Agenda Item G.3.a
Attachment 5
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Canada (Department of Fisheries and Oceans) Swept-Area Trawl Survey

Report of Methodology Review Panel Meeting

National Marine Fisheries Service (NMFS)
Southwest Fisheries Science Center (SWFSC)
La Jolla, California
29-31 May 2012

Methodology Review Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), University of Washington
Ray Conser, SSC, NMFS, Southwest Fisheries Science Center (SWFSC)
Olav Rune Godø, Center for Independent Experts (CIE)
John Simmonds, Center for Independent Experts (CIE)

Pacific Fishery Management Council (Council) Representatives:
Kirk Lynn, Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Kerry Griffin, Pacific Fishery Management Council Staff (PFMC)

Technical Team:
Linnea Flostrand, DFO, Canada
Jake Schweigert, DFO, Canada
Kevin Hill, NMFS, SWFSC
Paul Crone, NMFS, SWFSC

OVERVIEW

A review of the surface trawl survey conducted by the Department of Fisheries and Oceans (DFO), Canada for estimating the abundance of Pacific sardine off Vancouver Island, Canada was conducted by a Methodology Review Panel (Panel), at the Southwest Fisheries Science Center (SWFSC) Torrey Pines Court Laboratory, La Jolla, CA, from 29-31 May 2012. The Panel followed the Council's Terms of Reference for Stock Assessment Methodology Reviews (April 2012 version).

Dr. André Punt opened the meeting and Dr. Francisco Werner, SWFSC Director, welcomed the participants. Dr. Punt noted that the aim of the review was to address six key questions: (a) are the design of the survey and the sampling methods appropriate?; (b) how are the raw data analysed to estimate a survey index and associated age- and length-composition information?; (c) how appropriate are the methods used to estimate the uncertainty associated with the data?; (d) can the survey index / age composition data be used in assessments and if so, how?; (e) what selectivity assumptions are appropriate for including the data in the assessment?; and (f) what are the implications of the survey being conducted at the current northern extent of the distribution of Pacific sardine? The reason for considering the final question is that availability of fish to the survey may be impacted by the timing of seasonal migrations and local environmental conditions. If availability of sardine to the survey varies from year to year, this may need to be accounted for in the assessment model, for example by allowing for time-varying survey catchability ('q'). Dr Punt noted that the 2012 assessment of Pacific sardine will be an 'update' assessment so data from the surface trawl survey could only be included in the next full sardine stock assessment.

The Panel reviewed the survey methodology and related analysis methods firstly in terms of whether the data collected can be used to estimate an index of abundance for the core area (operationally-defined as the eight strata used to analyse the data from the 2011 survey; Figure 1), then how the biomass for this area relates to the biomass north of the USA border and to stock-wide biomass, and finally, how time-varying migration impacts the interpretation of the data collected during the survey. The Panel did not review how the data from the survey are used to provide advice for management of the sardine fishery in Canada.

The Panel was provided with extensive background material, including a number of primary documents, through an FTP site two weeks prior to the review meeting. The proponents provided the Panel with a number of presentations including an overview of the survey, the data collected in the past, and aspects of the stock assessment for Pacific sardine.

The Panel identified several ways in which the survey can be improved, noting that the 2011 survey was based on a design and operational procedures that most closely match its recommendations. In contrast, earlier surveys were based on markedly different designs than that used for the 2011 survey. Implementing the Panel's suggestions will lead to changes to the survey design and analysis methods. However, the Panel cautions against continual changes to survey design if the aim is to develop a comparable series of biomass estimates.

The Chair thanked the SWFSC for hosting the meeting and the participants for the excellent and constructive atmosphere during the review, the results of which should help the Council and its advisory bodies determine the best available science for the assessment of Pacific sardine.

1. DISCUSSION AND REQUESTS MADE TO THE TECHNICAL TEAM DURING THE MEETING

A) Make plots of (i) density as a function of tow speed and (ii) density as a function of tow duration. <u>Rationale</u>: In principle, tow speed and duration should not be related to estimates of density. The plots will be useful diagnostics for examining some of the underlying assumptions. Response: There does not appear to be a relationship between tow duration or tow speed and density. However, there are some very short tow durations and there is concern that the density estimates for such tows may be positively biased by catches during setting and retrieval of the net.

B) What kind of sensor has been used for mensuration of the width of the trawl net mouth opening during a tow? Under what conditions would the fishing master estimate the width rather than rely upon the mensuration? Rationale: It appears that the fishing master estimates are used frequently. The Panel would like to have a better understanding of the instrumentation, and why the width measurements are not routinely used. Response: Additional information on gear configuration was provided (see Appendix 4).

C) Develop an index for 2006-11 using the eight survey strata developed for the 2011 survey (Figure 1). Compute and report the samples size and mean density for each stratum, and an overall density based on the area-weighted average density and CV. Rationale: Examination of the survey results to date (density estimates and survey length-frequencies) indicate that area stratification may be important for both mean and variance estimation. Response: Area-stratified densities differed from the raw densities in 2006 and 2009 (Table 1), although this was likely related to strata in which no sampling took place or the density was estimated to be zero. Unstratified and stratified mean estimates for other years were similar and the general trend of the index was not greatly affected, but the area-stratified index was less variable. The area-stratified approach is preferable especially given the differences in mean size of sardine from north to south.

D) Compute spatial autocorrelation between tow densities for 2006-11. Prioritize by starting with 2011 and work backwards in time. Rationale: If significant spatial autocorrelation exists, it should be fully accounted for in the variance estimates for the index of abundance. Response: Spatial autocorrelation is evident for the 2008-11 surveys (especially 2010-11), but not for earlier surveys (Figure 2). For 2008-09, variance should be estimated using geostatistics.

E) Provide summary statistics (mean densities and interquartile range) from the 2005 survey that may shed some light on day-night differences. Rationale: This may provide information related to using or dropping the surveys for 2004 and earlier. Response: CVs are large for both day and night sampling (>2). Mean estimated densities are quite similar. Nevertheless, sampling may be more efficient at night (sardine are less clustered at night) (see Section 2.2.3 for further discussion).

F) Provide a conceptual discussion of the factors that may potentially bias an index of abundance derived from the core area. For example, what is the effect of some portion of the population being north of the core area; offshore/inshore of the core area; at greater depth; etc. Consider possible inter-annual differences in migration rates, size and/or age-structure differences, etc. Rationale: To facilitate Panel discussion on how the trawl survey index might be used in the sardine stock assessment. Response: The proponents summarized the various factors that may affect the utility of an index. Considerable discussion ensued. The impact of migration on the interpretation of the estimates of abundance is a key factor. It is difficult (if not impossible) to estimate migration and abundance from a single survey because these factors are confounded. If the timing of migration into the core area differs greatly from year to year, the best approach may be to model the migration separately (e.g., using a model of potential habitat) and use the survey for abundance estimation only.

G) For 2006-11, plot catch rate vs. time of day by year. Rationale: To examine the effect of sunset and sunrise on catch rates. Response: Although a few large densities were observed near sunset and sunrise, this should not pose a major problem in developing an index of abundance.

H) Provide summary statistics and other information that may be useful for determining how many survey years could be in a potential index, e.g. 2002-11; 2006-11; 2010-11; other? What are the pros and cons? Rationale: It seems clear that not all survey years can be used as a single index. What subset is most defendable? Response: In terms of design, sample size, and consistent survey protocols, the 2011 survey is the best to date. The key question is how many survey years prior to 2011 should be included in an index. Incorporation of years prior to 2006 is questionable due to the predominance of daytime and deep tows during those surveys.

I) Provide plots of the length composition by 2011 survey strata and year (2006-11). Show results for the raw data and data weighted by tow densities. Rationale: To better understand the change in size composition over space and time. Response: As expected, mean size appears to increase from south to north (e.g., Figure 3). As such, length composition data weighted by the densities within stratum should be used in the sardine stock assessment.

J) For 2006-11, compare age 3+ and age 4+ biomass estimates from the last stock assessment with the respective biomass estimates from the trawl surveys using the core area developed for the 2011 survey. Rationale: To compare scale and trend from the survey with the estimates of overall sardine biomass. Response: The proponents provided plots of age 2+ and age 3+ population biomass estimates from the 2011 stock assessment vs. density estimates from the Canadian trawl survey, 2006-11. Results were also computed for the age 4+ biomass, but not plotted due to a negative correlation. No relationship was apparent between either the age 2+ nor the age 3+ biomass and the trawl survey biomass estimates. It was noted, however, that such comparisons are more properly done within a stock assessment model that simultaneously considers the selectivity properties of the trawl survey.

