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

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

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Contents

1 Executive Summary

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

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

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

2 Background

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

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

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

3 Reviewers' role and review activities

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

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

4 Summary of findings for each TOR

4.1 ATM survey documentation.

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

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

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

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

a. delineate the survey area (sampling frame).

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

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

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

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

c. *specify the rule for stopping a transect (offshore boundary by species).*

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

Issue: Not enough information was provided on stopping rules for offshore sections of transect.

Potential solution: Document the stopping rules and guiding principles in a document outlining all methodologies for the ATM surveys.

d. *specify the rules for conducting trawls to determine species composition.*

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

Issue: Strategies to select trawl locations were not fully documented and provided. There is a risk that some areas may be subject to (trawl) under-sampling due to survey time constraints.

Potential solutions: Document the guiding principles that dictate where trawl samples occur in a complete methodology document, and how trawl clusters are assigned. Consider prioritizing sampling over time constraints (being back at waypoint in the morning) when distribution of CPS backscatter during the day warrant more sampling trawl stations. Inter-cluster variance should also be documented and reported.

e. *specify the rules for adaptive sampling (including the stopping rule).*

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

f. *specify the rules for post-stratification, and in particular how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account densities should be considered (PFMC 2017).*

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

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

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

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

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

4.2 Estimated target strengths of CPS from the California Current.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.4 Effects of trawl survey design.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.5 Effects of upgrading from the Simrad EK60 to EK80.

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

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

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

4.6 Effects of vessel avoidance for the upper water column.

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

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

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

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

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

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

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

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

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

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

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

4.8 ATM data analysis and quantification of uncertainty.

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

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

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

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

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

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

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

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

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

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

5 Conclusions and recommendations

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

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

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

6 NMFS review process

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

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Appendix 1 – Bibliography of materials provided for review

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

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Appendix 2 – CIE Statement of Work

Statement of Work

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

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

Background

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

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

Scope

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

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

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

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

Tasks for reviewers

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

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

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

Panel Review Meeting

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

Contract Deliverables - Independent CIE Peer Review Reports

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

Other Tasks – Contribution to Summary Report

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

Foreign National Security Clearance

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

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

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

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

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

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

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

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

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

NMFS Project Contact:

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

SOW Appendix 1: Terms of Reference for Peer Review

Background

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

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

Scope

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

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

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

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

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

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

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

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

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

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

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

3. **Trawl Survey Design Protocols for Using a CPS Preferred Habitat Model to Determine Adaptive Sampling Areas**
   In relation to a preferred habitat model for Pacific sardine, as well as other coastal pelagic species:
   a. To the extent possible, address the fact that low population size likely affects the probability of acoustic detection in a non-linear way. This could create a negatively

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

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

4. **Effects of Trawl Survey Design**

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

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

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

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

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

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

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

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

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

References

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

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

SOW Appendix 2: Draft Agenda - ATM Methodology Review Panel

Monday, 29 January

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

Tuesday, 30 January

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

Wednesday, 31 January

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

Thursday, 1 February

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

Friday, 2 February

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

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

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

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

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

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

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

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

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

3. The report shall include the following appendices:

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

SOW Appendix 4: ATM Methodology Review Panel Summary Report

1. Names and affiliations of Methodology Review Panel members

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

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

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

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

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

7. Prioritized recommendations for future research and data collection

Appendix 3 – Panel membership

Methodology Review Panel

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

Pacific Fishery Management Council (Council) Advisers:

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

Acoustic-Trawl Method Technical Team:

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

Attendance:

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

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

David Demer

1. Immediate (prior to the next stock assessments)

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

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

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

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

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

2. Short-term

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

References:

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

Appendix 5 – Panel requests to the team and their answers

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

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

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

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

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

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

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

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

1.H. Request: Provide plots of histograms of the distance from a trawl cluster to the 100 m Equivalent Distance Sampling Units (EDSUs) (and the cumulative distribution), restricting the

data to (a) transects with non-zero CPS Nautical Areas Scattering Coefficients (NASCs) and (b) transects with a non-negligible CPS NASCs.
Rationale: The Panel wished to more fully understand the distribution of the CPS relative to trawl catches.
Response: The plot (Figure 1) showed that the most of the biomass is based on trawl samples whose centroid is less than 25 miles from associated EDSUs.

