NATIONAL MARINE FISHERIES SERVICE REPORT

Mr. Mark Helvey (NMFS SWR) will provide the Council a report on the 2010 and 2011 coastal pelagic species (CPS) fisheries, the upcoming CPS survey workshop, and other recent activities. Dr. Russ Vetter will give a report on the Southwest Fisheries Science Center's research cruise.

Council Task:

Discussion.

Reference Materials:

1. Agenda Item C.1.a, Attachment 1: NMFS and SWFSC Report.

Agenda Order:

a.	Regulatory Activities	Mark Helvey
b.	Fisheries Science Center Activities	Russ Vetter
c.	Reports and Comments of Management Entities and Advisory Bodies	
d.	Public Comment	
e.	Council Discussion	

PFMC
03/24/11

NATIONAL MARINE FISHERIES SERVICE REPORT

Southwest Region:

Coastal Pelagic Species - Regulatory Activities

Annual Specifications for 2011 Pacific Sardine Fishing Season: On January 27, 2011, the proposed rule for the 2011 Pacific sardine annual specifications and management measures was published in the *Federal Register* (76 FR 4854). On March 5, 2011, based on the best available landings information, NMFS suspended directed fishing for Pacific sardine off the coasts of Washington, Oregon and California through June 30, 2011, with the publication of a temporary emergency rule in the *Federal Register* (76 FR 4854).

This action was necessary because the proposed directed harvest allocation total for the first seasonal period (January 1 - June 30) of 15,214 metric tons (mt) was projected to be reached. As of March 7, 2011, approximately 15,181 mt of sardine had been landed, leaving approximately 30 mt that will be added to the second period directed harvest total. Until July 1, 2011, Pacific sardine can only be harvested as part of the live bait fishery or incidental to other fisheries; the incidental harvest of Pacific sardine is limited to 30-percent by weight of all fish caught per trip. The final rule for this action is currently going through the rulemaking process and NMFS expects it to publish in the *Federal Register* in the near future.

Southwest Fisheries Science Center:

Coastal Pelagic Species - Research Activities

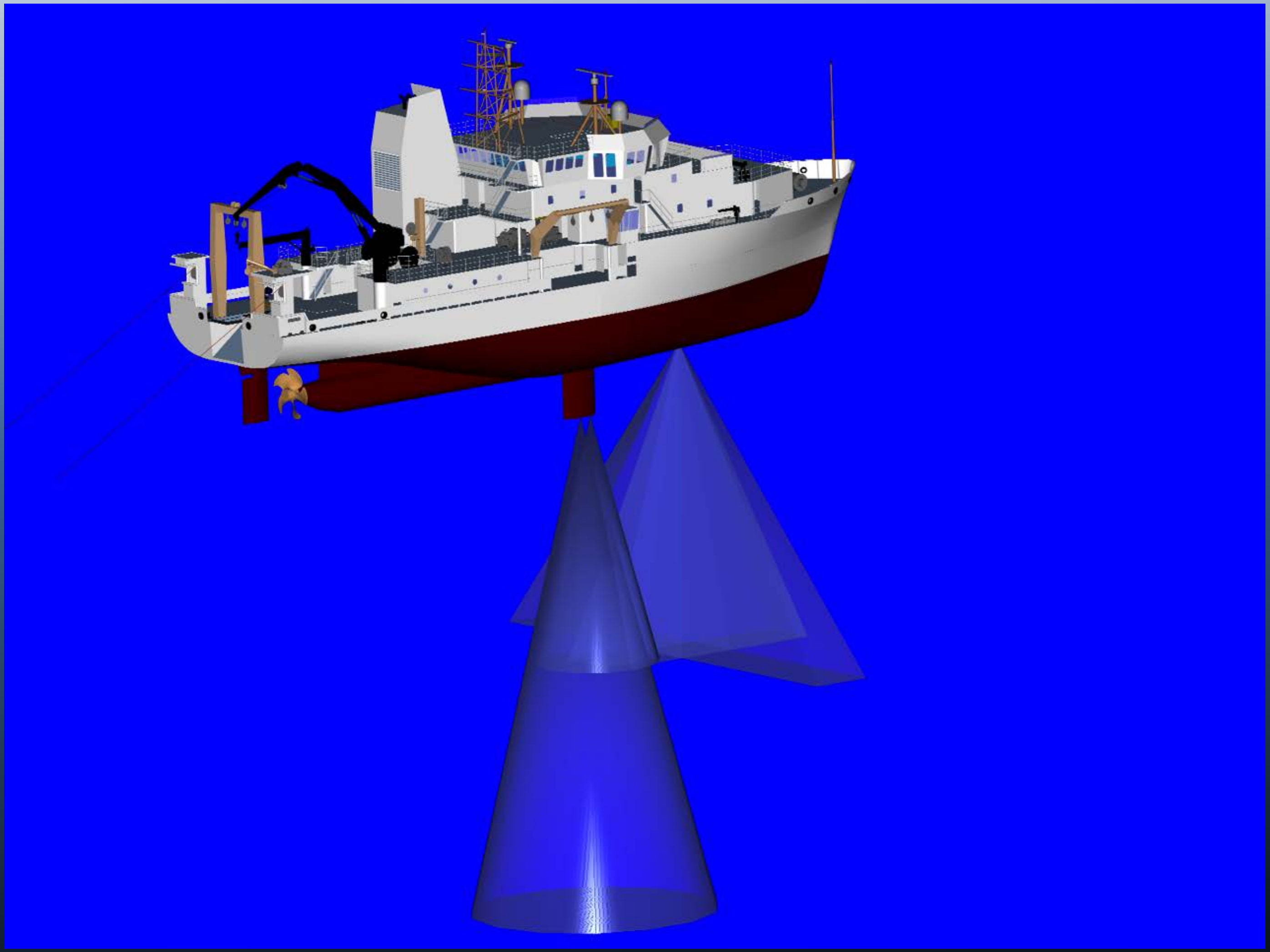
From 17 March through 27 April 2011f the SWFSC will be conducting a research cruise on the *RV Bell Shimada* to survey the distributions and abundances of pelagic fish stocks, their prey, and their biotic and abiotic environments in the California Current between Cape Flattery, Washington and San Diego, California.

PFMC
03/24/11

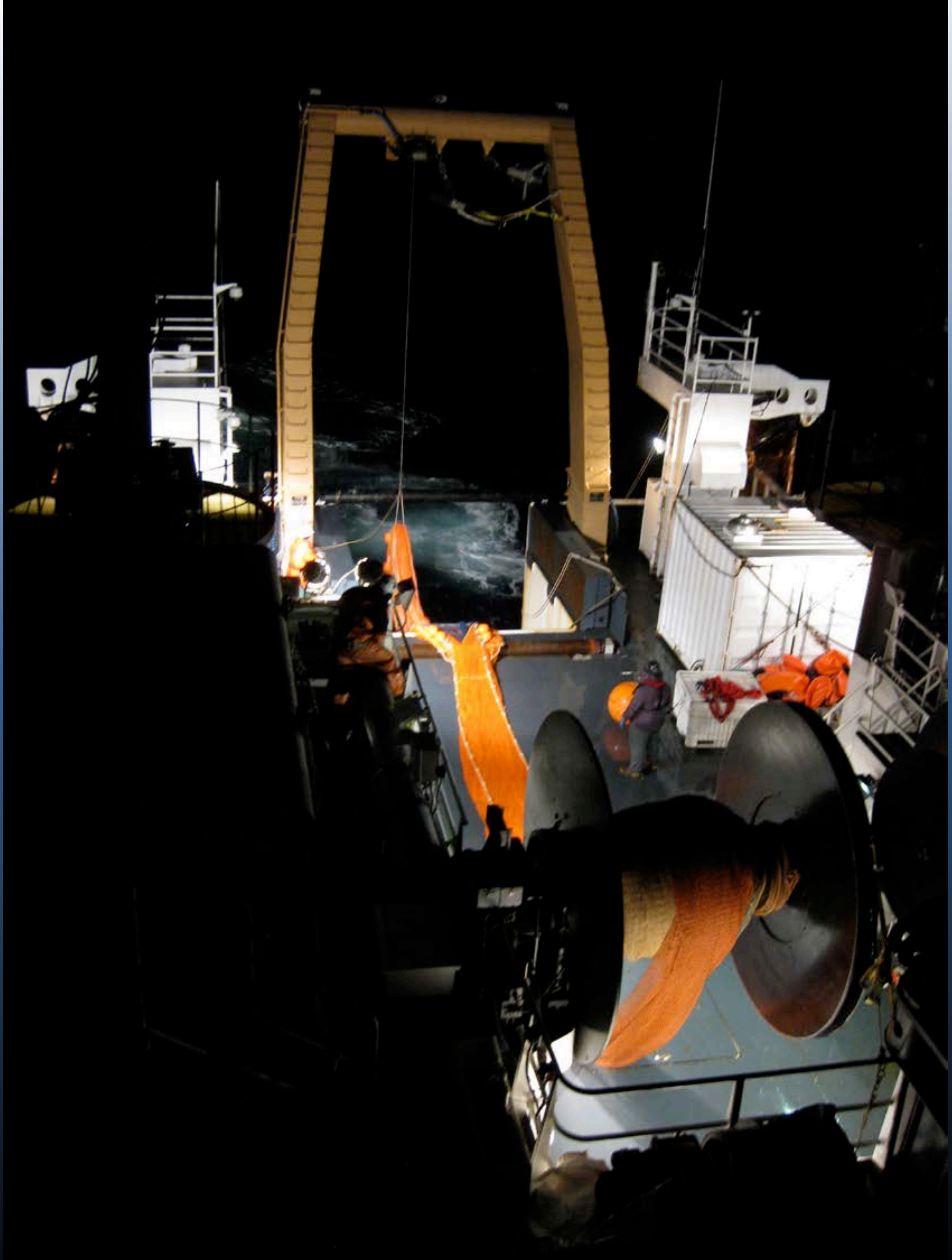
Agenda Item C.1.b
Supplemental SWFSC PowerPoint
April 2011

Underway Mapping of Fish and Habitat

MS 70
EK 60




22
BELL M SHIMADA
2




VWR
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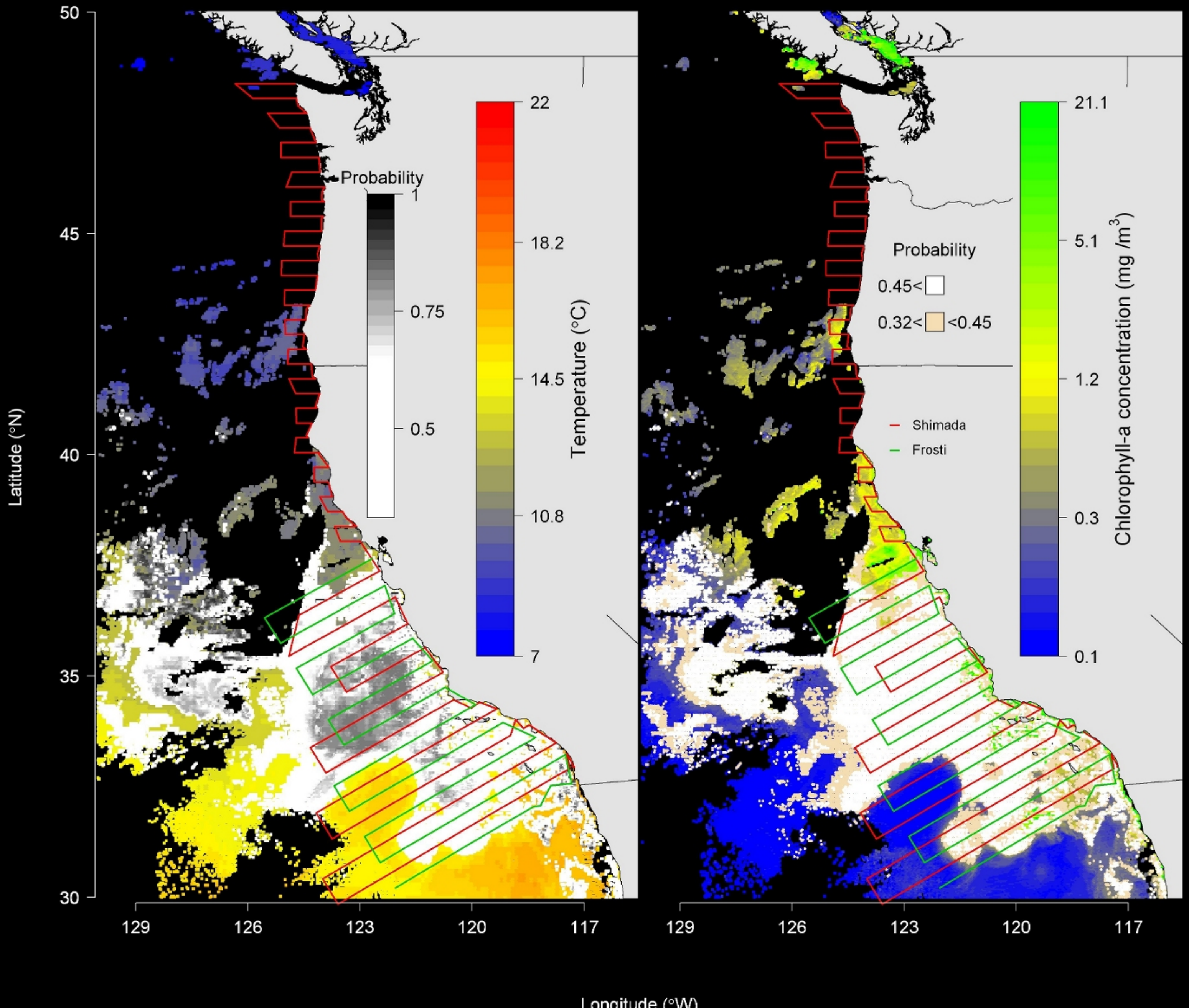
KC500


