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) 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 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) 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.

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.

7. REFERENCES

– Barange, M., Hampton, I. and Soule, M. (1996) Empirical determination of in situ target strengths of three loosely aggregated pelagic fish species. ICES Journal of Marine Science 53(2), 225-232.

– Brehmer, P., Lafont, T., Georgakarakos, S., Josse, E., Gerlotto, F. and Collet, C. (2006) Omnidirectional multibeam sonar monitoring: applications in fisheries science. Fish and Fisheries 7(3), 165-179.

– De Robertis, A. and Handegard, N.O. (2013) Fish avoidance of research vessels and the efficacy of noise-reduced vessels: a review. ICES Journal of Marine Science 70(1), 34-45.

– De Robertis, A. and Wilson, C.D. (2006) Walleye pollock respond to trawling vessels. ICES Journal of Marine Science 63(3), 514-522.

– De Robertis, A. and Wilson, C.D. (2011) Silent ships do not always encounter more fish (revisited): comparison of acoustic backscatter from walleye pollock recorded by a noise-reduced and a conventional research vessel in the eastern Bering Sea. ICES Journal of Marine Science 68(10), 2229-2239.

– De Robertis, A., Wilson, C.D., Williamson, N.J., Guttormsen, M.A. and Stienessen, S. (2010) Silent ships sometimes do encounter more fish. 1. Vessel comparisons during winter pollock surveys. ICES Journal of Marine Science 67(5), 985-995.

– Fernandes, P.G., Brierley, A.S., Simmonds, E.J., Millard, N.W., McPhail, S.D., Armstrong, F., Stevenson, P. and Squiress, M. (2000) Oceanography - Fish Do Not Avoid Survey Vessels. Nature 404(6773), 35-36.

– Gauthier, S. and Horne, J.K. (2004) Acoustic characteristics of forage fish species in the Gulf of Alaska and Bering Sea based on Kirchhoff-approximation models. Canadian Journal of Fisheries and Aquatic Sciences 61(10), 1839-1850.

– Jamieson, A.J., Godø, O.R., Bagley, P.M., Partridge, J.C. and Priede, I.G. (2006) Illumination of trawl gear by mechanically stimulated bioluminescence. Fisheries Research 81(2-3), 276-282.

– Kang, D., Cho, S., Lee, C., Myoung, J.G. and Na, J. (2009) Ex situ target-strength measurements of Japanese anchovy (Engraulis japonicus) in the coastal Northwest Pacific. ICES Journal of Marine Science 66(6), 1219-1224.

– McClatchie, S., Thorne, R.E., Grimes, P. and Hanchet, S. (2000) Ground truth and target identification for fisheries acoustics. Fisheries Research 47(2-3), 173-191.

– Misund, O., Luyeye, N., Boyer, D., Coetzee, J., Cloete, R., Dalen, J. and Oechslin, G. (2005) Observations on the near-surface behaviour of sardinella schools in Angolan waters. African Journal of Marine Science 27(1), 169-176.

– Misund, O.A., Aglen, A., Hamre, J., Ona, E., Rottingen, I., Skagen, D. and Valdemarsen, J.W. (1996) Improved mapping of schooling fish near the surface: Comparison of abundance estimates obtained by sonar and echo integration. ICES Journal of Marine Science 53(2), 383-388.

– Ona, E. (1994) Recent Developments of Acoustic Instrumentation in Connection with Fish Capture and Abundance Estimation. Ferno, A. and Olsen, S. (eds), pp. 200-216, Fishing News Books, Blackwell Science Ltd, Oxford.

– Ona, E. (2003) An expanded target-strength relationship for herring. ICES Journal of Marine Science 60(3), 493-499.

– Ona, E., Godø, O.R., Handegard, N.O., Hjellvik, V., Patel, R. and Pedersen, G. (2007) Silent Research Vessels Are Not Quiet. Journal of the Acoustical Society of America 121(4), EL145-EL150.
– Patel, R., Handegard, N.O. and Godø, O.R. (2004) Behaviour of herring (Clupea harengus L.) towards an approaching autonomous underwater vehicle. ICES Journal of Marine Science 61(7), 1044-1049.
– Patel, R. and Ona, E. (2009) Measuring herring densities with one real and several phantom research vessels. ICES Journal of Marine Science 66(6), 1264-1269.
– Petitgas, P., Masse, J., Beillois, P., Lebarbier, E. and Le Cann, A. (2003) Sampling variance of species identification in fisheries-acoustic surveys based on automated procedures associating acoustic images and trawl hauls. ICES Journal of Marine Science 60(3), 437-445.
– Rieucau, G., De Robertis, A., Boswell, K.M. and Handegard, N.O. (2014) School density affects the strength of collective avoidance responses in wild-caught Atlantic herring Clupea harengus: a simulated predator encounter experiment. Journal of Fish Biology 85(5), 1650-1664.
– Simmonds, J. and MacLennan, D.N. (2005) Fisheries acoustics : theory and practice, Blackwell Sciene, Oxford.
– Thomas, G.L., Kirsch, J. and Thorne, R.E. (2002) Ex situ target strength measurements of Pacific herring and pacific sand lance. North American Journal of Fisheries Management 22(4), 1136-1145.

