematic, will contribute to an improvement in precision (Rivoirard et al. 2000); however, it was undetectable at the transect level and given the highly zero inflated data, may also be at the EDSU level. This is not unusual (see for example (Fernandes and Simmonds 1997), but the team might be encouraged to try the methods described in Woillez et al. (2009) which are now more amenably described in Petitgas et al. (2017) and cater for zero inflation.

3.1.7 How echogram backscatter is analyzed to exclude non-CPS backscatter.

The statement, "The echo energy attributed to CPS, based on empirical echo spectra (Demer et al., 2012), are apportioned to species using trawl-catch proportions" (Zwolinski et al., 2014), summarizes the approach but hides much of the detail which, eventually, was revealed. The data are corrected for local sound speed and filtered to reduce noise in accordance with standard practice. The Sv data are averaged (11 samples vertically and 3 transmissions horizontally) and then filtered based on empirical predictions of CPS according to Demer et al. (2018) as : -13.85≤Sv 70 kHz − Sv 38 kHz<9.89; -13.5≤Sv 120 kHz − Sv 38 kHz< 9.37; and -13.51≤Sv 200 kHz− Sv 38 kHz<12.53 dB. The stated references "For more details are…" Demer et al. (2009) and Demer et al. (2012), but the former relates to demersal fish (rockfish) and reports no multifrequency thresholds, and the latter, not only has a different set of thresholds, but provides no justification whatsoever of the derivation of thresholds. No explanation was given as to where these values have come from and the stated references do not provide any detail. The data are then further filtered according to the standard deviation of each averaging bin, and a simple Sv threshold (< 60 dB). The outcome of this process is to isolate strong scatterers across all frequencies, characteristic of geometric scatterers, in a manner analogous to multifrequency thresholding described in Fernandes (2009); in common with the latter technique, areas of intense unknown midwater scattering (Mair et al. 2005) can remain (not documented, but very evident when the panel inspected echograms). The data are then selected from 10 m down to the depth of the bottom of the "surface mixed layer (typically between 10 and 12°C)" or to the maximum logging range (350 m). Manual adjustment then takes place by inspection of each EDSU to remove any scattering from the unknown midwater scattering layer or demersal fish. So the process is neither objective nor automatic, but it does make use of some spectral and statistical properties of fish schools.

A major drawback here is that despite this complex processing, what is taken into the next stage of analysis is CPS backscatter as opposed to species specific backscatter. So despite the progress made in signal processing, these surveys seem to have regressed in their ability to identify echotraces from the 1970s, when, for example, Mais (1974) states: "*Fish school targets detected by sonar and echo sounder were identified by a variety of methods which included visual observation, echogram characteristics, midwater trawling, and commercial catches. Echogram characteristics was the prevalent method of identification. Characteristics of species previously identified by other means were used as criteria. These include depth below surface or in relation to bottom, school thickness, shape and density of echogram, aggregation of schools into school groups, location of school groups from shore, and orientation to bottom topography. The characteristics of individual species are based on confirmation of echogram identification by a wealth of midwater trawl catch data, extensive experience and knowledge by commercial fishermen, and direct visual observation of schools.* ***The problem of confusing two or more species when schooled together was not as serious as expected.*** *Commercial catch records and midwater trawl data indicate none of the major species under survey school in the same manner and localities simultaneously in appreciable quantities.*" As a consequence, CPS backscatter is then apportioned to species according to the night time trawl catch compositions. This has implications for the precision of the abundance estimate and is considered further in Section 4.4.

3.2 TOR 2. Estimated target strengths of CPS from the California Current

Current ATM estimates rely on target strengths of similar CPS species identified in other studies around the world. The ability to measure target strengths of live fish collected from the survey area can now be conducted at the Technology Tank at the SWFSC, La Jolla, CA. Target strengths of CPS from the California Current should be provided for the review meeting.

Target strength is a vital component of an acoustic survey that purports to be absolute. Generally, uncertainties in TS estimation are the major determinant in stipulating whether the survey estimates are used as absolute or relative indices of abundance. There are very few acoustic surveys where the surveys are considered as absolute abundance estimates: Icelandic capelin being one of the few in north-east Atlantic. So an absolute estimate would be expected to have very specific evidence of the TS of the fish from the stock in question. Demer et al. (2018) state that length distributions "…are input to TS-versus-length models for sardine (*Sardinops ocellatus/Sardinops sagax*) (Barange et al. 1996), horse mackerel (*Trachurus trachurus*) (Barange et al. 1996)…", which was rather cryptic. After some discussion it was clear that the Barange et al. relationship for South African pilchard (*Sardinops ocellatus*), is used for California sardine (*Sardinops sagax*) and Pacific herring; while their horse mackerel equation is used for the Pacific and jack mackerel. These are not the same species, never mind the same stock.

All of these species have open swim bladders (physostomes), so their target strength is impacted by compression or expansion of the swim bladder over the vertical range. Fishermen have observed vertical migrations of both sardine and anchovy below 70 m (*pers. comm.* David Crabbe). However, no depth compensation is applied to sardine TS. Depth-dependent target strength has been documented for Atlantic herring (Ona 2003, Fässler et al. 2009). However, models of depth-dependent target strength have not been applied to date in the North Sea herring assessments, mostly due to the impracticality in updating long time-series. While depth-dependent models have been discussed widely, especially in Europe, they are not routinely implemented. It was acknowledged that maintaining consistency in the method applied is critical, irrespective of whether a depth-varying target strength is applied or a target strength applied to a mean depth. Such considerations are consistent with the use of the resulting estimates as indices rather than absolute estimates.

For anchovy, the target strength is based on the target strength of another anchovy species (Japanese anchovy) from (Kang et al. 2009), with an added (fixed) term for depth dependence. The validity of this model was tested against empirical target strength data collected from three trawls within a single transect in southern California where anchovy were abundant and estimated to constitute 99% of all CPS finfish. The target strength (TS) measurements at each location were combined with the associated total length (TL) distribution from each catch and resulted in an estimate of the b_{20} parameter of 67.3 dB. Given the mean depth of the schools during this measurement at 13 m and estimated compression of the swim bladder, this value is in agreement with the value for b_{20} estimated for the Japanese anchovy (67.2). The frequency distribution of the measured target strength was broader than would be expected from the length frequency distributions, but this is likely due to added variability from the tilt angle distribution, a commonly observed phenomenon echoed by the experts in the room. For the summer surveys, when the mean depth of schools increased to 21 m, the b_{20} value was adjusted to 68.1 dB. This is the value used throughout the surveys, which again is consistent.

The impact of depth may also be significant for herring because vertical distribution of Pacific herring has been documented to 200 m (pers. comm. Stephane Gauthier). Notwithstanding issues of depth-dependence, there are some published target strength models for Pacific herring (Thomas et al. 2002, Gauthier and Horne 2004) which may be more appropriate than the current model used, which is based on pilchard.

The last review recommended that efforts should be made to obtain TS measurements for in situ CPS. However, with the exception of anchovy, no progress has been made. Given the desire to use the estimates as absolute, the continued use of the TS relationships from other species (Barange *et al.* 1996) is curious. Several suggestions for making measurements were discussed. Measuring target strength at night when fish are acoustically resolved in single targets either in layers or at the outskirts of schools might give a biased estimate of target strength, because such individuals are not necessarily representative for the bulk for fishes in daytime school recordings both in terms of size and tilt angle distribution. Little discussion was had about the excellent facility, the acoustic technology tank, available at SWFSC. This can accommodate fish and would be an excellent facility to make controlled experiments and observations of species and stock specific TS.

3.3 TOR 3 Trawl survey design protocols for using a CPS preferred habitat model to determine adaptive sampling areas.

In relation to a preferred habitat model for Pacific sardine, as well as other coastal pelagic species: a) To the extent possible, address the fact that low population size likely affects the probability of acoustic detection in a non-linear way. This could create a negatively biased estimate at low population levels and potentially a non-detection threshold below which the stock size cannot be reliably assessed. b) Evaluate the costs and benefits of targeting sampling effort based on the preferred habitat model for Pacific sardine in terms of biomass estimates for Pacific sardine and for other CPS stocks.

3.3.1 Low population effects.

Low stock abundance may potentially lead to higher relative observation variability and thus greater uncertainty in population size, e.g. see Simmonds et al. (2009). The abundance index will be hyperstable if the relative proportion of a stock that occurs outside of the sampling frame has an inverse relationship with stock size (e.g. if a larger proportion of the anchovy stock is closer to shore than the inshore boundary of the acoustic survey). Additional inshore transects conducted by the FV Lisa Marie in the Pacific Northwest during summer 2017 indicated that only a small portion of the stock (1.6%) of anchovy occurred in the nearshore in the summer in that area during that season. In contrast, the summer 2017 aerial survey off central California is suggestive that a substantial portion of both anchovy and sardine may be shoreward of the shoreside limit of the acoustic survey in the summer in California.

Uncertainty in the estimates of stock biomass at small stock size also can be affected by changes in species composition, either within schools or in the areas for which species composition is assigned to a particular trawl cluster. Further, interaction and competition among species undergoing large changes in abundance might lead to behavioral changes, including altered distribution patterns. At small stock size, there is a greater chance of completely missing a species in the trawls or capturing a substantially higher proportion of that species than is actually in that area, and thus assigning a substantially wrong proportion to the estimated biomass (as well as calculating a somewhat incorrect target strength relationship). Further investigation into these potential sources of bias is needed.

3.3.2 Costs and benefits of targeting sampling effort

The focus of sampling effort depends on the goal of a particular survey. Most surveys have been focused on surveying Pacific sardine. However, the 2017 summer survey was focused on the northern subpopulations of northern anchovy and Pacific sardine. The habitat model for Pacific sardine is used to help determine the sampling for those surveys focused on Pacific sardine (all surveys except that for summer 2016). The amount of ship time available for the survey influences the northern and/or southern boundaries of a particular survey. In principle, the summer surveys extend from the northern end of Vancouver Island to the U.S.—Mexico border. When survey time was limited, the surveys extended as far south as necessary to survey the entire northern stock of Pacific sardine. The summer survey typically moves from north to south, and uses various sources of information to determine the southern boundary of the survey. However, the southern boundary may fall short of the likely distribution of sardine, as evidenced from the presence of fish on the most southerly transect (Figs. 2 and 3).

The survey design includes areas with 20 n.mi. and others with 10 n.mi. inter-transect distances, based on previous observations of where CPS are expected to occur in substantial numbers. Additional transects are held in reserve, and added between the 20 n.mi. interval transects when substantial biomass is seen on a transect. However, even though there are a limited number of these additional transects allotted, the practice may limit the southern boundary because the time taken to conduct these transects impinges on completing the southern order and hence the entire sampling frame, even when designated by the habitat model.

3.4 TOR 4. Effects of trawl survey design

In relation to trawl survey design, the following should be considered and addressed:

a) *The consequences of the time delay and difference in diurnal period of the acoustic surveys versus trawling need to be understood; validation or additional research is critical to ensure that the fish caught in the trawls from the night time scattering layer share the same species, age and size structure as the fish ensonified in the daytime clusters. To the extent possible, the ATM team should conduct paired trawls during daytime acoustic sampling, to validate (or to generate a correction factor for) nighttime species composition trawls.*

b) *Consider suitable sample sizes of CPS in the ATM survey. The ability of a single vessel following fixed transects along the entire northern sardine subpopulation region over a single period to sufficiently observe and sample a highly mobile schooling species that exhibits high variability in recruitment, migratory patterns and timing, school structure, and depth distribution, remains a core challenge. The relatively small sample size of sardine for biological analysis remains a concern related to acoustic expansions, population model estimates, and projection forecasts that depend on age composition and size-at-age information. Conduct an analysis of effect of fish sample size on the uncertainty in the ATM biomass estimates and model outputs. Use this information to re-evaluate and revise the sampling strategy for size and age data that includes target sample sizes for strata (see Pacific Sardine STAR Panel Meeting Report, PFMC, April 2017).*

c) *Test the efficiency (relative catchability) and selectivity of the trawl among and within species by comparing samples from the same area taken with the survey trawl and purse seine.*
d) *Estimate trawl selectivity by species. Cameras attached to the trawl in front of the cod end have been developed and used extensively since the 2013 surveys to observe and quantify fish behavior and Marine Mammal Excluder Device (MMED) performance. The ATM team should report on findings from the camera research and quantify the selectivity of the trawl. If unquantifiable, describe state-of-the-art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl, and how the data would be incorporated into the biomass estimation process. Cannot see any information relating to this?*

3.4.1 Time delay between trawling and acoustic detection of CPS

Trawls are conducted during an acoustic survey to obtain biological information (notably length and age) and to verify the species composition of the echotraces. The latter is often referred to as ground-truthing, analogous to other remote sensing techniques that require validation (see (McClatchie et al. 2000). Therefore, in a typical acoustic survey, trawls are conducted shortly after detecting fish and/or fish schools. There are few pre-defined design criteria to the allocation of trawl samples, instead time is usually allocated for trawling, and trawls are conducted as and when targets are detected (Simmonds 1995). In relation to the issue of using the trawls for species allocation, (Simmonds and MacLennan 2005) state the following: "*Although it is often the best available, pelagic trawling is a poor method of sampling fish densities, and substantial errors may arise in estimating the proportions of species in mixed aggregations. If there is any possibility of partitioning the echo-integrals to species level from examination of the echograms, this should be attempted in preference to the catch-partitioning technique described by Nakken and Dommasnes (1975). Even if the interpretation of the echogram is uncertain, the error in acoustic partitioning may well be less than that based on the catch analysis…*". In their analysis of the requirements for ground truthing (McClatchie et al. 2000) go further, stating that "*It must be feasible to direct the sampler to capture a "mark" seen on the echogram, and the sampler should have the capacity to capture a series of discrete marks without contamination between the catches. It is necessary to be able to locate the sampler precisely in relation to the targets during its deployment.*" They go on to conclude that "*Correlations between acoustic and ground truth observations are always best when they are synoptic.*"

There are many surveys for small pelagic species around the world, most of which do both acoustics and net sampling during the day, indicating that identification along with the acoustic sampling is possible when using the proper gear. In similar circumstances, i.e. an acoustic survey for sardine, anchovy and mackerels, Petitgas et al. (2003) compared four methods of allocating echotraces to species with information from trawl hauls conducted shortly after echotrace detection: i) nearest haul; ii) expert; iii) a post-stratified acoustic image classification method (AICASA); and iv) a post-stratified trawl-haul classification method (THC). Very little difference was found between these in terms of the abundance estimates, with the exception of mackerel (which was a different species, without a swimbladder, and so had a very different target strength). However, the ATM practice does not conform to any of these methods, largely because of the time delay between the respective components (acoustic data during the day allocated to trawl hauls at night). Trawling at night based on daytime recordings is not a generally used approach to estimating species proportions and their lengths, but has been used in the Mediterranean, apparently without negative consequences (Tugores et al. 2010). In the present case, it is a practical approach to addressing logistical difficulties in a multispecies survey when trawling by day is problematic, but consequences are unknown. The sampling takes place in the surface layer (top 15 m) at night under the assumption that all CPS finfish spread out at the surface, but this requires validation.

In the ATM surveys there is substantial time lag [and some distance lag] between trawling and acoustically detected CPS. This raises an obvious concern that the proportions of fish species and the length distributions detected by day may not be the same as those which are trawled on by night. This may occur for several reasons:

a) Differential horizontal distribution due to movement.
b) Differential vertical distribution. The trawl has a vertical opening of 15 m and the headline is at 5-10 m, at best the trawl samples down to 25 m; epipelagic CPS occur at greater depths than this and individuals may segregate vertically by size at night (Stockwell et al. 2010, Jensen et al. 2011, Busch and Mehner 2012). More importantly, it was noted that the approach used to eliminate non-CPS epipelagic fishes during day-time acoustic sampling may lead to some species (e.g. herring) being excluded from the acoustic data used to estimate total CPS biomass, but that such species are likely included in the trawl catches used to apportion total CPS as they migrate into upper waters also.
c) Differential species trawl selectivity. There are considerable size differences between the species: anchovy ranges from 9 to 16 cm; sardine from 9 to 26 cm; and the mackerels from 6 to 61 cm (Demer et al. 2012). So the smaller fish (anchovy) are more likely to pass through the anterior meshes than successively larger species such as sardine and more so mackerel. O'Driscoll (2003) document such effects and account for species vulnerabilities in the mixture allocation: this approach might be considered here.
d) Differential dispersal of fish. Fish are concentrated in schools, potentially monospecific, by day, and mixtures of individuals by night. The concentration of individuals may not reflect those of schools. During the course of the review it was evident that some schooling was maintained at night although it was not clear which species these were likely to be.

Other than consistency of results, the team provided no evidence to dispute that any of these effects could be occurring. Furthermore, the wide confidence intervals associated with each survey would mean that statistically significant differences are difficult to determine.

Several approaches to dealing with these issues were discussed, including spending a full day and night at a location with a variety of schools observed during the daytime and then following them at twilight and at night using, for example, a multi-beam sonar. Validating the identity of fish seen on the echosounder by fishing or otherwise observing the fish during the day is desirable. While fishing was previously attempted using auxiliary vessels, it was not successful, perhaps due to inappropriate gear. However, a midwater trawl is used in the hake (aka Pacific whiting) surveys, and it is capable of catching Pacific herring.

Experiments to understand and improve the trawl presently in use, as well as testing a larger and more efficient trawl are relevant approaches. To conduct such an experiment, it would be useful to consult with industry in the choice of approach, equipment, and experimental design. Several European nations engage with industry specialists (skippers) to assist with fishing operations during acoustic surveys on research vessels, recognizing that this is a specialized activity with which research vessel crew often have little experience. It would not only be directly useful to the ATM survey to include such experience by inviting a skipper on board to advise on fishing practices, but indirectly this would contribute greatly to improved relations between scientists and industry stakeholders, which at the present time seem strained.

3.4.2 Consider suitable sample sizes of CPS in the ATM survey

No results were reported, but this should be taken forward. The current method for estimating biomass is to link backscatter with cluster-specific trawl catches. Error from low sample sizes translates to error in mean target strength, reducing confidence in the biomass estimates. An alternative method would be to define a region across multiple transects where the length-frequencies are not significantly different and pooling the data at this scale. The effects of the sample size of fish collected in trawls in terms of uncertainty and variability in indices and size and age compositions, should be examined. Well informed length distributions are important for estimating size and age structure. While increasing the length of trawls will help to some extent, other approaches may be more efficient (weighted pooling where similarities are confirmed). There were examples of very low sample sizes which should be avoided.

3.4.3 Efficiency (relative catchability) and selectivity of the trawl

No results were reported. But comparisons with alternative ground truth devices (purse seine, gillnet, cameras) would help to understand the selectivity of the trawl.

3.4.4 Estimate trawl selectivity by species.

No results were reported, but as noted above (4.4.1.c) this should be investigated, as suggested, with camera work, but also by considering alternative approaches (O'Driscoll 2003).

3.5 TOR 5. Effects of upgrading from the Simrad EK60 to EK80

After 10+ years of service, Simrad discontinued the EK60 series and introduced the EK80 series of transceivers and control software, which shifts from narrow-bandwidth transmit pulses to wide-bandwidth pulses using existing hull-mounted transducers. The ATM team should review the initial outcomes of the EK80 and provide information on the proposed benefits including: a) fish echoes captured from more complete band of frequencies allowing improvement in species identification; b)increased range resolution allowing detection of fish close to the bottom and individual fish within an aggregation; c) increased signal-to-noise ratio allowing improvements in detection capabilities and effective range; d) extension and miniaturization of wide-band technology allowing autonomous deployment on smaller vessels (i.e., rigid hull inflatables which could sample nearshore areas, surface buoys, deep moorings, and ROVs).

This response to this TOR focused on summarizing the relevant conclusions of a 2016 workshop that evaluated the performance of the new Simrad EK80 broadband echosounder (Demer et al. 2017). It should be noted that the workshop was hosted by the Team, and the ensuing report's lead author was the Team leader: the SWFSC is, therefore, at the leading edge of this technology.

The Simrad EK60 scientific echosounder has been the standard instrument used worldwide to collect acoustic survey data since ~2000. Simrad's EK series typically gets updated every 20 years or so, and in 2016/17, Simrad introduced the next generation of EK echosounders, the EK80. The EK80, when used in conjunction with the appropriate transducer, has the capability of generating broadband signals: these may also be referred to as wideband, or frequency modulated (FM) signals, and are distinguished from the continuous wave (CW) narrowband signals generated by the EK60. As an example, a typical EK60 echosounder may transmit signals (simultaneously) at three narrowband frequencies of (approximately) 38 ± 0.35 kHz, 120 ± 1.5 kHz and 200 ± 1.5 kHz; an EK80 with similar center frequency transducers may, in FM mode, transmit frequencies of 34-45 kHz, 90-170 kHz and 160-260 kHz respectively. The EK80 is also capable of generating CW pulses. The benefits of transmitting FM pulses are reflected in the following four topics as listed in the Terms of Reference.

3.5.1 *Improvement in species identification.*

Different objects and animals produce different quantities of sound at different frequencies depending on their size, material properties, geometrical dimensions and behavior. Generally, objects that are small relative to the wavelength scatter more sound with increasing frequency (Rayleigh scatterers), whereas objects that are large relative to the wavelength scatter a similar quantity of sound regardless of frequency (geometric scatterers). This is a generalization, and depends on several other factors, notably the material properties of the object, which may allow for resonance to occur that leads to a scattering peak at a particular (resonance) frequency. These frequency-dependent properties have hitherto been exploited using several CW signals transmitted simultaneously, which provide four points on a frequency spectrum (scattering on the y-axis and frequency on the x-axis). These spectra can be used to distinguish various classes of objects and are used, for example, in the ATM CPS filters to distinguish CPS schools. The transmission of FM signals, with their wider bandwidths, allows for many more points to be determined in the spectrum. In the aforementioned example, using transducers at the three center frequencies, a CW EK60 system would provide three data points on a spectrum, whereas the EK80 with equivalent transducers would have 191 data points. This allows for a much greater characterization of the spectrum and potentially aids species identification. Demer et al. (2017) allude to this potential, but the ICES workshop did not collect any data to support it: rather, the ICES workshop focused on issues related to the consistent operation of the instrument, such as data volume and processing, power output, noise and calibration. At the range of frequencies employed, it is yet to be established if having the additional information across a more complete spectrum will provide an enhanced ability to distinguish objects. Although this is certainly possible for certain objects in the Rayleigh region, CPS are largely in the geometric region which means that their spectrum should be flat. Exceptions might be small anchovy, which have a resonance peak between 1 and 2 kHz (Holliday 1977), such that the downwards slope of the spectrum may be detectable at the range of frequencies deployed. The approach is not yet used much and there is a need for validation.

3.5.2 *Increased range resolution.*

The ability to separate objects in a smaller vertical space is also a feature of a broadband signal (Demer et al., 2017). This may potentially allow for the detection of fish close to the bottom and of individual fish within an aggregation. The latter was not examined, but has been demonstrated elsewhere, e.g. (Stanton et al. 2010). Demer et al. (2017) did consider detection close to the seabed by making measurements using an EK80 from the RV "Reuben Lasker" of ten ~4 cm diameter spherical lead targets spaced 1 m apart in a vertical array deployed on a rocky seabed substrate. They found that short CW pulses better resolved targets near the seabed, compared to FM pulses. This was because processing the FM signal introduces side lobes (scattering to the side of the main beam) and if the echo from one target is much weaker than another, e.g. a fish near the seabed, the side lobes from the seabed echo may eclipse the fish echo. However, their measurements were carried out on a rocky substrate, which is more susceptible to side lobe interference so it remains to be seen if improvements are possible on other, notably flatter, substrates. The improved range resolution will improve sampling of individual in schools and thus strengthen the *in situ* target strength estimates.

3.5.3 *Signal to noise ratio.*

Broadband systems, such as the EK80, allow for increased signal-to-noise ratio, allowing improvements in detection capabilities and effective range. In the case of CPS, this feature is unlikely to provide significant benefits because the schools are relatively shallow (range is not an issue), large and dense (signal to noise ratio is good). Although this is mentioned as a feature of the EK80 in Demer et al. (2017), nothing further is elaborated.

3.5.4 Extension and miniaturization.

The wide-band technology contained in the EK80 can be packaged in a number of different products, some of which are small and allow for autonomous operation (see Table 1.1. in Demer et al. (2017)). The ATM has three wideband autonomous transceiver (WBAT) systems that are battery powered autonomous EK80's which can be deployed on moorings, surface buoys, Remotely Operated Vehicles and small vessels such as AUVs and inflatables. The Team has access to this equipment, and is therefore extremely well equipped to deploy this technology for a variety of applications (see, for example, Item 6). Such instrumentation might substantially improve target strength measurements of *in situ* CPS.

3.6 TOR 6. Effects of vessel avoidance for the upper water column.

Multibeam systems (Simrad EK80s, ME70, MS70, and SX90) are now available on the FSV Reuben Lasker. These represent state-of-the-art instrumentation that will improve overall survey effectiveness and clarify issues related to school behavior around the survey vessel. These systems must be fully utilized to clarify vessel impact factors, and the ATM team should estimate what proportion of biomass is missed with the standard down-looking sonar.

If fish avoid the vessel by moving away from its path during the day, this could lead to bias in acoustic estimates of biomass. Similarly, if differential avoidance by species or size occurs at night, this could bias catches and consequently biomass estimates by species or size. Given the nature of the epi-pelagic species surveyed here, there is a potential for species avoidance of the vessel, and experience tells us that avoidance behavior is species-, life stage-, and situation-dependent (De Robertis and Handegard 2012). For example, avoidance behavior of a species may change during spawning or when predators such as marine mammals are present and actively foraging. The sound profile of the ship can potentially affect avoidance behavior and, in some instances the pressure wave formed by the moving platform may be a factor, especially for larger vessels. The ICES specification for “quiet” vessels is based on herring avoidance at 30-m depth (Mitson 1995). It should not be expected that fish at the surface have the same reaction, even to vessels with sound signatures quieter than the ICES recommendation. It was also stated that avoidance during cruising may be different from avoidance during trawling. Avoidance during trawling might be minimized by running the vessel around a school at the same time as navigating the trawl through the school, a technique that has been used in other surveys.

Several approaches have been used to study avoidance. Using an AUV in front of a quiet vessel, some have found no signs of avoidance (Fernandes et al. 2000a, Fernandes et al. 2000b). Other studies using an instrumented buoy or comparisons among vessels found varying effects (Ona et al. 2007, De Robertis et al. 2008, De Robertis et al. 2010, De Robertis and Wilson 2011, De Robertis et al. 2012), with one example providing evidence of vessel attraction (Røstad et al. 2006); pointing to the complexity of the issue. There are no universal approaches on this topic, but there are a number of methods that could be used to estimate vessel avoidance. These involve technologies attached to the front or side of the vessel (sonar, LIDAR, spectral cameras), using relatively quiet instrumented platforms (buoys, moorings, AUVs, surface drones) or aerial platforms equipped with various optical sensors (spotter planes, aerial drones). Some of these instruments can be operated as part of or in conjunction with the acoustic survey, while others would require dedicated experimental time. Survey vessels with multibeam sonar systems can collect 3-D data under and on the side of the vessel that can be used to estimate distribution statistics, detecting the potential impact of the vessel on fish distribution (Patel and Ona 2009). Experimental approaches require dedicated time, but may offer clearer and independent quantification of vessel effects. Experiments could include use of instrumentation such as Lidar (Gauldie et al. 1996), spectral camera (Borstad et al. 1992), or stationary acoustics, which are capable of measuring distribution patterns or trends in the absence and presence of the survey vessel.

3.7 TOR 7. ATM survey design in areas where the ATM vessel is currently not sampling

The 2017 Council STAR Panel concluded that lack of nearshore coverage by the ATM survey persists. The ATM team should, to the extent possible, describe ways (e.g., cooperative sampling, use of drones, etc.) to achieve the goal of providing an estimate of abundance or correction factor *for those unsurveyed areas. The ATM team should also address the potential effects of reduced sea days, relative to generating estimates of un-sampled areas, as well as relative to the conduct of the overall survey itself. The ATM team should provide information on what a sufficient number of sea days is, and information on tradeoffs between spatial coverage and transects, etc.*

During the 2011 ATM method review for CPS (Agenda Item C.3.a, Attachment 1, April 2011), the topic of survey design in areas not surveyed was reviewed, requests were presented, and recommendations were provided. One request concerned providing an estimate of the area between the eastern ends of transects and the coastline by survey and strata. Using data from the 2008 survey in a region north of Cape Mendocino, an inshore area correction factor was estimated, CPS density was shown to increase towards the inshore ends, and the analysis provided indicated a survey abundance increase of 15% if this inshore higher density was applied to the inshore area outside the normal survey expansion region. The recommendation related to this request suggested examining trends in density from the inshore ends of the survey transects to provide best available information for expansion of estimates to un-surveyed inshore regions.

Results from the 2016-2017 California Department of Fish and Wildlife (CDFW) aerial survey program were presented. This survey aims to produce minimum estimates of anchovy and sardine tonnage or an index of abundance in the nearshore region surveyed out to a maximum of 1.3 nm offshore, along with digital photo documentation of schools. Data from an August 2017 aerial survey off northern California at the same time as ATM surveys offshore show anchovy and sardine biomass inshore of ATM transects. Also shown were data from synoptic survey efforts from 2016-2017 where CDFW conducted aerial transects overlapping the inshore sections of several ATM transects conducted over the same time period. The aerial surveys were inshore of the ATM survey transects, with some overlap with the ATM transects at the extreme inshore end. The results from this effort were inconclusive because binned acoustic data had not yet been compared. Although a thorough analysis has not been completed, few schools were identified by both methods and a preliminary conclusion was that the two survey methods observe different schools. It is possible that the aerial survey observes surface schools in the dead zone of the area ensonified by the acoustic survey, whereas deeper schools observed by the ATM were not visible to aerial observations. It is unclear if further analysis of these data will be useful.

The California Wetfish Producers Association (CWPA) presented qualitative information showing large aggregations of anchovy in nearshore regions off southern California from digital images, photos of fishing boat sonar images, video footage of schools at the surface, and stomach contents of bluefin tuna full of anchovy. The group collected 26 point sets in 2010 where 90 to 100% of sardine schools were captured and weighed, although those data were not shown. The CWPA presentation also included aerial photos and photos of fishermen's electronics documenting large schools of both anchovy and sardine near Pismo Beach, Morro Bay, Monterey and Half Moon Bay. The fishermen from this group expressed their opinion that the biomass of both sardine and anchovy they observed has exceeded NOAA's ATM survey estimates at least since 2015, when fishermen began seeing a significant increase of both species in nearshore waters. Fishermen reported large aggregations north to Cape Mendocino as well as large aggregations of sardines "switching places with anchovy over the thermocline". This industry group requested that ATM survey results be treated as indices rather than absolute abundance estimates for all CPS finfish, largely because of under-represented nearshore aggregations. The majority of commercial catches in California are inside 3 miles or within state waters.