2. SUMMARY COMMMENTS ON THE TECHNICAL MERITS AND/OR DEFICIENCIES OF THE METHODOLOGY AND RECOMMENDATIONS FOR REMEDIES

2.1 Gear and Instrumentation

Sampling marine populations using trawls has wide application, and the need for operational standards has generated substantial international efforts to identify conventions that are applicable for most areas and conditions (Reid et al. 2007, ICES 2009). The Panel evaluated the survey equipment and protocols used in Canada relative to international standards.

Sampling of small pelagic fishes is challenging due to their high swimming speed and sensitivity to external stimuli, such as a moving and noisy trawling vessel (Misund 1999). The trawl net should include a large enough opening to allow a large volume of water to be sampled and should be constructed to allow high towing speed (>3.0 knots), thus enhancing catching efficiency. All surveys were conducted using a model 250/350/14 midwater rope trawl (Cantrawl Pacific Ltd., Richmond, B.C.). This is a relatively small pelagic trawl which appears easy and robust in routine operations. As such, it is an ideal survey trawl. Ropes and large meshes are used in the front part of the trawl opening, thus minimizing the resistance in water and allowing higher speed. Potentially, a disadvantage of this configuration is that the small size of the net may increase the probability of fish avoiding the gear (e.g., Suuronen et al. 1997, Misund 1999). The trawl is documented using drawings of trawl construction and rigging, including door specifications. However, some of the figures provided to the Panel were drawn by hand and were not always easy to interpret. The trawl construction should be included in the documentation of the survey standards.

Conducting swept-area surveys requires knowledge of trawl geometry to enable area or volume densities to be calculated. Trawls are sensitive to environmental conditions, such as strong currents and winds, as well as operational mistakes. These may seriously impact the trawl geometry (height and width) and thus, the trawl opening, which is basic information for estimating densities. Also, operating the trawl at depths in accordance with survey protocols is demanding. Thus, trawl instrumentation is normally used to ensure trawl operation according to certain standards (Walsh et al. 1991). The trawl net for the Canadian trawl survey is always equipped with one of three trawl sonars attached to the headline (Simrad FS-70, Westmar 770 SLED or Westmar 380 SLED). A third cable ensures continuous data stream and additional stretch to the headrope, which helps to stabilise the trawl opening. Trawl sonar is an ideal instrument for achieving a correct and constant trawl opening, and the trawl is probably functioning optimally when trawl opening is stable at target geometry. Also, this instrument draws the outline of the trawl, which is used to assess the amount of water filtered by the trawl. The footrope is expected to be directly under the headline, based on the construction of the trawl and its rigging as given in the trawl drawings. Assuming that the sonar is attached to the midpoint of the headline, it will draw the trawl opening at this part of the trawl, some meters behind the wingtips. The wingtips cover a wider area than that shown by the trawl sonar, and it could be argued that the trawl opening at the wingtips is more relevant for assessing densities because fish are probably herded by the wings. This would be an issue if catches are expressed as absolute densities, but is of minor importance for calculation of indices of relative abundance.

Operational protocols help in making decisions on the validity of tows. Without such protocols, ad hoc decisions by personnel on watch may lead to biased and variable results. There are fixed routines for operating the trawl at a standard tow location, but there seems to be no protocol for handling sonar observations with respect to the deviation from standard specification,e.g., no definitive protocols are in place regarding how much deviation from standard trawl net geometry can be tolerated, before the tow is discarded or stopped and repeated. Presently, this is a decision taken by the fishing master on watch. There is a need for operational specifications that describe acceptable variation in geometry measures, before trawling is terminated and repeated, to achieve standard operation of the gear (e.g., Walsh et al. 2009).

There are aspects of gear construction, rigging, and operational issues that were not mentioned in the report provided to the Panel. The experience gained in standardized bottom trawl surveys (e.g., Reid et al. 2007, ICES 2009, Walsh et al. 2009) represents excellent guidelines for how similar protocols might be developed for Canada’s surface trawl survey. Trawling has been conducted at various depths during the history of the survey. However, effort has been concentrated on surface tows covering the depths to 15m in recent years. There is some evidence for occasional catches of sardine in deeper water. However, these catches could have occurred shallower than 15m during shooting and retrieval of the net. Studies of the vertical distribution of sardines using acoustics have found some fish below 15m (i.e. 2011 WCVI survey EK60 records). However, the bulk of the fish were found in surface waters. Thus, it seems reasonable to assume that the stock is concentrated in the upper 15m, and sampling could be designed accordingly. It would be useful to keep track of the vertical distribution of the population by studying the fractions of the acoustic backscattering of sardines found above and below 15m, given the fraction of fish below 15m likely changes over time, to some degree, due to prevailing oceanographic conditions.

Catches of marine organisms often show large diel variability. This represents a source of variability and bias depending on the survey strategy. Pelagic fish often distribute close to the surface at night, and concentrate in schools in deeper waters during the day. Tows were carried out during the day and at night before 2005, while only night tows have been conducted recently. The depth range of the population impacts the volume that should be used when estimating stock biomass, i.e., towing at night might reduce the volume in which the population is located. In addition, patchiness is normally much higher during the day when fish are schooling, which will typically increase sampling error. Both of these factors indicate that only trawling at night will lead to the most precise estimates.

There was no evidence of large day-night effects in the data from the 2005 survey. Nevertheless, the Panel **recommends** fishing only at night. Presently, day and night are defined by fixed hours. However, they should be defined with reference to solar elevation.

2.2 Calculation of density

A swept-area/volume assessment of fish density requires that the properties of the gear and its operation are known. The effective opening of the trawl (the area effectively herding fish into the trawl) needs to be defined, measured, and monitored. The opening of the trawl has been defined as the area covered by the trawl sonar in the case of the West Coast Vancouver Island (WCVI) surveys. As noted above, this is likely to be a smaller area than that over which fish are herded, but it is the ideal area to measure and monitor and thus, a good choice for calculating estimates of relative densities.

Distance towed is needed to calculate swept volume. This is based on GPS records of speed times tow duration in the WCVI surveys. However, this might be an imprecise estimate of distance towed due to uncertainty measuring tow speed. Such uncertainty may explain the large variation in tow speeds recorded during the surveys (although this variation may also be due to strong currents). A more precise measure of distance towed is the distance between the GPS position at start and stop, which avoids the need for an estimate of tow speed. Distance over the ground might be an imprecise measure of filtered volume if currents are strong. Nevertheless, it is probably better to use the distance over the ground than trying to assess filtered volume by, for example, recording the speed of water through the trawl. Such procedures need additional instrumentation, and measures of water speed through the trawl are often highly uncertain. The present procedure is to use a tow direction against wind, which is sensible given the need to maintain operational stability. This will cause some uncertainty related to the impact of current on the towed volume, i.e., it would be useful to record current direction and strength during each tow as an impact variable for later analysis.

The survey report describes instances when catching might have taken place during shooting/retrieval. Thus, the effective distance towed might be longer than that recorded. This is particularly a problem when distance towed varies. Catching during shooting/retrieval will affect short tows more than long tows. Consequently, tow duration should be kept as constant as possible and this issue should be borne in mind as a potential bias when analysing the data. Setting the tow start as soon as the standard opening is established and stopping the trawl when trawl geometry is distorted might be a way of minimizing these impacts. Catching during shooting and retrieval is particularly a problem if the distribution of the fish requires that trawling take place at various depths. In these cases, opening-closing devices could be a solution, although good techniques for fast swimmers, such as sardines might not be readily available.

One aspect of catchability (q) is the relationship between observed trawl density in relation to true density. While, in general, q might impact density by size, in the case of small pelagic fishes, it will predominantly impact density measures, while size selection is less important. In general, changes to the survey vessel, as took place in the WCVI survey in 2005, could introduce unpredictable changes in q. The trawl is towed at the surface for a certain distance in the case of the WCVI survey, so the major factors are expected to be associated with vessel avoidance (Gerlotto et al. 2004, Ona et al. 2007) and trawl avoidance (Suuronen et al. 1997). Quantification of these factors is often difficult due to unpredictable variability and difficulties in obtaining appropriate measurements. Nevertheless, the issue should not be ignored because the trawling in the WCVI survey takes place close to the surface, with a short distance between the vessel and the trawl. Some straightforward studies could be implemented to monitor avoidance. For example, a vertical profile of the fish distribution under the vessel can be obtained if the vessel acoustics are monitored continuously. Similarly, the trawl sonar could be used to establish a depth distribution profile in the mouth of the trawl. There are many sources of uncertainty when comparing those two profiles, i.e., large impacts in the zone between the vessel and the trawl could be identified, but probably not quantified. Further, dedicated studies of avoidance, as have been conducted for the CPS acoustic-trawl survey, would be useful to provide an overview of the impact of these problems. Small pelagic species are high performing swimmers. In this context, escapement at the end of the tow caused by fish swimming in front of the trawl until retrieval may be more significant for shorter tows. The variability of all these factors affecting q emphasizes the importance of the Panel's conclusion to keep tow duration as fixed as possible.