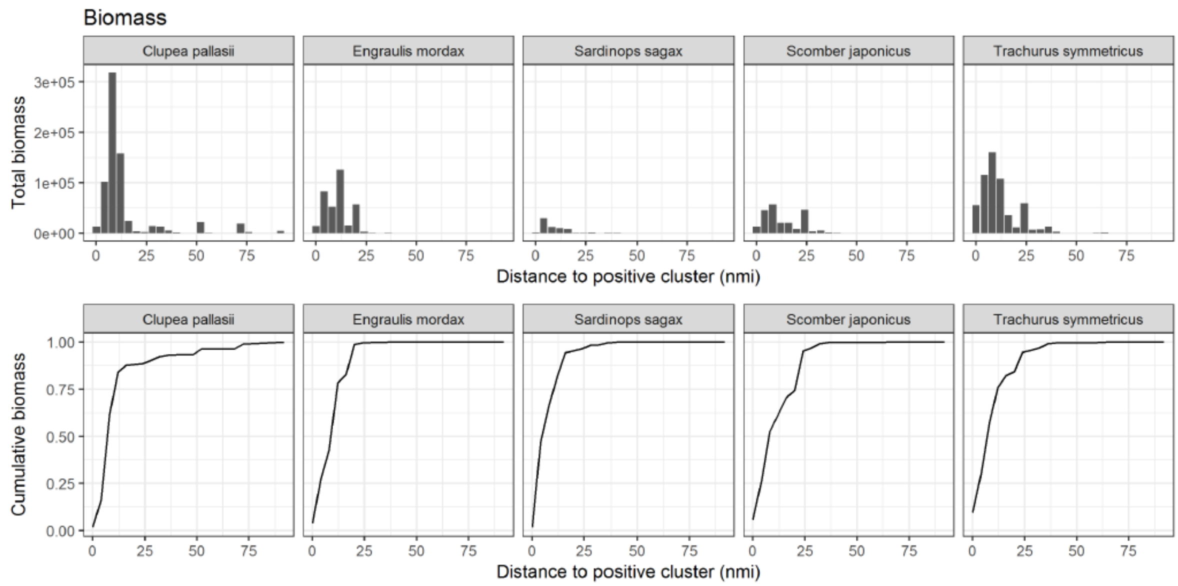


Figure 1. Acoustic biomass (upper panel) and cumulative relative biomass (lower panel) by the distance to the nearest positive trawl cluster.