The exclusion of nearshore CPS distribution is a global problem and it is up to managing bodies as well as assessment groups to solve the issue. Data from the targeted nearshore survey off of Oregon and Washington conducted from the F/V *Lisa Marie* in June of 2017 were presented. The nearshore transects were 5 n.mi., and extended inshore from the

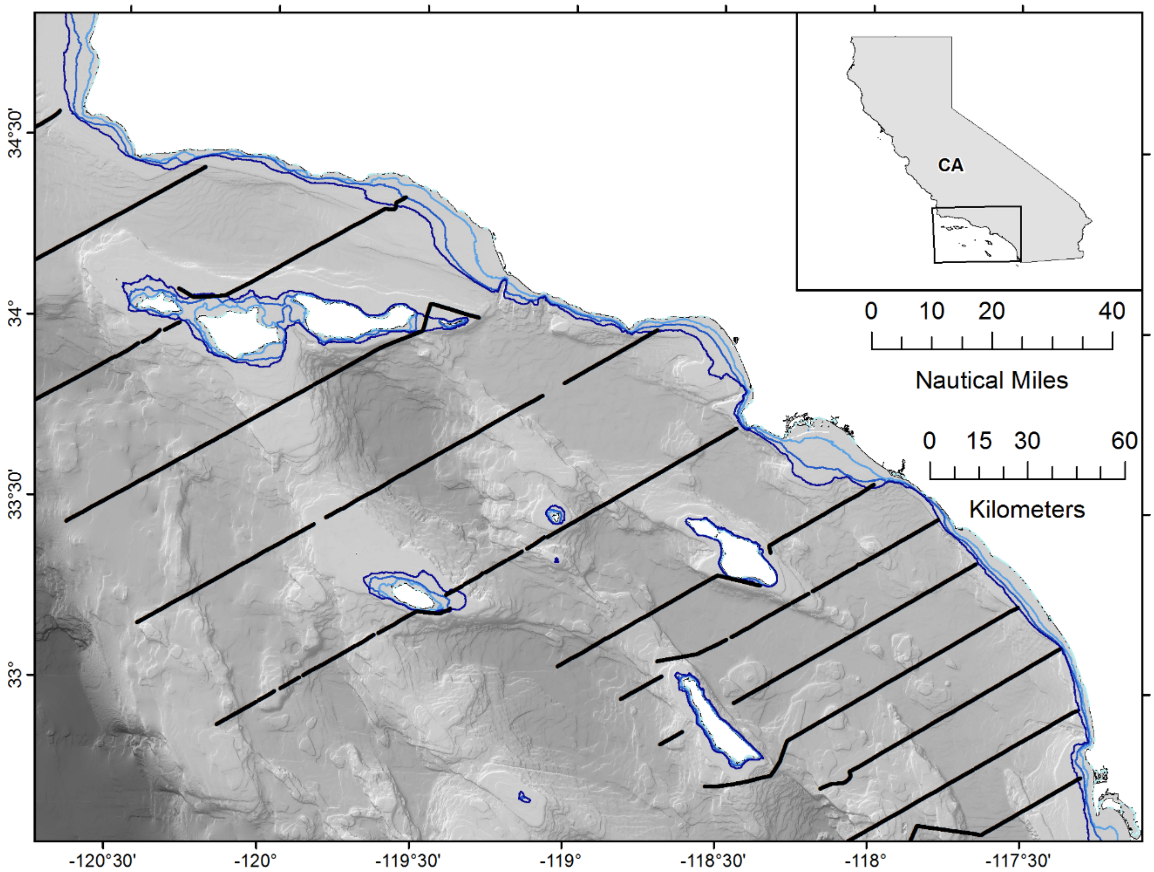

Figure 6 Map of the coast of California showing how close the acoustic survey transects (black lines) approach the coast, and bathymetric contours (blue lines at 20, 40, and 60 m seabed depth, respectively darker).

ATM survey tracks. 3-D visualization of the data did not suggest a higher biomass within the inshore region, although, fishermen noted that the cooperative survey timing in June may have been a little early. Except for the example provided in the 2011 review and work conducted in 2017 in the Pacific Northwest, no further efforts or examination of the acoustic backscatter in the nearshore portion of transects has been performed.

Other data sources and methods were discussed. The CPSMT representative reminded the Panel that fishermen's catch log book data have been digitized, which can provide catch data within the polygons. This information may be useful in examining the relative magnitude of fish available to fishers offshore versus onshore. Saildrones, able to collect acoustic information nearshore or to extend ship transects, may provide an important tool in the future to extend survey regions. A map was provided (Fig. 6) which indicates that the inshore areas that are not sampled by the ATM survey are relatively small. Nevertheless, the nearshore distribution information needs to be included as part of the abundance estimation process. The best way forward is to survey the inshore areas (e.g. with smaller vessels or other platforms). For existing (historical) data there are three options: 1) assume that there is no biomass in unsurveyed area (current status, not recommended); 2) extrapolate biomass into the unsurveyed inshore area using the intertransect data (see below); and 3) have an estimator with trend to estimate the biomass in the unsurveyed inshore area. The latter requires more information (from independent surveys or other sources) to estimate the nature of this trend.

The following text from Simmonds and MacLennan (2005) provides further insight on the latter options: "*There may be practical considerations near the coast that result in a lack of coverage in the shallow water. At first sight, excluding the inter-transect data seems the best choice. However, this implies that the average of the transect values is the most appropriate evidence to* *evaluate the unsurveyed region. This is not the most reasonable solution. The best method would be to extrapolate from the transect data over the unsurveyed region. One way to do this is to map the data by kriging, a geostatistical tool (Rivoirard et al. 2000). Simpler analysis methods might suggest that on a coastal boundary, the inter-transect sections should provide a good estimate by extrapolation. In that case a small section of the inter-transect record, equivalent in length to the distance from the coast, could be used to estimate the unsurveyed region.*"

3.8 TOR 8 ATM data analysis and quantification of uncertainty

Provide the appropriate level of documentation of data analysis and the degree to which the proposed methods describe and quantify the major sources of uncertainty. For each CPS stock under consideration (Pacific sardine, central subpopulation of northern anchovy, northern subpopulation of northern anchovy, Pacific mackerel, and jack mackerel), and to the extent possible, provide sufficient information for the review panel to determine whether the results of ATM survey as reviewed are suitable for: a) inclusion as an index of relative abundance as one of multiple inputs into an integrated stock assessment; b) inclusion as an index of absolute abundance (i.e. survey Q = 1) as one of multiple inputs into an integrated stock assessment; c) use the most recent estimate of absolute biomass to directly inform harvest management without the use of a formal integrated assessment. In addition, the ATM team should describe how echogram backscatter is analyzed to exclude non-CPS backscatter.

The 2011 Panel conclusions regarding the use of the ATM results were: "*Estimates from the acoustic-trawl surveys can be included in the 2011 Pacific sardine stock assessment as 'absolute estimates', contingent on the completion of two tasks. Estimates of absolute abundance for the survey area can be used as estimates of the biomass of jack mackerel in US waters (even though they may not cover all US waters). The estimates of abundance for Pacific mackerel are more uncertain as measures of absolute abundance than for jack mackerel or Pacific sardine. A major concern for this species is that a sizable (currently unknown) fraction of the stock is outside of the survey area. However, the present surveys cannot provide estimates of abundance for the northern anchovy stocks for use in management.*" Substantial new information on abundance and distribution has been obtained since the 2011 Methodology Review. However, to date, ATM results (biomass and age-composition) are only included in the assessment for Pacific sardine, where the biomass is used as a relative index. These results are not used in the model-based assessment of Pacific mackerel and no integrated stock assessments are available for jack mackerel and the two stocks of northern anchovy. The results of the current panel's evaluation of the use of ATM data in assessments and management are summarized in Table 2.

This reviewer does not support the use of the ATM biomass estimates as absolute estimates of biomass in assessments; i.e. where Q, the ratio between the assessed biomass and the ATM survey biomass, is 1. This is because of the uncertainties related to: (a) target strength (determined from relationships for other species in other areas, see Section 4.2); (b) the proportion of the biomass inshore (see Section 4.7), and to the north and south of the survey area (see Section 4.3.2); (c) target species identification (see Section 4.1.7); (d) avoidance (see Section 4.6); (e) migration during the survey (limited discussion); and (f) the surface blind zone (limited discussion). These factors may lead to Q values that may differ substantially from 1. These are multispecies surveys with total CPS backscatter converted to biomass by species. This implies that if Q differs from 1 for any of the species / stocks, the estimates for all other species / stocks will be biased. It was noted that the 2011 Panel supported use of the estimates of Pacific sardine as absolute biomass in assessments. However, it identified several research tasks that needed to be conducted, but little progress has been made on some key issues.

Currently the assessment incorporates a single estimate of biomass for each species from the ATM survey and, to comply with the model ALT formulation, estimates of abundance at length are converted into abundance at age using a pooled age length key. Estimates of abundance at age are a key component of many acoustic survey outputs (Simmonds 2003). A summary of an evaluation of the consistency of the age-determination for Pacific sardine was provided by Emmanis Dorval. There is no formal validation of the ageing process using, for example, tagging studies or otolith microstructure. However, age-reading error has been quantified based on

Table 2. Evaluation of possible use of ATM results in assessments and management. Q denotes the catchability coefficient between the biomass estimate and biomass in the model. This table does not discuss option (c) of TOR 8 given the Panel did not support using the ATM estimates as measures of absolute abundance, but provides options for how biomass estimates from the survey could be used to directly inform management. 1option (a) in the TOR 8; 2option (b) in the TOR 8; 3Only available from 2015; 4Only with MSE. Harvest control rules that use indices of biomass that are not considered absolute have been developed for other fisheries using Management Strategy Evaluation and generally involve examining changes in biomass indices.

Species / stock	**Inclusion in an integrated stock assessment**		**Use of biomass estimates from the survey to directly inform management (following an MSE)[4]**	**Ability to estimate abundance at age**
	Relative abundance (Q estimated)[1]	Absolute abundance (Q=1)[2]		
Pacific Sardine	Yes	No	Yes	Yes, but there are concerns with aging
Pacific mackerel	Yes, summer surveys only	No	Yes, summer only	Yes, but there are concerns with aging
Jack mackerel	Yes, summer surveys only	No	Yes, summer only	In principle, but there is currently no ageing program
Northern sub-population of northern anchovy	Yes, summer surveys only, if inshore area is addressed[3]	No	Yes, summer surveys only, if inshore area is addressed	Yes – no current ageing program that is ready to be used
Central sub-population of northern anchovy	Yes, but only if inshore areas is addressed[3]	No	Yes, but only if inshore areas is addressed	Yes – no current ageing program that is ready to be used

otoliths that have been double read. Ageing of Pacific sardine is conducted by a variety of laboratories, including CICIMAR-INP in Mexico. The same basic method (surface ageing) is used, but there are some differences among laboratories. The precision of the age estimates depends on ager, with ageing error increasing with age.

The Team showed plots of estimated length and age compositions from the summer surveys, where the age compositions were based on an age-length key in which data were pooled over years, as well as the raw age-compositions (no weighting). There appears to be some selectivity (age-0 animals appear to be under-sampled, although they have been caught during trawls, e.g. during 2015). The animals in the size-range 20-24cm are assigned to ages 2-4 and there is no clear evidence that the age-compositions track over time, even though the mode of the size-composition moves to the right as expected.

A key performance metric in the evaluation of an abundance at age estimate from any survey is a plot of internal consistency: this was provided for sardine at the end of the meeting (Fig. 7). One would expect a good survey, allied to an effective age reading program, to have consistent positive correlations between the number of any aged fish one year and the numbers of that same year group the following year. In the case of sardine, the age 0 versus age 1 correlation is indicative of fairly positive relationship ($r2=0.41$, $r=0.64$), but clearly age 1 versus age 2 are very poor, as are 2 versus 3, and 3 versus 4. This may reflect the age reading errors described above, but curiously things settle down again after 4 vs 5 (all subsequent

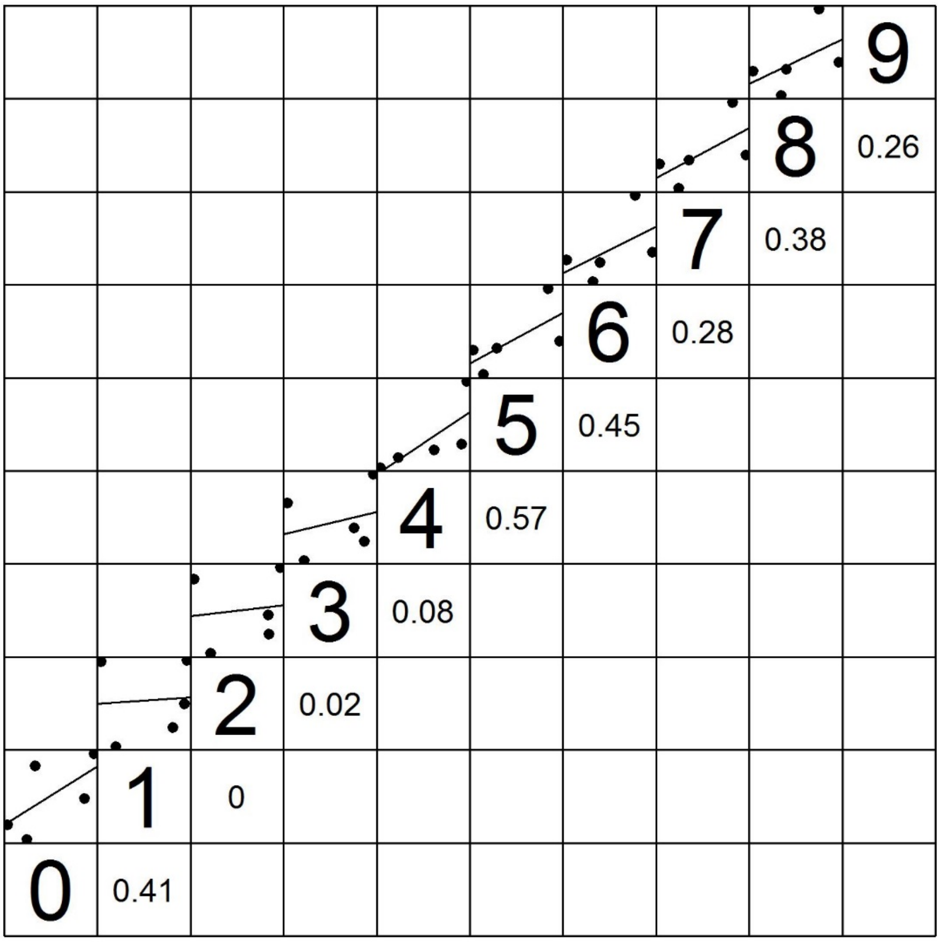

Figure 7 Internal consistency plot (log of numbers at age x in year t against numbers at age x+1 in year t+1) of the acoustic survey for sardine. Above the diagonal the fitted linear regression is shown including the observations (in points) while under the diagonal the r^2 value that is associated with the linear regression is given.

correlation coefficients, r, are greater than 0.5, indicating a moderate positive relationship). If age reading across all ages was so bad these might have expected to be equally bad, so this could also be a sign that the species or size allocations are astray.

Table 2 also lists an evaluation of whether it will be possible to obtain estimates of abundance by age, which could be included in an integrated assessment. This reviewer **strongly recommends** that ageing techniques be improved to allow use of age composition data for the survey in assessments.

It is important to highlight that the survey aims to cover the range of all four stocks. There are periods when jack mackerel and Pacific mackerel appear to be substantially in the survey frame, i.e. summer (Fig. 4). It is likely that a substantial proportion of the biomass of the central subpopulation of northern anchovy is in Mexican waters, particularly in spring, so extending the survey to Mexican waters should be an aim for the future. The ATM and stock assessment analysts should review each survey to decide whether to use the associated estimates in assessments.

The same approach to ageing is taken for Pacific mackerel so this should also be encouraged and developed. The anchovy in the survey have not been aged, although CDFW has started ageing anchovy using surface ageing (whole otoliths), but no agreement on ageing method has been achieved among ageing laboratories. Jack mackerel otoliths have been collected on the survey since 2012, but ageing of this species has not yet commenced.

It is beyond the current Terms of Reference to specify exactly how an ATM biomass index should be used directly in management. Specifying harvest control rules that directly use the ATM biomass index is complicated because the use of the estimates of biomass as absolute in assessments is not recommended. However, harvest control rules that use indices of biomass have been developed for other fisheries using Management Strategy Evaluation and generally involve examining changes in biomass indices, with lesser focus on the absolute value of the biomass index.

4 Recommendations

A long-term strategy is needed to address the various issues discussed in this report. Experimental work to improve the results should be an integral part of conducting the survey. A systematic approach over years starting with the crucial elements will support survey efficiency as well as ecological understanding. It was recognized that some of the field seasons are joint surveys with multiple goals (e.g. 2018 summer survey is a joint CPS and marine mammal and turtle survey), which adds complexity to the operational strategy as well as the methodology.

4.1 High priority

1. Construct a document, ideally a NOAA Technical Memo that lists all of the aspects of the ATM survey, including design and analysis. This document should be updated regularly given new information and decisions.
2. The team should continue to collect target strength data using best available technology with associated relevant biological information to improve current target strength models.
3. Improve ageing of survey and fisheries samples to allow age composition data to be used in assessments.
4. Develop methods to verify that daytime sound scatterers are the species and sizes caught in nighttime trawls; i.e. verify that efficient day time sampling of the acoustic record gives similar results as present night time sampling strategy. Such approaches could include alternative day-time sampling strategies (e.g. curved trawling trajectories) and/or different trawl gear, purse seining by day (either using research or industry vessels), or alternative sampling techniques such as drop cameras.
5. Use net monitoring devices to monitor the trawl during all hauls. The optimal instrumentation is trawl sonar, which monitors the variable geometry of the trawl opening, and the distribution of fish within and outside the trawl opening.
6. Study vertical distribution of fish to determine if CPS in the surface blind-zone represent a stable and/or variable portion of the overall density of significance to the stock assessment. This could be done using vessel sonars or acoustic moorings.
7. Continue to explore and expand independent nearshore survey methods and efforts to estimate the proportions of the populations that may not currently be surveyed by the ATM surveys.
8. Develop extrapolation methods from the existing data that would extend biomass estimates to the coastline, or, alternatively, document why such approaches are not needed for certain areas. Two potential methods include:
    a. extend the existing polygons to the coastline and assume the same mean density; and
    b. use backscatter information collected nearshore (in-between transects) to extrapolate to the coastline.
9. Analyze the effect of the adaptive sampling of the bias of estimates of biomass using simulation or through reanalyzing various subsets of conducted transects.

10. Test efficiency (and suitability) of the existing trawl. This can be done either by comparing acoustic density measures with swept volume densities of the trawl or compare swept volume densities with similar measures from larger trawls and other gear types.
11. The assumption that all CPS finfish spread out at the surface needs to be validated.

4.2 Medium priority

1. Conduct night trawls at different depths in the same area, with the headrope at the surface, at 15 m, and at 30 m depth, for example to compare estimates of species and length composition.
2. Develop methods to extract information from the acoustic data about numbers of schools and their size and spacing. Time series of school statistics, along with other stock characteristics, might become useful in studies of state and interaction dynamics of stocks.
3. Compare the area (e.g. over several transects) and the current cluster approach to convert backscatter data to biomass when sample sizes for a particular species are insufficient.
4. Examining certain school characteristics (e.g. frequency response) by day and by night may be instructive. In the case of "pure" species compositions the latter may also be instructive to detect species-specific characteristics that could be latter applied for acoustic mark classification.
5. Examine the effects of the sample size of fish collected in trawls in terms of uncertainty and variability in indices and size and age compositions, and consider ways to increase sample size. Low sample size to estimate relative abundance by species affects indices more than the sizes collected, but the latter is important for estimating size and age structure. While increasing the length of trawls will help to some extent, other approaches may be more efficient.
6. Explore options to quantify potential fish avoidance under a range of survey conditions. This could involve combining systematic collection of additional data during surveys, as well as dedicated experiments.
7. Examine trends in density from the inshore ends of the survey transects to provide best available information for expansion of estimates to un-surveyed inshore regions.
8. In relation to ageing, evaluate the trade-offs between ageing more animals, but with lesser precision vs. ageing more animals with greater precision. Consider polishing otoliths before reading them.
9. Design and execute field experiments (for example by tracking fish schools with sonars over 24 hrs) to study movements of fish between time of registration and time of sampling, to validate that the current sampling strategy is adequate to reflect the size and species composition of daytime acoustic records.
10. Utilize time series of survey data, including school statistics, to explore if changes in species dominance in the ecosystem causes changes in behavioral characteristics, such as vertical and horizontal distribution dynamics, which ultimately will impact survey efficiency for those species.

4.3 Lower priority

1. Study fish behavior in front of the codend and trawl opening and measure flow inside/outside the trawl using a high frequency Acoustic Doppler Current Profiler (ADCP). This will allow an evaluation of the frequency with which fish escape. Such work is needed because the codend is relatively short with a small mesh liner, and has probably insufficient filtering capacity at 4 knots. This might "block" the entrance of the codend

and lead to an increased flow of water through the meshes in front of the codend where some fish will probably escape.

5 Conclusions

TOR 1. ATM survey documentation. The documentation provided was inadequate to address the TOR. The ATM Team were, however, very forthcoming and diligent in providing further information: a more comprehensive document is in preparation. There is clearly a lot of good practice, particularly in the technical detail associated with the operation of the acoustic instruments. The summer surveys, in particular, seem to contain most of the stocks pretty well. Survey precision is generally poor (CV's > 20%) and is not [inversely] proportional to the effort applied (as it should). The former may be related to the major problem of species identification. The former may be related to the very challenging problem of species identification, which despite significant progress in signal processing, has been difficult to advance from the expert based methods of the 1970's (Mais 1974).

TOR 2. Target strength. The application of target strength to length relationships of other species from other parts of the world is one of the factors which inhibits the estimates of biomass for the ATM surveys being used as absolute values. Specific TS/L relationships should be determined for each stock, and these should also be depth dependent where appropriate (i.e. for physostomes).

TOR 3. Survey design. The sampling frame should be set with reference to the habitat model and results from former surveys, and surveyed in full. Adaptive sampling should not prejudice completing the survey design. Enhanced precision should not be sought at the cost of potentially significant bias, notwithstanding the problems highlighted of poor precision: it is better to be vaguely right than exactly wrong (Read 1906).

TOR 4. Trawl survey design. The time delay between acoustic detection and verification of species composition and size by trawling introduces several significant uncertainties. Chief amongst these is the differential selectivity given the different sizes of the animals concerned, but differential vertical distribution by species or by size may also have an effect. Such a delay is not standard practice, and in most cases, trawling to determine or verify species and size composition takes place as soon as significant echotraces are detected. In conjunction with efforts to improve species identification, methods to improve the biological sampling need to be pursued.

TOR 5. Use of the broadband EK80 echosounder. The EK80 has several interesting features which may enhance the identification of CPS species. The Team is well equipped and very well versed in broadband technology and are in as good a position to exploit it as anyone else in the world. Efforts to develop the systems are encouraged.

TOR 6. Vessel avoidance. Due to the epi-pelagic nature of the ATM target species, avoidance of the survey vessel is possible during the day and likely at night during trawling. Various approaches to investigating avoidance have been adopted throughout the world and the Team have all the necessary equipment and expertise to try one or more of these. They need to demonstrate that avoidance is not a source of bias if their estimates are to be considered absolute.

TOR 7. Unsampled (inshore) areas. There are fish in the inshore areas that are not surveyed by the ATM. There are legitimate concerns from the fishing industry, who fish extensively in these areas, that these fish are not accounted for. However, evidence points to the bias (as per the area) being small. This could be examined retrospectively by extrapolation, but in future, additional efforts should be made to survey inshore areas.

TOR 8. Suitability of ATM results for inclusion in assessments. It is recommended that ATM survey estimates of sardine, Pacific mackerel, Jack mackerel, the Northern sub-population of northern anchovy, and the Central sub-population of northern anchovy be used in an integrated stock assessment as indices of relative abundance. The use of the ATM biomass estimates as absolute estimates of biomass in assessments is not recommended. This is chiefly due to the aforementioned uncertainties related to target strength, target species identification, unsampled areas (inshore & south of the survey area) and potential avoidance. Many of these uncertainties can be addressed with research which the Team is eminently qualified and well equipped to tackle. Improvements in age reading are essential to improve the quality of the estimates at age.

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Appendix 2: A copy of the CIE Statement of Work

Statement of Work

National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

Acoustic Trawl Methodology Review for use in Coastal Pelagic Species Stock Assessments

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).

Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

The three CIE reviewers will serve on a Methodology Review (MR) Panel and will be expected to participate in the review of Acoustic Trawl Method (ATM) currently used to produce biomass estimates for Pacific sardine stock assessments. The Pacific sardine stock is assessed regularly (currently, every 1 year) by Southwest Fisheries Science Center (SWFSC) scientists and the Pacific Fishery Management Council (PFMC) uses the resulting biomass estimate to establish an annual harvest guideline (quota). Currently, ATM biomass estimates for three other coastal pelagic species—Pacific mackerel, northern anchovy (two sub-stocks) and jack mackerel have not been approved for use in PFMC stock assessments (see 2011 ATM Methodology Review). It is the intent of this review to evaluate usefulness of the ATM for these stocks even though portions of the population may be outside the range of the ATM survey either in international waters or in shallow nearshore waters that cannot be sampled by the ATM in its present configuration.

The Methods Review Panel will review current ATM survey results and associated stock assessment documents and any other pertinent acoustic information for coastal pelagic species, work with the ATM Stock Assessment (STAT) team to make necessary revisions, and produce a MR Panel report for use by the PFMC and other interested persons for developing management recommendations for these fisheries. The ATM Terms of Reference (TORs) provides the scope and range of issues that this methodology review should cover is provided in **Appendix 1** for the benefit of both the reviewers and the ATM STAT team. Additionally, the overarching PFMC TORs for the methodology review process for groundfish and coastal pelagic species for 2017 and 2018 are available at: https://www.pcouncil.org//wp-content/uploads/2017/01/Methodology_ToR_CPSGF-2017-18.pdf. The tentative agenda of the Panel review meeting is attached in **Appendix 2.** Each CIE reviewer shall complete the independent peer review according to required format and content as described in **Appendix 3**. Finally, a Panel summary report template is included as **Appendix 4**.

Requirements

Three CIE reviewers shall participate during a panel methodology review meeting in La Jolla, California during 29 January-2 February 2018, and shall conduct impartial and independent peer review accordance with this Statement of Work (SoW) and ToRs herein. The CIE reviewers shall have the expertise as listed in the following descending order of importance:

- The CIE reviewer shall have expertise in the design and application of fisheries underwater acoustic technology to estimate fish abundance for stock assessments.
- The CIE reviewer shall have expertise in the design and execution of fishery-independent surveys for use in stock assessments, preferably with coastal pelagic fishes.
- The CIE reviewer shall have expertise in the application of fish stock assessment methods, particularly, length/age-structured modeling approaches, e.g., 'forward-simulation' models (such as Stock Synthesis, SS) and how fishery-independent surveys can be incorporated into such models.
- The CIE reviewer shall have expertise in the life history strategies and population dynamics of coastal pelagic fishes.
- It is desirable for the CIE reviewer to be familiar with the design and application of aerial surveys to estimate fish abundance for stock assessments.

Tasks for reviewers

Pre-review Background Documents

Review the following background materials and reports prior to the review meeting. Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site to the CIE reviewers all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewers shall read all documents in preparation for the peer review, for example:

- *Recent Acoustic Trawl Method documents and journal articles completed* *since 2010 provided for this review; Stock Assessement Review (STAR) Panel- and* Scientific and Statistical Committee *(SSC)-related documents pertaining to reviews of past ATM survey results and; CIE-related summary reports pertaining to past methodology reviews; and miscellaneous documents, such as ToRs, logistical considerations, etc.*

Panel Review Meeting

Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The meeting will consist of presentations by NOAA and other scientists to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers.

Contract Deliverables - Independent CIE Peer Review Reports

The CIE reviewers shall complete an independent peer review report in accordance with the requirements specified in this SoW and OMB guidelines. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in **Appendix 1**. Each CIE reviewer shall complete the independent peer review according to required format and content as described in **Appendix 3**.

Other Tasks – Contribution to Summary Report

The CIE reviewers may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the ToRs. The CIE reviewers are not required to reach a consensus, and should provide a brief summary of each reviewer's views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs. The Panel summary report template is attached as **Appendix 4.**

Foreign National Security Clearance

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-U.S. citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance

The place of performance shall be at the contractor's facilities, and at the Southwest Fisheries Science Center in La Jolla, California.

Period of Performance

The period of performance shall be from the time of award through April 30, 2017. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
No later than January 15, 2018	Contractor provides the pre-review documents to the reviewers
January 29 - February 2, 2018	The reviewers participate and conduct an independent peer review during the panel methods review meeting
No later than February 23, 2018	Contractor receives draft reports
No later than March 23, 2018	Contractor submits final reports to the Government

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each ToR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $12,000.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:
Dale Sweetnam
8901 La Jolla Shores Drive

La Jolla, CA 92037-1509

Appendix 3: Panel Membership and contact details.

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Appendix 4: Participants **in the ATM review.**

Attendance List – ATM Review
Methodology Review Panel
André Punt, SSC, University of Washington, Chair
Evelyn Brown, SSC, Lummi Indian Nation
Owen Hamel, SSC, NWFSC
Stéphane Gauthier, CIE, Institute of Ocean Sciences, Canada
Paul Fernandes, CIE, University of Aberdeen
Olav Rune Godø, CIE, Institute of Marine Research, Norway

Pacific Fishery Management Council (Council) Representatives
David Crabbe, PFMC
Cyreis Schmitt, Coastal Pelagic Species Management Team (CPSMT)
Diane Pleschner-Steele, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Kerry Griffin, Council Staff

Acoustic-Trawl Method Technical Team*:*
David Demer, SWFSC
Juan Zwolinski, SWFSC
Kevin Stierhoff, SWFSC
Josiah Renfree, SWFSC
David Murfin, SWFSC
Steve Sessions, SWFSC
Dan Palance, SWFSC
Scott Mau, SWFSC

Other:
Josh Lindsay, NMFS WCR
Gerard DiNardo, SWFSC
Emmanis Dorval, SWFSC
Briana Brady, CDFW
Kirk Lynn, CDFW
Kevin Hill, SWFSC
Mike Okoniewski, Pacific Seafood
Steve Marx, Pew Trusts
Bev Macewicz, SWFSC
Alan Sarich, Quinault Indian Nation
Dale Sweetnam, SWFSC
Paul Crone, SWFSC
Roger Hewitt, SWFSC
Ed Weber, SWFSC
Sam McClatchie, SWFSC
James Hilger, SWFSC
Noelle Bowlin, SWFSC
Geoff Shester, Oceana
Kristen Koch, SWFSC
Toby Garfield, SWFSC
Trung Nguyen, CDFW
Phill Dionne, WDFW
Katie Grady, CDFW
Bill Watson, SWFSC

Dan Averbuj, CDFW
Kim Boone, CDFW
Steven Teo, SWFSC
Michael Kinney, SWFSC
Sharon Charter, SWFSC
Magumi Enomoto, Tokyo University
Anne Freire, SWFSC
Megan Human, SWFSC
Luke Thompson, SWFSC

ACOUSTIC TRAWL METHODOLOGY INDEPENDENT PEER REVIEW FOR USE IN COASTAL PELAGIC SPECIES STOCK ASSESSMENTS

A Center for Independent Experts (CIE) independent peer review by Dr. Stéphane Gauthier

March 2018

Contents

1 Executive Summary

A Methodology Review Panel took place in La Jolla (San Diego) from January 29 to February 2, 2018 to address the acoustic-trawl methodology (ATM) developed at the SWFSC to survey coastal pelagic species (CPS). The survey targets Pacific sardine, northern anchovy (central and northern stocks) as well as Pacific and jack mackerel. Biomass estimates from the ATM surveys have been used for the stock assessment of Pacific sardine, but not for the other species. The aim of this review was to evaluate if the ATM survey provides suitable results for use in the stock assessment of all four CPS. The methodology developed by the SWFSC does not follow traditional protocols for acoustic-trawl surveys, where acoustic data collection and verification (so-called ground-truthing by trawl or other sampling tools) are done in close succession. During the ATM survey, the acoustic data collection takes place along transects during the day, while fishing occurs at the surface at night (when all CPS are scattered in the upper water column). Nighttime fishing occurs at directed positions where CPS backscatter was observed during the day. There are underlying assumptions with this survey strategy that need to be addressed. The survey assumes quasi-stationarity of CPS between day-night, and that all targeted species mix and distribute evenly in the surface layer at night. This approach bears the risk of unevenly attributing trawl samples to acoustic backscatter measurements.