2.3 Use of historical surveys

The issue here is which surveys could form a useful time-series. There are a number of aspects to the organisation of data collection to be considered. The most important of these were identified to be the spatial distribution of the tows, and the changes in sampling by time of day and depth.

2.3.1 Tow locations.

The tow location design has changed over time. The surveys in 1999-2004, 2006, 2008 and 2009 generally followed similar approaches spatially. The 2005 survey was aimed primarily at comparing day and night tows, rather than achieving good spatial coverage. The surveys in 2010 and 2011 are based on random designs, but with a slightly different area basis. The primary question to address being can the data from these designs be used to estimate an index of abundance by year? The Panel considers that the sample data from the 2010 and 2011 surveys can be used directly based on the mean of the samples, over the design strata, because the tow locations for these years were specifically selected on a random basis. Also, the strata variances calculated from the samples for the surveys during 2010 and 2011 are unbiased estimates of the precision of the estimates.

The Panel noted that the 2005 survey had very poor spatial coverage and thus, the sample values cannot be relied upon to give either an unbiased estimate of abundance or variance.

The surveys during the other years followed a quasi-stratified transect strategy, with 5 or 6 sets of tows allocated in lines across the area in an approximately east-west direction. In addition to these tows, extra tows were added in a haphazard way. Raising the mean to the total survey area may lead to biased estimates of density and variance because the tows were not always located in the area in a way that is designed to be representative (e.g., stratified random or systematic). Inspection of the autocorrelation structure (Figure 2) suggests there is no spatial autocorrelation in the surveys for 1999-2005. Therefore, the samples for these years can be considered to be independently distributed in a statistical sense and consequently, the global mean and variance of the samples can be considered as representative.

There is evidence of autocorrelation between the observations during 2008 and 2009 (Figure 2). The spatial distribution of tows appears to differ across the area, particularly for 2009. The combination of differential spatial allocation and positive spatial autocorrelation suggests that the global mean and variance may be biased, although any biases may be small. Consequently, geostatistical analysis should be used to provide an unbiased estimate of mean and variance.

2.3.2 Trawl depth

The depth of trawl tows (quantified in terms of the depth of the headrope) was more variable prior to 2005 than after 2005. Indications are that there are differences in presence of sardine with depth. It is unclear how this might influence the mean density, but it is likely that variation in depth contributed to bias, to some degree, relative to the densities estimated in the more recent surveys. One solution is to filter the overall data set and use only the shallower tows from the earlier surveys for purposes of developing a potential time series.

2.3.3 Time of day

Tows were predominantly conducted during daylight before 2005, although night tows were also conducted on some trips. As noted above, catch-rates during the day appear to be more variable than at night. There is also a perception that the catches may be more representative during the night, given the fish are more dispersed and would see the trawl later than would be the case during the day (i.e., possibly, less net avoidance). The available resources during 2005 were used to evaluate the effect of sampling during the day and at night. This study indicated again that the presence / absence difference was greater during the day, but the standard deviations for day and night were rather similar (but higher during the day) and ultimately, the means were not significantly different. The 2005 survey was conducted on the *F/V* Frosti rather than the *R/V* Ricker. The Panel **agreed** that day and night data are different, but it is unclear by how much presently. More recent surveys have been carried out at night and CVs are generally lower than those from the earlier predominantly daytime surveys.

Given this range of differences pre/post 2005, the Panel **agreed** that the surveys prior to 2005 be considered potentially inconsistent with those from 2006 onwards, which necessarily hampers the utility of these data for developing a longer term time series of abundance indices for inclusion in formal stock assessments.

2.4 Definition of the core area

The primary spatial-related issue to address is how to specify the boundaries of a core area. If a survey is to be defined and tow locations set, the area must be defined either in advance or in a way that is coupled to the analysis. The current (2011) proposal for the core area (Figure 1) appears reasonably sensible, but could be modified slightly to make the rationale for the boundary more explicit, as well as allow one or two minor additional aspects to be further evaluated.

The southern boundaries for the survey are administrative, and should conform to the Canada/USA border. The eastern boundary should be as close to the coast of Vancouver Island as is practical. Fisheries typically operate inshore, including in some of the bays and inlets. It would be helpful to include areas covered by the fisheries, thus giving the survey direct relevance to those involved in the fishery, if possible. Use of a random placement grid (see below) could then be used to apportion tows to these areas appropriately. The northern and western boundaries should be in accordance with the substantive limits of the distribution of sardine. It is not possible to cover all areas in which sardine can occur, and excluding a small amount of low-density area is reasonable. No survey catches of sardine above 1 t/km^3 are reported north of Vancouver Island (Figure 1), and some catches at higher densities are observed a few miles south of this line. It seems reasonable to limit the northern extent of the core area by this geographically-located point. The westward extent of the survey is more difficult to specify.

Catches above 1 t/km^3 are observed out to 45 km and the 1,000 m depth contour (Figure 1). Finally, note that defining the survey boundary by the greater of these two criteria would result in an overall data set that contains all previously observed densities.

2.5 Influence of environment (habitat)

Sardine habitat is defined as waters between 12 and 16ºC off southern and central California. (Checkley et al., 2000; Lynn, 2003; Jacobson et al., 2005; Reiss et al., 2008; Zwolinski et al, 2011). High densities and spawning were observed off Oregon between 14 and 16 ºC (Emmett et al., 2005). The appearance of sardine off western Vancouver Island is associated with waters warmer than 12 ºC (Ware, 1999). A recent study based on egg presence and remotely-sensed information over a 12-year period (Zwolinski et al., 2011) further refined the envelope of sardine potential habitat, and identified oceanographic conditions that likely influenced the migrations and the seasonality of the fisheries, to some degree. The duration of the availability of sardine habitat off western Vancouver Island is shorter than that off Washington and Oregon, suggesting a 4 to 6-month sardine season.

Detailed analysis of the appearance of sardine off the Columbia River mouth suggests that sardine arrive, in general, 2 to 4 weeks after the arrival of the habitat, and peak densities occur generally 1 to 2 months later than this. Information on sardine arrival off western Vancouver Island and its relationship to the potential habitat has not yet been explored, and could benefit from data from ‘scouting trips.’ Fishery landings indicate that the peak abundance of sardine off Vancouver Island is delayed in relation to the peak of potential habitat, but other logistics affecting fleet behavior could be driving peak landings times observed in the fishery.

2.6 Stratification

The primary issue here is whether the core area should be split into strata and if so, at what scale? There is some evidence for different mean densities around the core area (Table 1). For example, the northern part of the region often has lower estimated densities. In addition, biological parameters change latitudinally (see below; Figure 3). If the variation in biological information is to be included in the analysis, some stratification is required to spatially assign / raise biomass and biological parameters. Currently, there is no straightforward way to set stratum boundaries in the overall data set to predictably reduce variance, but rather, the function of stratification is to spread sampling more evenly across the core area and allow regional estimates to be obtained. The current approach of eight strata allows sampling with strata and a similar number of samples within each stratum. This appears to be a reasonable approach, but it could be tested by simulation.

2.7 Trawl location design (random/ systematic)

The primary issue here is determination of the optimal placement of tows within the core area. The ICES held a workshop on survey design in 2005 in which a variety of designs were tested on simulated stock distributions with different spatial properties. Systematic and random punctual surveys were evaluated. The two simulated distributions (Section 2.1.1 of ICES (2005)) were used to evaluate the differences between a systematic survey design and a fully-random survey design. Two fields with properties similar to observed populations were used.

Field 1:

Coefficient of variation = 3.3
Mean fish density in the field of presence = 4 10^7 ind n.mi.$^{-2}$
Total abundance = 10^7 ind
Variogram = nugget effect (sill = 2.5 10^6 ind^2 n.mi.$^{-4}$) + spherical (sill = 8.3 10^6 ind^2 n.mi.$^{-4}$; range = 10 n.mi.); the nugget effect represents 23% of the total variance.

Field 2:

Coefficient of variation = 1.7
Mean fish density in the field of presence = 4 10^7 ind n.mi.$^{-2}$
Total abundance = 10^7 ind
Variogram = nugget effect (sill =0.23 10^6 ind^2 n.mi.$^{-4}$) + spherical (sill = 2.25 10^6 ind^2 n.mi.$^{-4}$; range =25 n.mi.); the nugget effect represents 9% of the total variance.