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

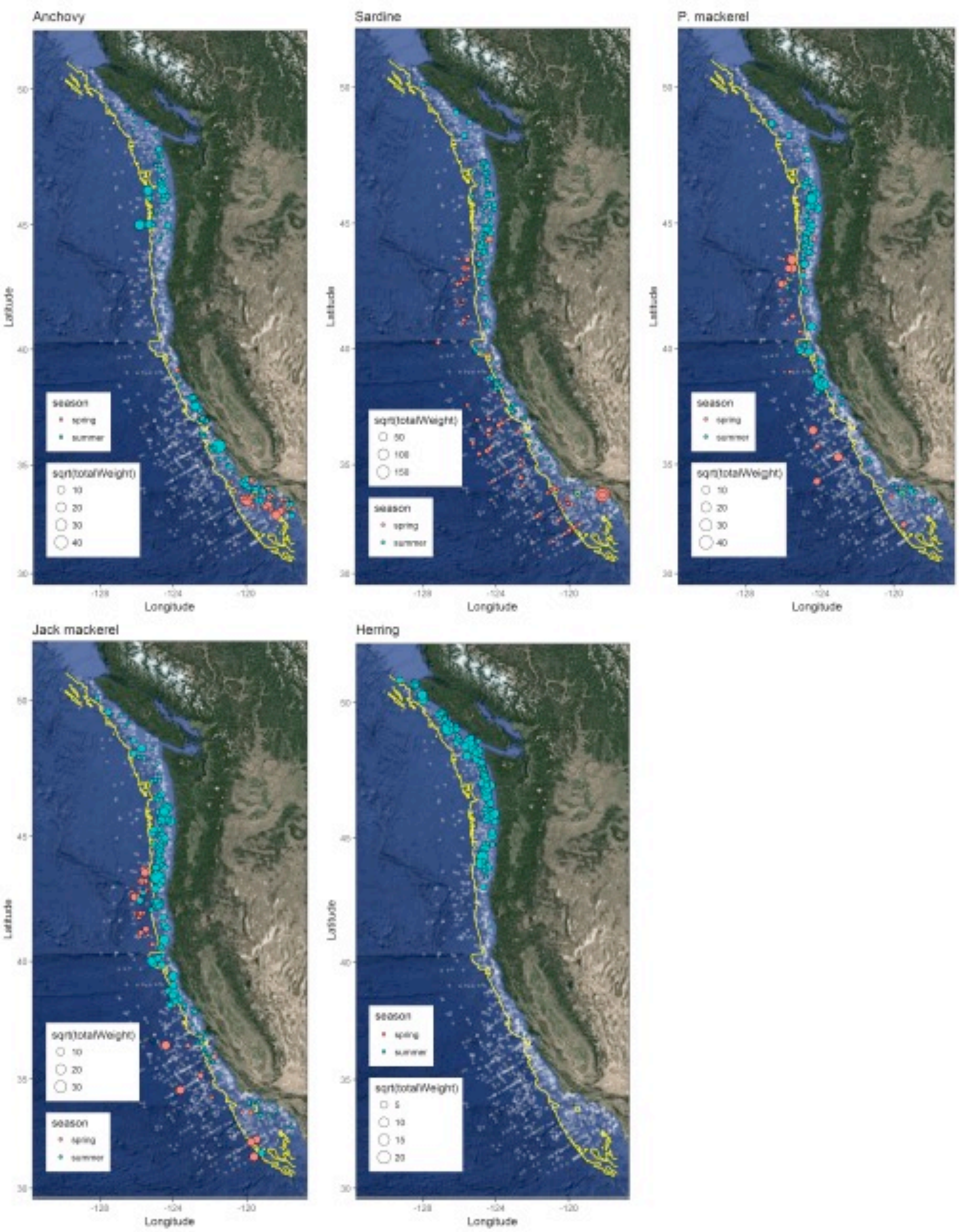


Figure 2. Maps of the west of the North America showing the total catch (square-root kg) of each CPS by season (spring ≤ May, summer > May) for ATM surveys conducted since 2006.