Despite these untested assumptions, The ATM survey has produced consistent and trackable results over the years, suggesting that the method is valid. Coverage of the survey is extensive and follows robust analytical procedures. In my opinion, the ATM survey represents the best available source of fishery independent data for the assessment of all four CPS, with some caveats. The underlying assumptions mentioned above should however be properly addressed, along with a list of other potential biases. Some of the elements that require particular attention include potential vessel avoidance of CPS and their distribution within the surface acoustic dead-zone, as well as the distribution of CPS in un-surveyed areas, particularly near-shore. The use of alternative acoustic platforms and survey strategies to address these issues under experimental designs (and potentially as future complementary approaches) are crucial for the expansion and evolution of the time-series.

The ATM team has invested much time and efforts into these surveys, and are encouraged to address some of these pressing issues, as well as continuing to expand research into fundamental acoustic topics, including target strength (TS) measurements, improved classification techniques, and the application of broadband technologies. From an assessment perspective, ageing issues should be addressed to provide better information on stock structure and cohorts. A more complete list of issues, along with suggested potential solutions, can be found in this review.

2 Background

The Southwest Fisheries Science Centre (SWFSC) has developed an acoustic trawl methodology (ATM) to survey coastal pelagic species (CPS) along the West Coast. The main species targeted by this survey are Pacific sardine, two sub-stocks of northern anchovy, as well as Pacific and jack mackerel. The ATM survey was first reviewed in 2011, and following the panel's recommendations the survey estimates for Pacific sardine were incorporated in stock assessments (for surveys in 2006, 2008, and 2010 onward). The ATM surveys were also reviewed in 2014 as part of the Center for Independent Experts (CIE) Sardine-Hake (SaKe) Methodology Review. The 2011 review document was available as background material for this review (see appendix 1), and progress on recommendations from the 2011 review are provided in appendix 4. As of 2017, the ATM biomass estimates for other species than Pacific sardine have not been approved for stock assessments.

A Methodology Review Panel took place at the SWFSC from January 29 to February 2, 2018 (appendix 2). The Terms of Reference (TOR) for this review were detailed and included a long list of considerations (the TOR are included in the CIE Statement of Work in appendix 3, as well as within this review). In this document, I will address each TOR in its own sub-section (with the TOR specifications in italics), give my perspective on the issues and how they were addressed, as well as provide recommendations for moving forward. The methodology review panel also made several requests to the ATM team during the review, and those, along with the ATM team responses, will be listed in appendix 5 (with associated tables and figures). For each specific aspect of the TOR I will provide recommendations by stating the issues and listing potential solutions. I will follow this format throughout most the document. I will close the review with a final list of conclusions and recommendations, as well as my perspectives on the NMFS review process.

The acoustic-trawl methodology employed by the SWFSC is quite unique and does not follow conventional acoustic-trawl survey protocols. Typically acoustic data collection and sampling for species identification (or verification) are done in parallel (McClatchie *et al*. 2000, Simmonds and MacLennan, 2005). When schools or shoals of fish are encountered along acoustic transects, they are sampled (e.g. using trawls) succinctly to verify species and biological characteristics, after which the acoustic survey continues. Sampling next occurs when new echo-signs are encountered, or when there is significant change in prevailing schools or shoal structures being monitored. Each school or aggregation of fish encountered is thus assigned to a species or species group based on their acoustic characteristics and the information provided by the associated targeted sampling. This type of survey design has also been employed for CPS, such as sardines and anchovies in other parts of the world (e.g. Barange and Hampton 1997). However, the survey designed by the SWFSC uses a completely different approach. In this case, acoustic transects are carried out during daytime, and trawling occurs at the surface at night, when fish are scattered in the upper water column. The trawls are not targeted on acoustic signs at night, but typically directed at positions where significant backscatters (i.e. schools) of CPS were observed during the day. The catch species composition is then used to partition the total backscatter of what was classified as CPS along the daytime transects (using a clustering approach). There are a lot of underlying assumptions behind this survey strategy, many of which remain untested. Nevertheless, the team managed to produce quite consistent results over the years, suggesting that their method is valid. Some of these aspects will be discussed in greater details throughout this document.

3 Reviewers' role and review activities

The Methodology Review panel was chaired by André Punt, Scientific and Statistical Committee (SSC) member, affiliated with the University of Washington. There were two other members of the SSC, Evelyn Brown (Lummi Nation) and Owen Hamel (Northwest Fisheries Science Center), as well as three reviewers from the Center for Independent Experts: myself, Paul Fernandes (University of Aberdeen) and Olav Rune Godø (Institute of Marine Research, Norway). There were also two Pacific Fishery Management Council advisers: Cyreis Schmitt (Coastal Pelagic Species Management Team), and Diane Pleschner-Steele (Coastal Pelagic Species Advisory Subpanel). This meeting was open to the public, and a complete list of participation and attendance at the Methodology Review is given in appendix 2, including the complete list of the acoustic-trawl method technical team members.

The review agenda followed the list of topics identified in the Terms of Reference (TOR). At the start of the review, there were presentations to give an overview of CPS on the West Coast and the management system currently in place, as well as a summary presentation by the acoustic-trawl methodology (ATM) technical team. For each TOR, the panel identified a list of requests (if any) directed at the ATM team, and the team provided their responses. Some of the request responses could not be produced within the short time frame of the review, and in these cases the clarifications were made verbally to the panel, or by providing demonstrations or examples. Accordingly, discussions on each TOR often focused on clarifications of the methods used and the steps currently involved in their implementation, and were carried out until panel members were satisfied with the level of information provided and reached consensus on recommendations for moving forward. Panel members were assigned rapporteur duties for different sections of the review to help gather all necessary information for the summary report. I was tasked with taking notes on the sections on target strength of CPS from the California Current (TOR 2), effects of vessel avoidance for the upper water column (TOR 6), and ATM survey design in areas where the ATM vessel is currently not sampling (TOR 7). Towards the end of the meeting, the recommendations and conclusions from each TOR were reviewed. There were no major disagreements between the panel and the ATM team, or among panel members.

4 Summary of findings for each TOR

4.1 ATM survey documentation.

Document the ATM survey design, protocols (sampling, data filtering, etc.), and estimation methods, including the following:

a. delineate the survey area (sampling frame);
b. specify the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification);
c. specify the rule for stopping a transect (offshore boundary by species);
d. specify the rules for conducting trawls to determine species composition;
e. specify the rules for adaptive sampling (including the stopping rule); and
f. specify the rules for post-stratification, and in particular how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account densities should be considered (PFMC 2017).
g. Describe how echogram backscatter is analyzed to exclude non-CPS backscatter.

The ATM team has been productive and put out several reports and publications over the past few years documenting the survey methodology and survey results. The details of the methodology were, however, often scattered across several documents, and some aspects were altogether missing. Some of the methods and the steps necessary to understand them were often unclear or missing details to fully evaluate them. This led to a long list of request made to the team to clarify some of these issues. The presentations from the ATM and their answers to the panel requests clarified a lot of the issues that the documentation made difficult to assess.

Issue: Methodological aspects of the ATM surveys were scattered or insufficient.
Potential solution: Create a technical document that contains all relevant information to carry the ATM surveys. The document should be reviewed by other staff that have sufficient knowledge in the field, but that have not participated in the surveys or their analyses. Having reproducible methods and results is a key element for the success of this time-series.

a. delineate the survey area (sampling frame).

The ATM team demonstrated that several elements come into play to delineate the survey area, and that it depends on the primary objective (targeted species) by the specific survey. In general, the team does a good job at delineating the survey and trying to keep bias constant; however, shifts in priorities and objectives is generally not a good thing for the stability of a time-series.

Issue: Shifting priorities or species focus may impact the survey area and its delineation.
Potential solution: The ATM team should attempt to standardize the survey objectives and deliverables to ensure shift in priorities do not impact the consistency of the time-series.

b. specify the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification).

The acoustic survey area is stratified in area of high and low density transects (according to the spacing between transects), based on expectations of CPS densities and survey objectives. There's also adaptive sampling, where transects are added (above and below the area) if high densities of CPS are encountered in a low density transect area. I don't have issues with this approach, since there will always be a compromise based on total area to survey and allocated vessel time. I believe this challenge is addressed adequately by the ATM team.

c. specify the rule for stopping a transect (offshore boundary by species).
The ATM team indicated that transects continue until there is no evidence or further signs of CPS. It was, however, unclear if there is a hard rule (fixed distance with no CPS schools observed) or if it was governed by additional parameters or guiding principles.

Issue: Not enough information was provided on stopping rules for offshore sections of transect.
Potential solution: Document the stopping rules and guiding principles in a document outlining all methodologies for the ATM surveys.

d. specify the rules for conducting trawls to determine species composition.
This is a critical aspect of the survey, and it was not documented appropriately. The trawls occur at night-time, and in general at pre-determined locations where CPS were observed acoustically during the preceding day. Other information is also taken into consideration (egg presence based on CUFES samples, industry catches). The vessel also needs to return to the start of transect for the next morning, limiting the time available for sampling. Trawls are also clustered (grouped) for the assignment of backscatter to species, and this clustering was not described in details prior to the review.

Issue: Strategies to select trawl locations were not fully documented and provided. There is a risk that some areas may be subject to (trawl) under-sampling due to survey time constraints.
Potential solutions: Document the guiding principles that dictate where trawl samples occur in a complete methodology document, and how trawl clusters are assigned. Consider prioritizing sampling over time constraints (being back at waypoint in the morning) when distribution of CPS backscatter during the day warrant more sampling trawl stations. Inter-cluster variance should also be documented and reported.

e. specify the rules for adaptive sampling (including the stopping rule).
As explained for item b), there's adaptive sampling when the survey encounter areas of CPS backscatter in areas of low-density transects. Transects are added above and below the CPS area to create a strata of equal transect density (i.e. with equal inter-transect distance). There is validity in doing this, and again a compromise to make such decision based on what is observed and available survey time. I believe this is dealt with adequately.

f. specify the rules for post-stratification, and in particular how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account densities should be considered (PFMC 2017).
Several discussions on post-stratification took place during the review, and this seems to be a point of contention in science in general. The idea behind post-stratification is to take into

account area where the transect distribution is constant (equal inter-transect distance), and identify area where assumption of stationarity is valid. The ATM team computed autocorrelation (for which there is no evidence) and compared variance from the estimates by defining strata based on observed density or simply based on simplified systematic sampling. The estimate of variance was found to be similar. I am satisfied that the team has explored the post-stratification strategy, and that it provides the best biomass estimates for this type of survey design, outweighing any small negative bias the technique may have on variance estimation.

g. Describe how echogram backscatter is analyzed to exclude non-CPS backscatter.
Again, the documents provided for the review did not paint the whole picture on this process, and several clarifications were requested from the ATM team. The backscatter associated to CPS is analyzed based on certain characteristics such as their frequency response. Backscatter retained as potentially CPS (i.e. fish backscatter) are then processed based on their position within the water column (and the depth of the mixed layer) and association with the bottom (to exclude demersal or semi-pelagic species). This latter process is done using the R language (visual plots) rather than in Echoview. Attempts have been made to automate the classification, but it remains somewhat subjective. The approach can also lead to important biases, for example in instances where CPS species adopt demersal-like behaviors (which is often the case for species like Pacific herring).

Issue: Lack of documentation to document CPS classification methods.
Potential solution: Draft a detailed methodological document, which illustrates clearly the methods, algorithms, and tools used to isolate CPS backscatter.

Issue: The technique utilized to exclude non-CPS backscatter may lead to bias in case where CPS species have demersal type behaviors (such as Pacific herring).
Potential solutions: In the absence of daytime validation tools (such as effective daytime midwater trawling or optical sampling using dropped cameras or ROV) consider the composition of species in nighttime catches to also guide the daytime CPS classification (or exclusion of non-CPS), and go through these in an iterative process. This information can also be used to estimate uncertainty in biomass estimates (e.g. more uncertainties in areas where Pacific herring are present).

4.2 Estimated target strengths of CPS from the California Current.

Current ATM estimates rely on target strengths of similar CPS species identified in other studies around the world. The ability to measure target strengths of live fish collected from the survey area can now be conducted at the Technology Tank at the SWFSC, La Jolla, CA. Target strengths of CPS from the California Current should be provided for the review meeting.

Target strength (TS) is an important aspect of any acoustic survey, as it is used to convert measured quantities (acoustic backscatter) into fish biomass. The ATM surveys currently use TS to length models published by Barange et al. (1996), where values for pilchard are applied to sardine and Pacific herring and values from Horse mackerel applied to both mackerel species. Values for northern anchovies are based on another species of anchovy (Kang et al. 2009; Japanese anchovy) and adjusted with a fixed depth-dependence term (Zwolinski *et al*. 2017). The choice of these models is warranted in the absence of other data, but they are far from ideal. Usually, a deviation from true TS is not necessarily a huge problem for acoustic surveys, especially if the acoustic estimates are used as relative indices of biomass (the change in TS simply shifts the time-series up or down, as long as the TS-L model slope remains constant). However, in this case, changes in TS for one species affect the biomass of all other species in the assemblage, and can lead to important biases, since the total CPS backscatter is partitioned based on trawl sample species composition. It is then a bit concerning that the TS values for one species (anchovy) are corrected for depth dependence, while other similar species (e.g. sardine and Pacific herring) are not. TS is also highly variable and depend on many other factors, including feeding and spawning conditions (Ona 1990, Thomas *et al*. 2002), and such factors should be taken in considerations down the line. This is why it is crucial to continue working on improved TS estimation of all CPS and associated species. This is especially true for this particular type of survey, where total backscatter is partitioned to species and not individually assigned. To date, only the TS of northern anchovy has been corroborated with limited empirical data.

Issue: Target strength models used are from different species.
Potential solutions: 1) Collect TS information on all CPS species: this should include *in situ* measurement associated with catches, *ex situ* experiments in cages using acclimated live fish, as well as TS modelling. 2) Consider using alternative TS models that are currently available, for example for Pacific herring (Thomas *et al*. 2002; Gauthier and Horne, 2004), and examine the potential effect this would have on CPS partitioning.

Issue: Depth dependence of TS for physostomous species (Pacific Sardine, northern anchovy, Pacific herring) may have a significant impact on biomass calculations.
Potential solutions: Depth-dependence of TS has been documented for some species such as Atlantic herring (e.g. Ona 2003). The ATM team should aim to conduct research on CPS species to determine if depth dependence of TS is an important factor. Although difficult to implement, experiments should be conducted to address this particular issue, along with data collected as above (*in situ*, *ex situ*, and based on modelling). Available data or information on potential depth-dependence TS should be used in sensitivity analyses to consider the amplitude of the potential biases this may have on resulting biomass calculations and species apportionment.

4.3 Trawl survey design protocols for using a CPS preferred habitat model to determine adaptive sampling areas.

In relation to a preferred habitat model for Pacific sardine, as well as other coastal pelagic species:

a. *To the extent possible, address the fact that low population size likely affects the probability of acoustic detection in a non-linear way. This could create a negatively biased estimate at low population levels and potentially a non-detection threshold below which the stock size cannot be reliably assessed.*
b. *Evaluate the costs and benefits of targeting sampling effort based on the preferred habitat*

model for Pacific sardine in terms of biomass estimates for Pacific sardine and for other CPS stocks.

Using a preferred habitat model to determine a survey area can definitely increase sampling efficiency by focusing the effort in areas that are more likely to harbor large biomass, but it can also lead to issues for other species surveyed that have a difference in preferred habitat. This comes down to the priorities of the survey, and my earlier comment on switching objectives, which is not advisable for the consistency of time-series.

a. *To the extent possible, address the fact that low population size likely affects the probability of acoustic detection in a non-linear way. This could create a negatively biased estimate at low population levels and potentially a non-detection threshold below which the stock size cannot be reliably assessed.*

This issue depends on several factors. If a species change its behavior or distributional patterns at low population size it can certainly bias the survey results, particularly if a species change its distribution (or the relative proportion of its population) in un-surveyed or less surveyed areas, for example in offshore waters, or nearshore shallow waters. In such cases, the uncertainties or potential biases in the survey design would be unbalanced, and the population would be practically undetectable below a certain size (when those behavioral shifts take place). The same could be said for species that change their schooling behavior at low population size by scattering through the water column instead of forming dense schools, or by joining another (preferred) species and forming multi-species schools. In such cases this could affect their probability of being caught in trawl unevenly and the ensuing calculation of their contribution to total backscatter. The potential for having a non-detection threshold below which the stock size cannot be reliably assessed certainly exist, and more investigation into this issue should be carried out.

Issue: Change in distribution and/or schooling behavior may happen at low population size, biasing the survey results negatively.

Potential solutions: Address potential shortcomings in assessing distribution of species in currently un-surveyed areas. Using available survey data, explore potential trends in distribution and distributional shifts, particularly for species with decreasing biomass. Look at aggregation characteristics through time, for example by looking a school metrics (including school dimensions, densities) and school statistics (encountering rate, clustering, nearest-neighbors) to track potential changes. This type of exercise would certainly be more informative when daytime schools are identified to species, but this may still lead to useful results in the absence of such data.

b. *Evaluate the costs and benefits of targeting sampling effort based on the preferred habitat model for Pacific sardine in terms of biomass estimates for Pacific sardine and for other CPS stocks.*

Like I have mentioned earlier, focusing survey efforts based on a preferred habitat model for one species may not be ideal for the consistency of a time-series that seek to address multiple species (which could have differential preferred habitat). Based on the allotted survey time available, the ATM reserve some transects to be allocated when significant CPS backscatter values are encountered. The effects of allocating higher-density transects in area of lower sampling efforts could be investigated by using a subset of them in simulations.

Issue: Survey effort is allocated unequally amongst species as it is based on the preferred habitat model of only one species.
Potential solution: If simulation studies suggest that adaptive sampling is valid (as opposed to randomly allocated areas of higher density transects), consider running the survey at a coarser scale (i.e. at 20 nmi inter-transect distance) and keep more time for the allocation of adaptive transects (with shorter inter-transect distance) when high values of CPS backscatter are encountered. Shifting this priority may allow coverage of a larger area, and focusing the effort on prevailing observations.

4.4 Effects of trawl survey design.

In relation to trawl survey design, the following should be considered and addressed:

a. *The consequences of the time delay and difference in diurnal period of the acoustic surveys versus trawling need to be understood; validation or additional research is critical to ensure that the fish caught in the trawls from the night time scattering layer share the same species, age and size structure as the fish ensonified in the daytime clusters. To the extent possible, the ATM team should conduct paired trawls during daytime acoustic sampling, to validate (or to generate a correction factor for) nighttime species composition trawls.*
b. *Consider suitable sample sizes of CPS in the ATM survey. The ability of a single vessel following fixed transects along the entire northern sardine subpopulation region over a single period to sufficiently observe and sample a highly mobile schooling species that exhibits high variability in recruitment, migratory patterns and timing, school structure, and depth distribution, remains a core challenge. The relatively small sample size of sardine for biological analysis remains a concern related to acoustic expansions, population model estimates, and projection forecasts that depend on age composition and size-at-age information. Conduct an analysis of effect of fish sample size on the uncertainty in the ATM biomass estimates and model outputs. Use this information to re-evaluate and revise the sampling strategy for size and age data that includes target sample sizes for strata. (see Pacific Sardine STAR Panel Meeting Report, PFMC, April 2017).*
c. *Test the efficiency (relative catchability) and selectivity of the trawl among and within species by comparing samples from the same area taken with the survey trawl and purse seine.*
d. *Estimate trawl selectivity by species. Cameras attached to the trawl in front of the cod end have been developed and used extensively since the 2013 surveys to observe and quantify fish behavior and Marine Mammal Excluder Device (MMED) performance. The ATM team should report on findings from the camera research and quantify the selectivity of the trawl. If unquantifiable, describe state-of-the-art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl, and how the data would be incorporated into the biomass estimation process.*

Trawling is an integral part of the survey. Trawl samples are used to assess species composition and obtain their size distribution to partition the acoustic backscatter. There are a lot of uncertainties and potential biases with the current survey design (acoustic sampling during the day, trawl sampling during the night), and I consider it imperative that some of the core assumptions behind the survey strategy be validated. It seems that some of this effort has been ignored or pushed back in favor of doing more surveys, but I fear that this approach may come with a high risk that should not be ignored.

a. *The consequences of the time delay and difference in diurnal period of the acoustic surveys versus trawling need to be understood; validation or additional research is critical to ensure that the fish caught in the trawls from the night time scattering layer share the same species, age and size structure as the fish ensonified in the daytime clusters. To the extent possible, the ATM team should conduct paired trawls during daytime acoustic sampling, to validate (or to generate a correction factor for) nighttime species composition trawls.*

No results on this topic have been presented by the ATM team. This is a critical assumption with the current survey design: that what is observed acoustically during the day is caught at the same location at the surface at night. It assumes equal stationarity among all the CPS species, and also that all these species distribute themselves equally in the top 15 m of the epipelagic layer at night. This assumption of stationarity must hold true to all species – if some of them are inheritably more mobile in their daytime vs nighttime distribution this may lead to bias. The approach also assumes that the distribution of fish in the surface layer at night will be mixed (all species scattered equally) and that there will be no schooling by species, as this would bias the night-time sampling. These assumptions must be thoroughly tested. In the examination of nighttime echograms during the review, some night schools were visible.

Issue: Distribution of CPS during daytime and nighttime may differ.
Potential solutions: There are several things that can be done to validate the assumption of stationarity. 1) Small areas could be surveyed using sonars over an extended period of time (e.g. 24 hours) to follow CPS schools and assess the distance they travel. 2) Other sampling gear (e.g. industry purse seines, larger pelagic trawls) could be used to target CPS schools during the day and sample the same area at night. These catches should be compared to those obtained using the current trawl used during night sampling. 3) Repeated trawls should be performed over the same general areas multiple times at night to assess variability in catch size and composition, and to ensure potential nighttime aggregation structures are not biasing the samples. 4) Trawl samples should also be performed over the same area at different depth at night (with the head rope at 15, 30 m), to test the assumption that all species distribute equally in the upper 15 m of the epipelagic (again addressing potential bias due to behavioral structures).

b. *Consider suitable sample sizes of CPS in the ATM survey. The ability of a single vessel following fixed transects along the entire northern sardine subpopulation region over a single period to sufficiently observe and sample a highly mobile schooling species that exhibits high variability in recruitment, migratory patterns and timing, school structure, and depth distribution, remains a core challenge. The relatively small sample size of sardine for biological analysis remains a concern related to acoustic expansions,* *population model estimates, and projection forecasts that depend on age composition and size-at-age information. Conduct an analysis of effect of fish sample size on the uncertainty in the ATM biomass estimates and model outputs. Use this information to re-evaluate and revise the sampling strategy for size and age data that includes target sample sizes for strata. (see Pacific Sardine STAR Panel Meeting Report, PFMC, April 2017).*

No results on this topic have been presented by the ATM team. Large (or adequate) sample size, especially at low population size, is a challenge to obtain. Analyses on the effect of low sample size should be conducted, and methods to ensure proper sample size collection should be explored.

Issue: Low sample size based on trawl catches.
Potential solutions: In the absence of better suitable gear to target daytime schools (such as larger trawls or purse seine, which would undeniably provide larger sample size), options to increase sample size would be to 1) increase the total tow duration and length, b) target nighttime trawls on areas of higher backscatter (a quick overview of nighttime echogram suggested that the presence of schools and areas of high backscatter do exist at night), and 3) consider pooling together samples from neighboring areas where there are no significant differences.

c. *Test the efficiency (relative catchability) and selectivity of the trawl among and within species by comparing samples from the same area taken with the survey trawl and purse seine.*

No results on this topic have been presented by the ATM team. I feel this is particularly important since so much rely on these trawl sample catches. The ATM team provided a diagram of the trawl used upon the panel's request (see appendix 6). The trawl appears to have good filtering capacity (tapering mesh sizes), but it is rather small. CPS species are highly mobile and fast swimmers, and trawling is not expected to be the best way to sample such species.

Issue: Trawl catchability and selectivity is not the same for all CPS species.
Potential solutions: In addition to the mentioned comparisons with purse seines, comparisons with different trawl gears should be made. A larger midwater trawl that can be towed at ~4 knots may be a more suitable option than the current trawl used. Larger midwater trawls have been used by the NWFSC and the AFSC. DFO Pacific Region has been using a Cantrawl 250 midwater net (with a typical mouth opening of 20 m height x 50 m width) and has been successful at capturing CPS during both daytime and nighttime trawling.

d. *Estimate trawl selectivity by species. Cameras attached to the trawl in front of the cod end have been developed and used extensively since the 2013 surveys to observe and quantify fish behavior and Marine Mammal Excluder Device (MMED) performance. The ATM team should report on findings from the camera research and quantify the selectivity of the trawl. If unquantifiable, describe state-of-the-art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl, and how the data would be incorporated into the biomass estimation process.*

No results on this topic have been presented by the ATM team. An important aspect of trawling is also to have proper net mensuration and monitoring tools. This is typically provided by a trawl sonar, such as Wesmar or Simrad FS70 systems operated from a third (conductive) wire. Such system not only ensure proper mouth opening, but also indicate if there is significant avoidance by monitoring fish diving under the footrope of the net.

Issue: Trawl performance may not be ideal and trawl selectivity may be biased.
Potential solutions: Use of proper monitoring trawl systems may help assess trawl performance. Trawl sonars may not perform well while the net is at the surface, but could function if the net is lowered by 10-20 m. As mentioned trawl cameras may be useful in assessing species selectivity, as long as the cameras do not interfere with the net dynamic (or by affecting avoidance and/or attraction behaviors of fish by using artificial lighting).

4.5 Effects of upgrading from the Simrad EK60 to EK80.

After 10+ years of service, Simrad discontinued the EK60 series and introduced the EK80 series of transceivers and control software, which shifts from narrow-bandwidth transmit pulses to wide-bandwidth pulses using existing hull-mounted transducers. The ATM team should review the initial outcomes of the EK80 and provide information on the proposed benefits including 1) fish echoes captured from more complete band of frequencies allowing improvement in species identification, 2) increased range resolution allowing detection of fish close to the bottom and individual fish within an aggregation, 3) increased signal-to-noise ratio allowing improvements in detection capabilities and effective range, 4) extension and miniaturization of wide-band technology allowing autonomous deployment on smaller vessels (i.e., rigid hull inflatables which could sample nearshore areas, surface buoys, deep moorings, and ROVs). This item should not take up a large amount of time during the review, and should focus on summarizing the conclusions of workshops on comparing outputs from the EK60 and EK80 echosounders.

The lead of the ATM team, Dr. David Demer, is the primary author on one of the most comprehensive report to date on this topic, based on a workshop that was held at the SWFSC (Demer et al. 2017). In as such, the ATM team is at the leading edge of this technology. The Simrad EK60 has long been the standard for fisheries acoustics surveys, and it is now being replaced with the EK80. Even though the EK80 has the capacity for broadband (where each transceiver transmits over a range of frequencies as opposed to a central frequency, i.e. narrow band), most of the surveys primarily uses them in narrow band configuration (also referred to as continuous wave transmit). A lot of the comparisons that have been made up to now between the EK60 and EK80 have been to ensure that both systems can produce comparable results in narrow band modes. The workshop indicated that both systems provide equivalent measures, and this has been confirmed by further comparisons at the Institute of Marine Research in Norway (Gavin Macaulay, personal communication). More work needs to be done on the broadband side, but results so far indicate great potential for future applications. As listed in the TOR, those include **1) improved species identification** due to complete band of frequencies. Although most of the systems used are in the high frequency range (higher than 20 kHz) and that most fish are in the geometric scattering range (i.e. their swim bladders are large scattering objects compared to the wavelength), this may still yield some interesting results and should be pursued further. Scattering properties are complex, and having broadband capacities will certainly help expand classification based on acoustic properties. **2)**

Increased range resolution. I think this is where the EK80 will make a big difference. In a broadband system, the range resolution is a function of the bandwidth (the larger the bandwidth, the greater the resolution). This will allow for the detection of individual fish targets in dense schools and at greater range. Near the seabed the expected benefits of increase in range resolution may not be fully realized, because of side-lobe issues, or until those are resolved in signal processing. The increase in range resolution will also enable increased measurements of target strength (TS) *in situ*, and may also provide valuable information for species identification or classification, as it will enable the study of behavior at smaller scales, down to individual level. **3) Improvement in signal to noise ratio**. The increase in signal to noise ratio that offer the EK80 may not be a direct benefit for CPS species, which are typically found in shallow waters with a strong signal. However, in an ecosystem context, the increase in signal to noise ratio will have the benefit of detecting and measuring more components of the ecosystem, such as plankton and scattering layers. It also means that the effective range for higher frequencies will increase, enhancing the benefits and capabilities for multi-frequency comparisons. **4) Extension and miniaturization.** There has been a lot of progress in that field over the past few years. With their expertise and equipment inventory, the ATM team is well positioned to take advantage of such technologies. A lot of the recommendations made by the review panel and within this report would greatly benefit from deployment of this broadband technology in autonomous and/or small platforms, such as surface and sub-surface moorings, Autonomous Underwater Vehicles (AUVs), Remotely Operated Vehicles (ROVs), gliders, and drones.