The two methods each with 1,000 different sampling realisations were defined as the following:

- **Systematic:** a regular grid of 64 points, arranged in an equally-spaced 8 by 8 grid, with a spacing of 1/8 of the survey dimension with a 2D random location on a scale of 1/8 by 1/8 of the dimension of the area; and
- **Random tow locations**: the procedure starts with 64 tows; the number of tows is then increased by adding new random tows and checking for time available using the travelling salesman algorithm until the maximum number possible in the time allocated is reached. The number of tows for each of the 1,000 random sampling realisations is given in Figure 4. This illustrates the increase in the number of samples that can be achieved with a random grid and a travelling salesman algorithm.

The results of the simulations were evaluated through examination of the distribution of the estimates of the total abundance for each method. These distributions are given separately for each simulated surface in Figure 5. The estimates of mean abundance are unbiased at $1*10^7$ for both methods and both simulated surfaces. Figure 5a shows the results from simulated surface 1, which has high variance and low spatial autocorrelation. In this case, the results indicate that the random survey design, which has the higher number of observations, has the lower root square error (RSE = 49%) and provides a more precise estimate than the systematic survey (RSE = 56%). Figure 5b shows the results for surface 2 with the lower variance and higher spatial autocorrelation. In contrast to surface 1, the improved precision due to even allocation of sampling with the systematic survey improves the estimate of abundance over the random survey. In this case, the systematic survey RSE is 14%, i.e., even with extra samples, the RSE for the random survey (23%) is poorer. These contrasting results for the two spatial distributions show that there is an interaction between spatial autocorrelation and sampling design. Further investigation of a wider range of surfaces with different properties would help to refine the parameters that influence when each survey strategy is the most efficient estimator of the abundance and variance.

The Panel was not aware of work that can explicitly determine the correct approach for the WCVI survey. It might be possible to simulate a range of spatial distributions based on the observations; however, this may not be necessary. The analyses of spatial variance carried out on the WCVI survey data from 1999 to 2011 suggest that there is spatial autocorrelation, but that this is limited to a distance that is a small proportion of the length of the core area. Consequently, it is likely that the WCVI is more like the low correlation surface tested during the ICES workshop, i.e., the ratio of range to the dimension of the area is more important than the absolute range. If this is the case, a random design augmented by an algorithm to maximise the number of tows would likely be the optimal choice. This supports the current approach of random tow allocation. The current methodology uses a 10 by 10 km grid for allocating ~3-5 km tows. It might be more appropriate to match the grid size to the trawl length. The Panel **reccomends** that the grid be generated before the survey is undertaken, and an algorthim developed to utilize the survey time optimally, including more travelling during the day which could increae the total number of tows which can be made during the survey.

2.8 Influence of migration (within area)

Evidence of temporal change in the population, which equates to changes during the survey, may influence how the data are collected. Migration of the stock is the most likely temporal issue, and this applies to any survey, whether by trawl or acoustic methods. The following approach is taken from Simmonds and MacLennan (2005) and rewritten in the context of trawl tows, rather than acoustic transects.

The movements of fish can be conceived as having two components, random motion and migration. In the former case, the fish swim at a particular speed in directions that change randomly with time. In the latter case, the fish swim consistently in the same direction. Simmonds et al. (2002) used a fine-scale model of North Sea herring schools, based on a spatial grid covering 120,000 km^2 with a node spacing of 40 m, to study the effect of fish movement on the results of simulated surveys. They found that reasonable amounts of random motion were unimportant to estimates of abundance or variance, but the effect of migration even at a modest speed could not be ignored. It is well known that some fish, such as Pacific sardine and related small pelagic species, migrate over long distances on an annual cycle. One factor in the survey design is the timing in relation to the migration cycle. The survey design should ensure that the surveyed area includes the entire stock. However, even if this condition is met, migration of the stock within the surveyed area can bias the abundance estimate. The extent of the bias depends on the direction of the migration in relation to the vessel motion.

Suppose the fish are migrating at speed v_f, and v_s is the speed at which the survey progresses in the direction of migration. If v_s is positive, this means that the fish tend to follow the vessel as it travels through the area. If the tows were drawn on a map whose frame of reference moved with the fish, the tows would be closer together than those on the geostationary map. Thus, the effective area applicable to the analysis is less than the actual area surveyed. The observed densities are unbiased, but since the abundance is the mean density multiplied by the effective area, the estimate of abundance **Error! Objects cannot be created from editing field codes.** is biased. The expected value of **Error! Objects cannot be created from editing field codes.** is:

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where Q is true abundance. If v_s is negative, this means that the fish tend to pass the vessel as it travels through the area and the bias is negative. Note that v_s is much smaller than the cruising speed of the vessel when the direction of vessel motion from tow to tow is generally perpendicular to the migration. For example, if the cruising speed is 5 m s^{-1}, and the rate of progress along the direction is reduced to 1/10 as the vessel zig-zags between tows and stops to fish, then the survey progresses at $v_s = 0.5$ m s^{-1}, a value which could well be comparable with v_f. Harden Jones (1968) suggests that herring are capable of migration speeds up to 0.6 m s^{-1}. The swimming capability of fish depends on their size, but adult herring and mackerel can sustain speeds around 1.0 m s^{-1} for long periods (He and Wardle 1988; Lockwood 1989).

The bias is greatly reduced if the survey can be run alternately with and against the migration, in which case:

and v_s is now nearer the cruising speed of the vessel. Taking the case as $v_f = 1$ m s^{-1} and $v_s = 5$ m s^{-1}, the bias is always an underestimate of 4%. In practice, the direction of the survey may be decided by other factors such as the coastline or depth contours. If the progress of the survey must be perpendicular to the migration, the surveyed area could be covered twice, in opposite directions, with the outward and return tows interleaved. Thus, the survey begins and ends at the same place. This need not be too costly in ship time if the place concerned is the home port. As regards the analysis, the best plan is to treat the outward and return sections as if they were replicate surveys, and to estimate the abundance as the average of the two results.

In the case of WCVI survey, it is likely that the only plausible approach is a single direction survey, either from north to south or vice versa because the vessel port of origin is east of Vancouver Island. In this case, v_s can be estimated from the survey timing. If v_f could be estimated, the potential bias could be calculated. The Panel **recommends** investigating the potential size of this effect for the WCVI survey.

2.9 Raising from tow to stratum density

The current approach assumes that the density estimates for 0-15 m are proportional to the area density. For computation of absolute biomass, the current approach for raising the observed trawl volume densities to the core area uses a standardized vertical extent of 30 m (e.g., Flostrand et al. 2011). The Panel **recommends** that this would benefit from further evaluation, and the vertical extent of sardine should be estimated. A number of approaches could be used, such as independent estimation, possibly using acoustics (see also Section 2.2).

The current method for raising area biomass density to the area of the strata is appropriate. Currently, the density estimates from the trawl are combined to calculate a global estimate of density, which is then raised to the abundance for the whole area. In contrast, currently the biological samples are treated so that each fish sampled has equal weight. The analyses presented show that there are annually repeatable trends in fish size with latitude (e.g., Figure 3), and indications of differences in sardine density, both latitudinally and onshore-offshore (Table 1). Combining all biological samples in the current way removes the influence of the catch rate, because the data are not weighted by the size of tows. An alternative is to raise the length and age distributions by the trawl-related density. The analysis carried out during the meeting suggests the differences are small (Figure 3), but weighting by tow size is nevertheless the preferred approach although care still needs to be taken when a small length-frequency sample is taken from a very large tow.

2.10 Estimating variance

Given the stratified random survey design, sample variance by stratum is the appropriate method to estimate the precision of the estimate of mean density. Bootstrap methods applied to tow data (including biological data) could be used to estimate overall sampling precision. If the design was to be replaced by a different tow allocation regime (e.g., systematic), a geostatistical estimator would be appropriate.

2.11 Abundance estimation

The estimate of total abundance for the core area is the sum of the estimates of total biomass for the individual strata, computed by multiplying the estimated stratum density by the stratum area. The sampling variance for the estimate of abundance is the sum of the sampling variances by stratum. The survey length-frequency should be the sum of the stratum-specific length-frequencies, where the stratum-specific length-frequencies are the sampled length-frequencies weighted by the estimates of density by tow. Given small sample sizes, the Panel **recommends** that the conditional age-at-length data for the survey be computed from the raw age-length data available.