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

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

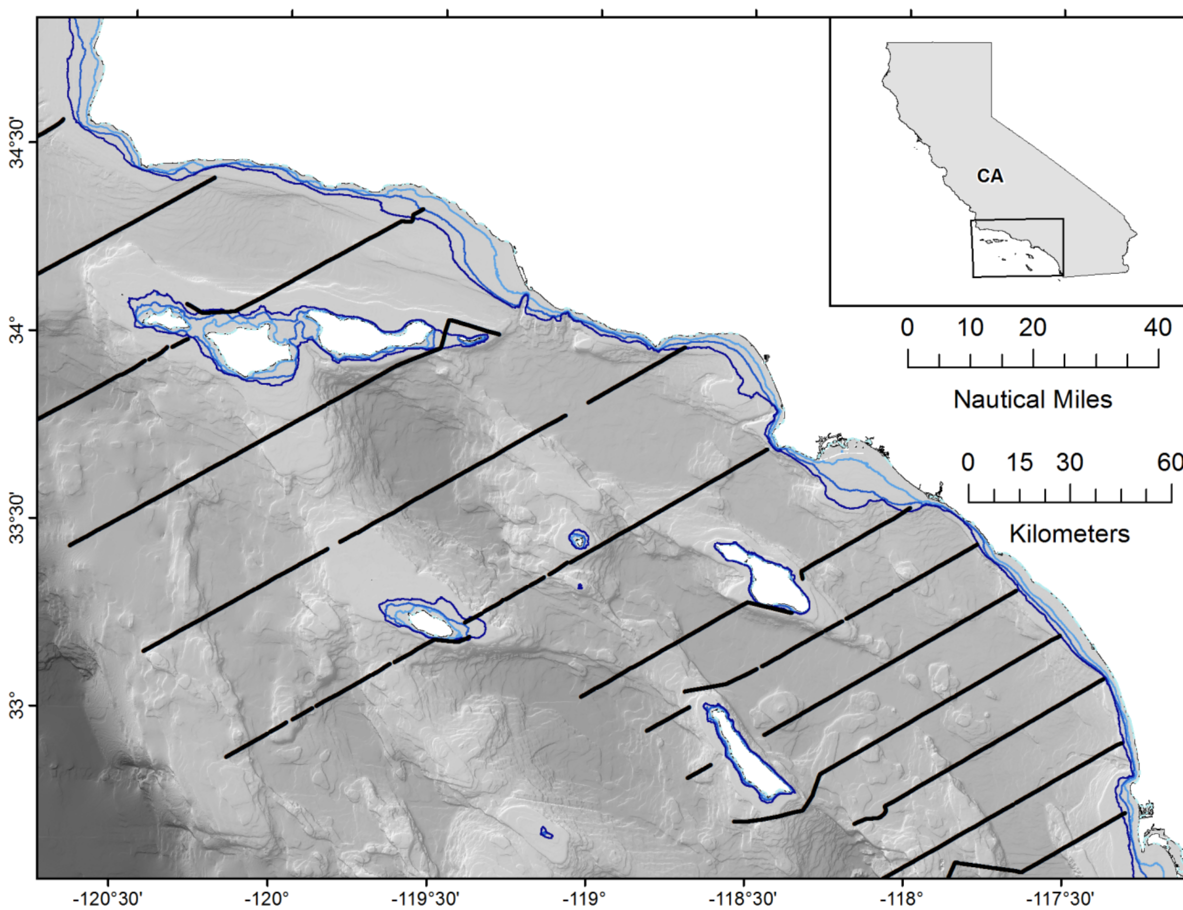


Figure 3. Map of the coast of California showing the acoustic survey transects (black lines) and bathymetric contours (blue lines at 20, 40, and 60 m seabed depth, respectively darker).

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

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

Response:

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

*Includes in-port days

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

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

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

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

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

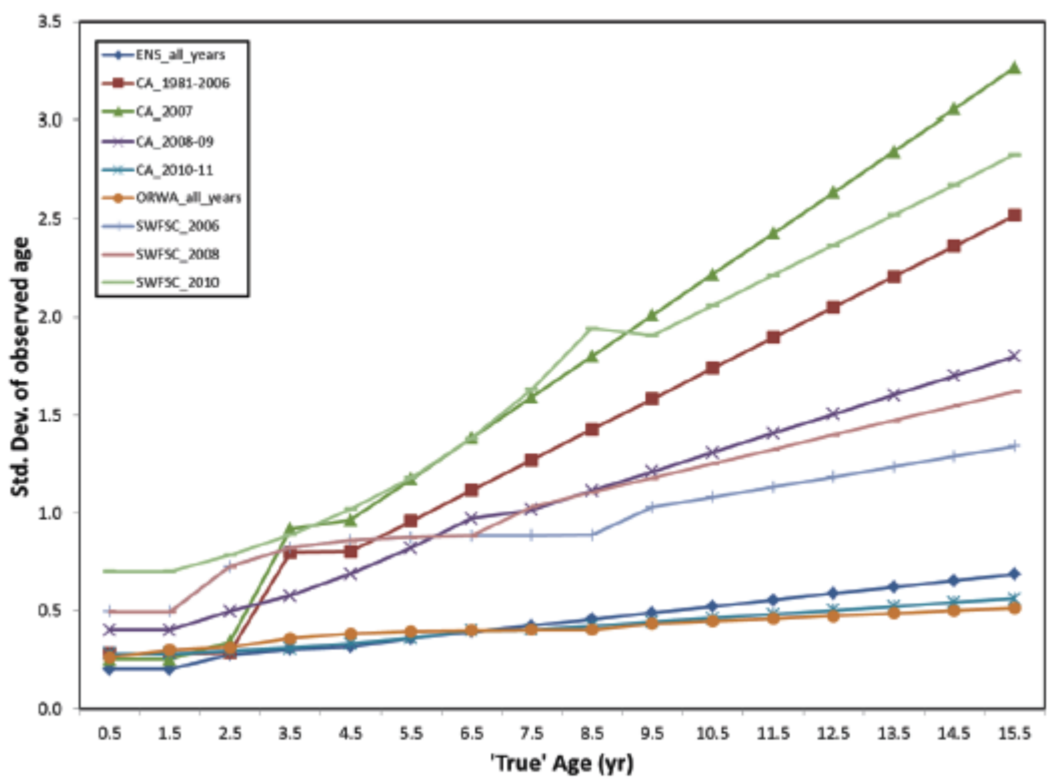


Figure 4. Laboratory and year-specific ageing errors for Pacific sardine. The 'True' age was a reference age estimated using a mixed effects model.