Appendix 1: Documents provided to the Panel before the meeting

Document prepared for the meeting

Demer, D.A, Zwolinski, J.P., Stierhoff, K.L., Renfree, J.S, Palance, D., Mau, S., Murfin, D. and Stevens, S. Acoustic-Trawl Methods for Surveying Coastal Pelagic Fishes in the California Current Ecosystem.

Other documents provided to the Panel

Barange, M., Hampton, I. and Soule, M. 1996. Empirical determination of in situ target strengths of three loosely aggregated pelagic fish species. *ICES Journal of Marine Science* 53: 225-232.

Conti, Stephane and D. Demer. 2003. Wide-Bandwidth Acoustical Characterization of Anchovy and Sardine from Reverberation Measurements in an Echoic Tank. In *ICES Journal of Marine Science*, 60: 617-624.

Cutter, G.R. and D. Demer. 2008. California Current Ecosystem Survey 2006 Acoustic Cruise Reports for NOAA FSV Oscar Dyson and NOAA FRV David Starr Jordan. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-415. La Jolla, CA.

Demer, D.A., and J.P. Zwolinski. 2017. A Method to Consistently Approach the Target Total Fishing Fraction of Pacific Sardine and Other Internationally Exploited Fish Stocks, *North American Journal of Fisheries Management*, 37:2, 284-293.

Demer, D.A., Andersen, L.N. Bassett, C., Berger, L., Chu, D., Condiotty, J., et al. 2017. 2016 USA–Norway EK80 Workshop Report: Evaluation of a wideband echosounder for fisheries and marine ecosystem science. *ICES Cooperative Research Report* 336: 69.

Demer, D.A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., *et al*. 2015. Calibration of acoustic instruments. *ICES Cooperative Research Report* No. 326. 133 pp.

Demer, D.A., G. Cutter, K. Stierhoff, J. Renfree. 2015. Two-Million-Liter Tank Expands the Boundaries of Marine Technology Innovation: National Resource Available for Advancing Marine Science. In *Marine Technology Society Journal*. March/April 2015 Vol. 15 no.2.

Demer, David and J.P. Zwolinski. 2012. Reply to MacCall et al.: Acoustic-trawl survey results provide unique insight to sardine stock decline. Letter in *Proceedings of the National Academy of Sciences*, Early Edition; doi: 10, 1073.

Demer, D., et al. 2018. Acoustic-Trawl Methods for Surveying Coastal Pelagic Fishes in the California Current Ecosystem. Preliminary Synthesis Report for the Pacific Fishery Management Council Methodology Review. 2018. National Oceanic and Atmospheric Administration (NOAA) Southwest Fisheries Science Center Advanced Survey Technologies Group. La Jolla California.

Demer, D., J. Zwolinski, K. Byers, G. Cutter, J. Renfree, T. Sessions, and B. Macewicz. 2012. Prediction and confirmation of seasonal migration of Pacific sardine (Sardinops sagax) in the California Current Ecosystem. In *Fishery Bulletin* 110:52-70 (2012).

Demer, D., J.P. Zwolinski, G. Cutter, K. Byers, B. Macewicz, and K. Hill. 2013. Sampling selectivity in acoustic-trawl surveys of Pacific sardine (*Sardinops sagax*) biomass and length distribution. In *ICES Journal of Marine Science*; doi: 10, 1093.

Demer, D., J.P. Zwolinski. 2013. Measurements of natural mortality for Pacific sardine (*Sardinops sagax*). In *ICES Journal of Marine Science*; 70: 1408-1415.

Demer, D., J.P. Zwolinski. 2014. Corroboration and refinement of a method for differentiating landings from two stocks of Pacific sardine (Sardinops sagax) in the California Current. *In ICES Journal of Marine Science;* 71: 328-335.

Demer, D., J.P. Zwolinski. 2014. Environmental and parental control of Pacific sardine (*Sardinops sagax*) recruitment. In *ICES Journal of Marine Science*; 71: 2198-2207.

Demer, D., J.P. Zwolinski. 2014Optimizing Fishing Quotas to Meet Target Fishing Fractions of an Internationally Exploited Stock of Pacific Sardine. In *North American Journal of Fisheries Management*, 34:6, 1119-1130.

Demer, D. 2004. An Estimate of Error for the CCAMLR 2000 Survey Estimate of Krill Biomass. In *Deep-Sea Research II* 51, 1237-1251.

Hill, K., B. Macewicz, P. Crone, and E. Dorval. 2016. Assessment of the Pacific Sardine Resource in 2016 for U.S. Management in 2016-17. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-562. La Jolla, CA.

Hill, K., B. Macewicz, P. Crone, E. Dorval, D. Demer, and J. Zwolinski. 2014. Assessment of the Pacific Sardine Resource in 2014 for U.S. Management in 2015. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-531. La Jolla, CA.

Hill, K., N. Lo, B. Macewicz, and P. Crone. 2015. Assessment of the Pacific Sardine Resource in 2015 for U.S. Management in 2015-16. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-546. La Jolla, CA.