2.12 Inclusion in future stock assessments

Several types of information (time series) calculated from the data collected during the WCVI survey could be included in the stock assessment for Pacific sardine: (a) the index of abundance; (b) the survey length-composition data; and (c) the survey conditional age-at-length data.

The index of abundance could be included in the assessment as an estimate of absolute abundance if it could be argued that catchability for at least one age- or length-class was known. However, given the nature of the survey area (i.e., the core area), any absolute abundance estimate would be primarily compromised by being limited to Canada waters, which do not contain the whole stock. In addition, there are other issues: (a) the survey does not extend far offshore and sufficiently far to the north to ensure the entire stock is covered; (b) uncertainty about the extrapolation of density estimates from the 15 m trawl samples to deeper in the water column; and (c) the inherent implications of bias by surveying north to south with a north-south migration. Based on all these aspects, the Panel did not see sufficient information to justify such an assumption at present and hence, **agreed** that the best use of biomass estimates from the survey would be as the basis for a relative index of abundance (i.e., catchability, q, estimated). The Panel noted that the index from the core area could be considered as an index of abundance, as long as the factors that relate survey-selected biomass to the expected index for the core area remain constant over time. However, time-varying proportions of potential sardine habitat (see Sections 2.4 and 2.7) suggest that this assumption is unlikely to be valid. The Panel identified two ways in which the problem of time-varying proportions of the population in the core area might be overcome: (a) the survey index can be assumed to be linearly related to survey-selected biomass, and the survey CVs increased to reflect among-year variability in the proportion of the survey-selected biomass in the core area; or (b) survey catchability can be allowed to vary over time, but be related to an independent measure of the proportion of the survey-selected biomass in the core area when the survey is conducted (e.g., be based on the output of a model of potential sardine habitat or sardine migration). The first of these options might effectively lead to the survey data being ignored within the assessment model, given the proportion migrating into Canadian waters may be highly variable. The Panel sees the second option as more desirable and **recommends** that work be undertaken to identify whether and how the model of potential sardine habitat can be used to provide an annual measure of relative survey catchability.

The surveys cover the more northerly component of the population, which is expected to include the largest and oldest sardine. As such, the Panel **recommends** that the survey be assumed to have an asymptotic (e.g., logistic) selectivity pattern, with an asymptote reflecting the maximum value at older ages. Size of sardine is observed to vary throughout the area. The Canada purse-seine fishery and the survey do not take place at exactly the same locations (the fishery tends to occur closer inshore). In this context, the Panel **recommends** that the fishery and survey selectivity patterns should be assumed to differ unless it can be shown otherwise, e.g., by comparing age and length distributions.

There are two approaches for including the available historical data from the WCVI surveys into the assessment: (a) start with the data for 2010 onwards and evaluate whether the model is able to mimic those data and, if so, consider including the data for 2006-09 as well, and (b) attempt to fit the entire time-series and if the model unable to do this, restrict the data to those for 2010 onwards. The Panel considers that data prior to 2006 may not be consistent (see above) and ultimately, not useful presently for conducting formal stock assessments. The advantage of option (a) is that it attempts to fit the 'best' data first. In contrast, option (b) focuses on a longer time series and reduces the probability of the model mimicking the data spuriously. An additional advantage of option (b) is that the Panel does not expect that the differences in survey design for the 2006-09 surveys from that for the 2010 and 2011 surveys will lead to marked biases in the estimates of biomass. Irrespective of which option is chosen, the assessment report needs to summarize the changes in survey design and protocol over time and explicitly discuss the consistency of the time series. Given that only the 2011 survey was conducted using what the Panel considers the 'best' design, the Panel **strongly recommends** that surveys be conducted during 2012 and 2013 to ensure that at least four years of comparable data are available if an assessment is conducted in 2013 (the next full assessment is currently scheduled for 2014).

The Panel **recommends** that the following tasks should be undertaken prior to inclusion of the data from WCVI survey in the stock assessment: (a) the sensitivity of the estimates of biomass should be explored to omitting very short and long tows, and extreme vessel speeds; (b) geostatistical methods should be applied to estimate abundance (only for the 2008 and 2009 surveys); and (c) measures of relative survey q for the WCVI area should be computed using the model of potential habitat.

The Panel **recommends** that either a spatial model be developed or Stock Synthesis be modified so that it is possible to fit simultaneously to two indices of abundance (aerial and WCVI surveys), which cover discrete areas such that the datum fitted is a weighted sum of each index (where the weighting factor is an estimated parameter). This feature will allow some of the impacts of migration to be accounted for (cancelled out). The Panel also **recommends** that the results of model fits be examined to assess whether the ageclasses predicted to be covered by the aerial and WCVI surveys are realistic.

3. AREAS OF DISAGREEMENT REGARDING PANEL RECOMMENDATIONS

There were no major areas of disagreement among Panel members nor between the proponents and the Panel.

4. UNRESOLVED PROBLEMS AND MAJOR UNCERTAINTIES

A) The major constraint on using the data from the survey in the assessment for Pacific sardine is how to determine the relative proportion of the total population biomass in the core area. There is evidence that this proportion varies among years. However, empirical estimates of the proportion of the total population in the survey area are not available.

B) The survey design (as well as the objective of the survey) has changed over time. Consequently, is not clear which estimates can be considered to be comparable (the effect of time-varying migration notwithstanding). The Panel **agrees** that the biomass estimates from the 2005 survey (which was conducted primarily to compare day and night tows and employed a different vessel than the remaining surveys) should not be included in the assessment. The data for the years 1999-2004 and 2006-11 are unlikely to be comparable owing to the tows being conducted primarily during the day before 2005 and at night from 2006 onwards. Further, approximately a third of the tows before 2005 were deep tows. The 2011 (and to a lesser extent 2010) survey was based on a random stratified design, but the surveys for 2006, 2008, and 2009 were based on transects.

5. COMMENTS BY THE CPSAS AND CPSMT REPESENTATIVES

The CPSAS representative was glad to see the Canada sardine trawl survey reviewed. The Panel and the representatives from Canada DFO did a thorough job evaluating the data and survey methods. The CPSAS representative and others in the sardine fishery have long felt that a large component of the sardine population inhabits Canada waters for much of the year. Fish size in the Canada fishery has usually been larger than that of the fish found in the Pacific Northwest fishery. A more comprehensive understanding of the Canada portion of the population and biology is necessary to accurately measure the entire sardine population off the West Coast, and establish appropriate harvest management practices. This review is an important step forward.

The CPSMT representative recognizes the survey team and review panel for their extensive preparation and hard work in conducting a productive and thorough review. The CPSMT representative noted several potential survey improvements and recommendations for inclusion of survey data in sardine assessment models. These include 1) continued use of the area strata scheme developed in 2011, 2) better-defined sampling protocols, and 3) developing habitat-abundance models for a time-varying catchability coefficient to reflect changing migratory patterns. The CPSMT representative also supported acoustic survey – swept-area trawl comparisons to validate WCVI survey results. The recommended use of the WCVI survey in future stock assessments with data on the northernmost component of the stock is a positive step in further informing northeast Pacific sardine stock status and management.

6. RECOMMENDATIONS FOR FUTURE RESEARCH AND DATA COLLECTION

The recommendations arising from the review follow (in priority order: H-high; M-medium; L-low; *-N/A).

1) Surveys should be conducted annually to ensure a time-series of comparable estimates is developed as quickly as possible. It is particularly important that surveys are conducted during 2012 and 2013 to ensure that at least four years of comparable data are available if an assessment is conducted in 2013. If it becomes necessary to conduct surveys every other year (rather than annually), it would be preferable to conduct the survey during a year in which a full stock assessment is conducted (H).
2) The following tasks should be undertaken prior to inclusion of the data from WCVI survey in the stock assessment: (a) the impact of ignoring short and long tows on the estimates of biomass should be explored, (b) geostatistical methods should be applied to estimate abundance (only for the 2008 and 2009 surveys), and (c) measures of relative survey q for the WCVI area should be computed using the model of potential habitat (H).
3) Consideration should be given to conducting an acoustic-trawl survey by towing at night and running acoustic transects during the day (H).
4) Trawl surveys should be conducted only at night (H).
5) Establish a trawl manual that describes how the gear is standardized, including trawl drawings and rigging that can be easily interpreted by users. This should be 'living' document, which is updated as needed. Develop and document standard routines for trawl operation that include better utilization of the trawl sonar output for standardizing and quality ensuring each tow (H).
6) Protocols for tow duration and speed should be established in advance of the survey (H).
7) Do not use GPS tow speed to compute tow length. Instead, use the start and stop points. If possible, ocean current velocities should be recorded for later impact studies (H).
8) The survey grid should be generated before the survey is undertaken and an algorthim developed to utilize the time optimally, including the use of longer intertow distances during the day (H).