HUNTER
SWFC

April 6, 2011



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30
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126
123
120
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Probability
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0.5
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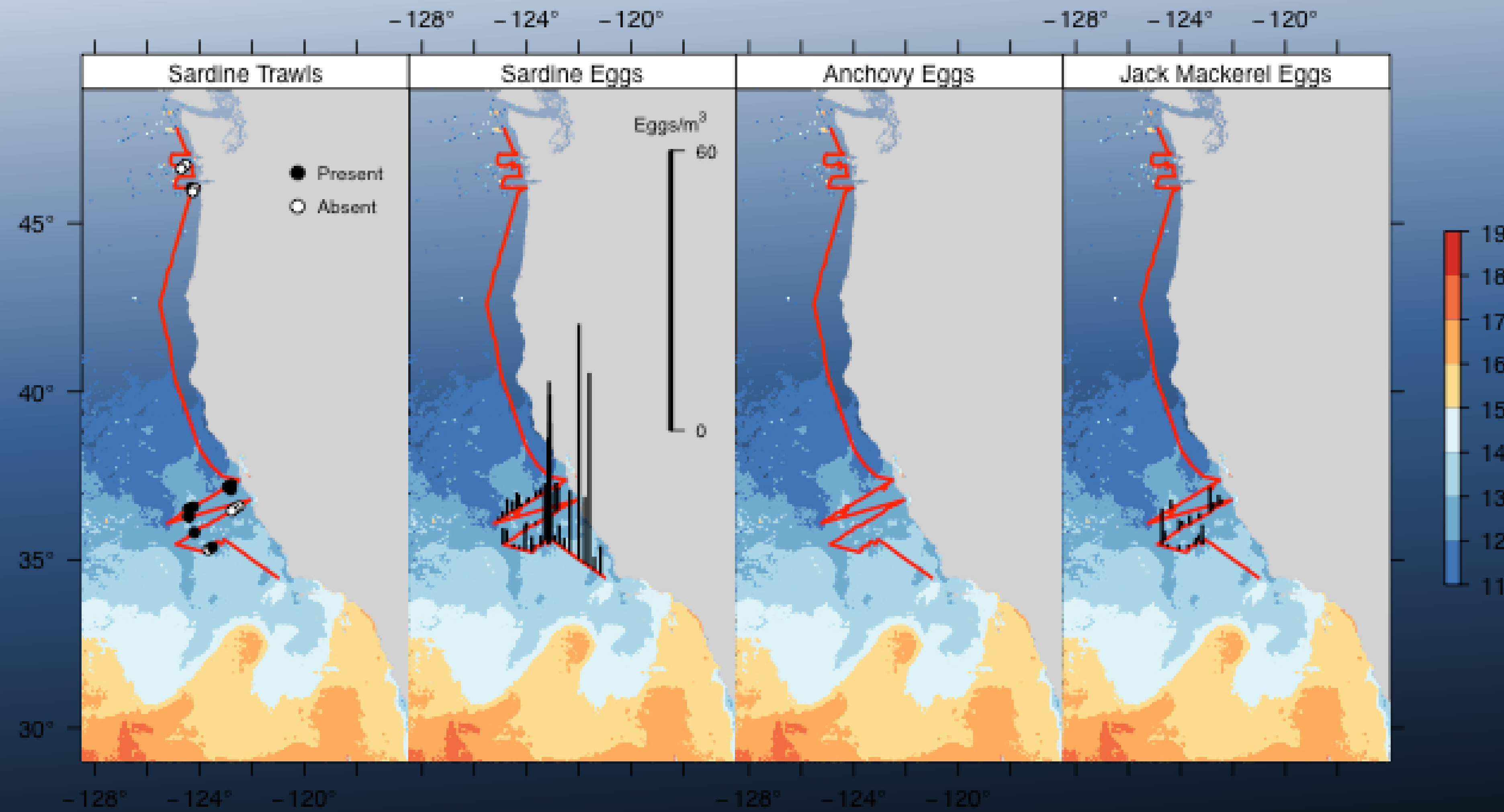
18.2
14.5
10.8
7
Temperature (°C)
21.1
5.1
1.2
0.3
0.1
Chlorophyll-a concentration (mg /m³)
Probability
0.45<
0.32<
<0.45
Shimada
Frosti
Longitude (°W)

RV Bell Shimada
23 March to 06 April 2011




NOAA
R 227
BELL M. SHIMADA

EXEMPTED FISHING PERMIT (EFP) FOR 2011 NORTHWEST AERIAL SARDINE SURVEY

At its March 2011 meeting, the Council adopted for public review a draft Exempted Fishing Permit (EFP) proposal submitted by the Northwest Aerial Sardine Survey (NWSS), LLC. The intent of the proposed research is to continue aerial surveys that were conducted in 2008, 2009, and 2010 by industry representatives. Because all or part of this activity may happen during an otherwise closed period, an EFP from the National Marine Fisheries Service (NMFS) will be required.

The NWSS amended its draft EFP proposal based on comments from the Coastal Pelagic Species Management Team (CPSMT) and the Scientific and Statistical Committee (SSC); and to reflect the fact that the EFP proposal would utilize 2,700 metric tons (mt), which is 600 mt more than proposed in the first draft. The revised proposal also includes additional point sets and transects, reflecting the additional EFP tonnage.

In November, 2010, the Council established a 4,200 mt research set-aside in anticipation of EFP proposals. The only EFP proposal submitted to the Council for consideration is the NWSS. Therefore, the remaining 1,500 mt will be reallocated to the third period directed fishery (September 15-December 31), as will any set-aside allocated to an EFP but not utilized during survey activities.

The Coastal Pelagic Species (CPS) advisory bodies and the Council expressed support for aerial sardine survey research that would utilize a portion of the 2011 harvest guideline (HG) for research that can be conducted outside of the directed fishery. The Coastal Pelagic Species Management Team made 11 recommendations in response to the March draft of the EFP proposal, of which nine were adopted by the Council. The SSC expressed support for the research, but noted concern about the lack of explicit protocols for the spatial distribution of point sets. The CPS Advisory Subpanel supported the EFP proposal.

The Council is tasked with making a final recommendation on EFPs for 2011. The EFP application will then be considered by NMFS, which would ultimately issue the EFP.

Council Action:

Adopt Final EFP Recommendation.

Reference Materials:

1. Agenda Item C.2.a, Attachment 1: West Coast Aerial Sardine Survey 2011 Application for Exempted Fishing Permit, revised.

Agenda Order:

a. Agenda Item Overview — Kerry Griffin
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action**: Adopt Final EFP Recommendations

PFMC
03/25/11

Agenda Item C.2.a
Attachment 1
April 2001

West Coast Aerial Sardine Survey

2011

Application for Exempted Fishing Permit

Applicant:

Northwest Sardine Survey, LLC
(Jerry Thon, Principal)

Science Advisor:

Tom Jagielo
Tom Jagielo, Consulting

Scientific Field Lead:

Ryan Howe

March 19, 2011

Table of Contents

I. Introduction

Advisory bodies of the Pacific Fishery Management Council (PFMC), including the Coastal Pelagic Species Advisory Subpanel (CPSAS), Coastal Pelagic Species Management Team (CPSMT), and the Scientific and Statistical Committee (SSC), have recommended that additional fishery-independent indices of abundance be developed for the assessment of Pacific sardine.

To meet the stated need for a credible index of sardine abundance, an aerial survey methodology was developed and successfully tested in 2008 by the Northwest Sardine Survey (NWSS), an industry group based in the Pacific Northwest (Wespestad et al. 2009). A stock assessment review (STAR) panel approved the approach in May 2009, and recommended that it be applied in a coastwide, synoptic survey. The PFMC subsequently approved an Exempted Fishing Permit (EFP) application to conduct a coastwide aerial sardine survey in the summer of 2009, submitted by an industry consortium formed by the NWSS and the California Wetfish Producers Association (CWPA). Work conducted under the 2009 sardine EFP resulted in a survey that extended from Cape Flattery, WA to Monterey Bay, CA (Jagielo et al. 2009). The results from that survey were reviewed by a STAR panel in September 2009 and were approved for use in the 2009 Pacific sardine stock assessment. The 2009 Pacific sardine stock assessment, which included the aerial survey index, was subsequently approved by the SSC and the PFMC for use in 2010 management. The survey was expanded again in 2010 with transect coverage extending further southward, into the southern California Bight. The 2010 results were reviewed by a STAR panel in September 2010 and were approved for use in the 2010 Pacific sardine stock assessment (Jagielo et al. 2010).

The present EFP application is for survey work proposed in 2011 by NWSS. It uses the same methodology employed in the 2009 and 2010 aerial sardine surveys. While work is not proposed for California in 2011, survey coverage could potentially be extended northward into Canada -- if Canadian governmental approvals can be obtained.

The purpose of this application is to document how the proposed survey meets the NMFS requirements for the approval of an EFP. Specifically, it provides: 1) the scientific study design, analytical methodologies, and a description of the overall logistics (in the main document that follows), 2) a detailed Fieldwork Operational Plan (Appendix I), and 3) a point by point discussion of how this EFP application follows the NMFS guidelines for preparation of an EFP application (Appendix II).

This EFP application is submitted to PFMC in order to obtain access to 2,700 mt of sardine which is requested to be withheld from the directed fishery management measures for the West Coast sardine OY for the purpose of funding and conducting the survey in 2011. The request of 2,700 mt of sardine in 2011 represents an increase of 600 mt over that requested for the Washington/Oregon area in 2010. The additional amount of EFP sardine will provide 1) increased funding to allow for a third survey airplane to conduct the additional transects planned for 2011 in a timely manner, and 2) an increased sample size to help reduce the variance of the survey biomass estimate.

The NWSS-LLC will conduct aerial survey work and point sets from the Canadian border to the Oregon-California border (survey area). Additional aerial survey work may be conducted by the NWSS-LLC in Canada if approval from the Canadian government is obtained in time to do so.

Scientific oversight for the Aerial Sardine Survey will be provided again in 2011 by Mr. Tom Jagielo. Mr. Jagielo will have the primary responsibility to analyze the survey data and will report the results to Dr. Kevin Hill, National Marine Fisheries Service (NMFS), Southwest Fisheries Science Center (SFSC), in a form suitable for input to the stock assessment model. Mr. Ryan Howe will be responsible again in 2011 for oversight of scientific sampling in the field. Mr. Jerry Thon (NWSS) will oversee the day to day logistic activities of the survey, including deployment of vessels and aircraft as needed to accomplish the projects objectives. Mr. Chris Cearns (NWSS) will serve as the West Coast Aerial Survey project Single Point of Contact (SPC), to comply with NMFS reporting requirements for the survey.

II. Survey Design

The aerial sardine survey employs a two-stage sampling design. Stage 1 consists of aerial transect sampling to estimate the surface area (and ultimately the biomass) of individual sardine schools from quantitative aerial photogrammetry; Stage 2 involves at-sea sampling to quantify the relationship between individual school surface area and biomass. Sampling will be conducted in July (following closure of the directed fishery), through August, and potentially into early September of 2011. Logistical details of the survey are provided in Appendix I (West Coast Aerial Sardine Survey - 2011 Field Operational Plan).

Stage 1: Aerial Transect Survey

Logistics

The 2011 aerial survey employs the belt transect method using a systematic random sampling design, with each transect comprising a single sampling unit (Elzinga et al. 2001). Parallel transects will be conducted in an east-west orientation, generally parallel to the onshore-offshore gradient of sardine schools distributed along the coast. Three alternative fixed starting points five miles apart were established, and from these points, three SETs of 41 transects were delineated for the survey. The order of conducting the three replicate SETs will be chosen by randomly picking one SET at a time without replacement. The east and west endpoints of each transect and corresponding shoreline position are given in Appendix I, Tables 1a-i and are mapped in Appendix I, Figures 1a-c for each of the three replicates (SET A, SET B, and SET C, respectively). Transects start at 3 miles from shore and extend westward for 35 statute miles in length. In addition to the 35 statute mile transect, the 3 statute mile segment directly eastward of each transect to the shore will be flown and photographed. Survey biomass will be estimated from the

35 statute mile transect data. Photographs from the shoreward segment will be used primarily to evaluate the potential need for future modification of the survey design.

For 2011, transect spacing will differ in two separate strata. In the northern portion of the survey area (From Cape Flattery, WA southward to approximately Tillamook, OR), transects are spaced 7.5 nautical miles apart. For the southern portion of the survey area (southward to the Oregon-California border) transects are spaced 15 nautical miles apart, as they have been previously. This stratification scheme follows from the observation that, in our previous surveys (2009-2010), this portion of the survey area accounted for 96% of the schools observed, and 99% of the sardine surface area measured.

Details regarding the airplanes and pilots participating in the survey, a description of the order in which transects will be flown to avoid "double counting", and other operational specifics are described in Appendix I.

Data Collection and Reduction

Each survey plane will be equipped with the same photogrammetric aerial digital camera mounting and data acquisition system that was used in the 2009 and 2010 aerial sardine surveys (Aerial Imaging Solutions; Appendix I, Adjunct 1). This integrated system will be used again to acquire digital images and to log transect data. The system records altitude, GPS position, and spotter observations, which are directly linked to the time stamped quantitative digital imagery. At the nominal survey altitude of 4,000 feet, the approximate width-swept by the camera with a 24 mm lens is 1,829 m (1.13 mi). Digital images will be collected with 60% overlap to ensure seamless photogrammetric coverage along transects.

A Transect Flight Log Form will be kept during the sampling of each transect for the purpose of documenting the observations of the pilot (Appendix I, Adjunct 2). Key notations will include 1) observations of school species identified and 2) documentation of any special conditions that could have an influence on interpreting the photographs.