Hill, K., N. Lo, B. Macewicz, P. Crone, and R. Felix-Uraga. 2010. Assessment of the Pacific Sardine Resource in 2010 for U.S. Management in 2011. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-469. La Jolla, CA.

Hill, K., N. Lo, B. Macewicz, P. Crone, D. Demer, and J. Zwolinski. 2012. Assessment of the Pacific Sardine Resource in 2012 for U.S. Management in 2013. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-501. La Jolla, CA.

Hill, K., N. Lo, B. Macewicz, P. Crone, E. Dorval, J. McDaniel, and Y. Gu. 2011. Assessment of the Pacific Sardine Resource in 2011 for U.S. Management in 2012. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-487. La Jolla, CA.

Hill, K., P. Crone, and J. Zwolinski. 2017. Assessment of the Pacific Sardine Resource in 2017 for U.S. Management in 2017-18. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-576. La Jolla, CA.

Lynn, K, Porzio, D. Nguyen, T.and Ryley, L. 2017. Southern California Aerial Survey for Pacific Sardine (*Sardinops sagax*) and Northern Anchovy (*Engraulis mordax*). Pacific Fishery Management Council June 2017 Agenda Item D.2.a, CDFW Report.

PFMC 2011. Acoustic-Trawl Survey Method for Coastal Pelagic Species; Report of Methodology Review Panel Meeting. April 2011 Agenda Item C.3.a Attachment 1. Pacific Fishery Management Council, Portland, Oregon.

PFMC 2016. Methodology Review Process for Groundfish and Coastal Pelagic Species for 2017 – 2018. Pacific Fishery Management Council. Portland, OR. June 2016.

Renfree, J. S., and Demer, D. A. 2016. Optimizing transmit interval and logging range while avoiding aliased seabed echoes. In *ICES Journal of Marine Science*, 73: 1955-1964.

Stierhoff, et al. 2015. Report on the Collection of Data During the Acoustic-Trawl and Daily Egg Production Methods Survey of Coastal Pelagic Fish Species and Krill (1504SH) within the

California Current Ecosystem, 28 March to 1 May 2015, Conducted Aboard Fisheries Survey Vessel Bell M. Shimada. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-580. La Jolla, CA.

Stierhoff, et al. 2016. Report on the Collection of Data During the Acoustic-Trawl and Daily Egg Production Methods Survey of Coastal Pelagic Fish Species and Krill (1604RL) within the California Current Ecosystem, 22 March to 22 April 2016, Conducted Aboard Fisheries Survey Vessel Reuben Lasker. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-581. La Jolla, CA.

Stierhoff, et al. 2017. Report on the Collection of Data During the Acoustic-Trawl and Daily Egg Production Methods Survey of Coastal Pelagic Fish Species and Krill (1704SH) within the California Current Ecosystem, 21 March to 22 April 2017, Conducted Aboard Fisheries Survey Vessel Bell M. Shimada. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-582. La Jolla, CA.

Stierhoff, et al. 2018. Report on the Collection of Data During the Summer 2017 California Current Ecosystem Survey (1706RL), 19 June to 11 August 2017, Conducted Aboard Fisheries Survey Vessel Reuben Lasker. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-593. La Jolla, CA.

Zwolinski et al. 2015. Southwest Fisheries Science Center Summary of Current Information Available on Coastal Pelagic Species with Emphasis on the Central Subpopulation of Northern Anchovy. In Pacific Fishery Management Council November 2016 Agenda Item G.4.a, Supplemental SWFSC Report.

Zwolinski et al. 2016. Acoustic-Trawl Estimates of Northern Stock Pacific Sardine Biomass during 2015. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-559. La Jolla, CA.

Zwolinski et al. 2017. Distribution, Biomass, and Demography of the Central-Stock of Northern Anchovy during Summer 2016, Estimated from Acoustic-Trawl Sampling. National Oceanic and Atmospheric Administration Technical Memorandum NOAA-TM-NMFS-SWFSC-572. La Jolla, CA.

Zwolinski, J.P. and D. Demer. 2011. A cold oceanographic regime with high exploitation rates in the Northeast Pacific forecasts a collapse of the sardine stock. In *Proceedings of the National Academy of Sciences*, vol. 109 no. 11; 4175-4180.

Zwolinski, J.P., D.A. Demer, G.R. Cutter Jr., K. Stierhoff, and B.J. Macewicz. 2014. Building on fisheries acoustics for marine ecosystem surveys. *Oceanography* 27(4):68–79, http://dx.doi.org/10.5670/oceanog.2014.87.

Zwolinski, J.P., R. Emmett, and D. Demer. 2011. Predicting habitat to optimize sampling of Pacific sardine (*Sardinops sagax*). In *ICES Journal of Marine Science*, 68(5), 867-879.

Zwolinsky, J.P., Demer, D.A., Macewicz, B.J., Mau, S., Murfin, D., Palance, D., Renfree, J.S., Sessions, T.S. and Stierhoff, K. 2017. Distribution, biomass and demography of the central-stock of northern anchovy during summer 2016, estimated from acoustic-trawl sampling. NOAA-TM-NMFS-SWFSC-572.

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

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: 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