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

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)*

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. However, questions continue to be raised as to how well the ATM survey adequately samples the Pacific sardine population as in the 2014 Pacific STAR Panel Report (see Appendix I, attached. taken from Agenda Item H.1.a Attachment 2, April 2014 Briefing Book).

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 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 (208 ft; 63m) home ported in San Diego. 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). 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. Regrettably, the first time the SWFSC will be able to use the *FSV Lasker* to assess sardine will be in the spring of 2016 (30 DAS) and again in the summer of 2016 (78 DAS).

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). The goals of this review were to:

1. *Evaluate the historic, independent sardine and hake survey designs, methods, and analytical approaches including data preparations and statistical (e.g. geostatistical) analyses to estimate target species abundances, distributions, and biomasses, and associated uncertainties:*
    - *Pacific sardine surveys;*
    - *Pacific hake survey;*
    - *Joint sardine and hake (SaKe) surveys.*
2. *Evaluate the current joint SaKe survey design, methods, and analytical approaches including data preparations and statistical (e.g. geostatistical) analyses to estimate target species abundances, distributions, and biomasses, and associated uncertainties.*

3. *Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of transitioning from independent surveys to a joint sardine-hake survey.*
4. *Evaluate the potential of the SaKe survey design and analysis, or an alternative, to evaluate the status and trends of hake, as managed by the International Hake Treaty, the southern stock of sardine, and other stocks in the Council's Coastal Pelagic Fisheries Management Plan (CPS-FMP) including: northern anchovy (northern and central stocks), Pacific mackerel, jack mackerel, market squid, and krill.*
5. *Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of:*
    - *separate hake and sardine surveys every year or every other year, with or without ecosystem sampling*
    - *joint sardine and hake surveys every year or every other year, with or without ecosystem sampling,*
    - *Alternative joint survey options for hake or sardine every year or every other year, with or without ecosystem sampling,*
6. *Evaluate proposals and provide recommendations to increase the efficacies and efficiencies (e.g., through advanced technologies) of sardine, hake, sardine-hake and sardine-hake-ecosystem surveys, based on Sake 2012 and 2013 survey experiences.*

The SaKe review led to a number of recommendations (see Appendix 2) that the NWFSC and SWFSC have incorporated into the 2014 and 2015 SaKe surveys. However, with the delay of the *FSV Lasker*, the NWFSC and SWFSC have been unable to test sampling configurations with multiple ships. The Panel's recommendation was:

> *"The concern about the limited time constraining what could be undertaken during the SaKe survey could be accommodated by using multiple vessels. This brought up an argument about inter-vessel difference and calibration of acoustic and fishing gear. In a previous review other reviewers implied that multiple vessels were problematic and that it was better to have a longer duration with fewer (one) vessel. The Panel did not completely agree with this argument. From an acoustic perspective two properly calibrated vessels should be fully comparable, especially if they are sister ships with essentially the same characteristics. While it was agreed that no two vessels will fish exactly the same, it is very probable that sister ships using the same fishing/sampling gear and protocols should be comparable. The NOAA vessels* ***Lasker*** *and* ***Shimada*** *are sister ships but are not identical vessels and are rigged differently for fishing. The vessel concerns were mainly associated with sampling logistics and time series. The Panel's view was that vessels will change over time and if it is a major concern then calibration or simulation studies for the fishing gear should be undertaken when the new vessel becomes available."*

The SWFSC proposes that the earliest that an ATM methodology review can be undertaken is fall 2016 or early 2017. This will allow adequate time for the NWFSC and the SWFSC to fully evaluate potential changes to current ATM survey protocols that an additional survey vessel in the SaKe survey may necessitate. And finally, it will allow the SWFSC to fully explore the use of the new advanced acoustic systems aboard the *FSV Lasker* that will, among other advantages, allow the evaluation of avoidance behavior of coastal pelagic species in the upper water column.

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 ichythoplankton 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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