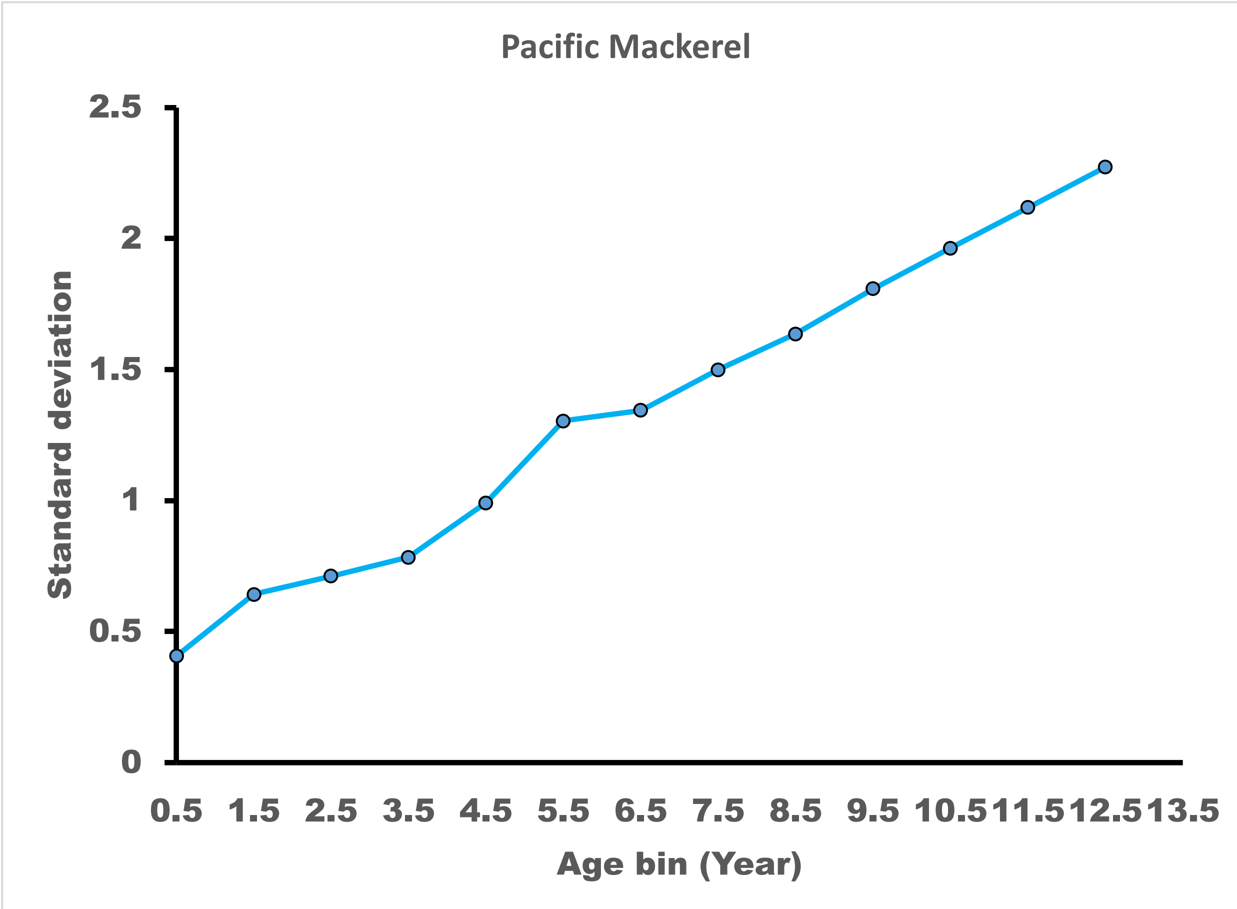


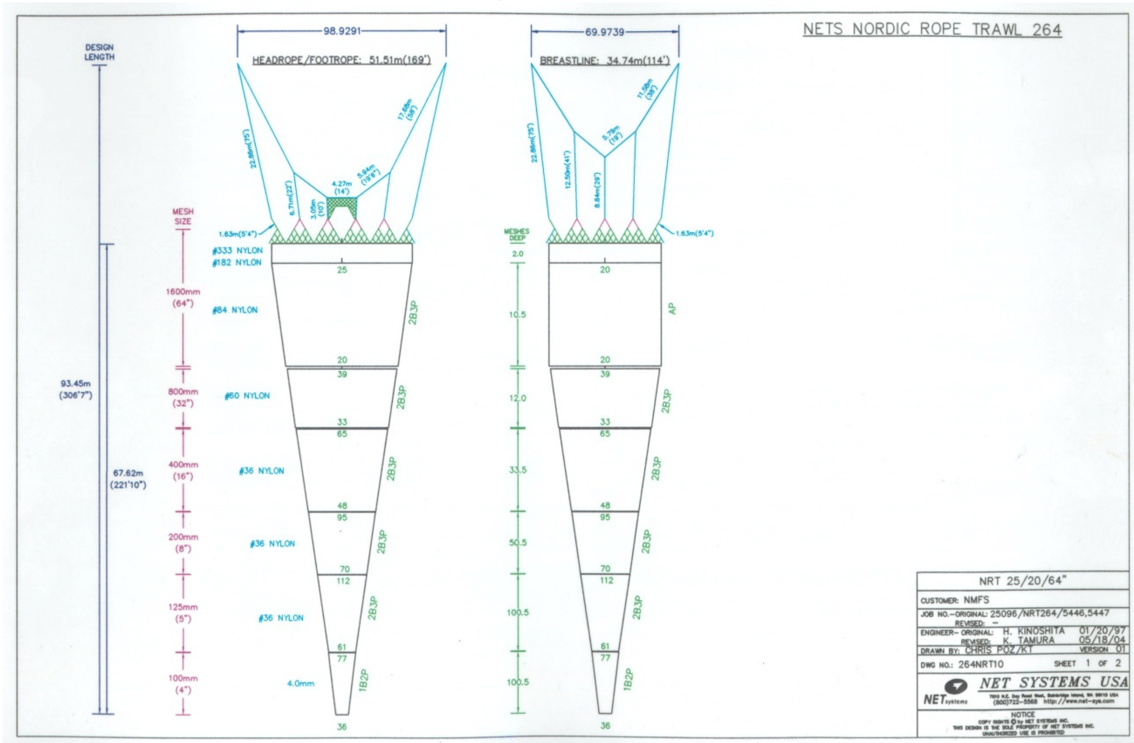
Figure 5. The standard deviation of age-reading error for Pacific mackerel (E. Dorvall, SWFSC).