4.6 Effects of vessel avoidance for the upper water column.

Multibeam systems (Simrad EK80s, ME70, MS70, and SX90) are now available on the FSV Reuben Lasker. These represent state-of-the-art instrumentation that will improve overall survey effectiveness and clarify issues related to school behavior around the survey vessel. These systems must be fully utilized to clarify vessel impact factors, and the ATM team should estimate what proportion of biomass is missed with the standard down-looking sonar.

Although the ATM team has collected multibeam sonar data as part of some of their surveys, those data have yet to be analyzed. Vessel avoidance is a complex and contentious issue (De Robertis and Handergard 2012). For several species, results using instrumented surface buoys or comparisons of vessels with different noise signatures have led to ambiguous if not sometimes contradictory results (Ona et al. 2007; De Robertis et al., 2008, 2010; De Robertis and Wilson, 2010, 2011), while in other cases, for example in a study using a relatively silent Autonomous Operated Vehicle (AUV), no avoidance to a (quiet) vessel was detected (Fernandes et al. 2000). But surely, if any species are susceptible to avoidance, CPS residing in the upper water column are of particular concern. Sonars (such as the one listed in the TOR above that are available on the FSV Reuben Lasker) are ideal tools to study schooling fish behaviour (Gerlotto *et al*. 1999, 2006, Patel and Ona 2009). These tools can be used to detect and monitor schools around the survey vessel during transects, and thus generate distribution statistics and probability functions for encountering surface schools (even those that are too close to the surface to be detected by the vessel EK80 systems). Sonars could also be used in different experimental setups (e.g. with the vessel remaining stationary) while observing school reactions to another incoming vessel. Those are only a few options, and there are numerous approaches and tools that can be used to get a better understanding of CPS potential avoidance during the survey. Even in the absence of remote avoidance, the survey is not taking into account the upper part of the water column (the so-called surface acoustic dead-zone, or blind-zone, which is anywhere between 10-15 m depending on conditions). CPS schools are surely encountered in these surface waters during the day (anecdotal accounts from many at-sea personnel, including this reviewer), and these fish will not stay in the path of the vessel if it's about to hit them! Unless all schools encountered at the surface dive directly under the vessel and are detected by the echosounder, there will be a bias because of this un-surveyed volume.

Issue: Fish avoidance to the vessel may occur and bias the survey results.
Potential solutions: Collect and analyze data from multibeam sonars during survey operations to compile and evaluate statistics of CPS schools at different distances and depths from the vessel. Design experiments using autonomous or semi-autonomous platforms, such as surface or sub-surface buoys, with different acoustic configurations (downward, upward, or laterally directed beams) to observe CPS over extended periods of time with and without the presence of the research vessel. Use Autonomous Underwater Vehicles (AUVs), Remotely Operated Vehicles (ROVs), or similar instrumented platform(s) to detect CPS schools in the upper water column (using for example upward or lateral acoustic beams). Ideally, experiments should also be designed with catcher vessels to sample fish, to determine if there are any species-specific patterns of avoidance (if avoidance is detected).

Issue: The survey does not account for the volume of water not sampled by the ATM surveys (near-surface acoustic dead-zone).
Potential solutions: Use similar methods as described above, particularly the use of sonars, and upward looking autonomous or semi-autonomous instruments, to detect CPS in the upper water column. Collected over long periods of time (over several transects and areas) this information can be compiled and analyzed to estimate a correction factor for implementation in the survey.

4.7 ATM survey design in areas where the ATM vessel is currently not sampling.

The 2017 Council STAR Panel concluded that lack of nearshore coverage by the ATM survey persists. The ATM team should, to the extent possible, describe ways (e.g., cooperative sampling, use of drones, etc.) to achieve the goal of providing an estimate of abundance or correction factor for those unsurveyed areas.

The ATM team should also address the potential effects of reduced sea days, relative to generating estimates of un-sampled areas, as well as relative to the conduct of the overall survey itself. The ATM team should provide information on what a sufficient number of sea days is, and information on tradeoffs between spatial coverage and transects, etc.

The limitations of a large research vessel such as the FSV Reuben Lasker to sample near-shore is a concern, especially for the survey of species such as northern anchovy, which have been sometimes observed in large numbers in shallow areas that would not be accessible to such a vessel. The ATM team presented results from experiments conducted with a smaller vessel, the F/V Lisa Marie, in June of 2017. Nearshore transects of 5 nmi were extended inshore from the ATM survey tracks. Only a small fraction of the total backscatter was in the inshore sections, but the team agreed that this was done in an area/time with low CPS abundance. I would also argue that this may not be the best approach to survey inshore areas, since vessel avoidance may become more significant in shallow waters. Aerial surveys are another option, and some data on this was presented during the review (California Department of Fish and Wildlife aerial survey program). Aerial surveys are subject to their own limitations, and will not detect deeper schools. Attempts to corroborate overlapping aerial and acoustic surveys have proved unsuccessful so far, probably because of their mismatch in detectable volumes (acoustic from a vessel can't sample near surface, optics can't see deeper areas). Another potential type of survey includes LIDAR (Churnside et al. 2011). This type of survey also has the advantage of covering large areas in little time (from a plane) but will be less dependent of visibility conditions. However, the LIDAR will have limited depth penetration, so will be subject to similar caveats. In my opinion, alternative platforms (such as AUVs and saildrones) offer the best way to acoustically sample un-surveyed areas. Parallel sampling using a smaller platform (small vessel) could be used to validate such surveys in the future. Although complicated by shallow bottom depth, sonars can also offer insights on the distribution of schools in nearshore environments.

Issue: An unknown proportion of the CPS is distributed in nearshore areas not accessible by the current ATM survey.
Potential solutions: Use alternative tools and platforms to survey the nearshore areas, giving particular attention to the risk of increased fish avoidance in shallow waters. Where and when possible, coordinate parallel surveys using various platforms for cross-validation (for example by combining types of aerial surveys with types of acoustic surveys). Another example would be to use a saildrone or AUV along one set of inshore tracks, and have a smaller vessel along parallel set tracks, to compare their outputs. These types of experiments could be used to design a robust and simplified survey for inshore areas, which could operate in conjunction with the ATM survey. Data from these experiments will also be invaluable to validate approaches used to extrapolate historical survey data within nearshore areas. One simple solution for this would be to use the data from the ATM survey collected in-between transects waypoints in the nearshore area to (virtually) extent transects by their distance to the coastline (Simmonds and MacLennan, 2005). Information collected from experiments in the nearshore survey areas will help the team determine whether or not this approach is valid, or if alternate extrapolation techniques would be warranted. This obviously needs to be addressed on a species-by-species level.

Issue: Survey allocation of time (and potential future reduction) constrains the ability to adequately sample all areas equally.
Potential solutions: The allocation of survey effort is certainly a challenge, and has been facing reduction in many parts of the world due to various (often economical) reasons. This is why I believe that in the short term the team should really invest in developing comprehensive nearshore experiments, that both address CPS distribution issues, but also cross-validation of techniques and testing of underlying assumptions. This way, economical

and robust survey approaches (whether it be using autonomous or alternative platforms), can be developed to operate in conjunction with the ATM survey, without using additional time. Survey efforts from the ATM survey could also be reduced (for example by running the survey at a coarser grid with 20 nmi spacing throughout) and complemented using alternative platforms (for example saildrones) in areas where higher density effort is warranted.

4.8 ATM data analysis and quantification of uncertainty.

Provide the appropriate level of documentation of data analysis and the degree to which the proposed methods describe and quantify the major sources of uncertainty. For each CPS stock under consideration (Pacific sardine, central subpopulation of northern anchovy, northern subpopulation of northern anchovy, Pacific mackerel, and jack mackerel), and to the extent possible, provide sufficient information for the review panel to determine whether the results of ATM survey as reviewed are suitable for:

a. inclusion as an index of relative abundance as one of multiple inputs into an integrated stock assessment;
b. inclusion as an index of absolute abundance (i.e. survey Q = 1) as one of multiple inputs into an integrated stock assessment;
c. use the most recent estimate of absolute biomass to directly inform harvest management without the use of a formal integrated assessment.

In addition, the ATM team should describe how echogram backscatter is analyzed to exclude non-CPS backscatter.

Data analyses were summarized and reviewed during the meeting. How echogram backscatter is analysed to exclude non-CPS backscatter was discussed in section 4.1. and will not be reiterated here. There are many sources of uncertainty in the ATM survey. The major sources of uncertainty were discussed throughout this document and include uncertainty in the accuracy of the method to partition backscatter to species, target strength of all CPS, vessel avoidance biases, and proportion of the population in un-surveyed areas. These sources of uncertainty are not quantified and reported in survey variance. In the review of the data and methodologies, it was also apparent that there were ageing issues for these species. Ageing techniques needs to be improved and validated for the assessment of these stocks, and to be able to better evaluate consistencies in the surveys by tracking age cohorts. Based on this information my recommendation for each aspect is as follow:

a. inclusion as an index of relative abundance as one of multiple inputs into an integrated stock assessment;

Yes, for all four species but with some caveats: For the two sub-populations of northern anchovy, the inshore area currently not surveyed needs to be addressed. For the two mackerel species, only the summer surveys should be considered, and each survey should be examined to determine if coverage was adequate.

b. inclusion as an index of absolute abundance (i.e. survey Q = 1) as one of multiple inputs *into an integrated stock assessment;*

No, absolute abundance should not be used for any of these stocks/species. The sources of uncertainties are too large and numerous. The fact that an estimated Q is very close to 1 may be spurious, but should not be taken at face value.

c. *use the most recent estimate of absolute biomass to directly inform harvest management without the use of a formal integrated assessment.*

No, at least not within the current formulation: Change in relative abundance (or change in the index of abundance) can be used within a Management Strategy Evaluation (MSE) to define harvest rules and directly inform harvest management, but this needs to be taken into general context (for example by looking at the index change over time). This could be applied to all 4 species, with the caveats stated above. Using only the most recent absolute biomass to directly inform harvest management would not be recommended.

5 Conclusions and recommendations

This review covered a wide range of aspects and issues related to the Acoustic Trawl Methodology (ATM) for coastal pelagic species. The ATM team has put an impressive amount of effort into the development and implementation of this survey, and their labour is to be commended. As I have stated through this review document, there are important underlying assumptions that need to be tested and validated, and some distinct improvements required into certain aspects of the methodology. Nevertheless, the ATM survey represents the best available science and source of fishery independent data for the assessment of Pacific sardine, northern anchovy, as well as Pacific and jack mackerel populations. However, particular issues, such as the inshore proportion of the population for stocks of northern anchovies, as well as overall coverage of the population for mackerel species, need to be taken under serious consideration.

This acoustic-trawl survey is unconventional, in that the acoustic data collection and biological sampling occur at different times (acoustic transects during the day, trawl sampling at night). The basic underlying assumption of stationarity or quasi-stationarity for a dynamic fish assemblage is problematic, and this is where the method received the most criticism. I would strongly urge the ATM team to dedicate research time to address this underlying assumption (ideally using several approaches) to alleviate this concern. In a climate where reduction in allotted sea-time is increasing, pressure to obtain survey results often trumps the ability to implement experimental designs and validation, but in the long run it is the quality of the time-series that is at stake.

Potential vessel avoidance (and the presence of CPS in the surface acoustic dead-zone), as well as proportion of populations in un-surveyed areas, particularly inshore shallow waters, need to be better understood. These issues would strongly benefit from the use of alternative acoustic platforms (e.g. smaller crafts, drones, AUVs) under experimental designs, and ultimately as tools to join and complement the ATM surveys. The team is also encouraged to continue research and investigation on fundamental acoustic issues, including target strength (TS) measurements, classification based on school metrics and other information, as well as advancement in application of broadband technologies. From an assessment perspective, ageing issues should be addressed to provide better information on stock structure and cohorts.

6 NMFS review process

The NMFS review process was effective and constructive. A good dynamic was established within the review panel and with the technical team, who was very collaborative. The review documents did not contain all the information necessary for a complete and thorough review, so a lot of the review process was focused on clarifications and expansion of methodological details. In my opinion, a review of this magnitude (with a long list of elements to cover) would benefit from a preliminary assessment. For example, the reviewers could be provided the chance to comment or request additional material or information 2-3 weeks prior to the review meeting. With the current format, many of the requests from the panel were too onerous for the team to provide in the short time frame available. Having a two-step approach could improve the process.

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Appendix 1 – Bibliography of materials provided for review

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Appendix 2 – CIE Statement of Work

Statement of Work
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

Acoustic Trawl Methodology Review for use in Coastal Pelagic Species Stock Assessments

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards.
(http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).
Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

The three CIE reviewers will serve on a Methodology Review (MR) Panel and will be expected to participate in the review of Acoustic Trawl Method (ATM) currently used to produce biomass estimates for Pacific sardine stock assessments. The Pacific sardine stock is assessed regularly (currently, every 1 year) by Southwest Fisheries Science Center (SWFSC) scientists and the Pacific Fishery Management Council (PFMC) uses the resulting biomass estimate to establish an annual harvest guideline (quota). Currently, ATM biomass estimates for three other coastal pelagic species—Pacific mackerel, northern anchovy (two sub-stocks) and jack mackerel have not been approved for use in PFMC stock assessments (see 2011 ATM Methodology Review). It is the intent of this review to evaluate usefulness of the ATM for these stocks even though portions of the population may be outside the range of the ATM survey either in international waters or in shallow nearshore waters that cannot be sampled by the ATM in its present configuration.

The Methods Review Panel will review current ATM survey results and associated stock assessment documents and any other pertinent acoustic information for coastal pelagic species, work with the ATM Stock Assessment (STAT) team to make necessary revisions, and produce a MR Panel report for use by the PFMC and other interested persons for developing management recommendations for these fisheries. The ATM Terms of Reference (ToRs) provides the scope and range of issues that this methodology review should cover is provided in **Appendix 1** for the benefit of both the reviewers and the ATM STAT team. Additionally, the overarching PFMC ToRs for the methodology review process for groundfish and coastal pelagic species for 2017 and 2018 are available at: https://www.pcouncil.org//wp-content/uploads/2017/01/Methodology_ToR_CPSGF-2017-18.pdf. The tentative agenda of the Panel review meeting is attached in **Appendix 2**. Each CIE reviewer shall complete the independent peer review according to required format and content as described in **Appendix 3**. Finally, a Panel summary report template is included as **Appendix 4**.

Requirements
Three CIE reviewers shall participate during a panel methodology review meeting in La Jolla, California during 29 January-2 February 2018, and shall conduct impartial and independent peer review accordance with this Statement of Work (SoW) and ToRs herein. The CIE reviewers shall have the expertise as listed in the following descending order of importance:

- The CIE reviewer shall have expertise in the design and application of fisheries underwater acoustic technology to estimate fish abundance for stock assessments.
- The CIE reviewer shall have expertise in the design and execution of fishery-independent surveys for use in stock assessments, preferably with coastal pelagic fishes.
- The CIE reviewer shall have expertise in the application of fish stock assessment methods, particularly, length/age-structured modeling approaches, e.g., 'forward-simulation' models (such as Stock Synthesis, SS) and how fishery-independent surveys can be incorporated into such models.
- The CIE reviewer shall have expertise in the life history strategies and population dynamics of coastal pelagic fishes.
- It is desirable for the CIE reviewer to be familiar with the design and application of aerial surveys to estimate fish abundance for stock assessments.

Tasks for reviewers

Pre-review Background Documents

Review the following background materials and reports prior to the review meeting. Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site to the CIE reviewers all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewers shall read all documents in preparation for the peer review, for example:

- *Recent Acoustic Trawl Method documents and journal articles completed since 2010 provided for this review; Stock Assessement Review (STAR) Panel- and* Scientific and Statistical Committee *(SSC)-related documents pertaining to reviews of past ATM survey results and; CIE-related summary reports pertaining to past methodology reviews; and miscellaneous documents, such as ToRs, logistical considerations, etc.*

Panel Review Meeting

Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The meeting will consist of presentations by NOAA and other scientists to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers.

Contract Deliverables - Independent CIE Peer Review Reports

The CIE reviewers shall complete an independent peer review report in accordance with the requirements specified in this SoW and OMB guidelines. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in **Appendix 1**. Each CIE reviewer shall complete the independent peer review according to required format and content as described in **Appendix 3**.

Other Tasks – Contribution to Summary Report

The CIE reviewers may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the ToRs. The CIE reviewers are not required to reach a consensus, and should provide a brief summary of each reviewer's views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs. The Panel summary report template is attached as **Appendix 4**.

Foreign National Security Clearance

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-U.S. citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the

Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance

The place of performance shall be at the contractor's facilities, and at the Southwest Fisheries Science Center in La Jolla, California.

Period of Performance

The period of performance shall be from the time of award through April 30, 2017. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
No later than January 15, 2018	Contractor provides the pre-review documents to the reviewers
January 29 - February 2, 2018	The reviewers participate and conduct an independent peer review during the panel methods review meeting
No later than February 23, 2018	Contractor receives draft reports
No later than March 23, 2018	Contractor submits final reports to the Government

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each ToR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $12,000.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:

Dale Sweetnam
8901 La Jolla Shores Drive
La Jolla, CA 92037-1509

SOW Appendix 1: Terms of Reference for Peer Review

Background

The National Marine Fisheries Service (NMFS) conducts scientific surveys to assess abundance estimates and trends in fish populations, for use in fisheries management decisions and other purposes. NMFS and the Pacific Fishery Management Council (Council) are jointly responsible for ensuring that survey design, protocols, and abundance estimates represent best scientific information available, and work cooperatively to ensure independent peer review of scientific products related to fisheries management. To this end, the Council developed a Terms of Reference (ToRs) to guide review of methodologies that are used in fisheries management decisions. These guiding ToRs are available at: https://www.pcouncil.org//wp-content/uploads/2017/01/Methodology_ToR_CPSGF-2017-18.pdf . In advance of such methodology reviews, NMFS and the Council will work with the Council's Scientific and Statistical Committee (SSC) to designate a methodology review panel, which includes a Chair, at least one member independent of the Council (often designated by the Center for Independent Experts [CIE]), and at least two additional members.

For each methodology review, a meeting-specific set of ToRs is produced to provide guidance on key questions to be addressed, additional background on any prior methodology reviews, and to describe expectations relative to the review. This document is the meeting-specific set of ToRs that will be used to guide the January 29 – February 2, 2018 methodology review of the Southwest Fisheries Science Center's (SWFSC) acoustic-trawl survey methodology (ATM) for coastal pelagic species (CPS) off the United States West Coast.

Scope

The Methodology Review (MR) Panel will conduct the review of the ATM currently used to produce biomass estimates for Pacific sardine stock assessments. The Pacific sardine stock is assessed annually by SWFSC scientists, and the Council uses the resulting biomass estimates to establish an annual harvest guideline and other harvest specifications. The ATM biomass estimates for three other coastal pelagic species (Pacific mackerel, two sub-stocks of northern anchovy, and jack mackerel) have not been approved for use in Council stock assessments (PFMC 2011). It is the intent of this review to also evaluate the usefulness of the ATM for these stocks even though portions of their populations are outside the range of the ATM survey, either in international waters or in shallow nearshore waters that the ATM survey cannot sample in its present configuration.

The MR Panel will review current ATM survey methodology and results in the context of recent stock assessment documents and any other pertinent acoustic information for CPS, work with the ATM team to make recommendations for any necessary modifications, and will produce a Panel report for consideration by the PFMC and for use by the SWFSC. That report will describe in detail the technical merits and deficiencies, recommendations for remedies, unresolved problems and major uncertainties, and recommendations for future research and data collection. This set of ATM ToRs provide the scope and range of issues that this methodology review should cover.

Background Information from Previous ATM Methodology Reviews

The Council first approved the use of the ATM at its April 2011 meeting after the ATM underwent a methodology review in February 2011, with the following conclusion:

> *"Overall, the Panel is satisfied that the design of the acoustic-trawl surveys, as well as the methods of data collection and analysis are adequate for the provision of advice on the abundance of Pacific sardine, jack mackerel, and Pacific mackerel, subject to caveats, in particular related to the survey areas and distributions of the stocks at the times of the surveys. The Panel concluded that estimates from the acoustic-trawl surveys could be included in the 2011 Pacific sardine stock assessment as 'absolute estimates', contingent on the completion of two tasks. Estimates of absolute abundance for the survey area can be used as estimates of the biomass of jack mackerel in U.S. waters (even though they may not cover all U.S. waters). The estimates of abundance for Pacific mackerel are more uncertain as measures of absolute abundance than for jack mackerel or Pacific sardine. A major concern for this species is that a sizable (currently unknown) fraction of the stock is outside of the survey area. However, the present surveys cannot provide estimates of abundance for the northern anchovy stocks for use in management. The Panel notes that the acoustic-trawl method potentially could be applied to survey CPS currently in low abundances, e.g., northern anchovy and Pacific herring, but the sampling design would need to differ from that used in the present surveys." (see Acoustic-Trawl Survey Method for Coastal Pelagic Species: Report of Methodology Review Panel Meeting Agenda Item C.3.a Attachment 1)*

Based on this conclusion, the ATM survey estimates of Pacific sardine abundance collected in 2006, 2008, 2010 and 2011 were incorporated into the 2011 Pacific sardine stock assessment. Since then, ATM abundance estimates collected both during spring and summer continue to be used as an integral part of the sardine assessment, including 2017. However, questions continue to be raised as to how well the ATM survey adequately samples the Pacific sardine population as well as other CPS (Pacific mackerel, jack mackerel and northern anchovy), mainly due to the unknown fraction of the population outside the survey area, either in the upper water column above the sensors or in spatial extent (e.g., Mexican waters, or nearshore or offshore areas where National Oceanic & Atmospheric Association (NOAA) vessels are unable to sample). (See Pacific Sardine STAR Panel Meeting Report, PFMC, April 2017).

Although the original MR Panel concluded that vessel avoidance had been studied using appropriate methods and there was no evidence of substantial avoidance effects, they did recommend further study, including that "long-term research should use more advanced instrumentation and methods for studying potential vessel effects and avoidance. In particular, the Panel suggests that a vessel by vessel study following the model of the

Bering Sea comparative studies be conducted" (from NMFS 2011).

The ATM survey was also reviewed as part of the 2014 CIE Sardine-Hake (SaKe) Methodology Review, the report of which was presented to the Council as a joint report from the Northwest Fisheries Science Center (NWFSC) and the SWFSC at the June 2014 meeting (Agenda Item F.1.c Fisheries Science Center Report). All of these summary reports as well as reports from individual CIE reviewers identified above will be provided as background material for the review.

Items to be addressed during this 2018 Methodology Review

These methodology ToRs require a draft methodology report to be made available at least two weeks prior to the review meeting. That report should address the following items, for consideration during the review meeting, and will follow the general procedures laid out by the PFMC (See https://www.pcouncil.org//wp-content/uploads/2017/01/Methodology_ToR_CPSGF-2017-18.pdf).

1. **ATM Survey Documentation**

   Document the ATM survey design, protocols (sampling, data filtering, etc.), and estimation methods, including the following:
   a. delineate the survey area (sampling frame);
   b. specify the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification);
   c. specify the rule for stopping a transect (offshore boundary by species);
   d. specify the rules for conducting trawls to determine species composition;
   e. specify the rules for adaptive sampling (including the stopping rule); and
   f. specify the rules for post-stratification, and in particular, how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account densities should be considered (PFMC 2017).
   g. Describe how echogram backscatter is analyzed to exclude non-CPS backscatter.

2. **Estimated Target Strengths of CPS from the California Current**

   Current ATM estimates rely on target strengths of similar CPS species identified in other studies around the world. The ability to measure target strengths of live fish collected from the survey area can now be conducted at the Technology Tank at the SWFSC, La Jolla, CA. Target strengths of CPS from the California Current should be provided for the review meeting.

3. **Trawl Survey Design Protocols for Using a CPS Preferred Habitat Model to Determine Adaptive Sampling Areas**

   In relation to a preferred habitat model for Pacific sardine, as well as other coastal pelagic species:
   a. To the extent possible, address the fact that low population size likely affects the probability of acoustic detection in a non-linear way. This could create a negatively

biased estimate at low population levels and potentially a non-detection threshold below which the stock size cannot be reliably assessed.

b. Evaluate the costs and benefits of targeting sampling effort based on the preferred habitat model for Pacific sardine in terms of biomass estimates for Pacific sardine and for other CPS stocks.

4. **Effects of Trawl Survey Design**

   In relation to trawl survey design, the following should be considered and addressed:

   a. The consequences of the time delay and difference in diurnal period of the acoustic surveys versus trawling need to be understood; validation or additional research is critical to ensure that the fish caught in the trawls from the nighttime scattering layer share the same species, age and size structure as the fish ensonified in the daytime clusters. To the extent possible, the ATM team should conduct paired trawls during daytime acoustic sampling, to validate (to generate a correction factor) nighttime species composition trawls.
   b. Consider suitable sample sizes of CPS in the ATM survey. The ability of a single vessel following fixed transects along the entire northern sardine subpopulation region over a single period to sufficiently observe and sample a highly mobile schooling species that exhibits high variability in recruitment, migratory patterns and timing, school structure, and depth distribution, remains a core challenge. The relatively small sample size of sardine for biological analysis remains a concern related to acoustic expansions, population model estimates, and projection forecasts that depend on age composition and size-at-age information. Conduct an analysis of effect of fish sample size on the uncertainty in the ATM biomass estimates and model outputs. Use this information to re-evaluate and revise the sampling strategy for size and age data that includes target sample sizes for strata. (See Pacific Sardine STAR Panel Meeting Report, PFMC, April 2017).
   c. Test the efficiency and selectivity of the trawl by comparing samples from the same area taken with the survey trawl and purse seine.
   d. Estimate trawl selectivity. Cameras attached to the trawl in front of the cod end have been developed and used extensively since the 2013 surveys to observe and quantify fish behavior and Marine Mammal Excluder Device (MMED) performance. The ATM team should report on findings from the camera research and quantify the selectivity of the trawl. If unquantifiable, describe state-of-the-art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl, and how the data would be incorporated into the biomass estimation process.

5. **Effects of Upgrading from the Simrad EK60 to EK80**

   After 10+ years of service, Simrad discontinued the EK60 series and introduced the EK80 series of transceivers and control software, which shifts from narrow-bandwidth transmit pulses to wide-bandwidth pulses using existing hull-mounted transducers. The ATM team should review the initial outcomes of the EK80 and provide information on the proposed benefits including: 1) fish echoes captured from more complete band of frequencies allowing improvement in species identification; 2) increased range resolution allowing detection of fish close to the bottom and individual fish within an aggregation; 3) increased signal-to-noise ratio allowing improvements in detection capabilities and effective range; and 4) extension and miniaturization of wide-band technology allowing autonomous deployment on smaller vessels (i.e., rigid hull inflatables which could sample nearshore areas, surface buoys, deep moorings, and ROVs). This item should not take up a large amount of time during the review, and should focus on summarizing the conclusions of workshops on comparing outputs from the EK60 and EK80 echosounders.

6. **Effects of Vessel Avoidance for the Upper Water Column**
   Multibeam systems (Simrad EK80s, ME70, MS70, and SX90) are now available on the FSV Reuben Lasker. These represent state-of-the-art instrumentation that will improve overall survey effectiveness and clarify issues related to school behavior around the survey vessel. These systems must be fully utilized to clarify vessel impact factors, and the ATM team should estimate what proportion of biomass is missed with the standard down-looking sonar.

7. **ATM Survey Design in Areas Where the ATM Vessel is Currently Not Sampling**
   The 2017 Council STAR Panel concluded that lack of nearshore coverage by the ATM survey persists. The ATM team should, to the extent possible, describe ways (e.g., cooperative sampling, use of drones, etc.) to achieve the goal of providing an estimate of abundance or correction factor for those unsurveyed areas.

   The ATM team should also address the potential effects of reduced sea days, relative to generating estimates of un-sampled areas, as well as relative to the conduct of the overall survey itself. The ATM team should provide information on what a sufficient number of sea days is, and information on tradeoffs between spatial coverage and transects, etc.

8. **ATM Data Analysis and Quantification of Uncertainty**
   Provide the appropriate level of documentation of data analysis and the degree to which the proposed methods describe and quantify the major sources of uncertainty. For each CPS stock under consideration (Pacific sardine, central subpopulation of northern anchovy, northern subpopulation of northern anchovy, Pacific mackerel, and jack mackerel), and to the extent possible, provide sufficient information for the review panel to determine whether the results of ATM survey as reviewed are suitable for:
   a. inclusion as an index of relative abundance as one of multiple inputs into an integrated stock assessment;
   b. inclusion as an index of absolute abundance (i.e. survey Q = 1) as one of multiple inputs into an integrated stock assessment; and
   c. use the most recent estimate of absolute biomass to directly inform harvest management without the use of a formal integrated assessment.

In addition, the ATM team should describe how echogram backscatter is analyzed to exclude non-CPS backscatter.

References

PFMC 2011. Report of the 2011 ATM Methodology Review, April 2011 Agenda Item C.3.a, Attachment 1.

PFMC 2017. Report of the 2017 Pacific Sardine STAR Panel Meeting, April 2017 Agenda Item G.5.a., STAR Panel Report.

SOW Appendix 2: Draft Agenda - ATM Methodology Review Panel

Monday, 29 January

13h00	Call to Order and Administrative Matters	
	Introductions	Sweetnam/Griffin
	Facilities, e-mail, network, etc.	Sweetnam
	Work plan and Terms of Reference	Sweetnam/Griffin
	Report Outline and Appointment of Rapporteurs	SSC Chair/CIE Cha
14h00	Pacific Sardine survey-based Acoustic Trawl Methods Procedures	ATM STAT
15h00	Break	
15h30	Pacific Sardine ATM results incorporated into Stock Assessment	STAR STAT
16h30	Public comments and general issues	
17h00	Adjourn	

Tuesday, 30 January

08h30	Pacific Sardine survey-based Acoustic Trawl Methods Procedures	ATM STAT
10h00	Break	
10h30	Pacific Sardine survey-based Acoustic Trawl Methods Procedures	ATM STAT
12h00	Lunch	
13h30	Target Strengths of California Current CPS	ATM STAT
14h30	Additional ATM Survey presentations	ATM STAT
15h00	Break	
15h30	Panel discussion and analysis requests	Panel
16h30	Public comments and general issues	
17h00	Adjourn	

Wednesday, 31 January

08h00	Additional ATM Survey presentations	ATM STAT
09h00	ATM STAT Team responses to analysis requests	ATM STAT
10h30	Break	
11h00.	Additional ATM Survey presentations	ATM STAT
12h30	Lunch	
13h30	Report drafting	Panel
15h00	Break	
15h30	ATM STAT Team Responses	ATM STAT
16h00	Discussion and MR Panel requests	
16h30	Public comments and general issues	
17h00	Adjourn	

Thursday, 1 February

08h00.	Assessment Team Responses	ATM STAT
10h30	Break	
11h00.	Discussion and STAR Panel requests	Panel
12h30	Lunch	
13h30	Report drafting	Panel
15h00	Break	
15h30	Assessment Team Responses	ATM STAT
16h00	Discussion and MR Panel requests	
16h30	Public comments and general issues	
17h00	Adjourn	

Friday, 2 February	
08h00. Assessment Team Responses	ATM STAT
10h30 Break	
11h00. Discussion and MR Panel requests	Panel
12h30 Lunch	
13h30 Finalize MR Panel Report	Panel
15h00 Break	
15h30 Finalize MR Panel Report	Panel
16h30 Public comments and general issues	

SOW Appendix 3: Format and Contents of CIE Independent Peer Review Report

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.

   a. Reviewers must describe in their own words the review activities completed during the panel review meeting, including a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each TOR even if these were consistent with those of other panelists, but especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.