In order to provide ground truth information and a cross comparison between survey aircraft, digital imagery of certain land-based features of known size (e.g., an airplane hangar, a football field, or a set of tennis courts) will again be collected at a series of altitudes ranging from 500 ft. to 4,000 ft. The observed vs. actual sizes of the objects will subsequently be compared to validate camera performance and to evaluate photogrammetric error.

Digital images from the survey will be analyzed to determine the number, size, and shape of sardine schools on each transect. Adobe *Photoshop Lightroom 3.0* software will be used to make the sardine schools visible. Measurements of sardine school size (m^2) and shape (circularity) will be made using Adobe *Photoshop CS5-Extended.* Transect width will be determined from the digital images using the basic photogrammetric relationship:

$$\frac{I}{F} = \frac{GCS}{A}$$

and solving for *GCS*:

$$GCS = \frac{I}{F}A$$

where *I* = Image width of the camera sensor (e.g. 36 mm), *F* = the focal length of the camera lens (e.g. 24mm), *A* = altitude, and *GCS* = "ground cover to the side" or width of the field of view of the digital image. Transect width will be obtained by taking the average of *GCS* for all images collected on transect. Transect length will be obtained from the distance between start and stop endpoints using the GPS data logged by the data acquisition system.

Data Analysis

Estimation of total sardine biomass for the survey area will be accomplished in a 3 step process, requiring: 1) measurement of individual school surface area on sampled transects, 2) estimation of individual school biomass (from measured school surface area and estimated school density), and 3) transect sampling design theory for estimation of a population total.

Individual school surface area (a_i) will be measured on the photo-documented transects using the measurement tool feature of *Adobe Photoshop*, employing the photogrammetric relationships described above. Individual school density (d_i) is specific to school size and will be determined from the empirical relationship between surface area and biomass obtained from Stage 2 (point-set) sampling (described below). Individual school biomass (b_i) is estimated as the product of school density and surface area ($b_i = d_i a_i$). The sum of individual school biomass (b_u) will then be determined for each transect (u). The mean sampled biomass for the study area ($\bar{b}$) is computed as:

$$\bar{b} = \sum_{u=1}^{n} b_u \ / n \ .$$

Total biomass for the study area $(\hat{B})$ will be estimated using the unbiased estimator for a population total (Stehman and Salzer 2000),

$$\hat{B} = N\bar{b} \ ,$$

As in 2010, three replicate sets of transects (SET A, SET B, and SET C) will be completed and thus three estimates of $\hat{B}$ will be calculated: $\hat{B}_A$, $\hat{B}_B$, and $\hat{B}_C$, respectively. The point estimate of total biomass for the study area ($\hat{B}_T$) will be obtained by averaging these three estimates of biomass.

Individual School Biomass

The biomass of individual schools observed on the transects (b_i) will be calculated using 1) measurements of school surface area, and 2) the relationship between school surface area and biomass, obtained from point sets (see Stage 2, below). The three parameter

Michaelis-Menten (MM) model assuming log-normal error will again be used to describe the sardine surface area– density relationship

d_i = (yint * cc + asymp * a_i) / (cc + a_i)

where

d_i = school density (mt/m^2)
a_i = school area (m^2)
yint = y intercept
asymp = asymptote as x -> infinity
asymp/cc = slope at the origin .

As noted above, individual school biomass (b_i) will then estimated as the product of school density and surface area ($b_i = d_i a_i$).

Total Biomass Coefficient of Variation (CV)
The CV of the total biomass estimate will again be obtained by employing a bootstrapping procedure implemented with the R statistical programming language (Jagielo et al 2010). The intent of the procedure is to propagate error from the point of school density estimation forward -- to the ultimate goal of total biomass estimation from the three replicate sets of transect data.

Stage 2: At-Sea Point Set Sampling

Logistics
Empirical measurements of biomass will be obtained by conducting research hauls or "point sets" at sea. Point sets are the means used to determine the relationship between individual school surface area (as documented with quantitative aerial photographs, described above) and the biomass of individual fish schools (Figure 1). Four purse seine vessels will participate in the survey under the direction of Mr. Thon. The identification and gear configuration of the participating vessels is given in Appendix I, Adjunct 3.

For the purposes of the aerial survey, a valid point set is defined as a sardine school first identified by a survey pilot and subsequently captured in its entirety by a survey purse seine vessel. The criteria that will be used for determining the acceptability of point sets for the school density analysis are given in Appendix I, Adjunct 4. Attempts will be made to conduct point sets over as wide an area as feasible; however, point sets may occur in any area covered by aerial transects where sardine schools of the desired size are found. Additional details on the logistics of point set sampling are provided in Appendix I.

Data Collection and Reduction
For fully captured schools, the 1) total weight of the school, 2) numbers per unit weight, and 3) species composition will be determined from biological sampling of the point set

hauls (see below). Additionally, school height in the water column will be recorded from vessel sonar and down-sounder equipment.

The point set sampling design is based on school size, with the goals of: 1) obtaining a range of sizes representative of schools photographed on the transects, and 2) keeping within a size range consistent with the safe operation of the vessels participating in the survey. Thus, point sets will generally not be attempted for schools larger than approximately 130 mt (approximately 10,000 m^2). It is anticipated that 2,700 mt of sardine will be available for point sets in 2011; a total of 76 point sets are planned for the Washington/Oregon survey area in 2011 (Appendix I, Table 2).

Biological Sampling of Point Sets

Fishermen participating in the survey will keep the point set hauls in separate holds upon capture so the tonnage of each aerially photographed and measured haul can be determined separately upon landing. Fish will be collected at fish processing plants upon landing. Samples will be collected from the unsorted catch while being pumped from the vessels. Fish will be taken systematically at the start, middle, and end of each set as it is pumped. The three samples will then be combined and a random subsample of fish (n = 50) will be taken from the pooled sample. Length, weight, sex, and maturity data will be collected for each sampled fish. Sardine weights will be taken using an electronic scale accurate to 0.5 gm; lengths will be taken using a millimeter length strip provided attached to a measuring board. Standard length is determined by measuring from sardine snout to the last vertebrae. Sardine maturity will be documented by referencing maturity codes (female- 4 point scale, male- 3 point scale) supplied by Beverly Macewicz NMFS, SWFSC (Appendix I, Table 3). A subsample of 25 fish from each point set sample will be frozen and retained for collection of otoliths.

III. Survey Logistics

A description of: 1) the roles and responsibilities of project personnel, 2) EFP purse seine vessel selection, 3) the disposition of fish harvested under the EFP, and 4) the project budget, are provided below. Additionally, a detailed Field Operational Plan is presented in Appendix I, and a point by point discussion of NMFS EFP guidelines and requirements is presented in Appendix II.

Key Project Personnel: Roles and Responsibilities

Name: Mr. Jerry Thon
Affiliation: Principal, Northwest Sardine Survey, LLC
Address: 12 Bellwether Way, Suite 209, Bellingham, WA 98225
Email: jthon2@msn.com
Phone: (360) 201-8449

Role: Industry Coordinator; EFP Applicant: NWSS-LLC

Responsibilities: Oversee day to day logistic activities of the survey, including deployment of vessels and aircraft as needed to accomplish the projects objectives. Coordinatate sale of EFP sardine with participating processors. Administrate EFP funds; direct funds as required to accomplish the projects scientific objectives. Contract with scientists, vessels, pilots, and others as needed to execute the project with scientific oversight from Mr. Jagielo (Science Advisor).

Name: Mr. Tom Jagielo, MSc
Affiliation: Tom Jagielo, Consulting
Email: TomJagielo@msn.com
Phone: (360) 791-9089

Role: Science Advisor

Responsibilities: Develop survey design. Provide scientific guidance and oversight for project execution. Analyze survey data. Provide survey results in a form suitable for use by NMFS/SWFSC in the Pacific sardine stock assessment. Prepare final report. Represent the project in public fora (e.g., PFMC, STAR panels, and SSC) to present and interpret scientific results from the survey.

Name: Mr. Ryan Howe, BSc
Affiliation: Consultant
Email: ryanhowe9@yahoo.com

Role: Scientific Field Leader

Responsibilities: Under direction of Mr. Jagielo, coordinate field data collection and ensure scientific validity of field data from the survey. Compile data for analysis. Provide leadership of photogrammetric analysis staff. Assist with survey data analysis, preparation of final report, and presentation of project results as appropriate and/or required.

EFP Purse Seine Vessel Selection

Our priorities for selecting vessels to participate under this EFP include: 1) vessels having the ability to separate the point sets into different hatches, 2) vessels committing to follow scientific protocol as directed during this study period, and 3) vessels that have installed or have the capacity to install or carry any electronic equipment necessary.

With the narrow time window for sampling it is desirable to have a field of boats we can draw on. The main reason to have several boats in this period is to maximize the number of point sets we can bring in during optimum weather and sea conditions. These boats will only be used for point sets. Some vessels do not have recording sounders, but all vessels do have sonar's that can measure school height and log it. Having a slate of potential vessels to draw from removes the possibility of losing operational days from problems like engine failure. Being able to pick vessels from the list of available boats, and reporting the vessels that will be operating at any given time to local enforcement will help to meet the EFP goals efficiently and cost-effectively. We request approval to deploy up to four vessels per 24 hour period (See Appendix I, Adjunct 3). Participating vessels may make EFP landings in either one or both states (Washington or Oregon).

Disposition of fish harvested under the EFP

Fish harvested under this EFP will be sold to help fund the sardine research described above. Participating processors receiving point set EFP product from sardine quota set-aside to NWSS-LLC will be identified prior to any fish deliveries made under this EFP, and they will process the fish by bid. Fish Tickets will be tabulated to verify that the sardine harvested under the EFP do not exceed the amount of harvest allocated for the research set-aside to the recipients, and that the amounts harvested correspond to the total of the amounts harvested while conducting the point set research.

Budget

An itemized budget is provided as Appendix II, Adjunct 2. The amount of funds that will be available to the project from the sale of sardine harvested and sold under the EFP is of necessity a rough estimate; this number will be refined as bids for processing are received and the amount of funds potentially available can be established. On the cost side, we have detailed components of the project that will be required to complete the work proposed. Field work always includes uncertainty (weather, fish availability, etc.) and contingency amounts have been included to attempt to address some of this uncertainty.

The financial structure of the project is as follows:

1. Funds derived from the capture and sale of the sardine research set-aside will be used to pay for the research to be conducted under this proposed EFP. The costs of the project will be the responsibility of the NWSS-LLC and will be paid for by the sale of the fish captured during the point sets.

2. Fishing vessels will be chartered by NWSS-LLC to catch the sardines during point sets and conduct echo soundings of fish schools with ES-60 or other suitable electronic equipment.

3. Participating processors will not profit on the sale of the EFP sardine quota; rather, they will process the fish at cost. The processor(s) for this project will be chosen after submitting bids. The lowest bid(s) will be accepted.

4. Airplanes conducting the photo surveys and assisting in point set captures will work under hourly rates or by contract to NWSS-LLC.

5. Equipment needs and operational costs, including scientific support, will be paid for by the NWSS-LLC from the sale of the 2,700 mt research quota. We anticipate the revenue from the fish sales will be sufficient to cover the costs to capture, process, and conduct the survey.

IV. Exempted Fishery Permit Application - Conclusion

In summary, the proposed EFP will contribute substantially toward improving the data available to assess the sardine stock for management on the Pacific Coast. Building on the successful survey work conducted and used in the 2009 and 2010 stock assessments, the EFP research study in 2011 will enable us to obtain a third biomass estimate. The research set-aside of OY under the EFP will provide a reliable source of funds and will allow us to conduct our work in a controlled, methodical manner, separate from the race for fish, which ensues during the directed fishery. This will enable us to obtain a larger and more representative sample of point sets to more precisely and accurately estimate sardine school density – an important parameter needed for sardine biomass estimation using the aerial survey method.

V. Literature Cited

Elzinga, C. L, D. W. Salzer, J. W. Willoughby, and J. P. Gibbs. 2001. Monitoring Plant and Animal Populations. Blackwell Science, Inc., Maiden, MA.

