REQUEST FOR METHODOLOGY REVIEW OF THE ACOUSTIC TRAWL METHOD FOR ASSESSING COASTAL PELAGIC SPECIES

Title: Southwest Fisheries Science Center (SWFSC) Acoustic Trawl Method (ATM) Survey

Proposers: Fisheries Resources Division, SWFSC, Gerard DiNardo, Director

How will this methodology improve CPS stock assessments: ATM abundance estimates collected both in spring and summer were incorporated into the Pacific sardine stock assessment in 2011 and have been an intricate part of the assessment every year since, 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). This proposed review will attempt to answer research questions such as what proportion of the population is not counted in the upper water column and the potential for sampling in the nearshore areas that are not normally sampled by the ATM survey (see Background Information below for full description of the questions).

Description of analytical methods: A description of the ATM survey was presented to the Council at its March 2011 meeting (see Agenda Item C.3.a Attachment 2: Zwolinski et al. Acoustic Trawl Surveys of the Pacific sardine, Part I and Agenda Item C.3.a Attachment 3: Demer, et al. Acoustic Trawl Surveys of the Pacific sardine, Part II). Basically, the ATM survey uses multi-frequency echosounders to record acoustic backscatter data beneath the survey vessel and along parallel-line transects spanning the sardine habitat. Catch information from a series of trawls along each transect is used to ascribe the backscatter data present in the echograms to sardine and other CPS. The total backscatter from each species is divided by the backscatter representative of an average individual of that species to estimate and map their respective biomass densities. The total biomass of each species is then estimated by multiplying their mean biomass density by the survey area. An updated description of the current ATM survey methods will be included as background materials for the methodology review.

Background information from previous ATM methodology reviews: The Council first approved the use of the Acoustic Trawl Method (ATM) at its April 2011 Council meeting after the ATM underwent a methodology review in February 2011with 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 can be included in the 2011 Pacific sardine stock assessment as 'absolute estimates', contingent on the completion of two tasks. Estimates of absolute abundance for the survey area can be used as estimates of the*

biomass of jack mackerel in US waters (even though they may not cover all US waters). The estimates of abundance for Pacific mackerel are more uncertain as measures of absolute abundance than for jack mackerel or Pacific sardine. A major concern for this species is that a sizable (currently unknown) fraction of the stock is outside of the survey area. However, the present surveys cannot provide estimates of abundance for the northern anchovy stocks for use in management. 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."
(Agenda Item C.3.a Attachment 1 April 2011)

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 in spring and summer continue to be used as an intricate part of the sardine assessment every year, 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 or in spatial extent (e.g., Mexican waters, or nearshore or offshore areas where NOAA vessels are unable to sample) (see Appendix I).

Although the original Methodology Review 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:

"Future studies should resolve the information by species and address the possibility of spatial and temporal variability in potential vessel effects.

• The frequency response of schools should be studied for trends versus depth, e.g. utilising frequency-dependent directivity (Godø et al., 2006). A change in fish tilt angle due to vessel-induced avoidance will affect higher frequencies more than lower frequencies. The frequency response may change versus depth if avoidance behavior diminishes with depth beneath the vessel.

• Differences in the transducer beamwidths (12^o for the 18 kHz transducer versus 7^o for the other frequencies) could be used to observe fish diving beneath the vessel. The wider beamwidth will be less sensitive to changes in fish orientation than narrower beamwidth. Thus, an avoidance reaction may be indicated if depths measured at the top of schools are shallower in the 18 kHz recordings compared to the other frequencies.

• 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.

The Panel was informed that sophisticated multibeam systems (Simrad MS70 and ME70) will be available on the new SWFSC vessel in near future. This represents state-of-the-art instrumentation to clarify issues related to school behavior in the vicinity of the vessel and should be fully utilised to clarify vessel impact factors. Presently, not all vessels have been noise measured according to the ICES standard. Standard vessel noise measurements should routinely be conducted to allow comparison of stimuli and fish reactions to allow vessel comparisons in the future."

The ATM survey was also reviewed as part of the 2014 CIE SaKe Methodology Review and was presented to the Council as a joint report from the NWFSC and the SWFSC at the June 2014 meeting (Agenda Item F.1.c Fisheries Science Center Report). And, the 2017 Pacific Sardine STAR panel held February 21-24, 2017 at the SWFSC in La Jolla (see Agenda Item G.5) provided the following recommendations that should be addressed during the 2018 ATM review:

A. In relation to the habitat model:
    a. Investigate sensitivity of the assessment to the threshold used in the environmental-based method (currently 50% favorable habitat) to further delineate the southern and northern subpopulations of Pacific sardine.
    b. Further validate the environmentally-based stock splitting method. The habitat model used to develop the survey plan and assign catches to subpopulation seems to adequately predict the spawning/egg distribution in the CalCOFI core DEPM region, but eggs were observed where they were not expected in northern California, Oregon and Washington during one of the two years when the survey extended north. It may be possible to develop simple discriminant factors to differentiate the two sub-populations by comparing metrics from areas where mixing does not occur. Once statistically significant discriminant metrics (e.g. morphometric, otolith morphology, otolith micro-structure, and possibly using more recent developments in genetic methods) have been chosen, these should be applied to samples from areas where mixing may be occurring or where habitat is close to the environmentally-based boundary. This can be used to help set either a threshold or to allocate proportions if mixing is occurring.
    c. Consider including environmental covariates in model-based approaches that would account quantitatively for environmental effects on distribution and biomass. The expertise from a survey of fishermen could be extremely useful in identifying covariates that impact the distribution of clusters.
B. The SWFSC plans to examine ship avoidance using aerial drone sampling; there is an ongoing significant effort by Institute of Marine Research in Norway to understand the same issue using sonar, and the SWFSC acoustics team should communicate and coordinate with those researchers.
C. The effect of population size affecting the number and spacing of school clusters 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. A simulation exercise should be conducted using the current, decreased and increased survey effort over a range of simulated population distribution scenarios to explore this.
D. 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.
E. The ATM survey design and estimation methods need to be more precisely specified. A document must be provided to the ATM review (and future assessment STAR Panels) that:
    - delineates the survey area (sampling frame);

- specifies the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification);
- specifies the rule for stopping a transect (offshore boundary);
- specifies the rules for conducting trawls to determine species composition;
- specifies the rule for adaptive sampling (including the stopping rule); and
- specifies rules for post-stratification, and in particular how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account density should be considered.

The SWFSC has been attempting to address many of these issues by using a new research vessel which has the sophisticated multibeam systems mentioned above. Fortunately, after an unscheduled delay of over a year, the *FSV Reuben Lasker* is now fully operational. The *Lasker* is the fifth in a series of Oscar Dyson-class ships (208ft; 63m) home ported in San Diego. The ship is engineered to produce less noise than other survey vessels and should facilitate studies of fish behavior that could potentially impact our current estimations of sardine as well as other CPS abundance. It is equipped with technologies for fisheries and oceanographic research, including advanced navigation systems and acoustic sensors, five-frequency split-beam echosounders, and scanning, multi-beam and imaging sonars (EK60s, ME70, MS70, SX90). For 2017, the joint SaKe survey has been put on hold in lieu of separate CPS and hake surveys.

Last year, after 10 years of service, Simrad discontinued the EK60 series and introduced the EK80 series of transceivers and control software. The *Lasker* was the first ship in the in the NOAA fleet to be outfitted with the EK80 that shifts from narrow-bandwidth pulses to wide-bandwidth pulses using the existing hull-mounted transducers and went through extensive testing last year. An EK80 workshop was convened at the SWFSC from September 6-9 and 12-16, 2016 which included a sea-going field component aboard the *Lasker*. The aim of the workshop was to expedite the use of the wideband echosounder in surveys and science. Participants included industry leaders such as Simrad and Echoview as well as researchers from every science center Evaluations included compression of the EK80 data, noise measurements in active and passive modes, uncertainty in standard sphere calibrations, and scattering spectra from mixed assemblages.

In addition, the SWFSC will evaluate several uses of the APH-22 Hexacopter UAS platform for ship-based and small boat based CPS detection in 2017. Specifically, to test the capability and utility of the APH-22 for obtaining photographs of CPS schools that may be used for nearshore confirmation of CPS schools and CPS reactions to the ship on transect. While the APH-22 Hexacopter has previously flown from the NOAA Ship Oscar Elton Sette and small vessels this will be the first from the *FSV Lasker*. The initial goals of our 2017 survey will be to refine launch, recovery and communication protocols between the ship's command and the UAS pilots. This will also be an opportunity to evaluate CPS school detection in various weather conditions in nearshore areas outside the normal footprint of NOAA survey vessels.

At the November 2016 Council meeting the SWFSC proposed that the ATM methodology review can be undertaken in early 2018 (proposed dates were January 30-February 2, 2018). This

will allow adequate time for the SWFSC to fully evaluate potential changes to current ATM survey protocols using the EK80 and to fully evaluate the other advanced acoustic systems aboard the *FSV Lasker* that will, among other benefits, allow the estimation of avoidance behavior of coastal pelagic species in the upper water column. The SWFSC requests that in addition to endorsing the methodology review, the Council's SSC provide specific recommendations that should be addressed before or during the 2018 ATM review. These recommendations will form the basis for the questions expected to be asked at the review, and will help expedite the review process.

Appendix I

2014 Pacific Sardine STAR Panel Meeting Report
Agenda Item H.1.a Attachment 3 (Appendix 3 only)

Appendix 3
Progress related to the recommendations from ATM survey review
Juan Zwolinski and 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 ichthyoplankton surveys south of the survey area, and catch information) to provide best estimates for the biomass outside of the survey area, as well as the range of possible biomass levels.