3. The report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of this Statement of Work
   Appendix 3: Panel membership or other pertinent information from the panel review meeting.

SOW Appendix 4: ATM Methodology Review Panel Summary Report

1. Names and affiliations of Methodology Review Panel members

2. List of analyses requested by the Methodology Review Panel, the rationale for each request, and a brief summary the STAT responses to each request

3. Comments on the technical merits and/or deficiencies in the assessment and recommendations for remedies

4. Explanation of areas of disagreement regarding Methodology Review Panel recommendations
   - among Methodology Review Panel members (including concerns raised by the CPSMT and the Coastal Pelagic Advisory Subpanel (CPSAS) representatives)
   - between the Methodology Review Panel and STAT Team

5. Unresolved problems and major uncertainties, e.g., any special issues that complicate scientific assessment, questions about the best model scenario, etc.

6. Management, data or fishery issues raised by the public and CPSMT and CPSAS representatives during the Methodology Review Panel

7. Prioritized recommendations for future research and data collection

Appendix 3 – Panel membership

Methodology Review Panel

André Punt, Scientific and Statistical Committee (SSC), University of Washington, Chair
Evelyn Brown, SSC, Lummi Indian Nation
Owen Hamel, SSC, Northwest Fisheries Science Center
Stéphane Gauthier, Center for Independent Experts (CIE), Canada
Paul Fernandes, CIE, University of Aberdeen
Olav Rune Godo, CIE, Institute of Marine Research, Norway

Pacific Fishery Management Council (Council) Advisers:

Cyreis Schmitt, Coastal Pelagic Species Management Team (CPSMT)
Diane Pleschner-Steele, Coastal Pelagic Species Advisory Subpanel (CPSAS)

Acoustic-Trawl Method Technical Team:

David Demer, SWFSC
Juan Zwolinski, SWFSC
Kevin Stierhoff, SWFSC
Josiah Renfree, SWFSC
David Murfin, SWFSC
Steve Sessions, SWFSC
Dan Palance, SWFSC
Scott Mau, SWFSC

Attendance:

Kerry Griffin, Council Staff
David Crabbe, PFMC
Josh Lindsay, NMFS WCR
Gerard DiNardo, SWFSC
Emmanis Dorval, SWFSC
Briana Brady, CDFW
Kirk Lynn, CPSMT/CDFW
Kevin Hill, SWFSC
Mike Okoniewski, CPSAS/Pacific Seafood
Steve Marx, Pew Trusts
Bev Macewicz, SWFSC
Alan Sarich, CPSMT/Quinault Indian Nation
Dale Sweetnam, SWFSC
Paul Crone, SWFSC
Roger Hewitt, SWFSC
Ed Weber, SWFSC
Sam McClatchie, SWFSC
James Hilger, SWFSC
Noelle Bowlin, SWFSC
Geoff Shester, Oceana
Kristen Koch, SWFSC
Toby Garfield, SWFSC
Trung Nguyen, CDFW
Phill Dionne, WDFW
Katie Grady, CDFW
Bill Watson, SWFSC
Dan Averbuj, CDFW
Kim Boone, CDFW
Steven Teo, SWFSC
Michael Kinney, SWFSC
Sharon Charter, SWFSC
Magumi Enomoto, Tokyo University
Anne Freire, SWFSC
Megan Human, SWFSC
Luke Thompson, SWFSC

Appendix 4 – Progress related to the recommendations from the 2011 ATM-survey review

David Demer

1. Immediate (prior to the next stock assessments)

a. Analyses be conducted using auxiliary information (e.g. trends in density along transects, information from ichythoplankton surveys south of the survey area, and catch information) to provide estimates for the biomass outside of the survey area, as well as the range of possible biomass levels.

Response: The ATM survey results are for the survey area. If some biomass for particular species resides outside of the survey area, this should bias should be estimated by the associated stock assessment. If the bias is significant, the survey sampling should be refined appropriately.

The Pacific sardine assessments have either assumed Q=1 or estimated Q≈1, indicating no or insignificant bias in the ATM results for this species. This finding is supported by analyses of data collected outside of the ATM survey area. These include eggs counts obtained from the continuous underway fish egg samples (CUFES) offshore off Southern California (https://swfsc.noaa.gov/textblock.aspx?Division=FRD&id=1121) and aerial observations in the nearshore region of the Southern California Bight (Lynn et al., 2014). Prior to 2016, the biomass of Pacific sardine residing in those areas was negligible in relation to the biomass observed in the survey area. In 2017, the biomass in schools of fish observed nearshore off southern California, putatively Pacific sardine and northern anchovy, may have increased (unpublished data; Lynn, pers. Comm.). Also in 2017, the ATM survey area was extended to the nearshore region off Washington and Oregon, facilitated by a collaboration with the fishing industry, and the biomass there was insignificant compared to the anchovy biomass sampled offshore (unpublished data; ATM team). Nearshore sampling is expected to continue in 2018.

b. The CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.

Response: The between-transect CV approximates the overall sampling variability and is insensitive to trawl sampling error when a species is abundant and geographically separate from others species.

2. Short-term

a. Investigate potential species selectivity effects by comparing the ratios of catch rates and acoustically-estimated densities in areas where single species dominate.

Response: The FRD trawl group initiated catch selectivity experiments in 2017.

b. Compare total CPS backscatter along transects to trawl catch rates using statistical techniques.

Response: Positive trawls were associated with acoustic samples with significantly higher than average backscatter (Zwolinski et al., 2012).

c. Conduct sensitivity tests in which stations are pooled and allocated to acoustic values over a larger area.

Response: The trawl catches from each night are pooled. Species and size composition data from these "trawl clusters" are associated to the nearest acoustic samples (see Appendices A and B in Hill et al., 2012).

d. Consult experts in trawl design to evaluate the current trawl design in relation to the survey objectives.
Response: The FRD trawl group will consult the report of the 2018 ATM review for recommendations from independent experts on the current trawl design.

e. Develop methods that categorize the acoustic record and thus support automatic species identification and continue to work on definition and precision of the VMR process.
Response: The Echoview algorithm includes a set of filters, but not the VMR, to retain backscatter of schooling, swimbladder fishes. Echo classification to species is not presently possible, but improved classification of CPS using wideband signals will continue to be explored.

f. Evaluate the potential use of the echosounder in a non-vertical position.
Response: FSV Reuben Lasker is equipped with Simrad EK60 and ME70 echosounders (vertical beams or beam swath) and MS70 and SX90 sonars (horizontal beams), to sample fish behaviors and abundances throughout the water column. Since 2016, data have been collected routinely from these instruments. Dedicated personnel are needed to analyze these data.

g. Check the filtering algorithm every year to ensure that it is still suitable under changing conditions.
Response: The efficacy of the filtering algorithm is evaluated for each survey, and refined as necessary (see 2e Response).

h. Study trends in the frequency response over depth strata in schools.
Response: The frequency responses of CPS aggregations within the mixed layer do not vary significantly versus depth in areas with sardine, anchovy, or mackerels in the associated catches.

i. Compare results from the 18-kHz and other transducers to examine possible avoidance reactions.
Response: The possibility that near-surface CPS may move to the side of the vessel and therefore negatively bias estimates of their biomass could perhaps be evaluated by comparing data from wide- versus narrow-beam echosounders. However, comparison of data from an 18-kHz, 11-degree beamwidth transducer and that from a 38-kHz, 7-degree beamwidth transducer, as proposed, requires accurate knowledge of the relative frequency response which may vary with any changes in incidence angle resulting from possible reaction of fish to the survey vessel. The analysis may be better done with a dual-beam 38-kHz transducer, e.g., if the narrowband narrow-beam ES38B is replaced by the new wide-band, dual-beam ES38-7, or by comparing data from an ME70 70-kHz wide-beam (e.g., 20 degree beamwidth) to that from an EK60 70-kHz narrow beam (7 degree beamwidth). Even using the same frequency, however, any differences in volume backscatter may be caused by either avoidance reaction or scattering directivity.

j. Continue to consider the advantages and disadvantages of conducting ATM surveys at different times of the year.

Response: The Winter/Spring ATM survey is conducted during ~30 days and targets sardine or anchovy aggregated and spawning offshore of southern and central California; and the results are complemented by those from concomitant DEPM surveys. In comparison, the Summer ATM survey is conducted during ~50-80 days and targets the CPS assemblage when the species are typically closer to shore and more geographically separate, the days are longer and the weather is generally better, and the survey area overlaps more or all of the regional fisheries.

k. Evaluate the potential to give age-based abundance or biomass estimates for sardine and consider their utility in the SS3 assessment, given the lack of contrast in length at-age at older ages and the ability to directly estimate total mortality from the survey result.
Response: As the veracity of age estimation improves, year-specific age-length keys will be derived and used to estimate age-based abundances from the ATM surveys.

l. Conduct standard (ICES) vessel noise measurements for all vessels.
Response: Measurements of vessel noise have been made for all NOAA FSVs and the results have been compared to the ICES standard. Since 2016, recordings of underwater sound have been made using hydrophones mounted on the survey-vessel hull.

3. Long-term
a. Evaluate if different trawling practices or gears, or both would be beneficial.
Response: The FRD trawl group continues to evaluate different trawling practices and gears for their benefits.

b. Use the current variance estimation procedure to investigate the trade-offs in terms of variance of different time allocations between acoustic transect and trawl data collection.
Response: Nighttime trawl catches are used to apportion the closest CPS backscatter to species and their sizes. Additional nighttime trawling in an area may be achieved by reducing the transect spacing. However, unless the survey duration is increased, this approach will reduce the total survey area. Consequently, reductions in variance through additional trawling may increase estimation bias.

c. Use a trawl/vessel configuration that can support directed trawl sampling.
Response: Directed trawling may be used to achieve spatial-temporal matches between echoes and catches, to perhaps elucidate frequency responses for each species. If the frequency responses are sufficiently unique, they may be used to accurately apportion echoes to target species, even for schools not trawled. However, sardine, anchovy, jack mackerel, Pacific mackerel and herring have presently indistinguishable frequency responses, so nighttime trawl catches must be used to apportion the closest CPS backscatter to species and their sizes. The accuracy of this apportioning is related to their geographic separations and relative abundances.

d. Conduct repeated trawl sampling experiments to obtain a better understanding of small-scale variability.
Response: Typically, a maximum of three trawls are conducted per night, each separated by less than 10 nmi. Small-scale variability can be evaluated by comparing species proportions and length distributions estimated from nightly trawl clusters including data from 1, 2, or 3 trawls. An

analysis with additional trawl samples from the same area will require an assumption of stationarity and additional ship time necessary to remain in and trawl more in one location.

e. Test the efficiency and selectivity of the trawl by comparing samples from same area taken with the survey trawl and purse seine.
Response: The FRD trawl group will consider the merits of this recommendation and whether it can be practically facilitated by future collaboration with the fishing industry.

f. Apply state-of-the-art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl.
Response: Video data were collected inside the trawl net to observe the performance of the marine mammal excluder device. During successive trawls, the light-source was randomly changed between white, red, or no illumination. These data and the associated catches could be analyzed to glean some information about fish behavior inside the net. Additional personnel is needed to analyze these data. The FRD trawl group is pursuing other methods to investigate fish escapement.

g. Conduct validation tows on various kinds of backscatter to assure that the filtering algorithm is performing as intended to apportion backscatter to CPS.
Response: The FRD trawl group will investigate the net and trawl gears needed for such investigations.

h. Make efforts to obtain TS measurements for in situ CPS in the California Current Ecosystem.
Response: TS measurements of in situ CPS are made during nighttime trawls. Results for northern anchovy served to refine the TS(L) model used. Analyses of these data continue for anchovy and other CPS.

i. Focus on utilizing more advanced instrumentation and resource-demanding research for studying vessel impacts.
Response: See response to 2f. These data will be analyzed as priorities and resources permit.

References:

Lynn, K., Porzio, D., and Kesaris, A. 2014. Aerial sardine surveys in the Southern California Bight. California Fish and Game, 100: 260-275.

Appendix 5 – Panel requests to the team and their answers

Request numbers refer to the TOR (1 through 8).

1.A. Request: Document the strategy used to select and cluster the trawl stations and how that strategy has changed over time. Summarize how the trawl clusters are included in later analyses.
Rationale: The documentation provided to the Panel did not fully specify the trawling strategy.
Response: The Panel heard several presentations that outlined aspects of how the trawl stations were selected and clustered, but there was insufficient time for the ATM Team to assemble the requested document.

1.B. Request: Document the strategy used to decide when to stop the acoustic sampling in the offshore area.
Rationale: The documentation provided to the Panel did not fully specify this aspect of the acoustic survey methodology.
Response: The Panel was informed that the transects continue until no CPS are encountered, but there was insufficient time for the ATM Team to assemble the requested document.

1.C. Request: Provide more information about the trawl system being applied. Specifically provide (a) drawings giving the main properties of the trawl; (b) drawings of trawl rigging – sweep wires, flotation and doors; (c) measurements of trawl geometry; and (d) trawl sonar of Echosounder data from the trawl opening (if available).
Rationale: Sampling efficiency of trawls depends on the behaviour of the fish in front of the trawl, the filtering capacity of the trawl and the mesh selection. The mesh selection and the filtering capacity are determined by the trawl construction, such as mesh sizes in the various panels, and the cutting angle of the panels (determining the overall length of the trawl). Low filtering capacity will enhance the impact of fish behaviour in front of codend as well as in front of the trawl, such as size- and species- dependent behaviour.
Response: The Team provided trawl drawings and information about rigging as requested (Appendix 6). The opening of the trawl is stated to be ~20x15 m, but might be slightly smaller. The flotation is attached to the trawl headline in front of the ropes where the vertical opening of the breast is ~35 m. Thus, while the headline of the breast part will be at surface, the net headline will probably be at about 5-10 m depth. The mesh sizes decrease from 1,600 mm in the front of the net to 100 mm in the end. The codend (100 mm netting) is 8.5 m long and has a liner with 8 mm square mesh netting. The trawl design indicates a good filtering capacity due to the large meshes in the front. Mesh selection for small individuals must be expected due to their limited swimming capacity. The Team also mentioned some constraints that could impact trawl efficiency such as the operation of trawl instrumentation to monitor trawl performance. There are however some issues related to the trawl that require attention (see recommendations).

1.D. Request: Provide examples of the coherence of daytime acoustic data and night-time trawl results using Echoview outputs.
Rationale: The Panel wished to better understand the rationale for basing species and size compositions from night-time trawling and to explore how variable the density of epi-pelagic species is at night-time.
Response: The team showed the Panel several Echoview outputs, and the Panel and ATM Team examined them. There were evidence of CPS schools during the day that were below the 70 meter depth limit assumed as the lower limit of CPS. The evidence for schools in the output at night was particularly noteworthy and was confirmed by industry members present at the review.

1.E. Request: Provide an outline (e.g. for 2017) for how the objectives for a survey are determined, and how those objectives lead to the acoustic survey design.
Rationale: The Panel wished to more fully understand the approach used for survey design.
Response: There was insufficient time during the review to complete this request.

1.F. Request: Document the approach used to process the acoustic data, including filtering algorithms and algorithms for removing non-CPS "epi-pelagic" fish (Echoview and R-based approaches).
Rationale: The documentation provided to the Panel did not fully specify the strategy to process acoustic data.
Response: The Panel heard presentations that outlined several aspects of how the acoustic data were processed, but there was insufficient time for the ATM Team to assemble the requested document.

1.G. Request: Construct a plot of the distribution of CPS at the trawl level that includes bathymetry and represents the magnitude of the catches.
Rationale: These plots will provide additional information on species distribution, which relates to survey design.
Response: The plots were produced for spring and summer separately. However, it was hard to interpret the plots because of the presence of one large catch of sardine. This led to request 1.I.

1.H. Request: Provide plots of histograms of the distance from a trawl cluster to the 100 m Equivalent Distance Sampling Units (EDSUs) (and the cumulative distribution), restricting the data to (a) transects with non-zero CPS Nautical Areas Scattering Coefficients (NASCs) and (b) transects with a non-negligible CPS NASCs.

Rationale: The Panel wished to more fully understand the distribution of the CPS relative to trawl catches.

Response: The plot (Figure 1) showed that the most of the biomass is based on trawl samples whose centroid is less than 25 miles from associated EDSUs.

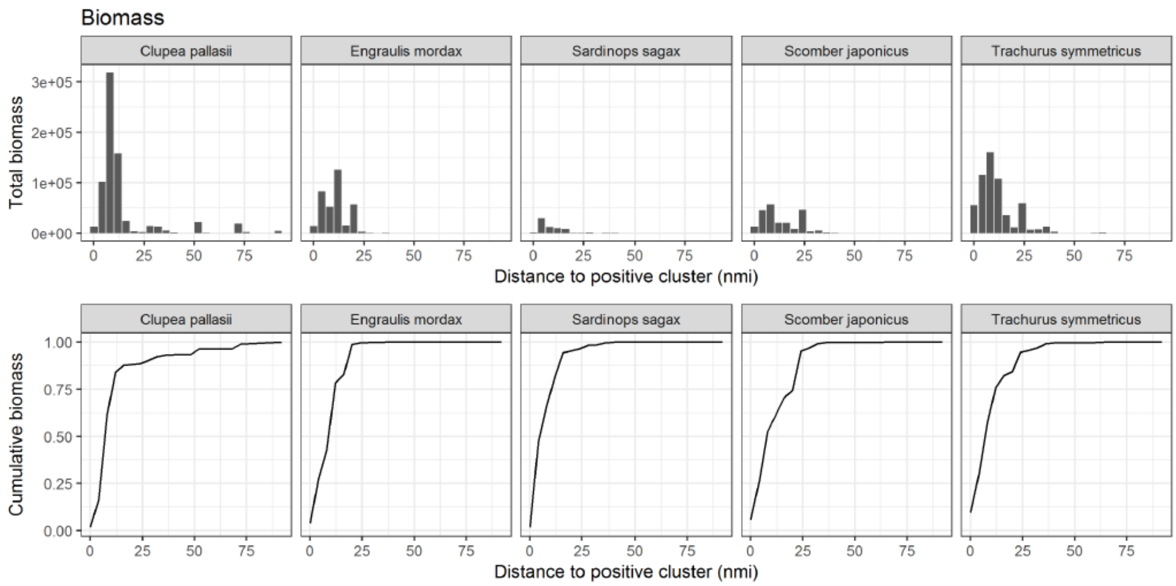


Figure 1. Acoustic biomass (upper panel) and cumulative relative biomass (lower panel) by the distance to the nearest positive trawl cluster.

1.I. Request: Construct a plot of the distribution of the CPS at the trawl level that includes bathymetry and represents the magnitude of the catches where the catches are square-root transformed.
Rationale: These plots will provide additional information on species distribution, which relates to survey design.
Response: The request plot was created (Figure 2).

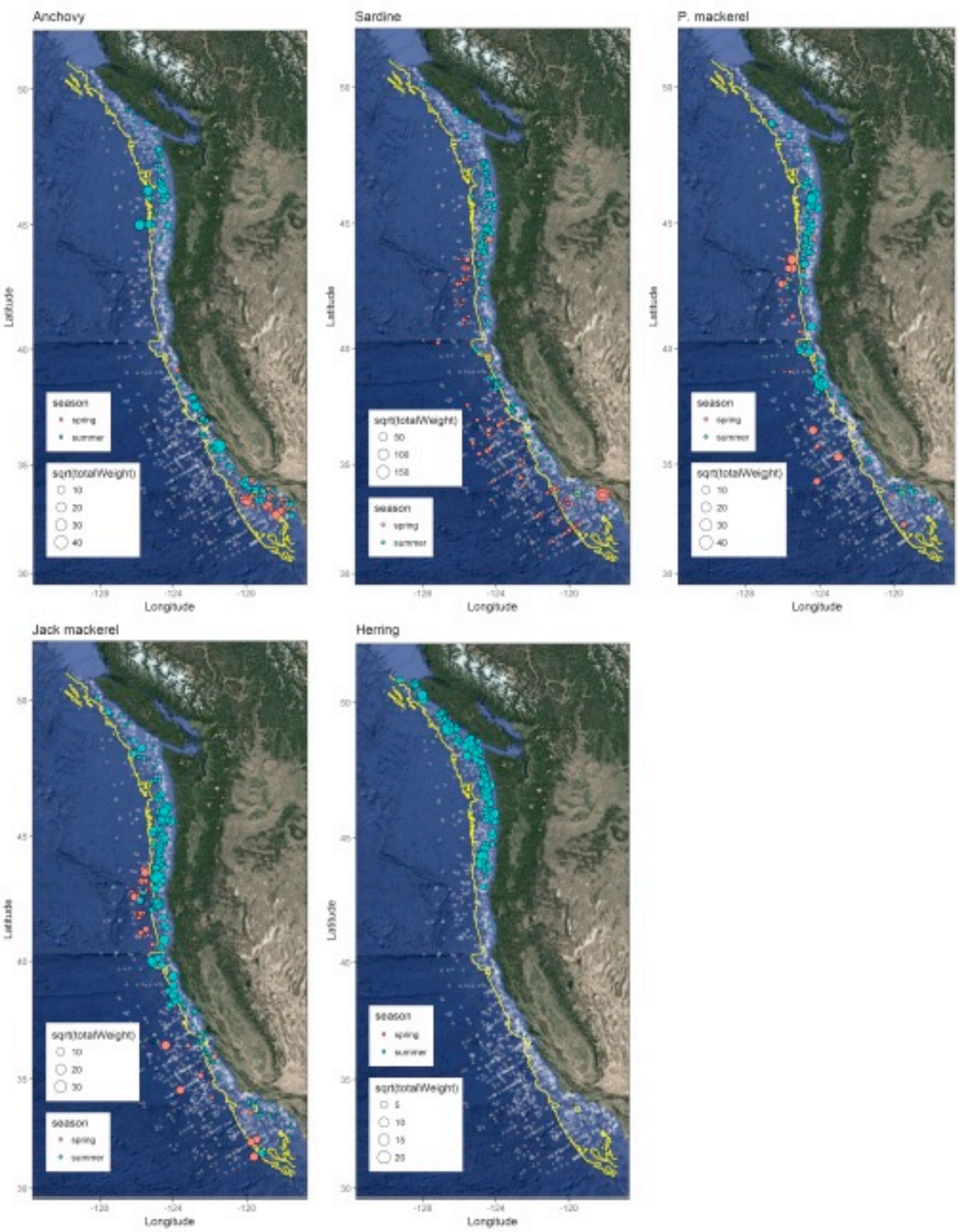


Figure 2. Maps of the west of the North America showing the total catch (square-root kg) of each CPS by season (spring ≤ May, summer > May) for ATM surveys conducted since 2006.

1.J. Request: Evaluate variability among trawls in a cluster for species proportions.
Rationale: If the trawl species compositions are dissimilar, then there is high uncertainty in species composition, even assuming that the night trawl sampling approach is perfectly unbiased.
Response: Plots of variability in species proportions against species catch for the summer 2016 survey shown to the Panel showed the expected pattern with higher variability for lower biomass. This was most evident for anchovy, which constituted the bulk of the biomass in the survey concerned. This type of information should be reported routinely in survey reports.

1.K. Request: Provide zoomed-in graphics of how close the survey transects get to the shore, with bathymetry lines if possible.
Rationale: The Panel needed a visual to demonstrate how close the ATM vessel can approach the coastline.
Response: These figures are given as Figure 3.

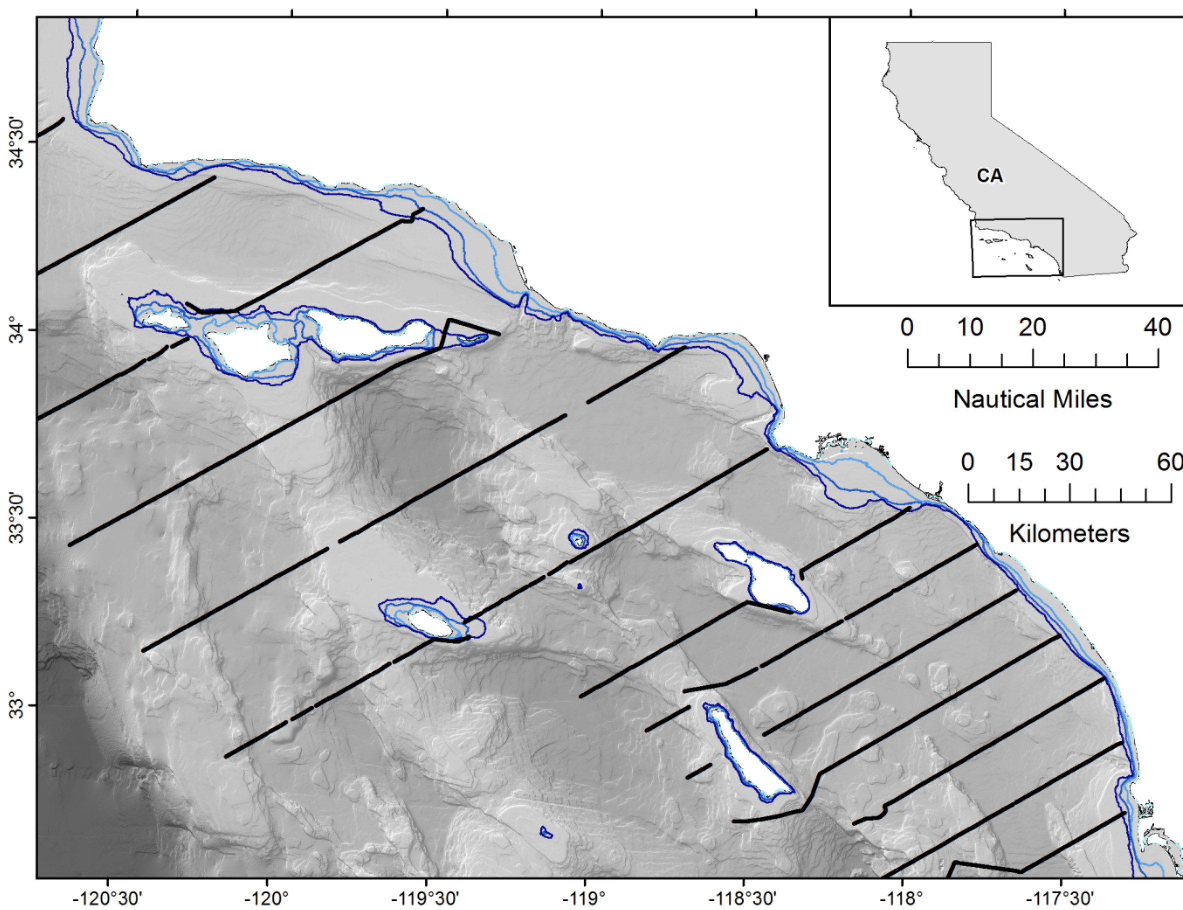


Figure 3. Map of the coast of California showing the acoustic survey transects (black lines) and bathymetric contours (blue lines at 20, 40, and 60 m seabed depth, respectively darker).

1.L. Request: Provide a table that lists the ATM surveys conducted to date, with start date (dd/mm/yyyy), duration (days), principal objective (target species), sardine biomass estimate (mt, CV), anchovy biomass estimate (mt, CV), area covered (n.mi.^{2}), total cruise track length (n.mi.), number of trawls conducted, numbers of trawl clusters, and number of non-zero clusters.
Rationale: This is core information needed to fully understand the survey results.
Response: This information is given as Table 1.

Table 1. Summary of the characteristics of the surveys conducted to date. Note that the values reported are preliminary. The ATM team should be contacted prior to citing these values for updates.

Response:

Survey ID	Date start	Date end	Duration (d)*	Target Species	Sardine biomass (10^3 mt) [CV]	Anchovy biomass (10^3 mt) [CV]	Number of transects (n)	Length of transects (nmi)	Area covered (nmi^2)	Acoustic equipment	Number of trawls (n)	Total number of trawl Clusters (n)	Number of positive trawl cluster (n)
0604OD	4/12/2006	5/8/2006	26	Sardine/CPS	1,947 [30.4]	n.a.	18	2,563	194,543	EK60	40	n.a.	n.a.
0804JD	4/12/2008	4/28/2008	16		751	n.a.	15	3,489	84,095	EK60	30	n.a.	n.a.
0804MF	4/12/2008	4/30/2008	18	Sardine/CPS	[9.2]		18	2,458	106,879	EK60	42	n.a.	n.a.
1004FR	3/30/2010	4/27/2010	28		357	n.a.	9	1,360	61,435	EK60	55	n.a.	n.a.
1004MF	4/3/2010	4/20/2010	17	Sardine/CPS	[43.3]		15	1,780	70,936	EK60	43	n.a.	n.a.
1104FR/1104SH	3/25/2011	4/25/2011	31	Sardine/CPS	494 [30.4]	n.a.	21	2,919	65,741	EK60	105	19	16
1204SH/1204OS	3/17/2012	4/30/2012	44	Sardine/CPS	470 [28.6]	n.a.	19	3,230	92,823	EK60/ME70	95	35	14
1206SH	6/24/2012	8/30/2012	67	Sardine/hake/CPS	341 [33.4]	n.a.	85	3,509	36,991	EK60/ME70	98	38	31
1304OS/1304SH	4/10/2013	5/4/2013	24	Sardine/CPS	305 [24.4]	n.a.	17	2,791	56,804	EK60	70	26	15
1306SH	6/6/2013	8/30/2013	85	Sardine/hake/CPS	314 [27.5]	n.a.	62	4,420	46,865	EK60/ME70	147	56	39
1404SH	4/13/2014	5/7/2014	24	Sardine/CPS	35 [39.6]	n.a.	10	3,890	85,265	EK60/ME70	39	16	8
1406SH	6/24/2014	8/5/2014	42	Sardine/CPS	26 [70.3]	n.a.	22	2,278	40,513	EK60/ME70	85	36	29
1504SH	3/28/2015	5/1/2015	34	Sardine/CPS	29 [29.9]	n.a.	13	1,843	50,038	EK60/ME70	54	22	15
1507SH	6/15/2015	9/10/2015	87	CPS	16 [80.2]	n.a.	32	2,614	47,188	EK60/ME70	160	58	50
1604RL	3/22/2016	4/22/2016	31	Sardine/CPS	83 [49.3]	n.a.	12	3,849	34,223	EK60/EK80/ME70/MS70/SX90	43	18	9
1607RL	6/28/2016	9/22/2016	86	CPS	79 [53.9]	152 [41]	54	4,627	50,477	EK60/EK80/ME70/MS70/SX90	121	49	40

*Includes in-port days

2.A. Request: What are the target strength to length functions that are used for each species and what is the basis for using these? Of those that include a depth-dependent component, how were the coefficient(s) derived? What experiments have been done, or which observations have been made, to determine or validate the selected model coefficients? Document the calculations that are carried out to estimate the mean backscattering cross section from the trawl information.
Rationale: The Panel wished to see a summary of the pertinent information in a single location.
Response: The equations used for sardine and mackerel come from Barange et al. (1996); the pilchard model is applied to sardine and Pacific herring, while the horse mackerel equation is used for the Pacific and jack mackerel (Table 2). For anchovy, the target strength is described in a technical memorandum (Zwolinski et al., 2017) and is based on the target strength of another anchovy species (Japanese anchovy) from Kang et al. (2009), with an added (fixed) term for depth dependence. The validity of this model was tested against empirical target strength data collected from three trawls within a single transect in southern California where anchovy were abundant and estimated to constitute 99% of all CPS finfish. The target strength (TS) measurements at each location were combined with the associated total length (TL) distribution from each catch and resulted in an estimate of the b_{20} parameter of 67.3 dB. Given the mean depth of the schools during this measurement at 13 m and estimated compression of the swim bladder, this value is in agreement with the value for b_{20} estimated for the Japanese anchovy (67.2). The frequency distribution of the measured target strength was broader than would be expected from the length frequency distributions, but this is likely due to added variability from the tilt angle distribution, a commonly observed phenomenon echoed by the experts in the room. For the summer surveys, when the mean depth of schools increased to 21 m, the b_{20} value was adjusted to 68.1 dB. This is the value used throughout the surveys. To apply target strength models for estimation of biomass, individuals of each species are randomly sampled from each trawl and the length frequencies are weighted by the catch sizes.