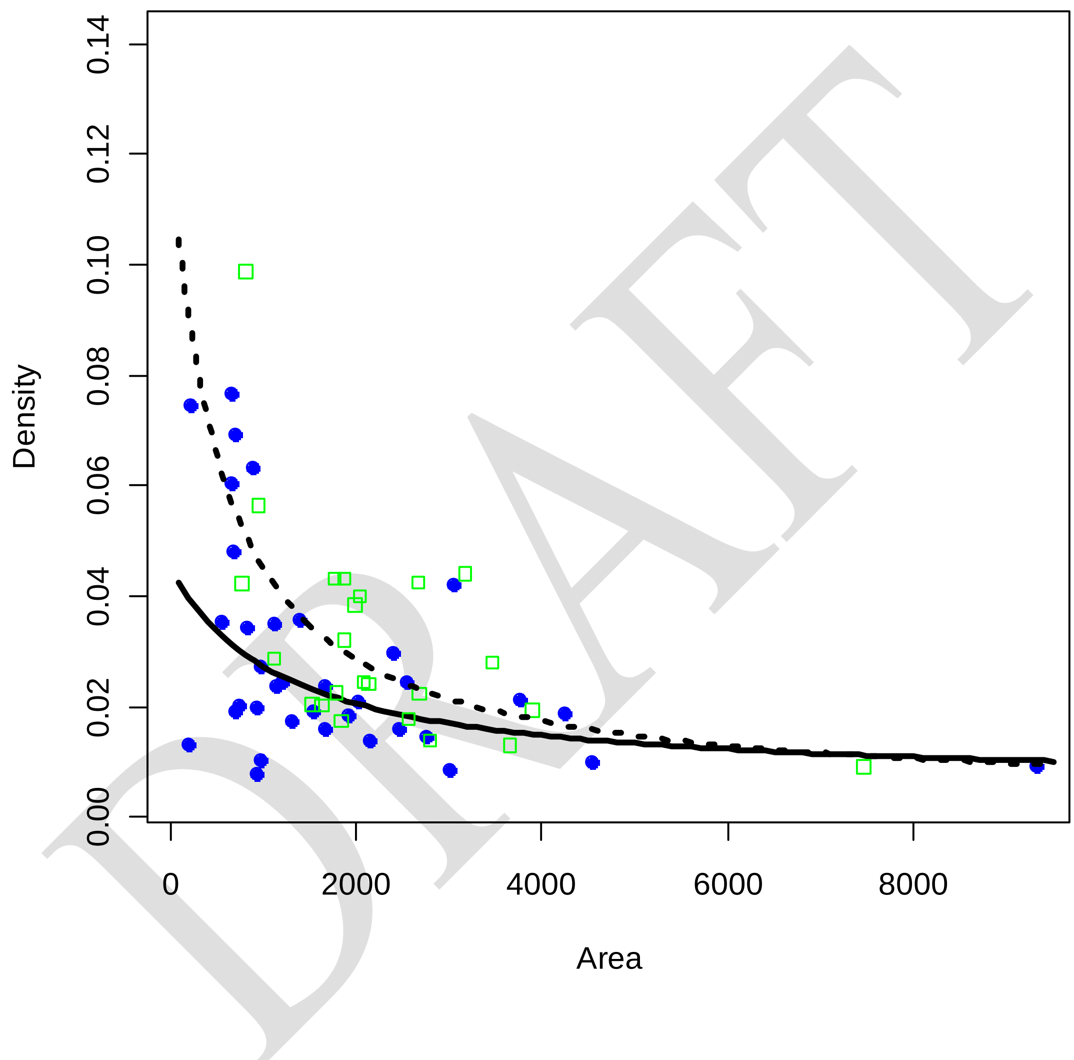
Jagielo, T.H., Hanan, D., and R. Howe. 2009. West Coast Aerial Sardine Survey. Sampling Results in 2009. Prepared for California Wetfish Producers Association, and the Northwest Sardine Survey. Submitted to Pacific Fishery Management Council, Portland, OR, October 14, 2009.

Jagielo, T. H., Hanan, D., Howe, R., and M. Mikesell. 2010. West Coast Aerial Sardine Survey. Sampling Results in 2010. Prepared for Northwest Sardine Survey and the California Wetfish Producers Association. Submitted to Pacific Fishery Management Council, Portland, OR, October 15, 2010. 51p.

Stehman, S. and D. Salzer. 2000. Estimating Density from Surveys Employing Unequal-Area Belt Transects. Wetlands. Vol. 20, No. 3, pp. 512-519. The Society of Wetland Scientists, McLean, VA.

Wespestad, V., Jagielo, T. and R. Howe. 2008. The Feasibility Of Using An Aerial Survey To Determine Sardine Abundance Off The Washington-Oregon Coast In Conjunction With Fishing Vessel Observation Of Surveyed Schools And Shoals. Report Prepared For: Northwest Sardine Survey, LLC. 12 Bellwether Way, Suite 209, Bellingham, WA 98225.

Figure 1. Relationship of surface area (m^2) (x axis) vs. density (mt/m^2) (y axis) determined from point sets. Legend: solid line: relationship used in the 2009 analysis; dashed line: relationship used in the 2010 analysis; solid circles: 2009 analysis data; open squares: 2010 analysis data.



Appendix I

West Coast Aerial Sardine Survey

2011

Field Operational Plan

Industry Coordinator:

Northwest Sardine Survey, LLC
(Jerry Thon, Principal)

Science Advisor:

Tom Jagielo
Tom Jagielo, Consulting

Scientific Field Project Leader:

Ryan Howe

March 19, 2011

Aerial Transect Survey

Overall Aerial Survey Design

Mr. Jerry Thon will oversee the day to day logistic activities of the survey, including deployment of vessels and aircraft as needed to accomplish the projects objectives. To ensure clear communications among participants and other interested parties, the Single Point of Contact (SPC) person for 2011 survey field work will be Mr. Chris Cearns (NWSS), working under the direction of Mr. Thon.

Scientific field work will be conducted in Washington and Oregon by Mr. Ryan Howe with oversight from Mr. Tom Jagielo. Mr. Howe will lead the digital photograph analysis team and will archive all photographic and biological data.

Mr. Jagielo will be responsible for analyzing the survey data and will report the results to Dr. Kevin Hill, NMFS, SWFSC, in a form suitable for input to the stock assessment model. Mr. Howe will be available to help with data analysis as requested.

The 2011 coastwide aerial survey design consists of 41 transects spanning the area from Cape Flattery in the north to the Oregon-California border in the south (Table 1, Figure 1). Each 41-transect series will be conducted as a SET, and will make up one survey replicate. The 2011 survey will strive to complete three replicate SETS, or 123 transects in total. Survey coverage could potentially be extended northward into Canada -- if Canadian governmental approvals can be obtained.

Location of Transects
The east and west endpoints of each transect and corresponding shoreline position are given in Tables 1a-c and are mapped in Figures 1a-c for each of the three replicates (SET A, SET B, and SET C, respectively). Transects start at 3 miles from shore and extend westward for 35 statute miles in length. Transect spacing differs in the north (7.5 nautical miles) compared to the south (15 nautical miles) of the survey area. In addition to the 35 statute mile transect, the 3 statute mile segment directly eastward of each transect to the shore will be flown and photographed. Survey biomass will be estimated from the 35 statute mile transect data. Photographs from the shoreward segment will be used primarily to evaluate the need for future modification of the survey design.

Aerial Resources
Two Piper Super Cubs and one Cessna 337 will be used to conduct survey transects and point sets. Survey airplanes will be equipped with a Canon EOS 1Ds in an Aerial Imaging Solutions FMC mount system (Adjunct 1), installed inside the fuselage of the plane.

Use of Aerial Resources
Aerial resources will be coordinated by Mr. Thon (NWSS). To conduct a SET, survey pilots will begin with transect number 1 at Cape Flattery in the north and will proceed to the southernmost transect off the southern Oregon coast. When operating together as a team, pilots will communicate via radio or cell phone. They will take a “Leap-Frog” approach: for example --

plane 1 will fly transects 1-5 while plane 2 is flying transects 6-10; then plane 1 will fly transects 11-15 while plane 2 flies Transects 16-20, and so on. The actual number of transects flown in a day by each plane will be determined jointly by the survey pilots and Mr. Thon and may be more or less than the example of five per plane given above.

Conditions Acceptable for Surveying

At the beginning of each potential survey day, the survey pilots will confer with Mr. Thon and will jointly judge if conditions will permit safe and successful surveying that day. Considering local conditions, they will also jointly determine the optimal time of day for surveying the area slated for coverage that day. Factors will include sea condition, time of day for best sardine visibility, presence of cloud or fog cover, and other relevant criteria.

Transect Sampling

Prior to beginning a survey flight, the Pre-Flight Survey Checklist (Adjunct 2) will be completed for each aircraft. This will ensure that the camera system settings are fully operational for data collection. For example, it is crucial to have accurate GPS information in the log file. It is also crucial that the photograph number series is re-set to zero. Transects flown without the necessary survey data are not valid and cannot be analyzed.

The decision of when to start a new SET of transects will be determined by Mr. Thon with input from Mr. Jagielo and/or others as requested. Transects will be flown at the nominal survey altitude of 4,000 ft whenever possible. Transects may be flown starting at either the east end or the west end.

A Transect Flight Log Form (Adjunct 2) will be kept during the sampling of each transect for the purpose of documenting the observations of the pilot and/or onboard observers. Key notations will include observations of school species ID and documentation of any special conditions that could have an influence on interpreting photographs taken during transects.

Sardine are believed to migrate from California, northward during the summer. Thus, to avoid the possibility of “double counting”, it is important that transects are conducted in a North-to-South progression. Once a transect (or a portion of a transect) has been flown, neither that transect, nor any transects to the north of that transect, may be flown again during that transect SET in progress. It will be acceptable to skip transects or portions of transects if conditions require it (e.g. if better weather is available to the south of an area), but transects may not be “made up” once skipped during the sampling of a transect SET. Once begun, the goal is to cover the full 41-transect SET in as few days as possible.

Data Transfer

Photographs and FMC log files will be downloaded and forwarded for analysis and archival at the end of each survey day. At the end of each flight, the Scientific Field Project Leader (Mr. Howe) will verify that the camera and data collection system operated properly and that images collected are acceptable for analysis. Mr. Howe will collect data from the pilots and will coordinate the transfer and archival of all aerial survey data.

I. Point Set Sampling

Location, Number, and Size of Point Sets

Point sets are fully captured sardine schools landed by purse seiners approved and permitted for this research. Each set by a purse seiner will be directed by one of the survey pilots. Point sets will be made over as wide an area as feasible within the survey area, in order to distribute the sampling effort spatially. We anticipate that point sets will be landed into both Washington and Oregon ports in 2011.

Point sets will be collected over a range of sizes, as set out in Table 2. The goal is to obtain 76 valid point sets.

Aerial Photography of Point Sets

Sardine schools to be captured for point sets will be first selected by the survey pilot and photographed at the nominal survey altitude of 4,000 ft. Following a discrete school selection, the pilot will descend to a lower altitude to better photograph the approach of the seiner to the school and set the seiner for capture of the school. Photographs will be taken before and during the vessels approach to the school for the point set capture. Each school selected by the pilot and photographed for a potential point set will be logged on the survey pilot's Point Set Flight Log Form (Adjunct 2). The species identification of the selected school will be verified by the Captain of the purse seine vessel conducting the point set and will be logged on the Fisherman's Log Form (Adjunct 2). These records will be used to determine the rate of school mis-identification by spotter pilots in the field and by analysts viewing photographs taken at the nominal survey altitude of 4,000 ft.

Vessel Point Set Capture

The purse seine vessel will encircle (wrap) and fully capture the school selected by the survey pilot for the point set. Any school not "fully" captured will not be considered a valid point set for analysis. If a school is judged to be "nearly completely" captured (i.e., over 90% captured), it will be noted as such and will be included for analysis. Both the survey pilot and the purse seine captain will independently make note of the "percent captured" on their survey log forms for this purpose. Upon capture, sardine point sets will be held in separate holds for separate weighing and biological sampling of each set after landing.

Biological Sampling

Biological samples of individual point sets will be collected at the landing docks or at the fish processing plants upon landing. Fish will be systematically taken at the start, middle, and end of a delivered set. The three samples will then be combined and a random subsample of fish will be taken. The sample size will be n = 50 fish for each point set haul.

Length, weight, maturity, and otoliths will be sampled for each point set haul and will be documented on the Biological Sampling Form (Adjunct 2). Sardine weights will be taken using an electronic scale accurate to 0.5 gm. Sardine lengths will be taken using a millimeter length strip attached to a measuring board. Standard length will be determined by measuring from sardine snout to the last vertebrae. Sardine maturity will be established by referencing maturity codes (female- 4 point scale, male- 3 point scale) supplied by Beverly Macewicz NMFS, SWFSC. A subsample of 25 fish from each point set sample will be individually bagged, identified with sample number and frozen with other fish in the subsample, clearly identified as to point set number, vessel, and location captured and retained for collection of otoliths.

Hydroacoustic Sounding of School Height

School height will be measured for each point set. This may be obtained by using either the purse seine or other participating research vessels' hydroacoustic gear. The school height measurements to be recorded on the Fisherman's Log Form are: 1) depth in the water column of the top of the school, and 2) depth in the water column of the bottom of the school. Simrad ES-60 sounders will be installed on two purse seine vessels. Data collected by the ES-60 sounders will be backed-up daily and archived onshore.

Number and Size of Point Sets to be Captured

Point sets will be conducted for a range of school sizes (Table 2). Point sets will be targeted working in general from the smallest size category to the largest. Each day, spotter pilots will operate with an updated list of remaining school sizes needed for analysis. Each spotter pilot will use his experience to judge the biomass of sardine schools from the air, and will direct the purse seine vessel to capture schools of appropriate size. Following landing of the point sets at the dock, the actual school weights will be determined. Every effort will be made to ensure, as soon as possible, that successfully landed point sets were also successfully photographed. This will in general be at the end of each fishing day or sooner. After verification of point set acceptability, the list of remaining school sizes needed from Table 2 will be updated accordingly for ongoing fishing. If schools are not available in the designated size range, point sets will be conducted on schools as close to the designated range as possible. Pumping large sets onto more than one vessel should be avoided, and should only be done in the accidental event that school size was grossly underestimated. Mr. Howe will oversee the gathering of point set landing data and will update the list daily. The total landed weight of point sets sampled will not exceed 2,700 mt.

Spatial Distribution of Point Sets

In order to distribute point sets spatially, sampling will occur both north and south of the Columbia River. This will be facilitated by landing point sets in both Washington and Oregon ports in 2011. Efforts will be made to distribute the point sets offshore vs. nearshore, as well. Quadrants have been identified to facilitate spatial distribution of the point sets (Figure 2).

Landing Reporting Requirements

Cumulative point set landings will be updated by Mr. Chris Cearns (NWSS), who will report the running total daily to NMFS, as per the terms of the Exempted Fishing Permit. Also included in this daily report will be an estimate of the weight of all by-catch by species.

Other EFP Reporting Requirements

To ensure clear communications among participants and other interested parties, the single point of contact (SPC) person during 2011 survey field work will be Mr. Chris Cearns.

Mr. Cearns (under the direction of Mr. Thon) will also be responsible for providing the other required reporting elements (as specified in the EFP permit) to NMFS. For example, a daily notice will be provided for enforcement giving 24 hour notice of vessels to be conducting point sets on any given day and will include vessel name, area to be fished, estimated departure time, estimated return time.