Response: During spring surveys (i.e., April and early May), the northern stock of Pacific sardine resides ~30-70 m deep and spawn offshore of central and southern California. During summer surveys, (i.e., June through August), the same stock resides shallower and closer to the shore off central California, Oregon, Washington, and Vancouver Island. The sardine biomass estimates from the spring and summer ATM surveys during 2008 (Demer et al., 2012), 2012 (Zwolinski et al. in Hill et al. 2012), and 2013 (Zwolinski et al. in Hill et al. 2013) were not statistically different, indicating that any biomass outside of the survey areas are small compared to the stock biomass and the survey precision.

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

Response: In the case that the trawl information was used to characterize independently the length and species composition of each transect (i.e., by having at least one transect per trawl), bootstrapping of the transect means would provide an unbiased of the sampling CV (Demer et al., 2012). Since 2011, efforts were made to obtain a larger number of trawls in order to get closer to the full independence of the transects.

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: There are strong limitations on the use of the surface, night-time trawls as quantitative measurements of fish density that preclude us to compare them to the measurements of daytime, depth-integrated fish densities from acoustics. The three main ones are: 1) There is strong vertical variability on the opening of the net by trawling at the surface, especially under bad weather; 2) It is difficult to determine with accuracy the horizontal dimension of the net to be used in the calculation of the swept area. Some studies suggest that the herding of fish begins at the doors, which have a distance much larger than that of the horizontal dimension of the net; 3) For the data already collected, there is no way to determine if all the fish that were vertically integrated by the echosounder are contained in the depth interval spanning the surface and the foot rope.

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 most proximate 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: Trawl experts have been consulted.

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: Due to the overlap in size of the various schooling CPS, acoustic classification of species is inherently difficult when the number of samples within a school is small (for example, when using a large interval between pings when recording acoustic data over 750 m depth while conducting at a survey 10 kts). The first approach to ameliorate the quality of the data was the development the EK60 Adaptive Logging software (EAL). This software allows the reduction of the interval between acoustic pings when the bottom is shallower than 750 meters, effectively increasing the sampling intensity of schools observed over the continental shelf and slope.
The VMR is part of a larger algorithm aiming to identify and eliminate the backscatter of non-CPS targets from echograms. The algorithm is tested on a survey basis to ensure that the retained backscatter of the echoes identified as CPS is at least 95% of the original backscatter.

f. Evaluate the potential use of the echosounder in a non-vertical position.

Response: Multibeam observations have been made of CPS schools since the initial ATM survey in 2006. These data have been used to evaluate potential avoidance of CPS to the survey ship (see report of the PFMC/CIE review of the ATM). The new *FSV Reuben Lasker* is equipped with Simrad EK60, ME70, MS70, and SX90 echosounders/sonars, which will facilitate improved characterizations of fish behaviours and abundances.

g. Check the filtering algorithm every year to ensure that it is still suitable under changing conditions.

Response: The filtering results are checked on a subset of fish schools during every survey to ensure that at least 95% of the acoustic backscatter of CPS schools is retained in the filtered echograms.
h. Study trends in frequency response over depth strata in schools.

Response: We observed that the CPS echoes of tightly schooling fish in areas with positive trawls for anchovy, mackerels, and sardine had very little depth contrasts due to their association with the mixed layer. There, there were no obvious patterns of variability in the frequency response of the schools.

i. Compare results from the 18-kHz and other transducers to examine possible avoidance reactions.

Response: The recommendation is unclear.

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

Response: This was addressed in the January 2014 CIE review of the summer sardine-hake survey (SaKe).

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: Age-based abundances can be estimated from the ATM using age-to-length keys derived from sardine collected on the survey themselves, or from a composite age-to-length key from the fisheries.
The ATM survey showed the persistence of dominant cohorts over time, allowing the estimation of total and natural mortality (Zwolinski and Demer, 2013).

l. Conduct standard (ICES) vessel noise measurements for all vessels.

Response: Vessel noise measurements are made for all NOAA FSVs. Noise measurements have not been made for RV Ocean Starr, formerly RV David Starr Jordan.

3. Long-term
a. Evaluate if different trawling practices or gears, or both would be beneficial.
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.
c. Use a trawl/vessel configuration that can support directed trawl sampling.
d. Conduct repeated trawl sampling experiments to obtain a better understanding of small-scale variability.

Response: The current sampling technique involves three trawls per night with inter-trawl distance of less than 10-nmi.

e. Test the efficiency and selectivity of the trawl by comparing samples from same area taken with the survey trawl and purse seine.
f. Apply state-of-the-art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl.

Response: Cameras attached to the trawl in front of the cod end have been developed and used extensively in the spring and summer 2013 surveys to observe and quantify fish behaviour and MMED performance.

g. Conduct validation tows on various kinds of backscatter to assure that the filtering algorithm is performing as intended to apportion backscatter to CPS.
h. Make efforts to obtain TS measurements for *in situ* CPS in the California Current Ecosystem.
i. Focus on utilizing more advanced instrumentation and resource-demanding research for studying vessel impacts.

Response: The state-of-the-art instrumentation aboard the FSV Reuben Lasker (EK60s, ME70, MS70, SX90) should facilitate studies of fish behaviour that could potentially impact the estimations of abundances.

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