Table 2. Parameters of the regression equations fitted to target strength data for anchovy, pilchard (sardine) and horse mackerel (s.e.m. denotes standard error of the mean; s.e. of Y indicates the standard error of the dependent variable). Source: Barange et al. (1996).

	(dB individual^{-1})		(dB kg^{-1})
	$Y=20 \log TL - b_{20}$	$Y=a \log TL - b$	$Y=a \log TL - b$
Anchovy	n=18	a=19.50	a= − 12.15
	b_{20}=76.10	b=75.57	b=21.12
	s.e.m.=0.15	r^2=0.81	r^2=0.59
		s.e. of Y=0.66	s.e. of Y=0.70
Pilchard	n=13	a=17.07	a= − 14.90
	b_{20}=70.51	b=66.73	b=13.21
	s.e.m.=0.10	r^2=0.87	r^2=0.87
		s.e. of Y=0.35	s.e. of Y=0.30
Horse mackerel	n=21	a=14.66	a= − 15.44
	b_{20}=66.80	b=58.72	b=7.75
	s.e.m.=0.16	r^2=0.78	r^2=0.80
		s.e. of Y=0.63	s.e. of Y=0.63

6.A Request: What work has been conducted by the ATM Team to address this issue?
Rationale: The document provided to the Panel did not include information relative to Topic 6.
Response: Some data have been collected during surveys using the multibeam system, but those data have not been processed or looked at so far.

8.A. Request: Summarize the approaches used to age the CPS for which ATM-based estimates of biomass are computed (sardine, anchovy, Jack mackerel, Pacific mackerel) and outline efforts to validate the ageing and quantify ageing error.
Rationale: The Panel wished to understand the nature of the ageing data that could be used in stock assessments.
Response: Emmanis Dorval provided a summary of an evaluation of the consistency of the age-determination for Pacific sardine. There is no formal validation of the ageing process using, for example, tagging studies. However, age-reading error has been quantified based on otoliths that have been double read. Ageing of Pacific sardine is conducted by a variety of laboratories, including CICIMAR-INP in Mexico. The same basic method (surface ageing) is used, but there are some differences among laboratories. The precision of the age estimates depends on ager, with ageing error increasing with age (Figure 4). The same approach is taken for Pacific mackerel (Figure 5). The anchovy in the survey have not been aged, although CDFW has started ageing anchovy using surface ageing (whole otoliths), but no agreement on ageing method has been achieved among ageing laboratories. Jack mackerel otoliths have been collected on the survey since 2012, but ageing of this species has not yet commenced.

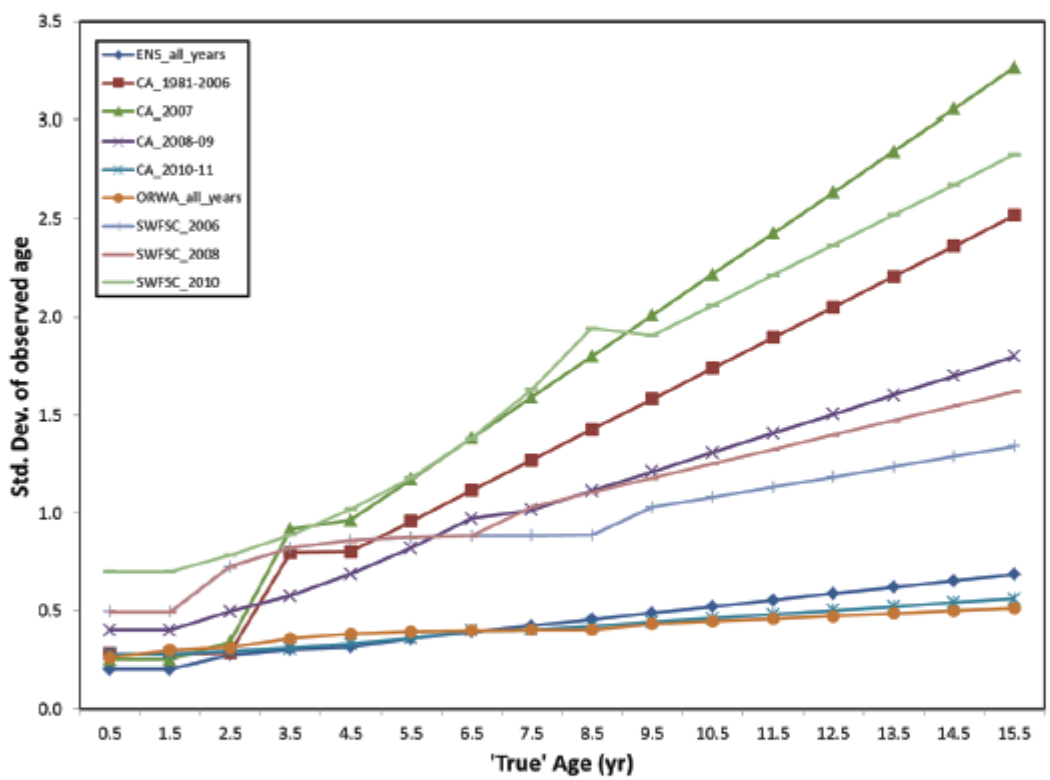


Figure 4. Laboratory and year-specific ageing errors for Pacific sardine. The 'True' age was a reference age estimated using a mixed effects model.

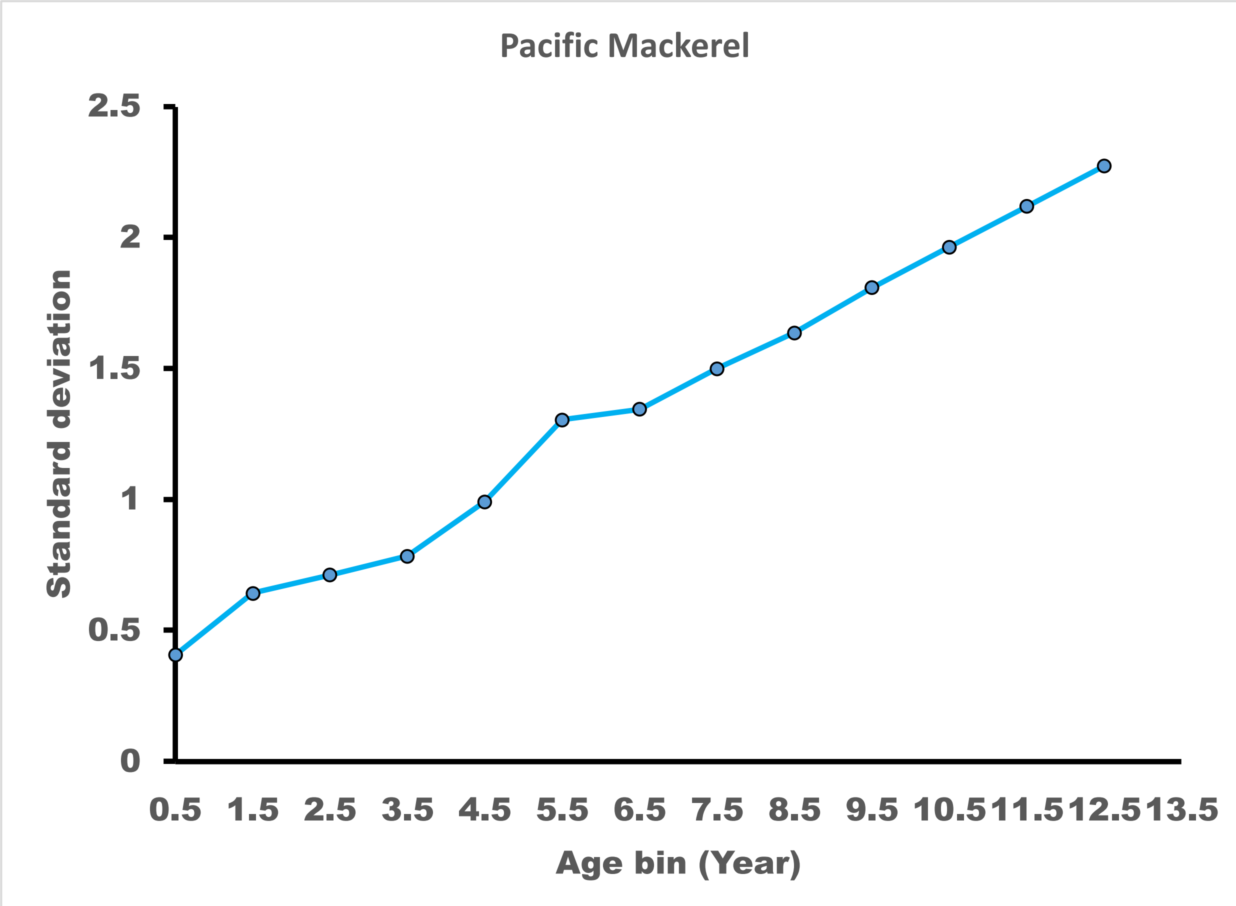


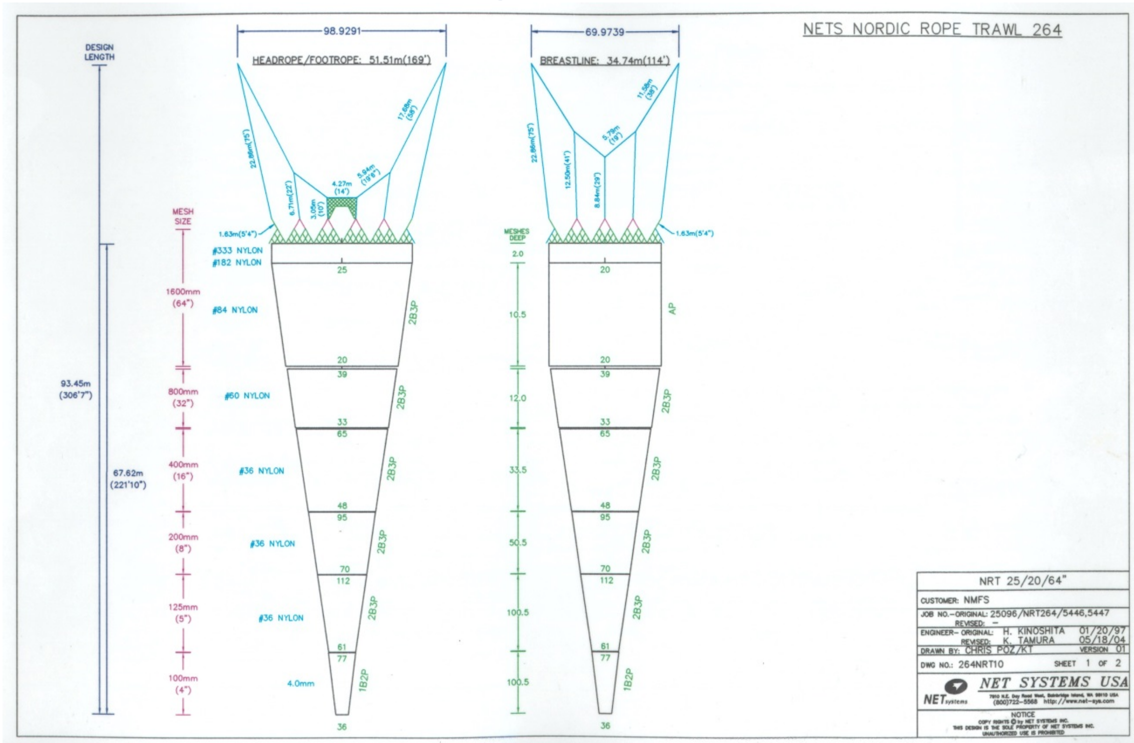
Figure 5. The standard deviation of age-reading error for Pacific mackerel (E. Dorvall, SWFSC).

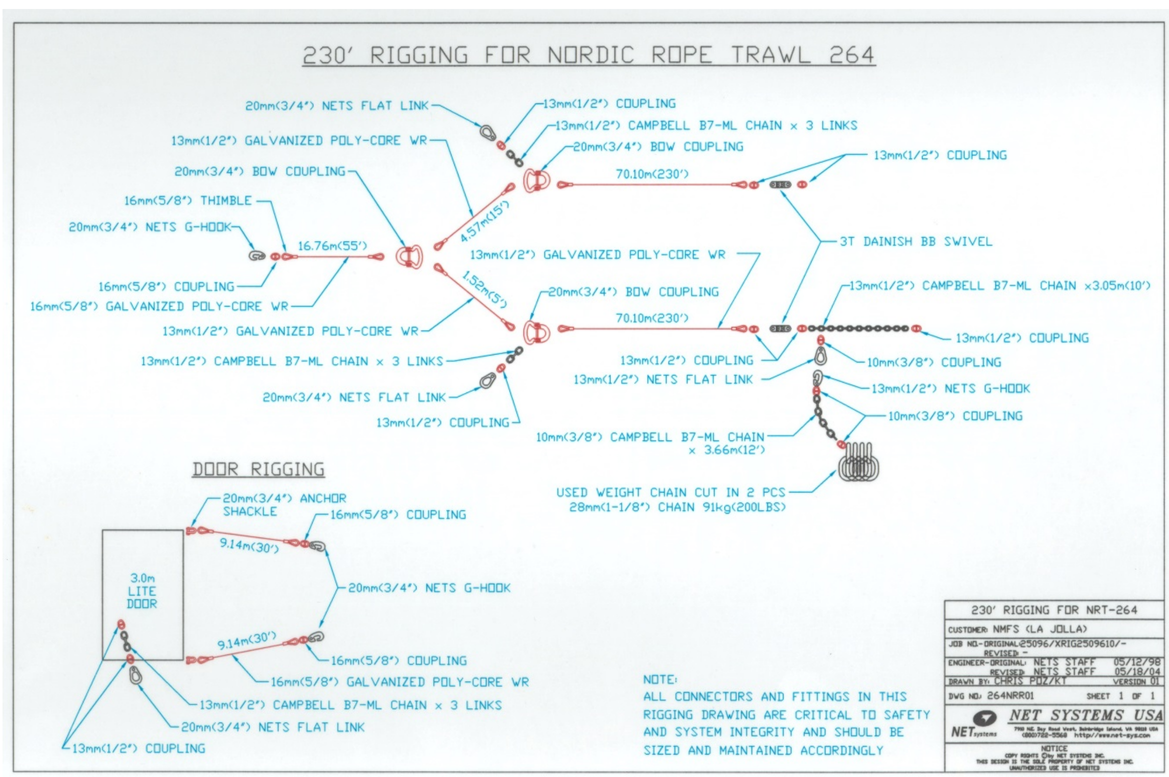
8.B. Request: Summarize how the ATM estimates are used to inform the age-structured stock assessment model for Pacific sardine.
Rationale: The Panel wished to understand the context in which ageing data are used in assessments.
Response: The ATM biomass estimates are treated as relative indices of abundance (although Q is estimated to be close to 1 (log(Q)=0.113, SD=0.109) and the age data from the survey (based on applying a pooled age-length key) are assumed to be multinomially distributed. Selectivity for the ATM survey was assumed to be uniform (fully-selected) above age 1 and zero for age 0.

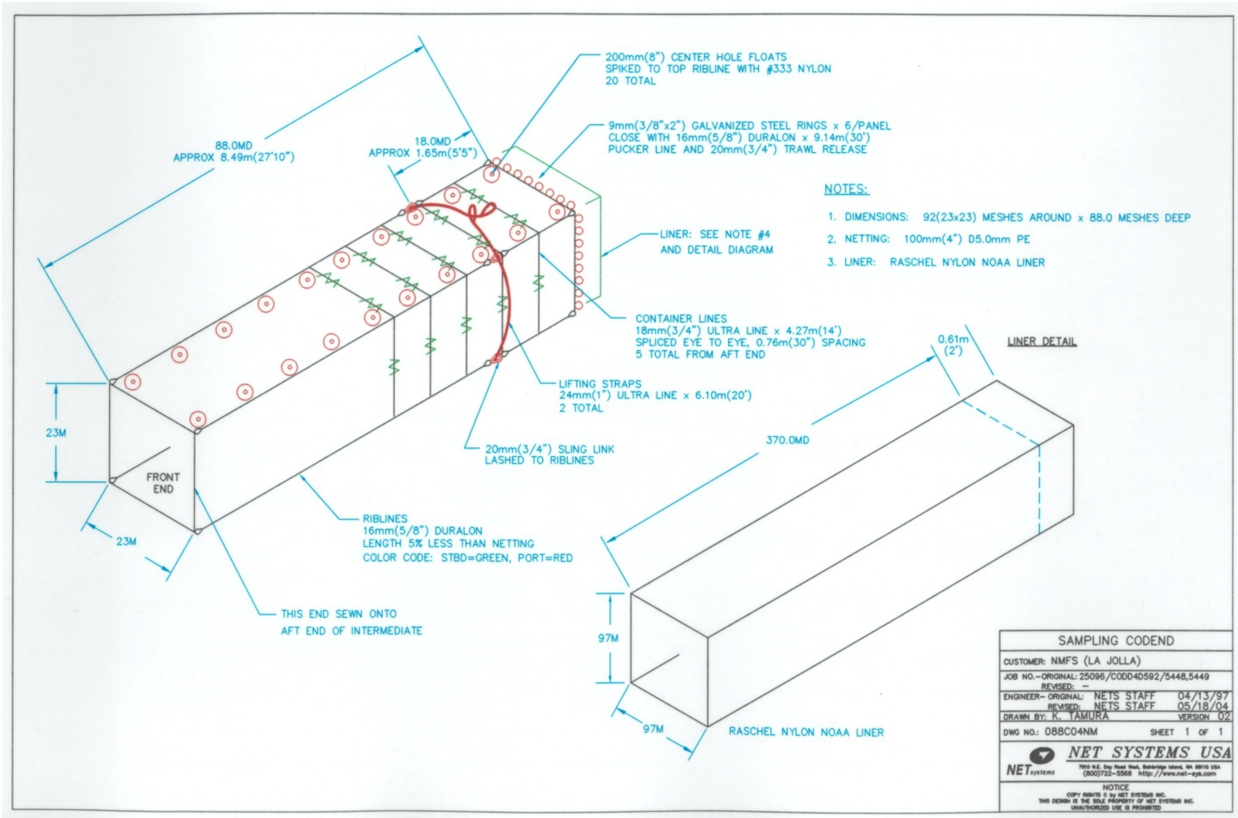
8.C. Request: Calculate ratios of age x+1 in year t+1 to age x in year t to look for consistency in age estimates across years. Across 3 years = 2 points per cohort.
Rationale: This should show if the age compositions across years are consistent or not.
Response: The Team showed plots of estimated length and age compositions from the summer surveys, where the age compositions were based on an age-length key in which data were pooled over years, as well as the raw age-compositions (no weighting). There appears to be some selectivity (age-0 animals appear to be under-sampled, although they have been caught during trawls, e.g. during 2015). The animals in the size-range 20-24cm are assigned to ages 2-4 and there is no clear evidence that the age-compositions track over time, even though the mode of the size-composition moves to the right as expected. There was insufficient time during the review to

complete this request in detail, however, a figure was prepared for sardine shortly after the meeting. This indicated no agreement between estimates of the number of fish between the ages of 1 and 2, and very little between ages 2 and 3, and 3 and 4; there is better agreement between ages 0 and 1; and at older ages up to 6. This may reflect uncertainties in age reading or misallocation of the acoustic data to species or size based on the use of night time trawls.

Appendix 6 – ATM trawl design






200mm(8") CENTER HOLE FLOATS
SPIKED TO TOP RIBLINE WITH #333 NYLON
20 TOTAL
9mm(3/8"x2") GALVANIZED STEEL RINGS x 6/PANEL
CLOSE WITH 16mm(5/8") DURALON x 9.14m(30')
PUCKER LINE AND 20mm(3/4") TRAWL RELEASE
88.0MD
APPROX 8.49m(27'10")
18.0MD
APPROX 1.65m(5'5")
NOTES:
1. DIMENSIONS: 92(23x23) MESHES AROUND x 88.0 MESHES DEEP
2. NETTING: 100mm(4") D5.0mm PE
3. LINER: RASCHEL NYLON NOAA LINER
LINER: SEE NOTE #4
AND DETAIL DIAGRAM
CONTAINER LINES
18mm(3/4") ULTRA LINE x 4.27m(14')
SPLICED EYE TO EYE, 0.76m(30") SPACING
5 TOTAL FROM AFT END
0.61m
(2')
LINER DETAIL
LIFTING STRAPS
24mm(1") ULTRA LINE x 6.10m(20')
2 TOTAL
370.0MD
23M
FRONT
END
20mm(3/4") SLING LINK
LASHED TO RIBLINES
23M
RIBLINES
16mm(5/8") DURALON
LENGTH 5% LESS THAN NETTING
COLOR CODE: STBD=GREEN, PORT=RED
THIS END SEWN ONTO
AFT END OF INTERMEDIATE
97M
97M
RASCHEL NYLON NOAA LINER
SAMPLING CODEND
CUSTOMER: NMFS (LA JOLLA)
JOB NO.–ORIGINAL: 25096/C0DD4D592/5448,5449
REVISED: –
ENGINEER– ORIGINAL: NETS STAFF 04/13/97
REVISED: NETS STAFF 05/18/04
DRAWN BY: K. TAMURA VERSION 02
DWG NO.: 088C04NM SHEET 1 OF 1
NET SYSTEMS USA
NET systems
7910 N.E. Day Road West, Bainbridge Island, WA 98110 USA
(800)722–5568 http://www.net-sys.com
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INDEPENDENT PEER REVIEW OF THE ACOUSTIC TRAWL METHODOLOGY FOR USE IN COASTAL PELAGIC SPECIES STOCK ASSESSMENTS

National Marine Fisheries Service (NMFS)
Southwest Fisheries Science Center (SWFSC)
La Jolla, California
29 January - 2 February 2018

Center for Independent Experts (CIE) Independent Peer Review Report

Olav Rune Godø

1. EXCECUTIVE SUMMARY

The review meeting of the Southwest Fisheries Science Center (SWFSC) acoustic-trawl method (ATM) for surveying coastal pelagic fish species (CPS) in the Californian Current off the American west coast was welcomed by Dr. Gerard DiNardo and chaired by Professor Andre Punt. The Chair initiated the discussions by introducing the Terms of Reference (ToR), including eight specific issues to be covered:

(a) ATM survey documentation;
(b) target strength of CPS from the California Current,
(c) trawl survey design protocols for using a CPS preferred habitat model to determine adaptive sampling areas,
(d) effects of trawl survey design,
(e) effects of upgrading from the Simrad EK60 to EK80,
(f) effects of vessel avoidance for the upper water column,
(g) ATM survey design in areas where the ATM vessel is currently not sampling, and
(h) ATM data analysis and quantification of uncertainty,

which also comprise the basis of this report, which I completed in my capacity as a Center of Independent Experts (CIE) reviewer.

Members of the team including Drs. David Demer, Paul Crone and Kevin Stierhoff presented the biological background and the survey approach, including the procedures for collecting and processing of the acoustic data together with the trawl information. This was followed by responses to several requests by the Panel for additional information.

As I participated in the 2011 review, I expected a substantial focus from the Team on what progress had been made since 2011. Several potential difficulties with the methodology were identified that required action and research to mandate the strong statement from that review supporting the use of the survey estimates as absolute measures of abundance for selected species. The Team provided detailed background material but concentrated on presenting the same methodology as in the previous review, and limited attention was paid to progress related to the 2011 recommendations. The Team demonstrated high competency in acoustic survey methodology but has a tendency to place emphasis on details, while some more crucial issues as listed in the ToR were given less attention. The Team was apparently aware of most issues that could impact the survey results but indicated that several of them were not solved since 2011 for various reasons. From my personal expertise, the fact that no progress was made in the evaluation of the efficiency of the trawl sampling efficiency is worrying. Similarly, although some documentation of progress was presented, there still appears to be large uncertainty associated to the issues raised in the 2011 review.

In summary, the acoustic-trawl surveys, as well as the methods of data collection and analysis, are adequate for the provision of advice on the abundance of all CPS finfish. Although the estimates from the survey are reported in absolute terms (i.e. biomass), they should not be used as such in assessments where catchability, Q, and selectivity (at size and/or age) are estimated. From my perspective, participating in the 2011 review, the limited progress in the issues highlighted in that review underline this conclusion. The survey method for sampling still suffer from the fact that acoustic sampling is taking place at day while trawl sampling is carried out at night. The relevance of this approach is yet to be validated. Further, the efficiency of the trawl appears very low, and poses questions on the selectivity both by size and species. The survey design emphasizes on minimizing the uncertainty in the estimated abundance, while this to some extent limits the effort available for reducing biases associated to vertical and horizontal distribution patterns. The adaptive sampling technique used is disputed, and I think the available effort rather should be used to ensure spatial coverage, including experiment to detect and quantify vertical distribution and avoidance. An improved interaction with the aerial survey and the CPS could potentially facilitate a monitoring less sensitive to the impacts of the changing environment on distribution and abundance of the CPS. The lack of adequate trawling expertise during the survey seem to be a limitation for improving the trawl sampling. A strengthening of the interaction with the industry would help removing this uncertainty, and potentially help establishing a trawl sampling method for day time sampling in concert with the acoustic sampling. Strengthening the interaction with the industry could also support stronger legitimacy among stakeholders.

The meeting was completed in a congenial atmosphere and with good and constructive discussions.

2. BACKGROUND

The National Marine Fisheries Service (NMFS) conducts scientific surveys to assess abundance estimates and trends in fish populations, for use in fisheries management decisions and other purposes. NMFS and the Pacific Fishery Management Council (Council) are jointly responsible for ensuring that survey design, protocols, and abundance estimates represent best scientific information available, and work cooperatively to ensure independent peer review of scientific products related to fisheries management. To this end, the Council developed a Terms of Reference (ToRs) to guide review of methodologies that are used in fisheries management decisions. These guiding ToRs are available at: https://www.pcouncil.org//wpcontent/uploads/2017/01/Methodology_ToR_CPSGF-2017-18.pdf. In advance of such methodology reviews, NMFS and the Council will work with the Council's Scientific and Statistical Committee (SSC) to designate a methodology review panel, which includes a Chair, at least one member independent of the Council (often designated by the Center for Independent Experts [CIE]), and at least two additional members.

The Pacific sardine stock is assessed regularly (currently, every single year) by Southwest Fisheries Science Center (SWFSC) scientists, and the Pacific Fishery Management Council (PFMC) uses the resulting biomass estimate to establish an annual harvest guideline (quota). Currently, acoustic trawl methodology (ATM) biomass estimates for three other coastal pelagic species—Pacific mackerel, northern anchovy (two sub-stocks) and jack mackerel have not been approved for use in PFMC stock assessments (see 2011 ATM Methodology Review). It is the intent of this review to evaluate the usefulness of the ATM for these stocks even though portions of the population may be outside the range of the ATM survey either in international waters or in shallow nearshore waters that cannot be sampled by the ATM in its present configuration.

As an expert in acoustic-trawl survey methodologies, I was selected to serve on a Panel to evaluate an acoustic-trawl method for surveying coastal pelagic species (CPS). The SWFSC has explored and further developed the use of acoustic-trawl methods, which are commonly used by other countries and regions, to estimate the abundances and distributions of CPS in Californian waters. Acoustic-trawl methods may also provide a robust (i.e., accurate and precise) and efficient means to routinely survey the Pacific sardine populations, as well as the populations of jack mackerel, Pacific mackerel, and anchovy. The SWFSC has conducted acoustic-trawl surveys off the U.S. west coast, from the Mexican to Canadian borders, and developed methods for estimating the abundances and distributions of CPS from these data. The data are used in analytical stock assessment. This review covers the acoustic-trawl survey design and analysis methods, documents, and other pertinent information for acoustic-trawl surveys of Pacific sardine, Pacific mackerel, jack mackerel, and anchovy. The confinement of the stocks within the survey area compared to inshore-offshore areas, as well as north into Canada and south into Mexican waters, are important design issues. Trawl sampling and the evaluation of uncertainty including behavioural aspects impact on survey results are important issues of the review.

3. DESCRIPTION OF THE REVIEWER'S ROLE IN THE REVIEW ACTIVITIES

My focus of research is presently related to acoustic-trawl survey methodologies. Behavioural impacts on assessments of fish stocks from surveys, acoustic as well as trawl surveys, have been an important part of my experience. I have also conducted several studies on efficiency and selectivity of trawl sampling methodologies, which is of particular relevance to the sampling challenges of the CPS survey. My practical experience comes from assessment surveys, stock assessment working groups, and the responsibility for a large number of experiments assessing quality of scientific surveys. I have field experience from European coastal waters, as well as from deep waters in the mid-Atlantic, and in the Vietnam-Thailand-Malaysia area. I have worked at the demersal fish department at the Institute of Marine Research (Norway), and served as section head at the pelagic fish department. In 2002, I started building a new research group in survey methodology. I also chaired an international initiative for development of marine ecosystem acoustics including using observations to support such studies. My main research interests include acoustic-trawl survey methodology, fish behaviour, biophysical interaction, and fisheries induced evolutionary changes. My work has been presented in about 80 publications in peer-reviewed journals, and, in addition, several book chapters and a number of technical papers and reports. I have served on the board of four research programs of the Research Council of Norway, have been a member of the scientific steering committee of Census of Marine Life and have also been a member of a SCORE WG in observation methods. I have also been a member of several working groups under the International Council of the Exploration of the Sea (ICES).

Based on the combination of my competence and the ToR for the review, my highest attention was associated to items 1-4 and 6 given in the SoW document.