II. Calibration and Validation

Aerial Measurement Calibration

Each survey year, routine calibration is conducted to verify aerial measurements. A series of photographs will again be collected from a feature of known size (e.g., a football field or tennis court) on the ground, from the altitudes of 1,000 ft, 2,000 ft, 3,000 ft, and 4,000 ft. For each altitude series, an aerial pass will be made to place the target onto the right, middle, and left portions of the photographic image.

Aerial Photographs and Sampling for Species Validation

The collection of reference photographs is updated each survey year, for the purpose of species identification. These photographs are used by the team of photograph analysts to continue to learn how to discern between sardine and other species as they appear on the aerial transect photographs.

Reference photographs will be taken at the nominal survey altitude of 4,000 ft for the purpose of species identification. The spotter pilots will find and photograph schooling fish other than sardine (e.g. mackerel, herring, smelt, anchovy, etc). For the actual schools photographed, a vessel at sea (typically a small, relatively fast boat) will collect a jig sample to document the species identification. This sampling will most likely occur in June, prior to commencement of the summer fishery opening.

Tables 1a -1i Transect SETs A, B, and C.

Table 1a. SET A

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Washington	N	A1	48	20.000	125	28.49	A1w	124	42.91	A1e	124	39.0	A1s
Washington	N	A1a	48	12.500	125	29.37	A1aw	124	43.90	A1ae	124	40.0	A1as
Washington	N	A2	48	5.000	125	29.24	A2w	124	43.89	A2e	124	40.0	A2s
Washington	N	A2a	47	57.500	125	26.13	A2aw	124	40.88	A2ae	124	37.0	A2as
Washington	N	A3	47	50.000	125	17.01	A3w	124	31.87	A3e	124	28.0	A3s
Washington	N	A3a	47	42.500	125	10.90	A3aw	124	25.86	A3ae	124	22.0	A3as
Washington	N	A4	47	35.000	125	8.78	A4w	124	23.85	A4e	124	20.0	A4s
Washington	N	A4a	47	27.500	125	7.67	A4aw	124	22.84	A4ae	124	19.0	A4as
Washington	N	A5	47	20.000	125	4.55	A5w	124	19.83	A5e	124	16.0	A5s
Washington	N	A5a	47	12.500	124	58.93	A5aw	124	14.32	A5ae	124	10.5	A5as
Washington	N	A6	47	5.000	124	57.32	A6w	124	12.81	A6e	124	9.0	A6s
Washington	N	A6a	46	57.500	124	57.20	A6aw	124	12.81	A6ae	124	9.0	A6as
Washington	N	A7	46	50.000	124	53.09	A7w	124	8.80	A7e	124	5.0	A7s
Washington	N	A7a	46	42.500	124	51.98	A7aw	124	7.79	A7ae	124	4.0	A7as
Washington	N	A8	46	35.000	124	50.87	A8w	124	6.78	A8e	124	3.0	A8s
Washington	N	A8a	46	27.500	124	50.26	A8aw	124	6.27	A8ae	124	2.5	A8as
Washington	N	A9	46	20.000	124	49.66	A9w	124	5.76	A9e	124	2.0	A9s
Washington	N	A9a	46	12.500	124	46.05	A9aw	124	2.25	A9ae	123	58.5	A9as
Oregon	N	A10	46	5.000	124	42.44	A10w	123	58.75	A10e	123	55.0	A10s
Oregon	N	A10a	45	57.500	124	44.33	A10aw	124	0.74	A10ae	123	57.0	A10as
Oregon	N	A11	45	50.000	124	43.22	A11w	123	59.73	A11e	123	56.0	A11s
Oregon	N	A11a	45	42.500	124	42.62	A11aw	123	59.22	A11ae	123	55.5	A11as
Oregon	N	A12	45	35.000	124	42.02	A12w	123	58.71	A12e	123	55.0	A12s
Oregon	N	A12a	45	27.500	124	42.91	A12aw	123	59.70	A12ae	123	56.0	A12as
Oregon	N	A13	45	20.000	124	43.81	A13w	124	0.70	A13e	123	57.0	A13s
Oregon	N	A13a	45	12.500	124	43.71	A13aw	124	0.69	A13ae	123	57.0	A13as
Oregon	N	A14	45	5.000	124	45.61	A14w	124	2.68	A14e	123	59.0	A14s
Oregon	N	A14a	44	57.500	124	46.51	A14aw	124	3.67	A14ae	124	0.0	A14as
Oregon	N	A15	44	50.000	124	49.41	A15w	124	6.66	A15e	124	3.0	A15s
Oregon	N	A15a	44	42.500	124	49.30	A15aw	124	6.66	A15ae	124	3.0	A15as
Oregon	N	A16	44	35.000	124	53.23	A16w	124	6.97	A16e	124	3.0	A16s
Oregon	N	A17	44	20.000	124	56.48	A17w	124	9.99	A17e	124	6.0	A17s
Oregon	N	A18	44	5.000	124	57.74	A18w	124	11.01	A18e	124	7.0	A18s
Oregon	N	A19	43	50.000	125	0.00	A19w	124	13.03	A19e	124	9.0	A19s
Oregon	N	A20	43	35.000	125	3.27	A20w	124	16.05	A20e	124	12.0	A20s
Oregon	N	A21	43	20.000	125	13.54	A21w	124	26.07	A21e	124	22.0	A21s
Oregon	N	A22	43	5.000	125	16.81	A22w	124	29.09	A22e	124	25.0	A22s
Oregon	N	A23	42	50.000	125	24.08	A23w	124	36.11	A23e	124	32.0	A23s
Oregon	N	A24	42	35.000	125	15.37	A24w	124	27.13	A24e	124	23.0	A24s
Oregon	N	A25	42	20.000	125	17.65	A25w	124	29.16	A25e	124	25.0	A25s
Oregon	N	A26	42	5.000	125	9.94	A26w	124	21.18	A26e	124	17.0	A26s

Table 1b. SET B

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Washington	N	B1	48	15.000	125	30.40	B1w	124	44.90	B1e	124	41.0	B1s
Washington	N	B1a	48	7.500	125	30.29	B1aw	124	44.89	B1ae	124	41.0	B1as
Washington	N	B2	48	0.000	125	28.17	B2w	124	42.88	B2e	124	39.0	B2s
Washington	N	B2a	47	52.500	125	21.05	B2aw	124	35.87	B2ae	124	32.0	B2as
Washington	N	B3	47	45.000	125	12.94	B3w	124	27.86	B3e	124	24.0	B3s
Washington	N	B3a	47	37.500	125	8.82	B3aw	124	23.85	B3ae	124	20.0	B3as
Washington	N	B4	47	30.000	125	7.70	B4w	124	22.84	B4e	124	19.0	B4s
Washington	N	B4a	47	22.500	125	6.58	B4aw	124	21.84	B4ae	124	18.0	B4as
Washington	N	B5	47	15.000	125	0.47	B5w	124	15.83	B5e	124	12.0	B5s
Washington	N	B5a	47	7.500	124	57.36	B5aw	124	12.82	B5ae	124	9.0	B5as
Washington	N	B6	47	0.000	124	57.24	B6w	124	12.81	B6e	124	9.0	B6s
Washington	N	B6a	46	52.500	124	54.63	B6aw	124	10.30	B6ae	124	6.5	B6as
Washington	N	B7	46	45.000	124	52.02	B7w	124	7.79	B7e	124	4.0	B7s
Washington	N	B7a	46	37.500	124	50.91	B7aw	124	6.78	B7ae	124	3.0	B7as
Washington	N	B8	46	30.000	124	49.80	B8w	124	5.77	B8e	124	2.0	B8s
Washington	N	B8a	46	22.500	124	49.19	B8aw	124	5.26	B8ae	124	1.5	B8as
Washington	N	B9	46	15.000	124	48.58	B9w	124	4.76	B9e	124	1.0	B9s
Washington	N	B9a	46	7.500	124	42.48	B9aw	123	58.75	B9ae	123	55.0	B9as
Oregon	N	B10	46	0.000	124	42.37	B10w	123	58.74	B10e	123	55.0	B10s
Oregon	N	B10a	45	52.500	124	42.76	B10aw	123	59.23	B10ae	123	55.5	B10as
Oregon	N	B11	45	45.000	124	43.16	B11w	123	59.72	B11e	123	56.0	B11s
Oregon	N	B11a	45	37.500	124	43.05	B11aw	123	59.71	B11ae	123	56.0	B11as
Oregon	N	B12	45	30.000	124	42.94	B12w	123	59.71	B12e	123	56.0	B12s
Oregon	N	B12a	45	22.500	124	43.34	B12aw	124	0.20	B12ae	123	56.5	B12as
Oregon	N	B13	45	15.000	124	42.74	B13w	123	59.69	B13e	123	56.0	B13s
Oregon	N	B13a	45	7.500	124	44.64	B13aw	124	1.68	B13ae	123	58.0	B13as
Oregon	N	B14	45	0.000	124	46.54	B14w	124	3.67	B14e	124	0.0	B14s
Oregon	N	B14a	44	52.500	124	48.44	B14aw	124	5.67	B14ae	124	2.0	B14as
Oregon	N	B15	44	45.000	124	48.33	B15w	124	5.66	B15e	124	2.0	B15s
Oregon	N	B15a	44	37.500	124	48.73	B15aw	124	6.15	B15ae	124	2.5	B15as
Oregon	N	B16	44	30.000	124	49.14	B16w	124	6.64	B16e	124	3.0	B16s
Oregon	N	B17	44	15.000	124	50.94	B17w	124	8.63	B17e	124	5.0	B17s
Oregon	N	B18	44	0.000	124	52.75	B18w	124	10.61	B18e	124	7.0	B18s
Oregon	N	B19	43	45.000	124	55.55	B19w	124	13.60	B19e	124	10.0	B19s
Oregon	N	B20	43	30.000	125	0.37	B20w	124	18.58	B20e	124	15.0	B20s
Oregon	N	B21	43	15.000	125	8.24	B21w	124	26.57	B21e	124	23.0	B21s
Oregon	N	B22	43	0.000	125	12.00	B22w	124	30.55	B22e	124	27.0	B22s
Oregon	N	B23	42	45.000	125	14.82	B23w	124	33.54	B23e	124	30.0	B23s
Oregon	N	B24	42	30.000	125	8.64	B24w	124	27.52	B24e	124	24.0	B24s
Oregon	N	B25	42	15.000	125	7.46	B25w	124	26.51	B25e	124	23.0	B25s
Oregon	N	B26	42	0.000	124	55.29	B26w	124	14.50	B26e	124	11.0	B26s

Table 1c. SET C

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Washington	N	C1	48	10.000	125	31.33	C1w	124	45.89	C1e	124	42.0	C1s
Washington	N	C1a	48	2.500	125	28.21	C1aw	124	42.88	C1ae	124	39.0	C1as
Washington	N	C2	47	55.000	125	25.09	C2w	124	39.88	C2e	124	36.0	C2s
Washington	N	C2a	47	47.500	125	14.97	C2aw	124	29.87	C2ae	124	26.0	C2as
Washington	N	C3	47	40.000	125	9.85	C3w	124	24.86	C3e	124	21.0	C3s
Washington	N	C3a	47	32.500	125	8.24	C3aw	124	23.35	C3ae	124	19.5	C3as
Washington	N	C4	47	25.000	125	6.62	C4w	124	21.84	C4e	124	18.0	C4s
Washington	N	C4a	47	17.500	125	2.51	C4aw	124	17.83	C4ae	124	14.0	C4as
Washington	N	C5	47	10.000	124	58.40	C5w	124	13.82	C5e	124	10.0	C5s
Washington	N	C5a	47	2.500	124	56.78	C5aw	124	12.31	C5ae	124	8.5	C5as
Washington	N	C6	46	55.000	124	55.17	C6w	124	10.80	C6e	124	7.0	C6s
Washington	N	C6a	46	47.500	124	53.06	C6aw	124	8.79	C6ae	124	5.0	C6as
Washington	N	C7	46	40.000	124	50.95	C7w	124	6.79	C7e	124	3.0	C7s
Washington	N	C7a	46	32.500	124	50.34	C7aw	124	6.28	C7ae	124	2.5	C7as
Washington	N	C8	46	25.000	124	49.73	C8w	124	5.77	C8e	124	2.0	C8s
Washington	N	C8a	46	17.500	124	50.62	C8aw	124	6.76	C8ae	124	3.0	C8as
Washington	N	C9	46	10.000	124	44.51	C9w	124	0.75	C9e	123	57.0	C9s
Washington	N	C9a	46	2.500	124	42.40	C9aw	123	58.74	C9ae	123	55.0	C9as
Oregon	N	C10	45	55.000	124	44.29	C10w	124	0.73	C10e	123	57.0	C10s
Oregon	N	C10a	45	47.500	124	44.69	C10aw	124	1.23	C10ae	123	57.5	C10as
Oregon	N	C11	45	40.000	124	41.09	C11w	123	57.72	C11e	123	54.0	C11s
Oregon	N	C11a	45	32.500	124	38.98	C11aw	123	55.71	C11ae	123	52.0	C11as
Oregon	N	C12	45	25.000	124	42.88	C12w	123	59.70	C12e	123	56.0	C12s
Oregon	N	C12a	45	17.500	124	43.27	C12aw	124	0.19	C12ae	123	56.5	C12as
Oregon	N	C13	45	10.000	124	43.67	C13w	124	0.68	C13e	123	57.0	C13s
Oregon	N	C13a	45	2.500	124	46.57	C13aw	124	3.68	C13ae	124	0.0	C13as
Oregon	N	C14	44	55.000	124	46.47	C14w	124	3.67	C14e	124	0.0	C14s
Oregon	N	C14a	44	47.500	124	48.37	C14aw	124	5.66	C14ae	124	2.0	C14as
Oregon	N	C15	44	40.000	124	48.27	C15w	124	5.65	C15e	124	2.0	C15s
Oregon	N	C15a	44	32.500	124	49.17	C15aw	124	6.64	C15ae	124	3.0	C15as
Oregon	N	C16	44	25.000	124	50.07	C16w	124	7.64	C16e	124	4.0	C16s
Oregon	N	C17	44	10.000	124	51.88	C17w	124	9.62	C17e	124	6.0	C17s
Oregon	N	C18	43	55.000	124	53.68	C18w	124	11.61	C18e	124	8.0	C18s
Oregon	N	C19	43	40.000	124	56.49	C19w	124	14.59	C19e	124	11.0	C19s
Oregon	N	C20	43	25.000	125	3.31	C20w	124	21.58	C20e	124	18.0	C20s
Oregon	N	C21	43	10.000	125	9.12	C21w	124	27.56	C21e	124	24.0	C21s
Oregon	N	C22	42	55.000	125	14.93	C22w	124	33.55	C22e	124	30.0	C22s
Oregon	N	C23	42	40.000	125	8.76	C23w	124	27.53	C23e	124	24.0	C23s
Oregon	N	C24	42	25.000	125	8.58	C24w	124	27.52	C24e	124	24.0	C24s
Oregon	N	C25	42	10.000	125	5.40	C25w	124	24.51	C25e	124	21.0	C25s
Oregon	N	C26	41	55.000	124	54.23	C26w	124	13.49	C26e	124	10.0	C26s