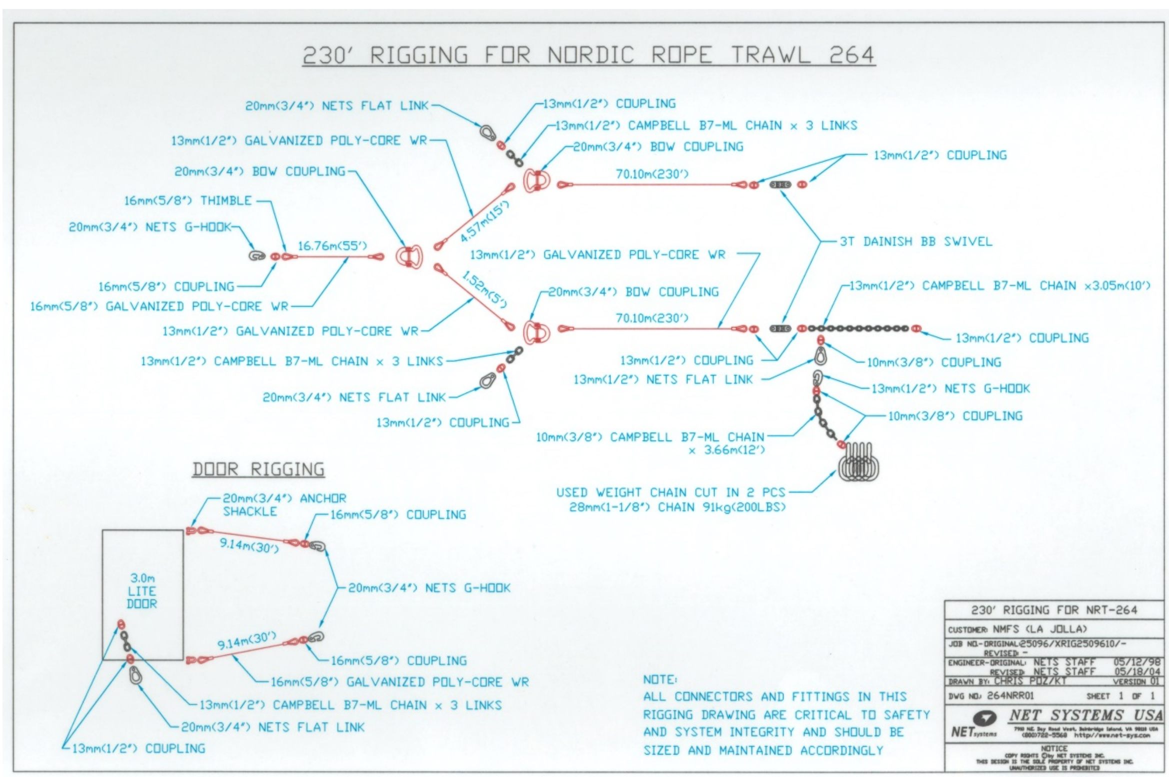
8.B. Request: Summarize how the ATM estimates are used to inform the age-structured stock assessment model for Pacific sardine.
Rationale: The Panel wished to understand the context in which ageing data are used in assessments.
Response: The ATM biomass estimates are treated as relative indices of abundance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