9) For future surveys, create a larger number of potential tow locations so that the number of randomly drawn tows will represent a smaller percentage of possible tow locations (and more a random selection) (H).
10) The conditional age-at-length data for the survey should be computed from the raw age-length data points (without weighting), but the length-frequency data should be scaled to tow density, used to compute stratum length-frequencies and these summed to obtain the length-frequency for the entire survey (H).
11) Extend the USA habitat model northward to the Alaska border and use this model to provide a measure of the inter-annual component of relative survey catchability (H).
12) The WCVI survey should be assumed to have an asymptotic (e.g. logistic) selectivity pattern (H).
13) The Canadian fishery and WCVI survey selectivity patterns should be assumed to differ unless it can be shown otherwise (H).
14) The results of model fits should be examined to assess whether the age-classes predicted to be covered by the aerial and WCVI surveys are biologically plausible (H)
15) Evaluate the possibility of using trawl opening and closing devices in case trawling at various depths become necessary (M).
16) Investigate the potential magnitude of migration on survey bias (M).
17) Investigate the assumption of a standardized vertical extent of 30m (M).
18) Develop a process for measuring volume sampled (M).
19) Investigate the impact of variation in the depth of sardine. Monitor the depth distribution of sardine (i.e. using acoustics) and consider changing the depth profile of the trawls if this changes (M).
20) Develop a modeling framework which can address having data for two subsets of the total stock area (aerial and WCVI surveys), along with the consequences of time-varying migration. For example, (a) Stock Synthesis could be modified so that it is possible to fit simultaneously to two indices of abundance which cover discrete areas such that the datum fitted is a weighted sum of each index, or (b) a two-area model which explicitly includes areas could be developed (M).
21) Carry out avoidance studies to assess the potential impact of fish behaviour on the survey outcome. Over the short term, this would include comparing vertical profiles from vessel acoustics and the trawl sonar. Over the long term, more advanced studies, e.g. as done by the CPS acoustic-trawl survey team would be useful (L).
22) Should survey vessels change in the future, the impact of changes in survey catchability should be evaluated and monitored regularly, ideally using some form of calibration experiment. (*)
23) Compare daytime acoustic biomass estimates with trawl-based estimates taken at the same time. If this proves to be impractical, then compare daytime acoustic estimates with trawl estimates taken the previous night. (*)

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Table 1. Estimates of biomass and associated with sampling CVs using unstratified and stratified estimators.

(a) Estimates by stratum (estimates with CVs in parenthesis)

Stratum	Area	2006		2008		2009		2010		2011	
		N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
Ae	2582.0	7	527.5 (0.87)	7	0.0 (2.63)	17	464.4 (1.42)	9	267.4 (2.70)	12	412.4 (3.29)
Aw	1924.7	2	800.1 (1.41)	8	14.8 (2.49)	2	0.0	2	0.1 (1.41)	6	506.8 (1.28)
Be	2246.2	15	1817.7 (1.13)	6	304.6 (1.42)	22	584.6 (2.24)	10	489.5 (2.19)	9	455.0 (1.05)
Bw	1985.3	4	396.5 (1.94)	9	48.7 (3.00)	8	0.0	9	2.5 (1.21)	8	391.9 (2.46)
Ce	3378.5	10	407.2 (1.38)	15	612.6 (1.27)	28	737.4 (1.56)	18	186.8 (1.85)	17	504.5 (1.34)
Cw	2150.2	0		8	663.0 (1.07)	9	0.7 (2.78)	5	54.5 (1.43)	6	0.0
De	1336.2	4	249.0 (1.94)	3	21.1 (1.25)	8	12.1 (1.85)	1	0.0	6	31.2 (2.42)
Dw	1136.9	2	60.2 (0.01)	2	483.8 (1.20)	1	0.0	3	4.9 (1.73)	4	1.8 (2.00)

(b) Total abundance for the core area

Year	**Unstratified**	**Stratified**
2006	874.1 (0.24)	570.4 (0.24)
2008	280.4 (0.26)	291.7 (0.19)
2009	460.5 (0.22)	299.9 (0.21)
2010	157.0 (0.43)	152.3 (0.40)
2011	352.8 (0.27)	333.9 (0.26)

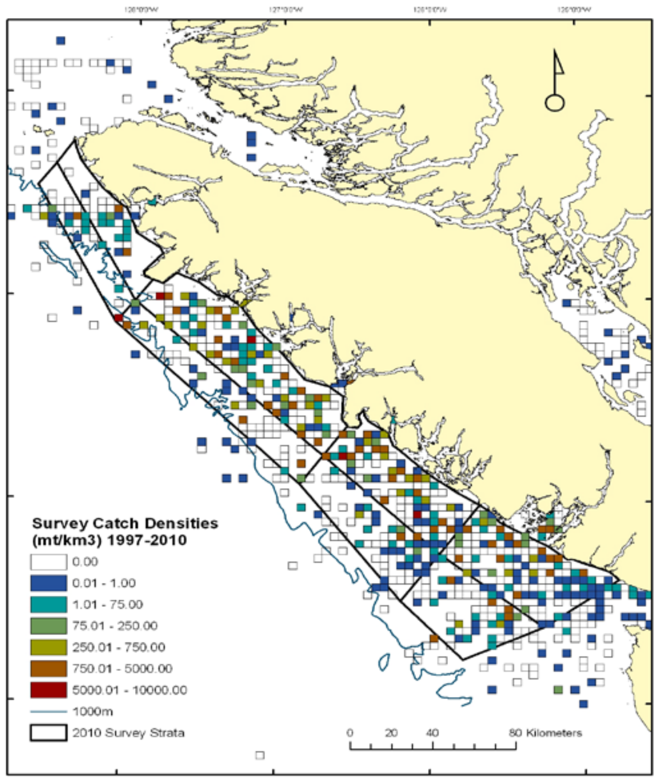


Figure 1. Mean sardine 1997-2010 trawl survey catch densities based on 4x4km sized grid cells and boundaries defining the core WCVI survey region applied in 2011.