Table 1g. SET A Canadian Transects

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Canada	CN	cnA1	48	35.00	125	30.73	cnA1w	124	44.93	cnA1e	124	41.0	cnA1s
Canada	CN	cnA2	48	50.00	125	56.98	cnA2w	125	10.95	cnA2e	125	7.0	cnA2s
Canada	CN	cnA3	49	5.00	126	43.23	cnA3w	125	56.97	cnA3e	125	53.0	cnA3s
Canada	CN	cnA4	49	20.00	126	52.48	cnA4w	126	5.99	cnA4e	126	2.0	cnA4s
Canada	CN	cnA5	49	35.00	127	23.74	cnA5w	126	37.01	cnA5e	126	33.0	cnA5s
Canada	CN	cnA6	49	50.00	127	29.00	cnA6w	126	42.03	cnA6e	126	38.0	cnA6s
Canada	CN	cnA7	50	5.00	128	40.27	cnA7w	127	53.05	cnA7e	127	49.0	cnA7s
Canada	CN	cnA8	50	20.00	128	48.54	cnA8w	128	1.07	cnA8e	127	57.0	cnA8s
Canada	CN	cnA9	50	35.00	129	5.81	cnA9w	128	18.09	cnA9e	128	14.0	cnA9s
Canada	CN	cnA10	50	50.00	129	3.08	cnA10w	128	15.11	cnA10e	128	11.0	cnA10s
Canada	CN	cnA11	51	5.00	128	29.37	cnA11w	127	41.13	cnA11e	127	37.0	cnA11s
Canada	CN	cnA12	51	20.00	128	39.65	cnA12w	127	51.16	cnA12e	127	47.0	cnA12s
Canada	CN	cnA13	51	35.00	128	41.94	cnA13w	127	53.18	cnA13e	127	49.0	cnA13s
Canada	CN	cnA14	51	50.00	128	45.23	cnA14w	127	56.20	cnA14e	127	52.0	cnA14s
Canada	CN	cnA15	52	5.00	128	30.53	cnA15w	127	41.23	cnA15e	127	37.0	cnA15s
Canada	CN	cnA16	52	20.00	129	13.83	cnA16w	128	24.25	cnA16e	128	20.0	cnA16s
Canada	CN	cnA17	52	35.00	129	7.13	cnA17w	128	17.27	cnA17e	128	13.0	cnA17s
Canada	CN	cnA18	52	50.00	129	22.44	cnA18w	128	32.30	cnA18e	128	28.0	cnA18s
Canada	CN	cnA19	53	5.00	129	26.76	cnA19w	128	36.32	cnA19e	128	32.0	cnA19s
Canada	CN	cnA20	53	20.00	129	47.08	cnA20w	128	56.35	cnA20e	128	52.0	cnA20s
Canada	CN	cnA21	53	35.00	130	33.40	cnA21w	129	42.37	cnA21e	129	38.0	cnA21s
Canada	CN	cnA22	53	50.00	130	53.73	cnA22w	130	2.40	cnA22e	129	58.0	cnA22s
Canada	CN	cnA23	54	5.00	131	0.07	cnA23w	130	8.43	cnA23e	130	4.0	cnA23s
Canada	CN	cnA24	54	20.00	131	24.41	cnA24w	130	32.45	cnA24e	130	28.0	cnA24s
Canada	CN	cnA25	54	35.00	131	21.75	cnA25w	130	29.48	cnA25e	130	25.0	cnA25s

Table 1h. SET B Canadian Transects

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Canada	CN	cnB1	48	30.00	125	29.65	cnB1w	124	43.92	cnB1e	124	40.0	cnB1s
Canada	CN	cnB2	48	45.00	125	56.90	cnB2w	125	10.94	cnB2e	125	7.0	cnB2s
Canada	CN	cnB3	49	0.00	126	28.15	cnB3w	125	41.96	cnB3e	125	38.0	cnB3s
Canada	CN	cnB4	49	15.00	126	50.40	cnB4w	126	3.98	cnB4e	126	0.0	cnB4s
Canada	CN	cnB5	49	30.00	127	23.66	cnB5w	126	37.00	cnB5e	126	33.0	cnB5s
Canada	CN	cnB6	49	45.00	127	26.92	cnB6w	126	40.02	cnB6e	126	36.0	cnB6s
Canada	CN	cnB7	50	0.00	128	3.18	cnB7w	127	16.04	cnB7e	127	12.0	cnB7s
Canada	CN	cnB8	50	15.00	128	40.45	cnB8w	127	53.06	cnB8e	127	49.0	cnB8s
Canada	CN	cnB9	50	30.00	129	0.72	cnB9w	128	13.08	cnB9e	128	9.0	cnB9s
Canada	CN	cnB10	50	45.00	129	15.99	cnB10w	128	28.10	cnB10e	128	24.0	cnB10s
Canada	CN	cnB11	51	0.00	128	23.27	cnB11w	127	35.13	cnB11e	127	31.0	cnB11s
Canada	CN	cnB12	51	15.00	128	36.55	cnB12w	127	48.15	cnB12e	127	44.0	cnB12s
Canada	CN	cnB13	51	30.00	128	37.84	cnB13w	127	49.17	cnB13e	127	45.0	cnB13s
Canada	CN	cnB14	51	45.00	128	45.13	cnB14w	127	56.19	cnB14e	127	52.0	cnB14s
Canada	CN	cnB15	52	0.00	128	32.43	cnB15w	127	43.22	cnB15e	127	39.0	cnB15s
Canada	CN	cnB16	52	15.00	128	46.73	cnB16w	127	57.24	cnB16e	127	53.0	cnB16s
Canada	CN	cnB17	52	30.00	129	7.03	cnB17w	128	17.27	cnB17e	128	13.0	cnB17s
Canada	CN	cnB18	52	45.00	129	1.34	cnB18w	128	11.29	cnB18e	128	7.0	cnB18s
Canada	CN	cnB19	53	0.00	129	25.65	cnB19w	128	35.31	cnB19e	128	31.0	cnB19s
Canada	CN	cnB20	53	15.00	129	42.97	cnB20w	128	52.34	cnB20e	128	48.0	cnB20s
Canada	CN	cnB21	53	30.00	130	27.29	cnB21w	129	36.37	cnB21e	129	32.0	cnB21s
Canada	CN	cnB22	53	45.00	130	46.62	cnB22w	129	55.39	cnB22e	129	51.0	cnB22s
Canada	CN	cnB23	54	0.00	131	1.96	cnB23w	130	10.42	cnB23e	130	6.0	cnB23s
Canada	CN	cnB24	54	15.00	131	10.29	cnB24w	130	18.44	cnB24e	130	14.0	cnB24s
Canada	CN	cnB25	54	30.00	131	22.64	cnB25w	130	30.47	cnB25e	130	26.0	cnB25s

Table 1i. SET C Canadian Transects

	Survey	Transect	Transect Latitude		West End			East End			Shoreline		
Location	Area	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #
Canada	CN	cnC1	48	25.00	125	29.57	cnC1w	124	43.91	cnC1e	124	40.0	cnC1s
Canada	CN	cnC2	48	40.00	125	41.82	cnC2w	124	55.93	cnC2e	124	52.0	cnC2s
Canada	CN	cnC3	48	55.00	126	19.06	cnC3w	125	32.95	cnC3e	125	29.0	cnC3s
Canada	CN	cnC4	49	10.00	126	34.31	cnC4w	125	47.97	cnC4e	125	44.0	cnC4s
Canada	CN	cnC5	49	25.00	127	24.57	cnC5w	126	37.99	cnC5e	126	34.0	cnC5s
Canada	CN	cnC6	49	40.00	127	16.83	cnC6w	126	30.01	cnC6e	126	26.0	cnC6s
Canada	CN	cnC7	49	55.00	128	2.09	cnC7w	127	15.03	cnC7e	127	11.0	cnC7s
Canada	CN	cnC8	50	10.00	128	41.36	cnC8w	127	54.05	cnC8e	127	50.0	cnC8s
Canada	CN	cnC9	50	25.00	128	46.63	cnC9w	127	59.08	cnC9e	127	55.0	cnC9s
Canada	CN	cnC10	50	40.00	129	13.90	cnC10w	128	26.10	cnC10e	128	22.0	cnC10s
Canada	CN	cnC11	50	55.00	128	9.18	cnC11w	127	21.12	cnC11e	127	17.0	cnC11s
Canada	CN	cnC12	51	10.00	128	39.46	cnC12w	127	51.14	cnC12e	127	47.0	cnC12s
Canada	CN	cnC13	51	25.00	128	30.74	cnC13w	127	42.16	cnC13e	127	38.0	cnC13s
Canada	CN	cnC14	51	40.00	128	46.03	cnC14w	127	57.19	cnC14e	127	53.0	cnC14s
Canada	CN	cnC15	51	55.00	128	42.33	cnC15w	127	53.21	cnC15e	127	49.0	cnC15s
Canada	CN	cnC16	52	10.00	128	19.63	cnC16w	127	30.23	cnC16e	127	26.0	cnC16s
Canada	CN	cnC17	52	25.00	129	7.93	cnC17w	128	18.26	cnC17e	128	14.0	cnC17s
Canada	CN	cnC18	52	40.00	129	4.24	cnC18w	128	14.28	cnC18e	128	10.0	cnC18s
Canada	CN	cnC19	52	55.00	129	24.55	cnC19w	128	34.31	cnC19e	128	30.0	cnC19s
Canada	CN	cnC20	53	10.00	129	30.87	cnC20w	128	40.33	cnC20e	128	36.0	cnC20s
Canada	CN	cnC21	53	25.00	129	48.19	cnC21w	128	57.36	cnC21e	128	53.0	cnC21s
Canada	CN	cnC22	53	40.00	130	38.51	cnC22w	129	47.38	cnC22e	129	43.0	cnC22s
Canada	CN	cnC23	53	55.00	131	0.84	cnC23w	130	9.41	cnC23e	130	5.0	cnC23s
Canada	CN	cnC24	54	10.00	131	6.18	cnC24w	130	14.44	cnC24e	130	10.0	cnC24s
Canada	CN	cnC25	54	25.00	131	23.52	cnC25w	130	31.46	cnC25e	130	27.0	cnC25s

Table 2. Distribution of point set sizes proposed for the 2011 Aerial Sardine Survey. Total Weight is in metric tons.

Size (m^2)	Weight (mt)	Total Weight (mt)	Number of point sets
100	3.8	45.6	12
500	10.6	127.2	12
1000	17	187	11
2000	26.5	291.5	11
4000	51.9	519	10
8000	70.5	705	10
10000	82.1	821	10
		2696.3	76

Table 3. Sardine maturity codes. Source: Beverly Macewicz NMFS, SWFSC.