Prior to the review meeting, I responded on requests from the CIE office. I had access to most of the review material and prepared for the meeting by reading the material. The main activity was participation in the panel meeting and the associated discussions and reporting. After the meeting, I repeatedly read and commented on the panel chair's updated versions of the panel review report. My particular emphasis was on impacts on behavioural aspects on survey results including the appropriateness of the applied trawl and trawl strategy. This includes aspects of the survey design (coverage), species compositions, trawl sampling and fish avoidance. Final activity included the preparation of this report.

4. SUMMARY OF FINDINGS

(a) <u>ToR 1 - ATM survey documentation</u>

Document the ATM survey design, protocols (sampling, data filtering, etc.), and estimation methods, including the following:

(a) delineate the survey area (sampling frame);
(b) specify the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification);
(c) specify the rule for stopping a transect (offshore boundary by species);
(d) specify the rules for conducting trawls to determine species composition;
(e) specify the rules for adaptive sampling (including the stopping rule); and
(f) specify the rules for post-stratification, and specify in particular, how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account densities should be considered (PFMC 2017).
(g) Describe how echogram backscatter is analyzed to exclude non-CPS backscatter.

The quality of scientific surveys is manifested in their ability to document appropriate standardisation of equipment, procedures and routines. Without appropriate documentation there is a limited possibility to ensure that the survey have followed internationally accepted standards. The CPS team presented the survey methods including the equipment, routines and procedures to the Panel but was not able to present a full coherent documentation within the time constraints.

(a) *delineate the survey area (sampling frame);*

The Team conducted the surveys with various objectives, and hence the survey area is defined by the objectives of the individual surveys, such as target species and the available ship time. The Team has developed and refined a pelagic habitat model that support distribution of effort in the main distribution area of CPS. They also use to some extent information from the industry. The focus on specific species like during the sardine survey may cause limitation in the coverage of other CPS. Trends and variability in the abundance of the various species might suffer from this. The dynamics in the spatial and temporal distribution patterns of CPS requires that survey strategy and design put emphasis on minimizing bias instead of precision in the abundance estimates. Otherwise unpredictable changes in survey efficiency might be expected.

(b) *specify the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification)*

The spatial stratification of the acoustic survey is determined by historically recorded high- and low-density areas. The predefined high and low-density areas are further influenced by the objectives of the survey, including the target species and target area. The Team uses part of the available effort in an adaptive sampling technique, which is disputed, and might lead to biased estimates. I think there is a need to analyse this in detail to evaluate the cost-benefit of spending effort on post stratification instead of being more spatially dynamic, i.e. include spatial flexibility in the effort distribution to ensure adequate spatial coverage when distribution changes.

(c) *specify the rule for stopping a transect (offshore boundary by species)*
The Panel was informed that transects continue until there is no evidence for further signs of CPS although no specification was given, for example how long distance has to be sailed without recordings before stop is decided. In the survey specification, such rules need to be detailed enough to avoid individual definitions.

(d) *specify the rules for conducting trawls to determine species composition*
The Panel clarified that trawl sampling is conducted each night by returning to positions where CPS schools were acoustically detected earlier that day, where CUFES samples indicated egg presences, and from reports on the locations of CPS catches by the industry. The first set is ~1 h after sunset, and the last set is concluded prior to sunrise. The ATM Team was unable to provide a fully specified protocol for how trawls are conducted.

(e) *specify the rules for adaptive sampling (including the stopping rule)*
We had a long discussion about the adaptive sampling technique including the definition of when high density of transects is taking place. Without further specification, the Panel was informed that at least three additional transects were conducted when large changes in transect backscattering is observed. Lower intra-transect distance areas are pooled into stratum for biomass estimation. Thus, from my understanding the available effort for post-stratification will vary from year to year and survey to survey according to the total accessible effort and the specified objectives.

(f) *specify the rules for post-stratification and specify in particular, how density observations are taken into account in post-stratification.*
The post-stratification process supports the following two goals: (a) to identify strata for which the assumption of approximate stationarity is valid, and (b) to create strata for which the number of transects per unit area is constant. The aim is to distinguish regions with ‘structural zeros’ from regions (which may include transects with observed zero acoustic density) for which density is likely non-zero. Juan Zwolinski explored the validity of the approach to post-stratification taken by the Team by computing autocorrelation functions (there was no evidence for significant autocorrelation within the post-stratified strata at any lag when transect means were considered). He also compared the variance estimates when they were computed using the current post-stratification approach and a simpler approach that defined strata without reference to density and found the estimates of variance to be similar (Appendix 6), suggesting that the expected negative bias in the variance estimates due to post-stratification is not likely to be substantial.

(g) *Describe how echogram backscatter is analyzed to exclude non-CPS backscatter.*

Processing and evaluation of echograms is a process that has moved from being determined by individual decisions, and thus very subjective, to become a more automated process determined by the spectrum of the multifrequency backscatter recorded during the survey. The Team presented the approaches behind the processing and evaluation of the data in detail. In general, the approach is a combination of automatic and manual processes. The methods applied are to a great extent consistent with those applied elsewhere. However, in common with analysis of acoustics data elsewhere, they involve some semi-subjective judgements. The background documentation for the meeting did not include specifications for the processes used to make these judgments but indicated that the process was more automated than appeared during the presentation. Subjective evaluation takes place after, instead of during, the survey, which is more common practice. Making decisions when most information is recent and available activates the learning-while-doing principle, a helpful tool for enhancing memory and securing future improvements.

Noise removal and calculation of frequency response for species identification are conducted in accordance with current practice. The Panel noted that account is not taken of the reduction of estimates of biomass from dense schools due to shadowing. It also noted that masking bubbles could potentially mask biomass.

Similarly, it was noted that the approach used to eliminate non-CPS epipelagic fishes during day-time acoustic sampling may lead to some species (e.g. herring) being excluded from the acoustic data used to estimate total CPS biomass, but that such species are likely included in the trawl catches used to apportion total CPS.

The extensive discussions following the responses on the multiple requests from the Panel that I want to highlight are as follows:

- Survey documentation- scientific surveys are becoming complex tools involving a number of steps and stages. Normally, these evolve over time to facilitate inclusion of new experience, knowledge and techniques into the methodology. This may impact all involved decision related to survey design. At present, the survey information is in multiple sources and not readily available to others aside from the Team. To ensure that standardisation is followed and/or that changes are implemented correctly, there is a need to develop a survey documentation document, preferably online, that can be updated and adjusted when needed. This will help future evaluation of the program but, most important, a well-documented survey will prevent individual interpretations of routines and procedures, and ensure a scientifically-based implementation of new information. To establish such a document is a matter of urgency and important for maintaining the quality of the survey and its external credibility.
- Vertical distribution close to survey remains an issue of uncertainty. The Team could not document substantial new information responding to the request/recommendation from the 2011 review. Various inputs were discussed, and I suggested two types of action: a) Using instrumentation onboard the survey vessel to map distribution patterns during the survey, such as multibeam sonar to assess vertical distribution at various distances away from the vessel (Patel and Ona 2009) or assessing densities of schools recorded by echosounder and horizontal sonar (see e.g. (Brehmer et al. 2006, Misund et al. 1996)).

b) Alternatively, the Team might use stationary (Ona et al. 2007) or movable (AUV) platforms (Fernandes et al. 2000, Patel et al. 2004) to evaluate vertical distribution independent of the vessel. This requires development of an easy operable technique that enables the team to quantify the amount of fish (if any) lost in surface layer during daytime surveying.

- The suitability of the trawl was critically discussed in the 2011 review (see my CIE report from 2011). No further evidence of its performance and efficiency was presented. There are some straightforward studies that could shed light on the issue. It was suggested that the overall size of the trawl might be too small, thus allowing the fish to see the trawl (Jamieson et al. 2006) and avoid it before entering. Using a trawl sonar to monitor the trawl opening and fish distribution within and around the trawl should be done (Ona 1994). The filtering capacity of the trawl can be studied by using a high frequency ADCP to measure speed of water inside and outside the trawl and cameras to study impacts of low filtering of the codend and successive escape of fish in front of the trawl.
- Although schooling of small pelagics is well known, the dynamics in the spacing and size is still not fully understood. Time series of school statistics, along with other stock characteristics, might become useful in studies of state and interaction dynamics of stocks. In addition, given that the shapes of schools of different species appear to look different, school shape should be considered as part of the system for deciding which schools are CPS. Having this information will also allow for easier back-calculation should a depth-dependent target strength model.
- The above information is collected as an integral part of the survey routine without substantial added effort if the used vessel has the needed sonar equipment. Thus, utilizing time series of survey data, including school statistics, to explore if changes in species dominance in the ecosystem causes changes in behavioural characteristics, like vertical and horizontal distribution dynamics, which ultimately will impact survey efficiency for those species, might become an invaluable tool to understand dynamics of small pelagics and the associated impact on the survey estimates.

Recommendation: The ATM involves many stages and steps, including decisions related to survey equipment, survey design, operational decisions during cruises, and analysis options. This is not unexpected for a methodology that is complex and involves multiple data sources. However, the overview document did not provide sufficient detail for the Panel to fully understand the entire process including actions taken to minimize identified problem in the methodology. While the Team demonstrates strong competence in acoustic methodologies, the biological trawl sampling still suffers from serious unclarity that requires action. Such action should involve using competence from the industry to evaluate the suitability of the trawl as well as development of alternative sampling approaches. Detailed documentation is currently in multiple documents and, for some matters, only known to the Team. Consequently, the Panel was not provided with full documentation and this needs to be addressed as a matter of urgency.

(b) <u>ToR 2 - Target strength of CPS from the California Current</u>,

Current ATM estimates rely on target strengths of similar CPS species identified in other studies around the world. The ability to measure target strengths of live fish collected from the survey *area can now be conducted at the Technology Tank at the SWFSC, La Jolla, CA. Target strengths of CPS from the California Current should be provided for the review meeting.*

Acoustic target strength is one of the essential parameters for assessing stock abundance with ATM. The Team has applied target strength (TS) values from the literature; sardine, horse mackerel and mackerel (Barange et al. 1996), and anchovy (Kang et al. 2009) (Table 2 in Panel report).

In situ studies of TS of anchovy by the Team have validated the used TS model. Repeated recordings were done of resolved targets in areas with relatively pure anchovy catches (99%) and is reported in a technical memorandum (by Zwolinski *et al.* see Panel report). The broader length frequency distribution indicated by the TS measurement could just as well be from the variable tilt angle distribution. It was noted that such TS studies in the outskirts of schools might not be representative of the TS in the school, both with respect to tilt angle distribution and size and species composition. For the summer surveys, when the mean depth of schools increased to 21 m, the b_{20} value was adjusted to 68.1 dB. This is the value used throughout the surveys. To apply target strength models for estimation of biomass, individuals of each species are randomly sampled from each trawl and the length frequencies are weighted by the catch sizes.

We had a substantial discussion on the use of a depth dependent TS as well as the actual depth distribution of the stock during surveying. The industry indicated that Pacific mackerel were recorded down to 200 m at daytime and vertical migration of sardine and anchovy is observed to below 70 m. Thus, using depth dependent TS models as developed for Atlantic herring (Ona 2003) and as used by the Team, might be appropriate. Notwithstanding issues of depth-dependence, there are some published target strength models for Pacific herring (Gauthier and Horne 2004, Thomas et al. 2002). These may be more appropriate than the current model used, which is based on pilchard.

Recommendation: Target strength remains a key uncertainty in the analysis of the acoustic data. Research to evaluate and improve target strength to length models should continue. The current choices for target species models seems appropriate, but the Team should continue to improve *in situ* TS measurement methodology including using the enhanced resolution offered by EK 60 (see chapter 5).

(c) <u>ToR 3 - Trawl survey design protocols for using a CPS preferred habitat model to determine adaptive sampling areas,</u>

In relation to a preferred habitat model for Pacific sardine, as well as other coastal pelagic species:
a. To the extent possible, address the fact that low population size likely affects the probability of acoustic detection in a non-linear way. This could create a negatively biased estimate at low population levels and potentially a non-detection threshold below which the stock size cannot be reliably assessed.

Low stock abundance will often lead to higher variability and thus greater uncertainty in population size. Potentially, this may in the end lead to highly variable management action in accordance with agreed decision rules with the associated problem for the industry. The abundance index will be hyperstable if the relative proportion of a stock that occurs outside of the sampling frame has an inverse relationship with stock size (e.g. if a larger proportion of the anchovy stock is closer to shore than the inshore boundary of the acoustic survey). Additional inshore transects conducted by the *FV Lisa Marie* in the Pacific Northwest during summer 2017 indicated that only a small portion of the stock (1.6%) of anchovy occurred in the nearshore in the summer in that area during that season. In contrast, the summer 2017 aerial survey off central California indicates a substantial portion of both anchovy and sardine may be shoreward of the shoreside limit of the acoustic survey in the summer in California.

As discussed above, the survey suffers due to great uncertainty in the trawl sampling. The uncertainty associated to small stock size including impacts in species composition might be accentuated by poor representativeness in the biological sampling. This could impact observations both within schools and in areas for which species composition is assigned to a particular trawl cluster. Further, interaction and competition among species undergoing large changes in abundance might lead to behavioural changes both in relation to acoustic observation volume and trawl efficiency. At small stock size, there is a greater chance of completely missing a species in the trawls or capturing a substantially higher proportion of that species than is actually in that area, and thus assigning a substantially wrong proportion to the estimated biomass (as well as calculating a somewhat incorrect target strength relationship).

b. Evaluate the costs and benefits of targeting sampling effort based on the preferred habitat model for Pacific sardine in terms of biomass estimates for Pacific sardine and for other CPS stocks.

Survey efficiency and cost benefit evaluation must be compared to the survey objectives. Most surveys have been focused on surveying Pacific sardine. The 2017 summer survey, in contrast, focused on the northern subpopulation of northern anchovy. The habitat model for Pacific sardine is used to help determine the sampling for those surveys focused on Pacific sardine. In general, the available vessel often influences the northern and/or southern boundaries of a particular survey. The summer survey moves from north to south, and uses various sources of information to determine the northern boundary of the survey. Nevertheless, the strong environmental driver of the north-south distribution creates an uncertainty of the spatial coverage of the survey.

The survey design includes areas with 20 nmi and others with 10 nmi inter-transect distances, based on previous observations where CPS are expected to occur in substantial numbers. Additional transects are held in reserve, and added between the 20 nmi interval transects when substantial biomass is seen on a transect. However, there are a limited number of these additional transects allotted. I question the strategy of allocating effort (or the amount of effort allocated) to additional transect in this strategy, as long as there is uncertainty in the overall coverage of the stock to the north and south.

Recommendation: Further investigation into the potential sources of bias is needed, both regarding the impact of stock size and the allocation of effort under the present state and development of the stocks. In particular, the present use of effort in adaptive sampling requires attention.

(d) ToR 4 - Effects of trawl survey design,

In relation to trawl survey design, the following should be considered and addressed:

a. The consequences of the time delay and difference in diurnal period of the acoustic surveys versus trawling need to be understood; validation or additional research is critical to ensure that the fish caught in the trawls from the nighttime scattering layer share the same species, age and size structure as the fish ensonified in the daytime clusters. To the extent possible, the ATM team should conduct paired trawls during daytime acoustic sampling, to validate (to generate a correction factor) nighttime species composition trawls.

The ATM has no trawl survey design as there is no trawl survey. Trawling is an integrated part of the overall method, and it supports biological information and verifies species composition of the acoustic record. Best practice for ATMs is to identify acoustic target at time of recording. The CPSs suffer dually from: a) the uncertainty in the efficiency of the applied trawl equipment and technique, and b) the time delay between acoustic and trawl sampling. This makes the CPS surveys vulnerable to uncertainty due to poor ground truthing. There are different approaches described in the literature on groundtruthing (see e.g. (McClatchie et al. 2000, Petitgas et al. 2003, Simmonds and MacLennan 2005). The ATM does not conform to any of the most used practices.

Validating the identity of fish seen on the echosounder by fishing or otherwise observing the fish during the day is desirable. While fishing was previously attempted using auxiliary vessels, it was not successful. This could be a gear issue, however (see Item 1 discussion of trawl design). Experiments to understand and improve the trawl presently in use, as well as testing a larger and more efficient trawl are relevant approaches. Relevant experiments would be night and day trawling at same location with headrope at different depths. Further, trawling on herring will, under certain conditions, only be successful if the skipper navigate the vessel around the school while the net passes through. To conduct such an experiment, it would be useful to consult with industry in the choice of approach, equipment, and experimental design. Several European nations engage with industry specialists (skippers) to assist with fishing operations during acoustic surveys on research vessels, recognizing that this is a specialized activity with which research vessel crew often have little experience. It would not only be directly useful to the ATM survey to include such experience by inviting a skipper on board to advise on fishing practices, but indirectly this would contribute greatly to improved relations between scientists and industry stakeholders. Most surveys for small pelagic species around the world do both acoustics and net sampling during the day, indicating that identification along with the acoustic sampling is possible when using the proper gear and suitable strategy during trawl operation.

b. Consider suitable sample sizes of CPS in the ATM survey. The ability of a single vessel following fixed transects along the entire northern sardine subpopulation region over a single period to sufficiently observe and sample a highly mobile schooling species that exhibits high variability in recruitment, migratory patterns and timing, school structure, and depth distribution, remains a core challenge. The relatively small sample size of sardine for biological analysis remains a concern related to acoustic expansions, population model estimates, and projection forecasts that depend on age composition and size-at-age information. Conduct an analysis of effect of fish sample size on the uncertainty in the ATM biomass estimates and model outputs. Use this information to re-evaluate and revise the sampling strategy for size and age data that includes target sample sizes for strata. (See Pacific Sardine STAR Panel Meeting Report, PFMC, April 2017).

No results were reported. The problems raised here are well known for this kind of species. Even in a multiple vessel survey conducted under a minimum of time (Norwegian survey on spawning population of herring with multiple fishing vessel) the migration bias is considered significant and has been accounted for based on migration speed measurement from sonar observations. It is therefore recommended that the Team start using similar approaches to quantify potential difficulties due the migration of fish during the survey time.

The low sample size recorded in the trawl catches might impact the estimates, both through wrong species representation and length frequency distribution.

c. Test the efficiency and selectivity of the trawl by comparing samples from the same area taken with the survey trawl and purse seine.

There were no results to report.

d. Estimate trawl selectivity. Cameras attached to the trawl in front of the cod end have been developed and used extensively since the 2013 surveys to observe and quantify fish behaviour and Marine Mammal Excluder Device (MMED) performance. The ATM team should report on findings from the camera research and quantify the selectivity of the trawl. If unquantifiable, describe state-of-the-art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl, and how the data would be incorporated into the biomass estimation process.

No results were reported.

Recommendation:

- There are multiple approaches described in the literature on how to apportion species category to acoustic recording (see Panel report), but the message should be that each individual survey need to find the appropriate way of apportioning acoustic values to species and lengths according to achieved experience and available technology.
- The Team's strong technology focus should be challenged to come up with acceptable solutions for this critical issue. This must also consider improved methods for biological sampling, including requesting support from the industry. There is a

need to develop appropriate methods for validating what is seen during day is reflected by the night time trawl samples.

- Use available sonar techniques to estimate migration speed of pelagic schools and thereby assess the potential impact of this factor to the present time difference between acoustic and biological sampling as well as impact on overall estimate of abundance.
- The only way of removing the uncertainty of the small sample sizes is to improve sampling efficiency as already recommended above.

(e) <u>ToR 5 - Effects of upgrading from the Simrad EK60 to EK80,</u>

After 10+ years of service, Simrad discontinued the EK60 series and introduced the EK80 series of transceivers and control software, which shifts from narrow-bandwidth transmit pulses to wide-bandwidth pulses using existing hull-mounted transducers. The ATM team should review the initial outcomes of the EK80 and provide information on the proposed benefits including: 1) fish echoes captured from more complete band of frequencies allowing improvement in species identification; 2) increased range resolution allowing detection of fish close to the bottom and individual fish within an aggregation; 3) increased signal-to-noise ratio allowing improvements in detection capabilities and effective range; and 4) extension and miniaturization of wide-band technology allowing autonomous deployment on smaller vessels (i.e., rigid hull inflatables which could sample nearshore areas, surface buoys, deep moorings, and ROVs). This item should not take up a large amount of time during the review, and should focus on summarizing the conclusions of workshops on comparing outputs from the EK60 and EK80 echosounders.

This issue was briefly discussed after a presentation given by Paul Fernandes. Four relevant issues were identified:

1. EK 80 allow new possibilities for *acoustic characterisation and species identification* due to the complete band width included in the available transducers. This is still considered a big step forward to minimize negative impacts from selective or inadequate trawl sampling. However, due to the variable tilt angle distribution in schools and layers, it is still uncertain how to utilize this new technology or what benefits there might be for identification. From my perspective, a more interesting approach would be to exploit the improved range resolution of EK 80 (see 2. below) to characterise spectrum of individuals which might better reflect unique backscattering properties that can be used to distinguish between target species.
2. *The increased range resolution* of EK 80 enhances the possibility to separate individuals in schools and layers, and thus open new possibilities for *in situ* acoustic TS observations. This is an important feature that could be exploited by the Team to obtain more realistic TS models to be used in the assessment. The improved range resolution also will help distinguishing fish target close to bottom from the bottom signal. For the present surveys this is not a major issue, but it might help under some circumstances in shallow water.
3. *The improved signal to noise ratio* may enhance range of the higher frequencies allowing improvements in detection capabilities and effective range. Thus, the full bandwidth might be effectively applied at deeper water than the present operational limitation of the EK 60 system.

4. *The miniaturisation* of the EK 80 system reflected in the wideband autonomous transceiver (WBAT) product allow self-sustained operation. The team has three available that could be used for multiple purposes including studies of fish close to surface (see discussion under ToR 1). Further, this development enables and/or makes it easier to use scientific echosounder systems on alternative platforms like AUV, bottom mounted systems and floating/submerged buoys.

Recommendation: The team should consider how the various advantages of the new broadband system can be used to reduce uncertainty in the CPS estimates.

(f) **ToR 6 - Effects of vessel avoidance for the upper water column.**

Multibeam systems (Simrad EK80s, ME70, MS70, and SX90) are now available on the FSV Reuben Lasker. These represent state-of-the-art instrumentation that will improve overall survey effectiveness and clarify issues related to school behavior around the survey vessel. These systems must be fully utilized to clarify vessel impact factors, and the ATM team should estimate what proportion of biomass is missed with the standard downlooking sonar.

The Team has in their portfolio a suite of multibeam systems that enable studies of behavioural and distributional issues identified during the 2011 review as sources of uncertainty for the quality of the CPS. The Team reported that some data had been collected, but there were no analyses completed for reporting to the Panel.

If fish avoid the vessel by changing its tilt angle and/or moving away from its path during the day, this will reduce the acoustic estimates of biomass. Similarly, if differential avoidance by species or size occurs at night, this could bias catches and consequently biomass estimates by species or size. There is no reason to believe that the CPS here are different from those elsewhere as a potential for species avoidance of the vessel, and experience tells us that avoidance behaviour is species-, life stage-, and situation-dependent. For example, avoidance behaviour of a species may change during spawning or when predators such as marine mammals are present and actively foraging. The sound profile of the ship can potentially affect avoidance behaviour, and in some instances the pressure wave it creates may be a factor, especially for larger vessels. The ICES specification for “silent” vessels is based on herring avoidance at 30 m depth. It should not be expected that fish at the surface have the same reaction, even to such a certified vessel. It was also stated that avoidance during cruising may be different from avoidance during trawling. Avoidance during trawling might be minimized by running the vessel around a school at the same time as navigating the trawl through the school, a technique that has been used in other surveys.

Several approaches have been used to study avoidance. Using an AUV in front of a quiet vessel, some have found no signs of avoidance (e.g.(Fernandes et al. 2000)). Other studies using an instrumented buoy or comparisons among vessels found various, if not sometimes contradictory effects (De Robertis and Handegard 2013, De Robertis and Wilson 2006, 2011, De Robertis et al. 2010, Ona et al. 2007), pointing to the complexity of the issue. There are no universal approaches on this topic, but there are a number of methods that could be used to estimate vessel avoidance. These involve technologies attached to the front or side of the vessel (sonar, LIDAR, spectral cameras), using relatively quiet instrumented platforms (buoys, moorings, AUVs, sail drones) or aerial platforms equipped with various optical sensors (spotter planes, aerial drones). Some of these instruments can be operated as part of or in conjunction with the acoustic survey, while others would require dedicated experimental time.

Recommendation: The Team has the needed equipment and the available competence to explore and quantify the potential impact of fish behaviour on survey results, also taking into account the varying survey conditions experienced during a survey. Such an experiment must be combined with collection of associated environmental information that can help characterising the survey condition, and thus understanding of the recorded behaviour. The available multibeam systems as well as the WBAT are excellent tools that should be exploited, also taking into account experience from similar studies elsewhere (De Robertis and Handegard 2013, Patel and Ona 2009, Rieucau et al. 2014). Using Lidar has proven a useful tool to study fish in the upper water masses and should be further explored.

(g) ToR 7 - ATM survey design in areas where the ATM vessel is currently not sampling

The 2017 Council STAR Panel concluded that lack of nearshore coverage by the ATM survey persists. The ATM team should, to the extent possible, describe ways (e.g., cooperative sampling, use of drones, etc.) to achieve the goal of providing an estimate of abundance or correction factor for those unsurveyed areas. The ATM team should also address the potential effects of reduced sea days, relative to generating estimates of un-sampled areas, as well as relative to the conduct of the overall survey itself. The ATM team should provide information on what a sufficient number of sea days is, and information on tradeoffs between spatial coverage and transects, etc.

During the 2011 ATM method review for CPS survey design associated to areas not surveyed was reviewed, requests were presented, and recommendations were provided. One request concerned providing an estimate of the area between the eastern ends of transects and the coastline by survey and strata. Data from the 2008 survey from a region north of Cape Mendocino indicated a survey abundance increase of 15% if this inshore higher density was applied to the inshore area outside the normal survey expansion region. The recommendation suggested further examination inshore the ends of the survey transects to provide best available information for expansion of estimates to un-surveyed inshore regions.

Results from the 2016-2017 CDFW (Californian Department of Fisheries and Wildlife) aerial survey program were presented and discussed. Simultaneous data from the ATM survey in August 2017 off northern California show significant anchovy biomass inshore of ATM transects (see Panel report). In 2016-2017 the aerial surveys had some overlap with the ATM transects at the extreme inshore end. The results from this effort were inconclusive because binned acoustic data had not yet been compared. Although a thorough analysis had not been completed, few schools were identified by both methods and a preliminary conclusion was that the two survey methods observe different schools. It is possible that the aerial survey observes surface schools in the blind zone of the area ensonified by the acoustic survey, whereas deeper schools observed by the ATM were not visible to aerial observations. If no further analysis of these data lead to conclusion, further experiments might be needed.

Information from the California Wetfish Producers Association (CWPA) gave further evidence of large aggregations of anchovy in nearshore regions off southern California from digital images, photos of fishing boat sonar images, video footage of schools at the surface, and stomach contents of bluefin tuna full of anchovy. The group collected 26 point sets where 100% of sardine schools were captured and weighed, although those data were not shown. They also demonstrated such distribution of large schools of both anchovy and sardine near Pismo Beach, Morro Bay, Monterey and Half Moon Bay. Their conclusion was that the biomass they observed exceeds NOAA's ATM survey estimate. Based on their numerous examples, the industry group requested that ATM survey results be treated as indices rather than absolute abundance estimates for all CPS finfish, largely because of under-represented nearshore aggregations. The majority of commercial catches in California are inside three miles (within state waters).

The inability of traditional echosounder surveys to cover inshore areas as well as the impacts of survey vessel on recording efficiency of pelagic fish in inshore areas (see e.g. (Misund et al. 2005) is a well-known problem worldwide (see reports from the Nansen program http://www.fao.org/in-action/eaf-nansen/topic/18005/en). Often stakeholder have different opinions, and it is up to managing bodies as well as assessment groups to solve the issue. The inconclusive evidence presented to the Panel from the nearshore survey conducted from the F/V *Lisa Marie* in June of 2017 compared to conducted aerial surveys and catch, and observation information from the industry still support a disagreement among stakeholders that undermine the credibility of the ATM survey to adequately cover target species.

Other data sources and methods were discussed. The CPSMT representative reminded the Panel that fishermen's catch log book data have been digitized, which can provide catch data within the polygons. This information may be useful in examining the relative magnitude of fish available to fishers offshore versus onshore. Sail drones, able to collect acoustic information nearshore or to extend ship transects, may provide an important tool in the future to extend survey regions.

Recommendation: I suggest that a better integration and ongoing effort from all stakeholders during the time of the survey could enhance understanding of distribution nearshore. Combined with new experiments using sail drones and/or other acoustic or visual methods to quantify inshore CPS abundance and species composition. There seem to be a need for dedicated effort to calibrate the acoustic and the aerial methods.

(h) ToR 8 - ATM data analysis and quantification of uncertainty,

Provide the appropriate level of documentation of data analysis and the degree to which the proposed methods describe and quantify the major sources of uncertainty. For each CPS stock under consideration (Pacific sardine, central subpopulation of northern anchovy, northern subpopulation of northern anchovy, Pacific mackerel, and jack mackerel), and to the extent possible, provide sufficient information for the review panel to determine whether the results of ATM survey as reviewed are suitable for:

a. inclusion as an index of relative abundance as one of multiple inputs into an integrated stock assessment;
b. inclusion as an index of absolute abundance (i.e. survey Q = 1) as one of multiple inputs into an integrated stock assessment; and
c. use the most recent estimate of absolute biomass to directly inform harvest management without the use of a formal integrated assessment.

In addition, the ATM team should describe how echogram backscatter is analyzed to exclude non-CPS backscatter.

The discussion around this ToR was associated to several questions to the Team on methodologies associated to the ATM data analysis.

Although much data have been collected on all pelagic species in the California Current since the 2011 review, only those collected on Pacific Sardine have been used in the assessment. The panel had a thorough discussion to uncover the potential use of the time series collected for the various species as is reflected in Table 1. A response on the question of aging uncovered substantial uncertainty in the age reading caused by inconsistency in the reading among readers/laboratories, which requires attention (also reflected in Table 1). For some of the species there is no aging at the moment. Consistency in aging can be studied by tracking abundance of a year class over years. These plots showed variable trends and no little agreement from year a to year a+1. The aging issue needs attention and directly impacts the data for further use in the assessment.

The 2011 review recommended Pacific sardine estimates to be used as absolute estimates in the stock assessment. Underlying this conclusion was several recommendations on research required to validate this conclusion. At present, they are used as indices but with a Q close to 1. Based on the presentation to the Panel, there seems to have been limited progress on any of those issues. Further, the difficulties revealed for the aging convince me that the Panel decision reflected in Table 1 is correct, in that the sardine estimate should be used as indices of abundance. The aging and inshore distribution seem to be a general difficulty for the application of the estimates in stock assessment.

Recommendation: The abundance estimates should be used as relative indices of abundance. The aging issued requires attention for all the involved stocks to ensure optimal use of the data in stock assessment along with the top priory recommendation discussed under the previous ToRs.