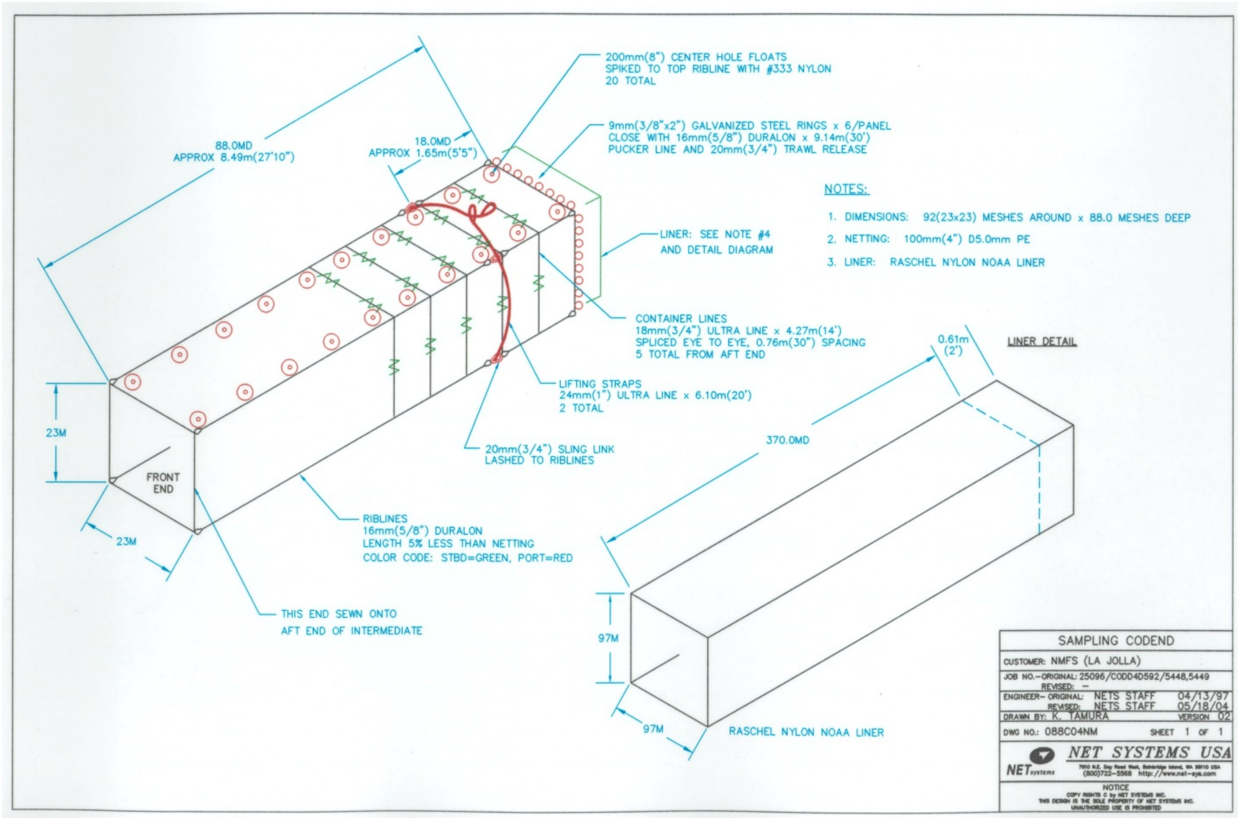
8.C. Request: Calculate ratios of age x+1 in year t+1 to age x in year t to look for consistency in age estimates across years. Across 3 years = 2 points per cohort.
Rationale: This should show if the age compositions across years are consistent or not.
Response: The Team showed plots of estimated length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

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

Appendix 6 – ATM trawl design







200mm(8") CENTER HOLE FLOATS
SPIKED TO TOP RIBLINE WITH #333 NYLON
20 TOTAL
9mm(3/8"x2") GALVANIZED STEEL RINGS x 6/PANEL
CLOSE WITH 16mm(5/8") DURALON x 9.14m(30')
PUCKER LINE AND 20mm(3/4") TRAWL RELEASE
88.0MD
APPROX 8.49m(27'10")
18.0MD
APPROX 1.65m(5'5")
NOTES:
1. DIMENSIONS: 92(23x23) MESHES AROUND x 88.0 MESHES DEEP
2. NETTING: 100mm(4") D5.0mm PE
3. LINER: RASCHEL NYLON NOAA LINER
LINER: SEE NOTE #4
AND DETAIL DIAGRAM
CONTAINER LINES
18mm(3/4") ULTRA LINE x 4.27m(14')
SPLICED EYE TO EYE, 0.76m(30") SPACING
5 TOTAL FROM AFT END
0.61m
(2')
LINER DETAIL
LIFTING STRAPS
24mm(1") ULTRA LINE x 6.10m(20')
2 TOTAL
23M
FRONT
END
20mm(3/4") SLING LINK
LASHED TO RIBLINES
370.0MD
RIBLINES
16mm(5/8") DURALON
LENGTH 5% LESS THAN NETTING
COLOR CODE: STBD=GREEN, PORT=RED
23M
97M
THIS END SEWN ONTO
AFT END OF INTERMEDIATE
97M
RASCHEL NYLON NOAA LINER
SAMPLING CODEND
CUSTOMER: NMFS (LA JOLLA)
JOB NO.–ORIGINAL: 25096/CODD4D592/5448,5449
REVISED: –
ENGINEER– ORIGINAL: NETS STAFF 04/13/97
REVISED: NETS STAFF 05/18/04
DRAWN BY: K. TAMURA VERSION 02
DWG NO.: 088C04NM SHEET 1 OF 1
NET SYSTEMS USA
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