Female maturity codes	Male maturity codes
1. Clearly immature- ovary is very small; no oocytes present	1. Clearly immature- testis is very small thin, knifed-shaped with flat edge
2. Intermediate- individual oocytes not visible but ovary is not clearly immature; includes maturing and regressed ovaries	2. Intermediate- no milt evident and is not a clear immature; includes maturing or regressed testis
3. Active- yolked oocytes visible; any size or amount as long as you can see them with the unaided eye in ovaries	3. Active- milt is present; either oozing from pore, in the duct, or when testis is cut with knife.
4. Hydrated oocytes present; yolked oocytes may be present	

Figure 1a. Maps showing locations of transects comprising Replicate SET A

SET A: Transects 1-8

SET A: Transects 9-16

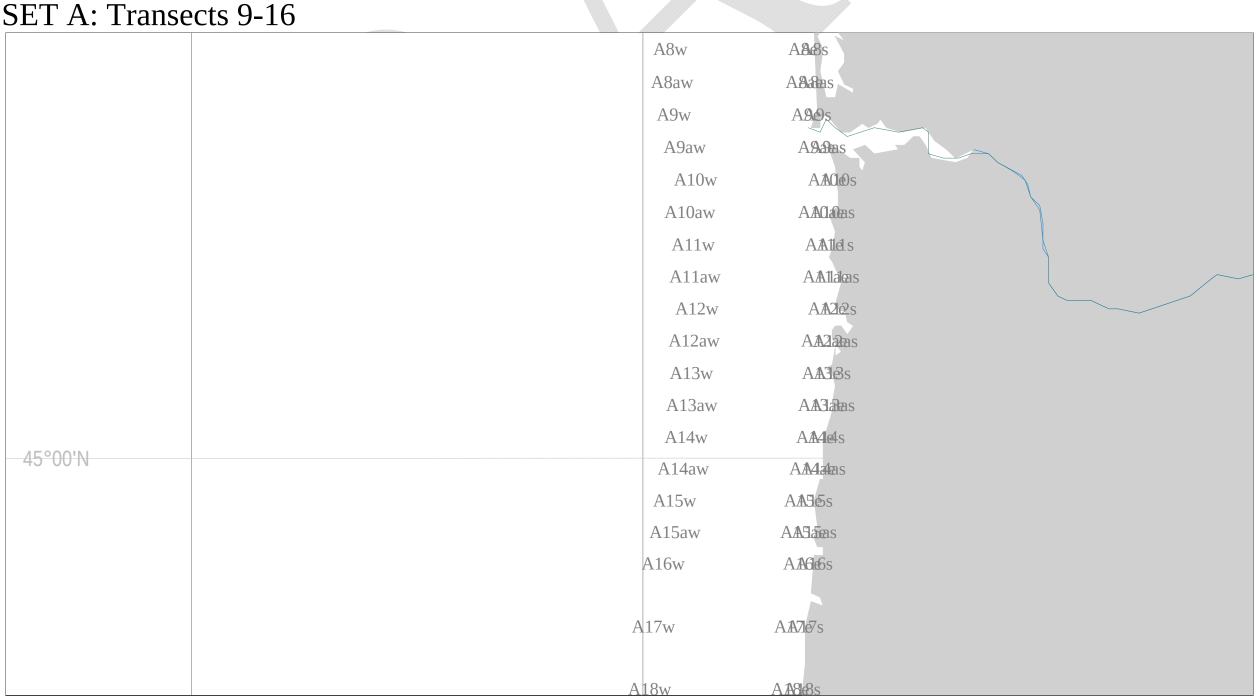


Figure 1a, Continued. Maps showing locations of transects comprising Replicate SET A

SET A: Transects 17-26

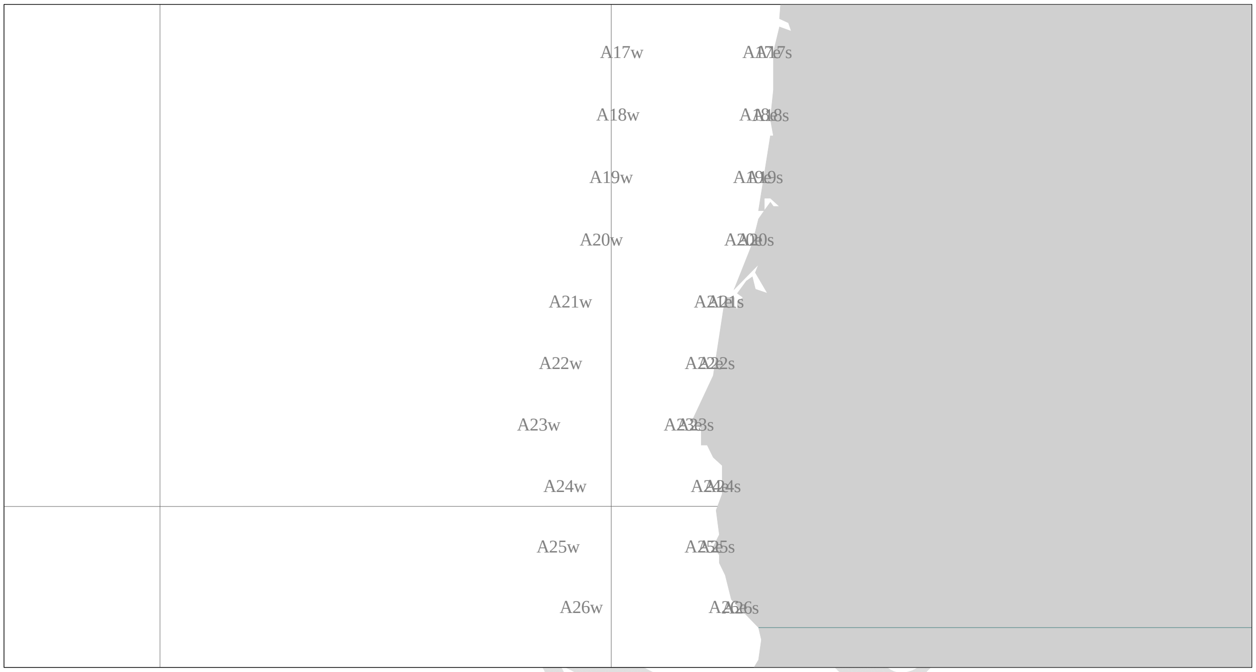


Figure 1b. Maps showing locations of transects comprising Replicate SET B

SET B: Transects 1-8

SET B: Transects 9-16

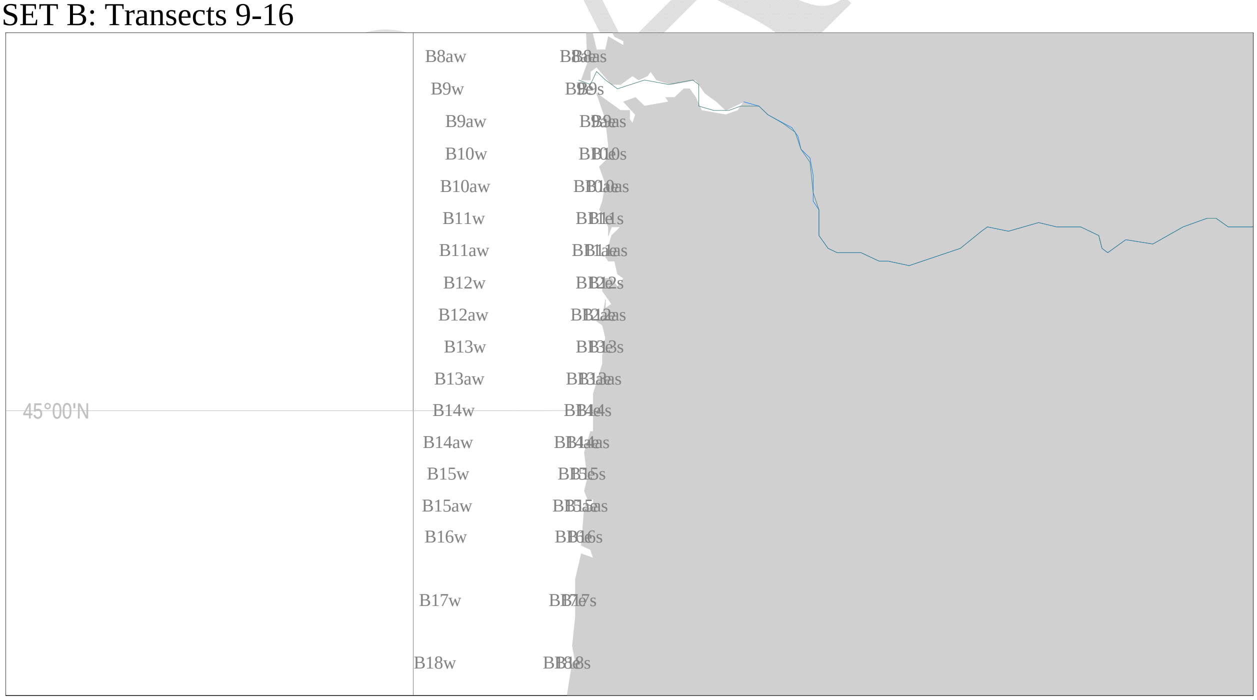


Figure 1b, Continued. Maps showing locations of transects comprising Replicate SET B

SET B: Transects 17-26

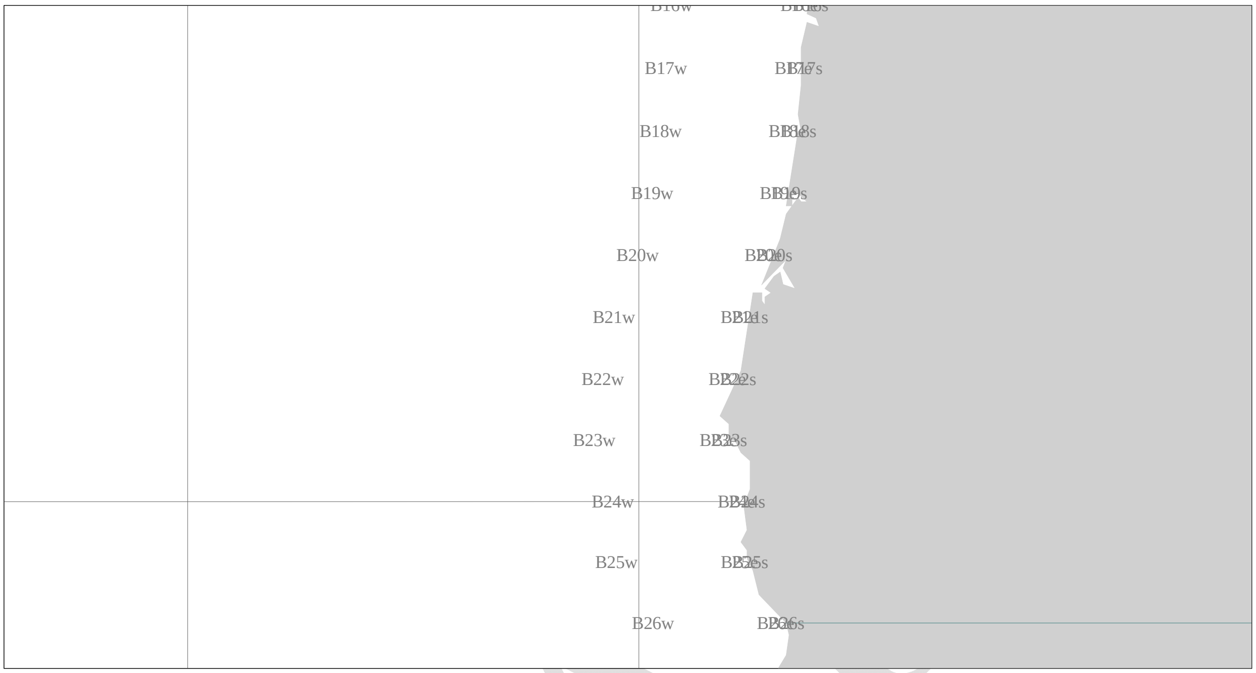
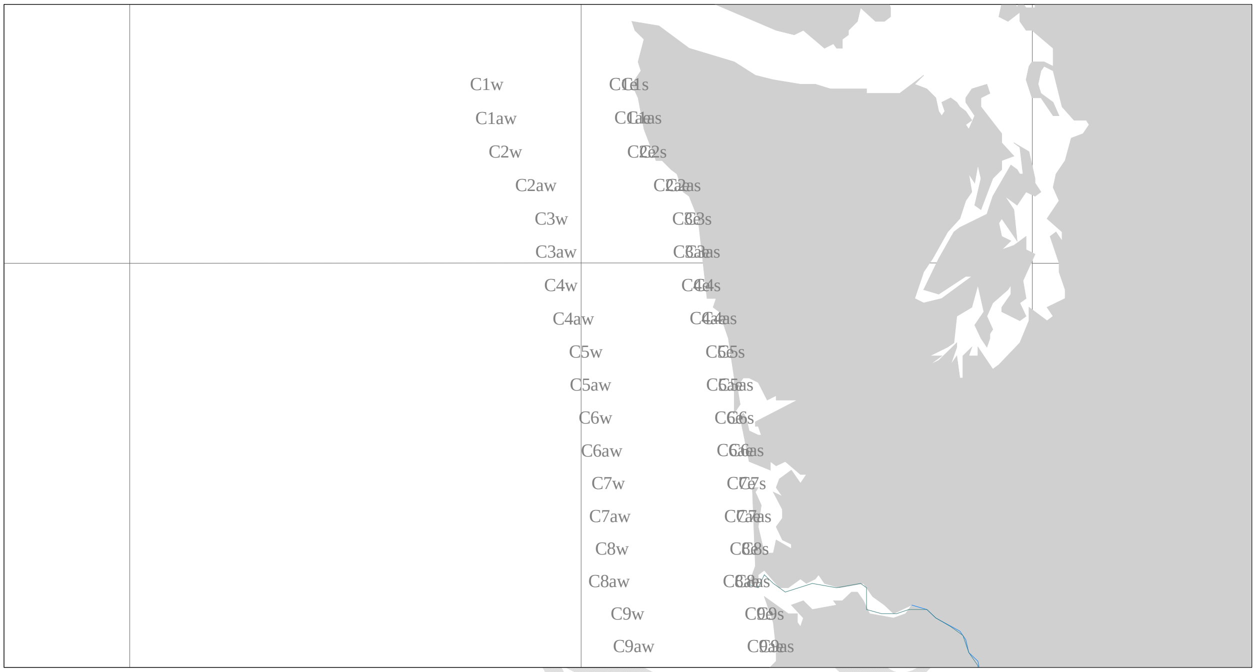