Table 1. Evaluation of possible use of ATM results in assessments and management. Q denotes the catchability coefficient between the biomass estimate and biomass in the model. This table does not discuss option (c) of TOR 8 given the Panel did not support using the ATM estimates as measures of absolute abundance, but it provides options for how biomass estimates from the survey could be used to directly inform management.

Species / stock	Inclusion in an integrated stock assessment		Use of biomass estimates from the survey to directly inform management (following an MSE)[4]	Ability to estimate abundance at age
	Relative abundance (Q estimated)[1]	Absolute abundance (Q=1)[2]		
Pacific Sardine	Yes	No	Yes	Yes, but there are concerns with aging
Pacific mackerel	Yes, summer surveys only	No	Yes, summer only	Yes, but there are concerns with aging
Jack mackerel	Yes, summer surveys only	No	Yes, summer only	In principle, but there is currently no ageing program
Northern sub-population of northern anchovy	Yes, summer surveys only, if inshore area is addressed[3]	No	Yes, summer surveys only, if inshore area is addressed	Yes – no current ageing program that is ready to be used
Central sub-population of northern anchovy	Yes, but only, if inshore areas are addressed[3]	No	Yes, but only if inshore areas are addressed	Yes – no current ageing program that is ready to be used

1: option (a) in the TOR 8
2: option (b) in the TOR 8
3: Only available from 2015.
4. Only with MSE. Harvest control rules that use indices of biomass that are not considered absolute have been developed for other fisheries using Management Strategy Evaluation, and generally involve examining changes in biomass indices.

5. CONCLUSIONS

The review was carried out efficiently and in a productive and stimulating atmosphere, although heated discussions sometimes uncovered that there are still issues of controversy and dispute. Being part of the 2011 Panel makes it easier to understand the strength and weaknesses of the Team. The methodological strengths of the Team are within acoustics, data processing and abundance modelling, and this work are of high scientific standard. They are following world standards and best practices, and indicate that Team mastered these parts of the methodology. The capability of the Team to solve the challenges associated to biological sampling seems less obvious. Further, it is surprising to see the lack of action towards high-ranked recommendation in the 2011 regarding fish distribution patterns (vertical and horizontal (mainly towards shore)), and impacts of behaviour on recorded densities even though most of the technology to shed light on these issues are available to the Team. Similarly, little progress in done on TS measurements. It is obvious that the Team has limited survey time for running the assessment cruise and simultaneously do methodological improvements. However, this is the way most surveys worldwide are improved; utilize the available time in the best way for the long-term benefit of the management. In particular, utilizing the state of art sonar technology onboard the vessels to collect data for further analysis, can be done with no additional cost. Some data were collected but no results presented. Inconsistency in the age readings and the distribution of fish close to shore were also highlighted as major sources of uncertainty. The lack of progress in validating the current practice of biological sampling at night of the acoustic recording obtained during day is also worrying. There is a need to set priorities to ensure a development that either follows best practice or otherwise is properly validated. I fully support the reverse of the 2011 Panel's recommendation of using estimates of sardines as absolute estimates of abundance. Further progress on the issues raised here is needed to get to that stage.

The strong divergence in view of the situation between the industry and the Team requires attention. This can undermine the legitimacy of the survey and the trust among stakeholders. Several issues were identified where industry effort and competence could be useful for the CPS ATM development. The associated recommendation should be followed.

As highlighted in my 2011 review, I still think the cycles in abundance of the various species require more attention. Being prepared for changes in species composition might require a different effort priority compared to minimizing variability of estimates of the current most abundant stock. I understand that a focused review of the acoustic-trawl survey methodology is needed, but I think that the usefulness of the survey and its review in coming years will depend on the survey's ability to adjust design according to the likely changes in distribution and abundance.

6. RECOMMENDATIONS FOR FUTURE RESEARCH AND DATA COLLECTIONS (IN PRIORITY ORDER)

A long-term strategy is needed to address the various issues discussed in this report. Experimental work to improve the results should be an integral part of conducting the survey.

A systematic approach over years starting with the crucial elements will support survey efficiency as well as ecological understanding. It was recognized that some of the field seasons are joint surveys with multiple goals (e.g. 2018 summer survey is a joint CPS and marine mammal and turtle survey), which adds complexity to the operational strategy as well as the methodology.

High priority

1. Construct a document, ideally a NOAA Technical Memo, that lists all the aspects of the ATM survey, including design and analysis. This document should be updated regularly given new information and decisions.
2. Study vertical distribution of fish to determine if CPS in the surface blind-zone represent a stable and/or variable portion of the overall density of significance to the stock assessment. This could be done using vessel sonars or acoustic moorings.
3. Continue to collect target strength data using best available technology with associated relevant biological information to improve current target strength models. Use net monitoring devices to monitor the trawl during all hauls. The optimal instrumentation is trawl sonar, which monitors the variable geometry of the trawl opening, and the distribution of fish within and outside the trawl opening
4. Continue to explore and expand independent nearshore survey methods and efforts to estimate the proportions of the populations that may not currently be surveyed by the ATM surveys.
5. Develop extrapolation methods from the existing data that would extend biomass estimates to the coastline, or, alternatively, document why such approaches are not needed for certain areas. Two potential methods include:
    a. Extend the existing polygons to the coastline and assume the same mean density.
    b. Use backscatter information collected nearshore (in-between transects) to extrapolate to the coastline.
6. Analyze the effect of the adaptive sampling of the bias of estimates of biomass using simulation or through reanalyzing various subsets of conducted transects.
7. Improve ageing of survey and fisheries samples to allow age composition data to be used in assessments.
8. Test efficiency (and suitability) of the existing trawl. This can be done either by comparing acoustic density measures with swept volume densities of the trawl or compare swept volume densities with similar measures from larger trawls and other gear types.
9. Develop methods to verify that daytime sound scatterers are the species and sizes caught in nighttime trawls; i.e. verify that efficient day time sampling of the acoustic record gives similar results as present night time sampling strategy. Such approaches could include alternative day-time sampling strategies (e.g. curved trawling trajectories) and/or different trawl gear, purse seining by day (either by the RV or using industry vessels), or alternative sampling techniques such as dropped cameras.
10. Validate the assumption that all coastal pelagic species spread out at the surface.

Medium priority

1. Conduct night trawls at different depths in the same area, with the headrope at the surface, at 15 m and at 30 m depth, for example to compare estimates of species and length composition.
2. Develop methods to extract information from the acoustic data about numbers of schools and their size and spacing. Time series of school statistics, along with other stock characteristics, might become useful in studies of state and interaction dynamics of stocks.
3. Compare the area (e.g. over several transects) and the current cluster approach to convert backscatter data to biomass when sample sizes for a particular species are insufficient.
4. Examine certain school characteristics (e.g. frequency response) by day and by night may also be instructive. In the case of "pure" species compositions, the latter may also be instructive to detect species-specific characteristics that could be latter applied for acoustic mark classification.
5. Examine the effects of the sample size of fish collected in trawls in terms of uncertainty and variability in indices and size and age compositions, and consider ways to increase sample size. Low sample size to estimate relative abundance by species affects indices more than the sizes collected, but the latter is important for estimating size and age structure. While increasing the length of trawls will help to some extent, other approaches may be more efficient.
6. Explore options to quantify potential fish avoidance under a range of survey conditions. This could involve combining systematic collection of additional data during surveys, as well as dedicated experiments.
7. Examine trends in density from the inshore ends of the survey transects to provide best available information for expansion of estimates to un-surveyed inshore regions.
8. In relation to ageing, evaluate the trade-offs between ageing more animals, but with lesser precision vs. ageing more animals with greater precision. Consider polishing otoliths before reading them.
9. Design and execute field experiments (for example by tracking fish schools with sonars over 24 hours) to study movements of fish between time of registration and time of sampling, to validate that the current sampling strategy is adequate to reflect the size and species composition of daytime acoustic records.
10. Utilize time series of survey data, including school statistics, to explore if changes in species dominance in the ecosystem causes changes in behavioural characteristics, like vertical and horizontal distribution dynamics, which ultimately will impact survey efficiency for those species.

Lower priority

1. Study fish behavior in front of the codend and trawl opening and measure flow inside/outside the trawl using a high frequency Acoustic Doppler Current Profiler (ADCP). This will allow an evaluation of the frequency with which fish escape. Such work is needed because the codend is relatively short with a small mesh liner, and it has probably insufficient filtering capacity at 4 knots. This might "block" the entrance of the codend and lead to an increased flow of water through the meshes in front of the codend where some fish will probably escape.

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Appendix 1: Documents provided to the Panel before the meeting

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Appendix 2: Statement of Work

Statement of Work

National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

Acoustic Trawl Methodology Review for use in Coastal Pelagic Species Stock Assessments

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf). Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

The three CIE reviewers will serve on a Methodology Review (MR) Panel and will be expected to participate in the review of Acoustic Trawl Method (ATM) currently used to produce biomass estimates for Pacific sardine stock assessments. The Pacific sardine stock is assessed regularly (currently, every 1 year) by Southwest Fisheries Science Center (SWFSC) scientists and the Pacific Fishery Management Council (PFMC) uses the resulting biomass estimate to establish an annual harvest guideline (quota). Currently, ATM biomass estimates for three other coastal pelagic species—Pacific mackerel, northern anchovy (two sub-stocks) and jack mackerel have not been approved for use in PFMC stock assessments (see 2011 ATM Methodology Review). It is the intent of this review to evaluate usefulness of the ATM for these stocks even though portions of the population may be outside the range of the ATM survey either in international waters or in shallow nearshore waters that cannot be sampled by the ATM in its present configuration.

The Methods Review Panel will review current ATM survey results and associated stock assessment documents and any other pertinent acoustic information for coastal pelagic species, work with the ATM Stock Assessment (STAT) team to make necessary revisions, and produce a MR Panel report for use by the PFMC and other interested persons for developing management recommendations for these fisheries. The ATM Terms of Reference (ToRs) provides the scope and range of issues that this methodology review should cover is provided in **Appendix 1** for the benefit of both the reviewers and the ATM STAT team. Additionally, the overarching PFMC ToRs for the methodology review process for groundfish and coastal pelagic species for 2017 and 2018 are available at: https://www.pcouncil.org//wp-content/uploads/2017/01/Methodology_ToR_CPSGF-2017-18.pdf. The tentative agenda of the Panel review meeting is attached in **Appendix 2**. Each CIE reviewer shall complete the independent peer review according to required format and content as described in **Appendix 3**. Finally, a Panel summary report template is included as **Appendix 4**.

Requirements
Three CIE reviewers shall participate during a panel methodology review meeting in La Jolla, California during 29 January-2 February 2018, and shall conduct impartial and independent peer review accordance with this Statement of Work (SoW) and ToRs herein. The CIE reviewers shall have the expertise as listed in the following descending order of importance:

- The CIE reviewer shall have expertise in the design and application of fisheries underwater acoustic technology to estimate fish abundance for stock assessments.
- The CIE reviewer shall have expertise in the design and execution of fishery-independent surveys for use in stock assessments, preferably with coastal pelagic fishes.
- The CIE reviewer shall have expertise in the application of fish stock assessment methods, particularly, length/age-structured modeling approaches, e.g., 'forward-simulation' models (such as Stock Synthesis, SS) and how fishery-independent surveys can be incorporated into such models.
- The CIE reviewer shall have expertise in the life history strategies and population dynamics of coastal pelagic fishes.
- It is desirable for the CIE reviewer to be familiar with the design and application of aerial surveys to estimate fish abundance for stock assessments.

Tasks for reviewers

<u>Pre-review Background Documents</u>
Review the following background materials and reports prior to the review meeting. Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site to the CIE reviewers all necessary background information and reports for the peer

review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewers shall read all documents in preparation for the peer review, for example:

- *Recent Acoustic Trawl Method documents and journal articles completed since 2010 provided for this review; Stock Assessement Review (STAR) Panel- and* Scientific and Statistical Committee *(SSC)-related documents pertaining to reviews of past ATM survey results and; CIE-related summary reports pertaining to past methodology reviews; and miscellaneous documents, such as ToRs, logistical considerations, etc.*

Panel Review Meeting

Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The meeting will consist of presentations by NOAA and other scientists to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers.

Contract Deliverables - Independent CIE Peer Review Reports

The CIE reviewers shall complete an independent peer review report in accordance with the requirements specified in this SoW and OMB guidelines. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in **Appendix 1**. Each CIE reviewer shall complete the independent peer review according to required format and content as described in **Appendix 3**.

Other Tasks – Contribution to Summary Report

The CIE reviewers may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the ToRs. The CIE reviewers are not required to reach a consensus, and should provide a brief summary of each reviewer's views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs. The Panel summary report template is attached as **Appendix 4**.

Foreign National Security Clearance

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-U.S. citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance
The place of performance shall be at the contractor's facilities, and at the Southwest Fisheries Science Center in La Jolla, California.

Period of Performance
The period of performance shall be from the time of award through April 30, 2017. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
No later than January 15, 2018	Contractor provides the pre-review documents to the reviewers
January 29 - February 2, 2018	The reviewers participate and conduct an independent peer review during the panel methods review meeting
No later than February 23, 2018	Contractor receives draft reports
No later than March 23, 2018	Contractor submits final reports to the Government

Applicable Performance Standards
The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each ToR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel
All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $12,000.

Restricted or Limited Use of Data
The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:
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SOW Appendix 1: Terms of Reference for Peer Review

Background

The National Marine Fisheries Service (NMFS) conducts scientific surveys to assess abundance estimates and trends in fish populations, for use in fisheries management decisions and other purposes. NMFS and the Pacific Fishery Management Council (Council) are jointly responsible for ensuring that survey design, protocols, and abundance estimates represent best scientific information available, and work cooperatively to ensure independent peer review of scientific products related to fisheries management. To this end, the Council developed a Terms of Reference (ToRs) to guide review of methodologies that are used in fisheries management decisions. These guiding ToRs are available at: https://www.pcouncil.org//wp-content/uploads/2017/01/Methodology_ToR_CPSGF-2017-18.pdf . In advance of such methodology reviews, NMFS and the Council will work with the Council's Scientific and Statistical Committee (SSC) to designate a methodology review panel, which includes a Chair, at least one member independent of the Council (often designated by the Center for Independent Experts [CIE]), and at least two additional members.

For each methodology review, a meeting-specific set of ToRs is produced to provide guidance on key questions to be addressed, additional background on any prior methodology reviews, and to describe expectations relative to the review. This document is the meeting-specific set of ToRs that will be used to guide the January 29 – February 2, 2018 methodology review of the Southwest Fisheries Science Center's (SWFSC) acoustic-trawl survey methodology (ATM) for coastal pelagic species (CPS) off the United States West Coast.

Scope

The Methodology Review (MR) Panel will conduct the review of the ATM currently used to produce biomass estimates for Pacific sardine stock assessments. The Pacific sardine stock is assessed annually by SWFSC scientists, and the Council uses the resulting biomass estimates to establish an annual harvest guideline and other harvest specifications. The ATM biomass estimates for three other coastal pelagic species (Pacific mackerel, two sub-stocks of northern anchovy, and jack mackerel) have not been approved for use in Council stock assessments (PFMC 2011). It is the intent of this review to also evaluate the usefulness of the ATM for these stocks even though portions of their populations are outside the range of the ATM survey, either in international waters or in shallow nearshore waters that the ATM survey cannot sample in its present configuration.

The MR Panel will review current ATM survey methodology and results in the context of recent stock assessment documents and any other pertinent acoustic information for CPS, work with the ATM team to make recommendations for any necessary modifications, and will produce a Panel report for consideration by the PFMC and for use by the SWFSC. That report will describe in detail the technical merits and deficiencies, recommendations for remedies, unresolved problems and major uncertainties, and recommendations for future research and data collection. This set of ATM ToRs provide the scope and range of issues that this methodology review should cover.

Background Information from Previous ATM Methodology Reviews

The Council first approved the use of the ATM at its April 2011 meeting after the ATM underwent a methodology review in February 2011, with the following conclusion:

> *"Overall, the Panel is satisfied that the design of the acoustic-trawl surveys, as well as the methods of data collection and analysis are adequate for the provision of advice on the abundance of Pacific sardine, jack mackerel, and Pacific mackerel, subject to caveats, in particular related to the survey areas and distributions of the stocks at the times of the surveys. The Panel concluded that estimates from the acoustic-trawl surveys could be included in the 2011 Pacific sardine stock assessment as 'absolute estimates', contingent on the completion of two tasks. Estimates of absolute abundance for the survey area can be used as estimates of the biomass of jack mackerel in U.S. waters (even though they may not cover all U.S. waters). The estimates of abundance for Pacific mackerel are more uncertain as measures of absolute abundance than for jack mackerel or Pacific sardine. A major concern for this species is that a sizable (currently unknown) fraction of the stock is outside of the survey area. However, the present surveys cannot provide estimates of abundance for the northern anchovy stocks for use in management. The Panel notes that the acoustic-trawl method potentially could be applied to survey CPS currently in low abundances, e.g., northern anchovy and Pacific herring, but the sampling design would need to differ from that used in the present surveys." (see Acoustic-Trawl Survey Method for Coastal Pelagic Species: Report of Methodology Review Panel Meeting Agenda Item C.3.a Attachment 1)*

Based on this conclusion, the ATM survey estimates of Pacific sardine abundance collected in 2006, 2008, 2010 and 2011 were incorporated into the 2011 Pacific sardine stock assessment. Since then, ATM abundance estimates collected both during spring and summer continue to be used as an integral part of the sardine assessment, including 2017. However, questions continue to be raised as to how well the ATM survey adequately samples the Pacific sardine population as well as other CPS (Pacific mackerel, jack mackerel and northern anchovy), mainly due to the unknown fraction of the population outside the survey area, either in the upper water column above the sensors or in spatial extent (e.g., Mexican waters, or nearshore or offshore areas where National Oceanic & Atmospheric Association (NOAA) vessels are unable to sample). (See Pacific Sardine STAR Panel Meeting Report, PFMC, April 2017).

Although the original MR Panel concluded that vessel avoidance had been studied using appropriate methods and there was no evidence of substantial avoidance effects, they did recommend further study, including that "long-term research should use more advanced instrumentation and methods for studying potential vessel effects and avoidance. In particular, the Panel suggests that a vessel by vessel study following the model of the Bering Sea comparative studies be conducted" (from NMFS 2011).

The ATM survey was also reviewed as part of the 2014 CIE Sardine-Hake (SaKe) Methodology Review, the report of which was presented to the Council as a joint report from the Northwest Fisheries Science Center (NWFSC) and the SWFSC at the June 2014 meeting (Agenda Item F.1.c Fisheries Science Center Report). All of these summary reports as well as reports from individual CIE reviewers identified above will be provided as background material for the review.

Items to be addressed during this 2018 Methodology Review
These methodology ToRs require a draft methodology report to be made available at least two weeks prior to the review meeting. That report should address the following items, for consideration during the review meeting, and will follow the general procedures laid out by the PFMC (See https://www.pcouncil.org//wp-content/uploads/2017/01/Methodology_ToR_CPSGF-2017-18.pdf).

1. **ATM Survey Documentation**
Document the ATM survey design, protocols (sampling, data filtering, etc.), and estimation methods, including the following:
    a. delineate the survey area (sampling frame);
    b. specify the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification);
    c. specify the rule for stopping a transect (offshore boundary by species);
    d. specify the rules for conducting trawls to determine species composition;
    e. specify the rules for adaptive sampling (including the stopping rule); and
    f. specify the rules for post-stratification, and in particular, how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account densities should be considered (PFMC 2017).
    g. Describe how echogram backscatter is analyzed to exclude non-CPS backscatter.

2. **Estimated Target Strengths of CPS from the California Current**
Current ATM estimates rely on target strengths of similar CPS species identified in other studies around the world. The ability to measure target strengths of live fish collected from the survey area can now be conducted at the Technology Tank at the SWFSC, La Jolla, CA. Target strengths of CPS from the California Current should be provided for the review meeting.

3. **Trawl Survey Design Protocols for Using a CPS Preferred Habitat Model to Determine Adaptive Sampling Areas**
In relation to a preferred habitat model for Pacific sardine, as well as other coastal pelagic species:
    a. To the extent possible, address the fact that low population size likely affects the probability of acoustic detection in a non-linear way. This could create a negatively biased estimate at low population levels and potentially a non-detection threshold below which the stock size cannot be reliably assessed.

b. Evaluate the costs and benefits of targeting sampling effort based on the preferred habitat model for Pacific sardine in terms of biomass estimates for Pacific sardine and for other CPS stocks.

4. **Effects of Trawl Survey Design**
   In relation to trawl survey design, the following should be considered and addressed:
   a. The consequences of the time delay and difference in diurnal period of the acoustic surveys versus trawling need to be understood; validation or additional research is critical to ensure that the fish caught in the trawls from the nighttime scattering layer share the same species, age and size structure as the fish ensonified in the daytime clusters. To the extent possible, the ATM team should conduct paired trawls during daytime acoustic sampling, to validate (to generate a correction factor) nighttime species composition trawls.
   b. Consider suitable sample sizes of CPS in the ATM survey. The ability of a single vessel following fixed transects along the entire northern sardine subpopulation region over a single period to sufficiently observe and sample a highly mobile schooling species that exhibits high variability in recruitment, migratory patterns and timing, school structure, and depth distribution, remains a core challenge. The relatively small sample size of sardine for biological analysis remains a concern related to acoustic expansions, population model estimates, and projection forecasts that depend on age composition and size-at-age information. Conduct an analysis of effect of fish sample size on the uncertainty in the ATM biomass estimates and model outputs. Use this information to re-evaluate and revise the sampling strategy for size and age data that includes target sample sizes for strata. (See Pacific Sardine STAR Panel Meeting Report, PFMC, April 2017).
   c. Test the efficiency and selectivity of the trawl by comparing samples from the same area taken with the survey trawl and purse seine.
   d. Estimate trawl selectivity. Cameras attached to the trawl in front of the cod end have been developed and used extensively since the 2013 surveys to observe and quantify fish behavior and Marine Mammal Excluder Device (MMED) performance. The ATM team should report on findings from the camera research and quantify the selectivity of the trawl. If unquantifiable, describe state-of-the-art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl, and how the data would be incorporated into the biomass estimation process.

5. **Effects of Upgrading from the Simrad EK60 to EK80**
   After 10+ years of service, Simrad discontinued the EK60 series and introduced the EK80 series of transceivers and control software, which shifts from narrow-bandwidth transmit pulses to wide-bandwidth pulses using existing hull-mounted transducers. The ATM team should review the initial outcomes of the EK80 and provide information on the proposed benefits including: 1) fish echoes captured from more complete band of frequencies allowing improvement in species identification; 2) increased range resolution allowing detection of fish close to the bottom and individual fish within an aggregation; 3) increased

signal-to-noise ratio allowing improvements in detection capabilities and effective range; and 4) extension and miniaturization of wide-band technology allowing autonomous deployment on smaller vessels (i.e., rigid hull inflatables which could sample nearshore areas, surface buoys, deep moorings, and ROVs). This item should not take up a large amount of time during the review, and should focus on summarizing the conclusions of workshops on comparing outputs from the EK60 and EK80 echosounders.

6. **Effects of Vessel Avoidance for the Upper Water Column**
   Multibeam systems (Simrad EK80s, ME70, MS70, and SX90) are now available on the FSV Reuben Lasker. These represent state-of-the-art instrumentation that will improve overall survey effectiveness and clarify issues related to school behavior around the survey vessel. These systems must be fully utilized to clarify vessel impact factors, and the ATM team should estimate what proportion of biomass is missed with the standard down-looking sonar.

7. **ATM Survey Design in Areas Where the ATM Vessel is Currently Not Sampling**
   The 2017 Council STAR Panel concluded that lack of nearshore coverage by the ATM survey persists. The ATM team should, to the extent possible, describe ways (e.g., cooperative sampling, use of drones, etc.) to achieve the goal of providing an estimate of abundance or correction factor for those unsurveyed areas.

   The ATM team should also address the potential effects of reduced sea days, relative to generating estimates of un-sampled areas, as well as relative to the conduct of the overall survey itself. The ATM team should provide information on what a sufficient number of sea days is, and information on tradeoffs between spatial coverage and transects, etc.

8. **ATM Data Analysis and Quantification of Uncertainty**
   Provide the appropriate level of documentation of data analysis and the degree to which the proposed methods describe and quantify the major sources of uncertainty. For each CPS stock under consideration (Pacific sardine, central subpopulation of northern anchovy, northern subpopulation of northern anchovy, Pacific mackerel, and jack mackerel), and to the extent possible, provide sufficient information for the review panel to determine whether the results of ATM survey as reviewed are suitable for:
   a. inclusion as an index of relative abundance as one of multiple inputs into an integrated stock assessment;
   b. inclusion as an index of absolute abundance (i.e. survey Q = 1) as one of multiple inputs into an integrated stock assessment; and
   c. use the most recent estimate of absolute biomass to directly inform harvest management without the use of a formal integrated assessment.

   In addition, the ATM team should describe how echogram backscatter is analyzed to exclude non-CPS backscatter.

References

PFMC 2011. Report of the 2011 ATM Methodology Review, April 2011 Agenda Item C.3.a, Attachment 1.

PFMC 2017. Report of the 2017 Pacific Sardine STAR Panel Meeting, April 2017 Agenda Item G.5.a., STAR Panel Report.

SOW Appendix 2: Draft Agenda - ATM Methodology Review Panel

Monday, 29 January

13h00	Call to Order and Administrative Matters	
	Introductions	Sweetnam/Griffin
	Facilities, e-mail, network, etc.	Sweetnam
	Work plan and Terms of Reference	Sweetnam/Griffin
	Report Outline and Appointment of Rapporteurs	SSC Chair/CIE Cha
14h00	Pacific Sardine survey-based Acoustic Trawl Methods Procedures	ATM STAT
15h00	Break	
15h30	Pacific Sardine ATM results incorporated into Stock Assessment	STAR STAT
16h30	Public comments and general issues	
17h00	Adjourn	

Tuesday, 30 January

08h30	Pacific Sardine survey-based AcousticTrawlMethodsProcedures	ATM STAT
10h00	Break	
10h30	Pacific Sardine survey-based AcousticTrawlMethodsProcedures	ATM STAT
12h00	Lunch	
13h30	Target Strengths of California Current CPS	ATM STAT
14h30	Additional ATM Survey presentations	ATM STAT
15h00	Break	
15h30	Panel discussion and analysis requests	Panel
16h30	Public comments and general issues	
17h00	Adjourn	

Wednesday, 31 January

08h00	Additional ATM Survey presentations	ATM STAT
09h00	ATM STAT Team responses to analysis requests	ATM STAT
10h30	Break	
11h00.	Additional ATM Survey presentations	ATM STAT
12h30	Lunch	
13h30	Report drafting	Panel
15h00	Break	
15h30	ATM STAT Team Responses	ATM STAT
16h00	Discussion and MR Panel requests	
16h30	Public comments and general issues	
17h00	Adjourn	

Thursday, 1 February

08h00.	Assessment Team Responses	ATM STAT
10h30	Break	
11h00.	Discussion and STAR Panel requests	Panel
12h30	Lunch	
13h30	Report drafting	Panel
15h00	Break	
15h30	Assessment Team Responses	ATM STAT
16h00	Discussion and MR Panel requests	
16h30	Public comments and general issues	
17h00	Adjourn	

Friday, 2 February

08h00. Assessment Team Responses	ATM STAT
10h30 Break	
11h00. Discussion and MR Panel requests	Panel
12h30 Lunch	
13h30 Finalize MR Panel Report	Panel
15h00 Break	
15h30 Finalize MR Panel Report	Panel
16h30 Public comments and general issues	

SOW Appendix 3: Format and Contents of CIE Independent Peer Review Report

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.

   a. Reviewers must describe in their own words the review activities completed during the panel review meeting, including a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each TOR even if these were consistent with those of other panelists, but especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.

3. The report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of this Statement of Work
   Appendix 3: Panel membership or other pertinent information from the panel review meeting.

SOW Appendix 4: ATM Methodology Review Panel Summary Report

1. Names and affiliations of Methodology Review Panel members

2. List of analyses requested by the Methodology Review Panel, the rationale for each request, and a brief summary the STAT responses to each request

3. Comments on the technical merits and/or deficiencies in the assessment and recommendations for remedies

4. Explanation of areas of disagreement regarding Methodology Review Panel recommendations
   - among Methodology Review Panel members (including concerns raised by the CPSMT and the Coastal Pelagic Advisory Subpanel (CPSAS) representatives)
   - between the Methodology Review Panel and STAT Team

5. Unresolved problems and major uncertainties, e.g., any special issues that complicate scientific assessment, questions about the best model scenario, etc.

6. Management, data or fishery issues raised by the public and CPSMT and CPSAS representatives during the Methodology Review Panel

7. Prioritized recommendations for future research and data collection

Appendix 3: List of Participants

Attendance List – ATM Review
Methodology Review Panel
André Punt, SSC, University of Washington, Chair
Evelyn Brown, SSC, Lummi Indian Nation
Owen Hamel, SSC, NWFSC
Stéphane Gauthier, CIE, Institute of Ocean Sciences, Canada
Paul Fernandes, CIE, University of Aberdeen
Olav Rune Godø, CIE, Institute of Marine Research, Norway

Pacific Fishery Management Council (Council) Representatives
David Crabbe, PFMC
Cyreis Schmitt, Coastal Pelagic Species Management Team (CPSMT)
Diane Pleschner-Steele, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Kerry Griffin, Council Staff

***Acoustic-Trawl Method Technical Team**:*
David Demer, SWFSC
Juan Zwolinski, SWFSC
Kevin Stierhoff, SWFSC
Josiah Renfree, SWFSC
David Murfin, SWFSC
Steve Sessions, SWFSC
Dan Palance, SWFSC
Scott Mau, SWFSC

Other:
Josh Lindsay, NMFS WCR
Gerard DiNardo, SWFSC
Emmanis Dorval, SWFSC
Briana Brady, CDFW
Kirk Lynn, CPSMT/CDFW
Kevin Hill, SWFSC
Mike Okoniewski, CPSAS/Pacific Seafood
Steve Marx, Pew Trusts
Bev Macewicz, SWFSC
Alan Sarich, CPSMT/Quinault Indian Nation
Dale Sweetnam, SWFSC
Paul Crone, SWFSC
Roger Hewitt, SWFSC
Ed Weber, SWFSC
Sam McClatchie, SWFSC
James Hilger, SWFSC
Noelle Bowlin, SWFSC

Geoff Shester, Oceana
Kristen Koch, SWFSC
Toby Garfield, SWFSC
Trung Nguyen, CDFW
Phill Dionne, WDFW
Katie Grady, CDFW
Bill Watson, SWFSC
Dan Averbuj, CDFW
Kim Boone, CDFW
Steven Teo, SWFSC
Michael Kinney, SWFSC
Sharon Charter, SWFSC
Magumi Enomoto, Tokyo University
Anne Freire, SWFSC
Megan Human, SWFSC
Luke Thompson, SWFSC