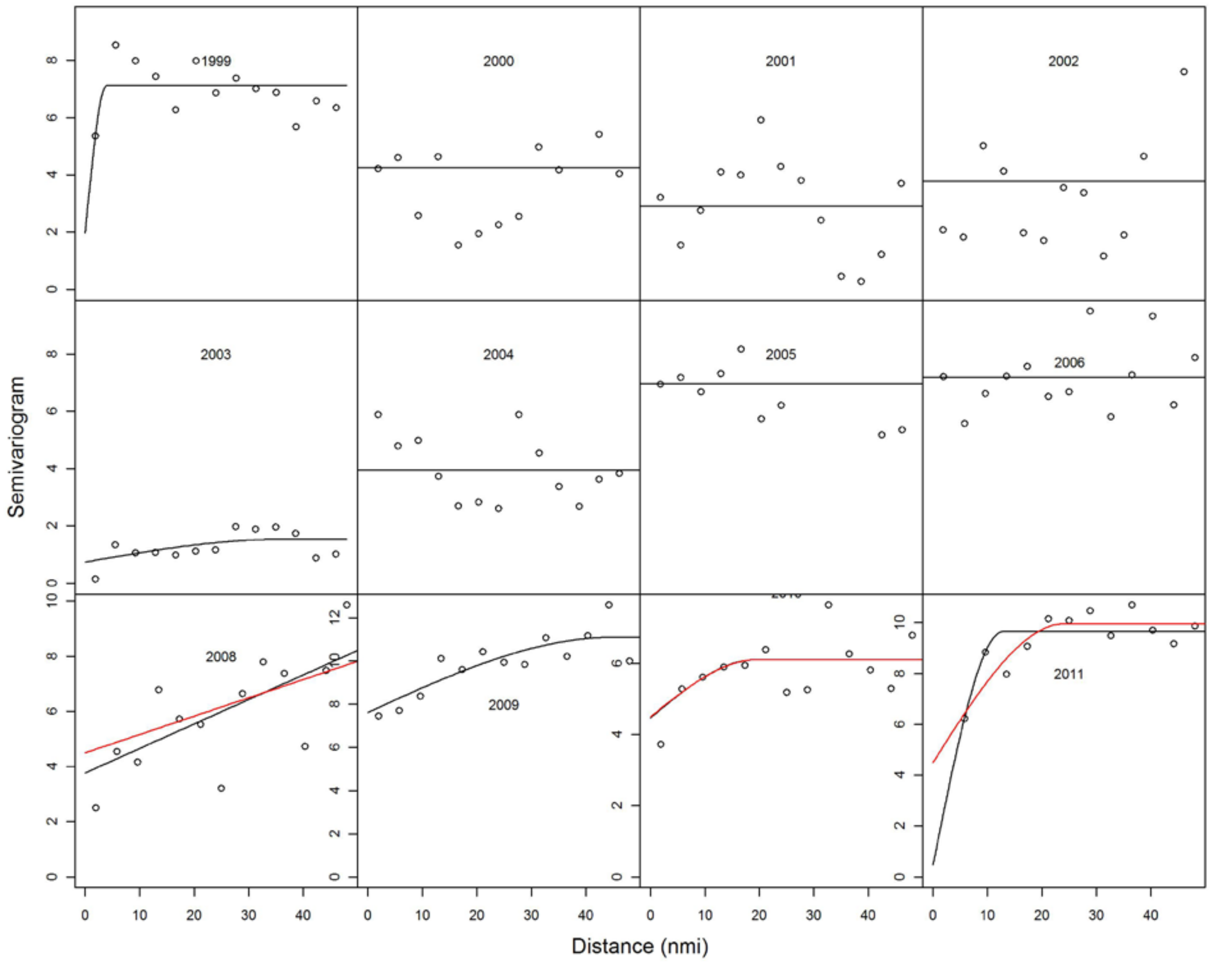


Figure 2. Empirical variograms for the surveys (dotted) and fitted parametric spherical variograms (lines).

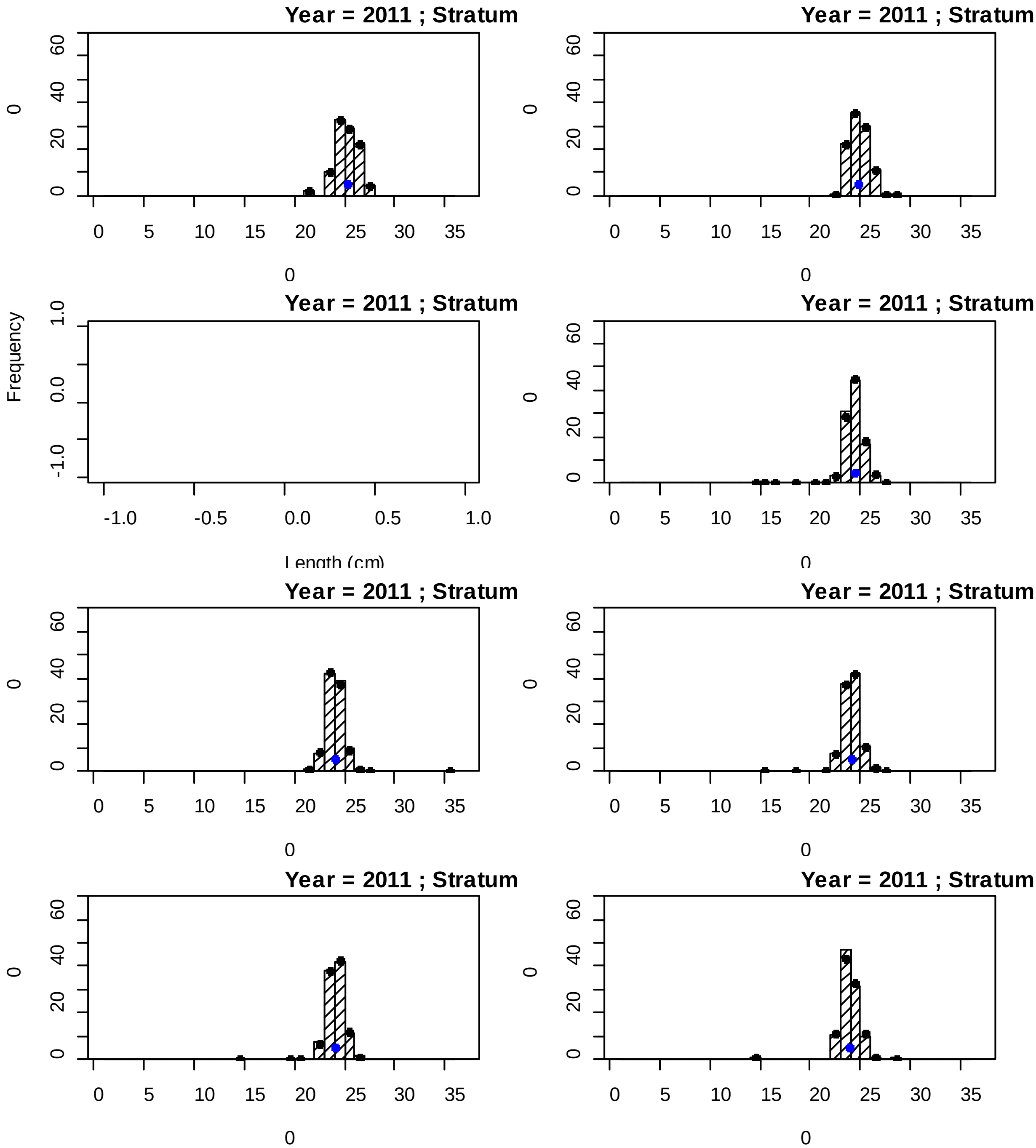


Figure 3. Length-frequencies for the 2011 survey. Results are shown when each fish length is given equal weight when constructing the length-frequency (bars; mean red dot), and in which the tow-specific length-frequencies are weighted by tow density (black dots; mean blue dot).

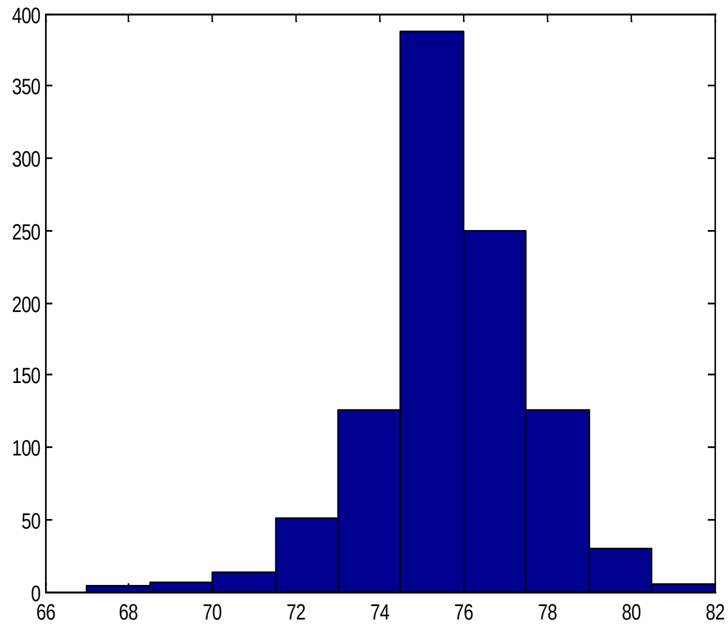
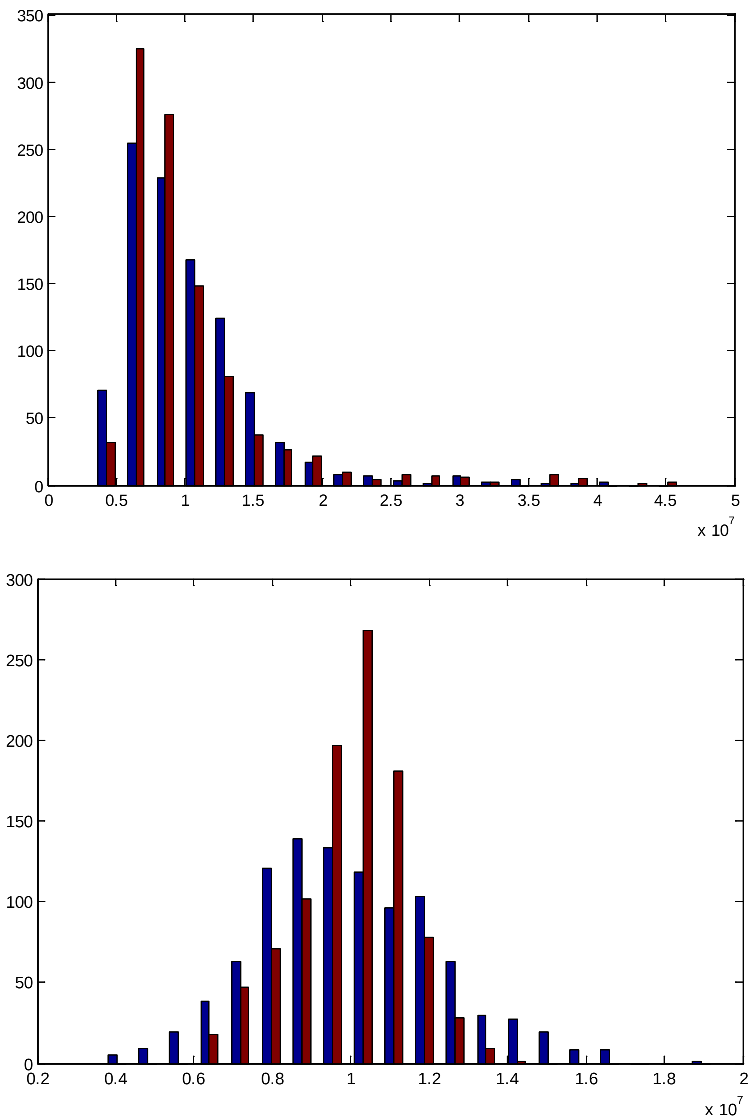


Figure 4. Number of randomly located tows in a fixed time with the minimum track obtained using the travelling salesman algorithm. (9 days with a survey speed of 10 knots and trawling time of 1.5 hours in a 14,400 N.mi^2 area) This compares with a systematic grid of 64 tows in the same time period.



.Figure 5. Frequency distribution of estimates of total abundance for a systematic survey design (red) and a random survey design (blue) for: a) a high variance, low correlation surface (upper panel); and b) a lower variance, but more correlated surface (lower panel).

Appendix 1: List of Participants

Methodology Review Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), University of Washington
Ray Conser, SSC, NMFS, Southwest Fisheries Science Center
Olav Rune Godø, Center for Independent Experts (CIE)
John Simmonds, Center for Independent Experts (CIE)

Pacific Fishery Management Council (Council) Representatives:
Kirk Lynn, Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Kerry Griffin, Council Staff

Technical Team:
Linnea Flostrand, DFO, Canada
Jake Schweigert, DFO, Canada
Paul Crone, NMFS, SWFSC
Kevin Hill, NMFS, SWFSC

Others in Attendance
David Demer, NMFS, SWFSC
Emmanis Dorval, NMFS, SWFSC
Kristen Koch, NMFS, SWFSC
Nancy Lo, NMFS, SWFSC
Josh Lindsay, NMFS, SWFSC
Sarah Shoffler, NMFS, SWFSC
Dale Sweetnam, NMFS, SWFSC
Russ Vetter, NMFS, SWFSC
Cisco Werner, NMFS, SWFSC
Juan Zwolinski, NMFS, SWFSC

Appendix 2: Panel Biographical Summaries

André E. Punt is a Professor of Aquatic and Fishery Sciences at the University of Washington. He received his B.Sc, M.Sc and Ph.D. in Applied Mathematics at the University of Cape Town. Before joining the University of Washington, Dr Punt was a Principal Research Scientist with the CSIRO Division of Marine and Atmospheric Research. His research interests include the development and application of fisheries stock assessment techniques, bioeconomic modelling, and the evaluation of the performance of stock assessment methods and harvest control rules using the Management Strategy Evaluation approach. He has published over 200 papers in the peer-reviewed literature, along with over 400 technical reports. Dr Punt is currently a member of the Scientific and Statistical Committee of the Pacific Fishery Management Council, the Crab Plan Team of the North Pacific Fishery Management Council, and the Scientific Committee of the International Whaling Commission. He is the Associate Editor of the journals *Fisheries Research*, *Population Ecology*, and the *Journal of Applied Ecology*.

Ray Conser is a senior stock assessment scientist with NOAA Fisheries in La Jolla, CA. He received his B.Sc and M.Sc in Applied Mathematics, followed by a Ph.D. in Quantitative Fisheries at the University of Washington. Dr. Conser is a member of the Scientific and Statistical Committee of the Pacific Fishery Management Council. He has extensive experience conducting stock assessments on tunas, small pelagics, groundfish, and invertebrates in support of the U.S. Fishery Management Councils as well as international fishery management organizations (e.g. International Commission for the Conservation of Atlantic Tunas (ICCAT) and International Council for Exploration of the Sea (ICES) in the Atlantic Ocean and the International Scientific Committee (ISC) in the Pacific Ocean). He has chaired numerous stock assessment review panels and stock assessment working groups, and has served as the USA representative on international scientific advisory bodies. His research interests include the development and enhancement of stock assessment methods, fishery management control rules, and biological reference points.

Olav Rune Godø is a senior scientist at Institute of Marine Research. He received his Cand. real. in fisheries biology and his Ph.D. in marine survey methods, both from the University of Bergen. He has worked in the Demersal Fish Department, served as Section Head in the Pelagic Fish Department before building a new Survey Methods Department, all duties at the Institute of Marine Research. Presently he is Chair of a new IMR initiative in marine ecosystem acoustics and Norwegian representative of CCAMLR scientific committee. His research interests include trawl-acoustic survey methods, fish behavior, biophysical interaction, and fisheries-induced evolutionary changes. He has published about 70 papers in peer-reviewed journals, several book chapters, and numerous technical papers and reports. Dr Godø has served on the board of four research programs of the Research Council of Norway, has been a member of the scientific steering committee of the Census of Marine Life, and has been a member of a SCORE WG on observation methods. He has also been a member of several ICES working groups.

John Simmonds is an expert in fisheries surveys, and their use in the assessment of pelagic stocks and in fish stock management. His background is that of a senior fisheries scientist, Aberdeen, UK. Currently, he works under short term contract chairing the development of fisheries management plans for the European Commission Scientific committee, STECF. Before this, he worked in fisheries research for 39 years, mostly at FRS Marine Laboratory Aberdeen in Scotland and for the last two years at European Research Centre JRC, Ispra Italy. He has worked with acoustic and trawl surveys for pelagic species for more than 30 years and carried out stock assessments involving acoustic-trawl, trawl and egg surveys for more than 15 years. He is the author of a books on Geostatistics (2000) and Fisheries Acoustics (1991 and 2nd Edition 2005), and has been responsible for developing approaches for combining acoustic-trawl, trawl and ichthyoplankton surveys in assessments for North Sea herring. He has worked on absolute assessments based on Total Annual Egg Production methods for North Eastern Atlantic mackerel, and has been involved in acoustic-trawl surveys for sardine and/or anchovy off Morocco, and in the Persian Gulf, the South China Sea, Ecuador and Peru. Since 1990, John has developed extensive experience of fish stock assessment and fisheries management, chairing among other groups the ICES herring survey planning group 1991-95, the ICES Fisheries Acoustics working group 1993-96, the ICES herring assessment working group 1998-2000, and the ICES study group on Management Strategies from 2004-2009. He currently chairs the STECF group that prepares evaluations of historic performance of management plans and the impact assessments for new multi-annual fisheries management plans.

Appendix 3: Primary Documents Reviewed

Documents prepared for the meeting

Flostrand, L., Schweigert, J. and V. Hodes. 2012. Canadian west coast of Vancouver Island summer sardine research trawl surveys, 1999-2011, sardine catch density and length, sex and age data sets.

Appendix 4: Further Information Regarding Net Width Measurements

Jake Schweigert and Sandy McFarlane

1) A "third eye" sensor is attached to the headrope for every set. The sensor sweep can be set from 180-360 degrees and is generally run at 180.
2) Measurements for mouth width and height are taken directly from the monitor. The monitor is set it to a small grid (around 2-3 ft) and then used to measure both width and height. This is done a few times during each set and average measurements are recorded. The configuration of the net limits the basic mouth opening provided the net is fishing properly, e.g., if the height is greater the width will be slightly less.
3) The fishing master monitors the 3rd eye and ensures the mouth opening is proper. He can also tell if there may be a problem from the angle of the warps etc. If for any reason there is a tear in the mid or back sections of the net this would be observed and fixed on the retrieval. If it is a serious tear the set is scrubbed. However this rarely happens when surface trawling, unless you hit a tree.
4) The net mouth opening can change slightly depending on speed, tides etc. It is generally slightly oval in shape, the harder it is towed the more rectangular it becomes. Because of the limitations in net construction, changes in one dimension are generally compensated by changes in the other, and total mouth area is not changed to any great degree.
5) The only instrumentation is the 3rd eye, and it is easy to detect any problems. The net is observed on the monitor and a total blackout, to skipping pictures, etc, will indicate an instrumentation problem. Fishing gear failure can be seen on the monitor if, for instance, a "door" flips, or warps were hooked up wrong, one can tell immediately, also from the way the warps themselves are behaving. If the net is torn up, it is evident when the net is retrieved.