Figure 1c. Maps showing locations of transects comprising Replicate SET C

SET C: Transects 1-8



SET C: Transects 9-16

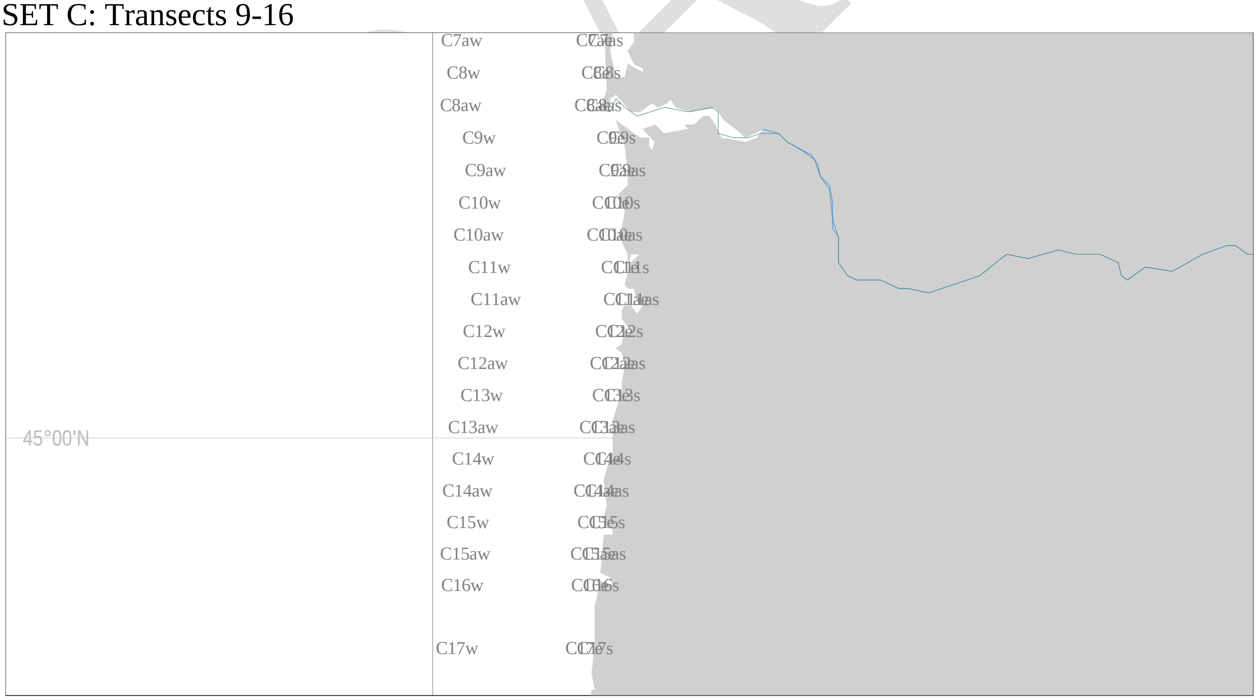


Figure 1c, Continued. Maps showing locations of transects comprising Replicate SET C

SET C: Transects 17-26

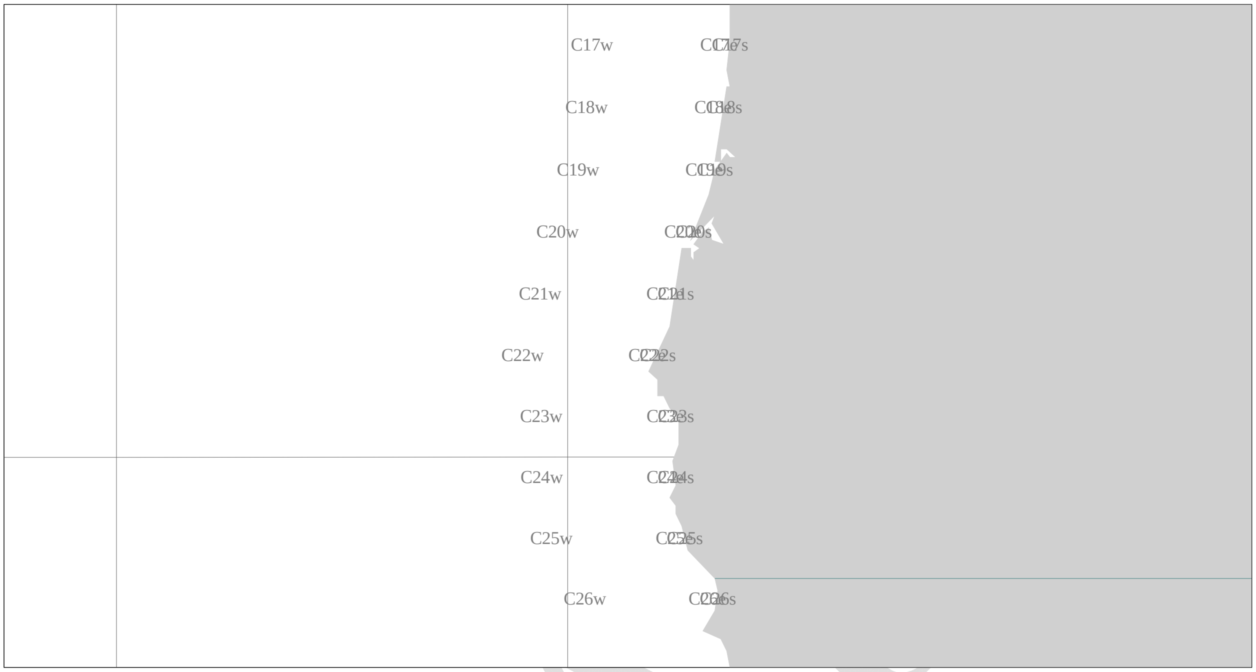
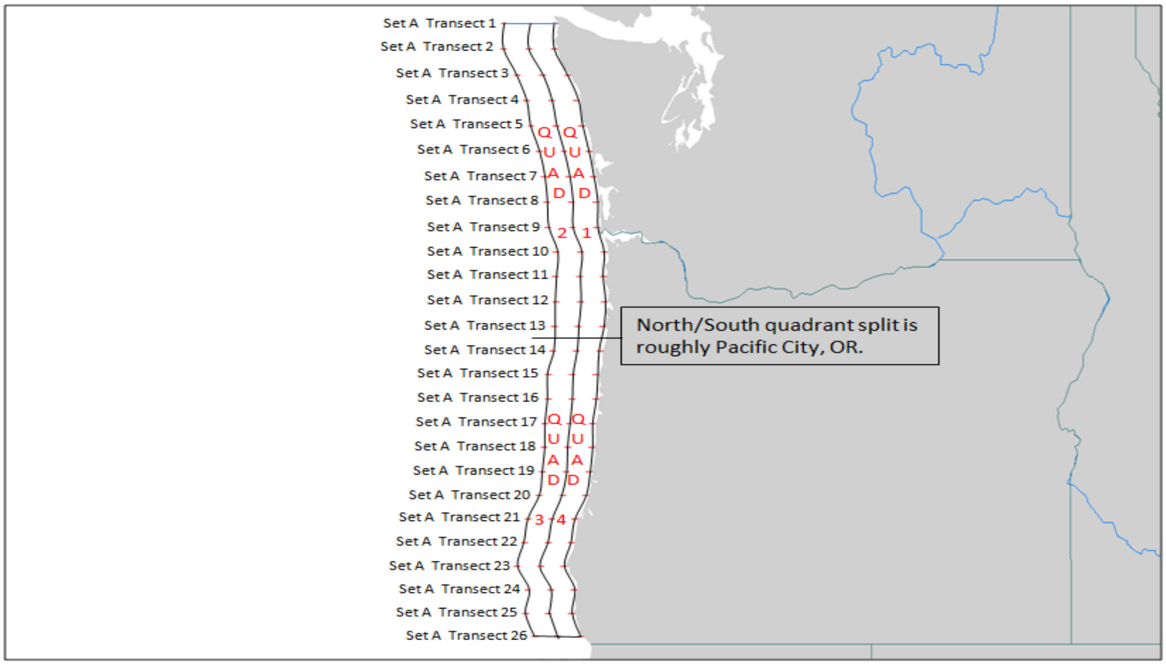
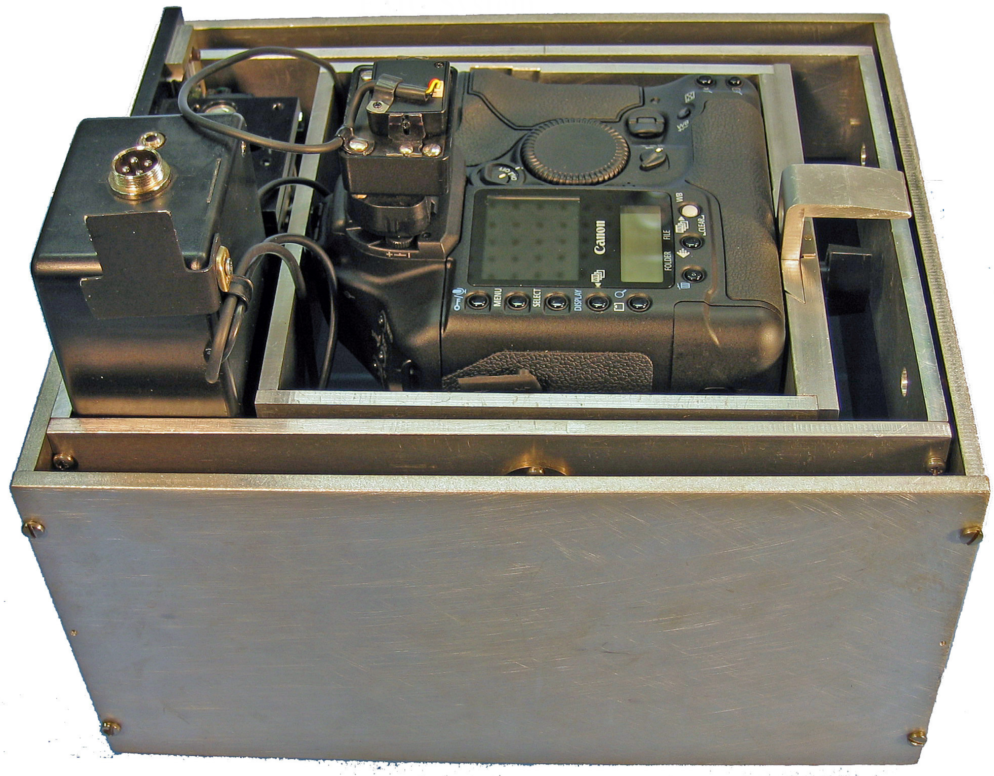


Figure 2. Maps showing quadrants for spatial distribution of point sets.



AERIAL IMAGING SOLUTIONS
FMC MOUNT SYSTEM



DESCRIPTION

An aerial mount system for digital cameras that reduces image blur caused by the forward motion of the aircraft while the shutter is open. The mount and camera are connected to, and remotely controlled by, a program running on a customer-supplied (Windows-based) computer. Flight and camera parameters entered by the computer's operator determine the required forward motion compensation (FMC) and camera firing interval. The system also takes inputs from the customer-supplied GPS and radar altimeter and will, optionally, use these data to automatically determine the required FMC and firing interval. The system includes a remote viewfinder that displays the image seen through the camera's eyepiece on a small monitor to permit the computer operator to observe camera operation to ensure successful coverage of sites. It also includes a data acquisition system that interfaces with the camera, GPS, radar altimeter, and computer to record position and altitude readings as each frame is collected.

Appendix I, Adjunct 2. Field Data Forms

West Coast Aerial Sardine Survey 2011
Pilot Pre-Flight Survey Checklist

Pre-Flight Checklist

- ☐ Check/clean the Plexiglas window on bottom of plane for condensation, dirt, etc.
- ☐ Check that the 28V Milwaukee battery is charged before departing.
- ☐ Ensure both memory cards are in the camera (CF – compact flash, SD – secured digital) and/or replace memory cards as they become full to prevent from filling up during flight.
- ☐ Check that a copy of the transect waypoint document is aboard the aircraft.
- ☐ Check GPS reading and enter waypoints if necessary.
- ☐ Check all camera system cables
    - ☐ Thick grey video cable: connect to black box on camera mount and to the computer box.
    - ☐ S-Video cable: connect to black box on camera mount and the splitter end to the camera.
    - ☐ Vaster (IOIOI) cable: connect to laptop and to computer box.
    - ☐ GPS cable: connect to GPS and to computer box.
    - ☐ Video cable: connect to camera, to USB converter, and to USB port on the laptop.
    - ☐ Portable power source: connect to shop light and to computer box.
    - ☐ Camera power source: connect to camera and to computer box.
    - ☐ Laptop power source: connect to laptop and to computer box.
- ☐ Power ON laptop, camera, inverter, 28V Milwaukee battery, and computer box.
- ☐ Open FMC Mount Control System 3.1 and FMC Mount Remote Viewfinder programs on the laptop.
- ☐ Adjust FMC Mount Control System settings as necessary.
    - ☐ Altitude: 4000ft (or TBD).
    - ☐ Speed: TBD.
    - ☐ Overlap: 60%.
    - ☐ Reset frame count to 0.
        - ☐ Admin
            - ☐ Frame Count
                - ☐ Enter 0.
    - ☐ FMC: On.
    - ☐ Ensure that GPS is functioning properly and that the location reading in the box is accurate.
- ☐ Adjust FMC Mount Remote Viewfinder settings as necessary.
    - ☐ Ensure that the number between the brackets (the number of photos remaining on the memory card) is higher than the number of photos to be taken that day.

  - Press the setting button in the center of the quick control dial on the camera and ensure that the camera view is displayed in the Viewfinder window.
- Press F9 (trip) to ensure that the camera system is functioning properly.
- Power OFF the camera system so that power does not spike when starting the airplane.
- Start up airplane.
- Power system ON and press the settings button in the center of the quick control dial on the camera and ensure that the camera view is displayed in the Viewfinder window.
- Again, verify that the camera system GPS reads approximately equal to the pilot's GPS.
- Press F9 (trip) to take a single photo to ensure that the camera system is functioning properly and that it can be seen through the Veiwfinder window. This is your last chance to make any corrections to the system before taking flight.

Mid-Flight Check

- Upon approaching the beginning of a transect/point-set, press F5 (auto) to begin automatic photo recording. Occasionally compare the camera system GPS to the pilots GPS. Also, remember to adjust the FMC altitude and speed settings when necessary.

Post-Flight Checklist

- Upon landing, the photos and FMC datalog will need to be downloaded.
- Connect USB/USB 2.0 cable from camera to laptop.
- The system will automatically recognize the photo folder to be downloaded.
- Press "ctrl A" to highlight all of the photos taken throughout the survey day of flying.
- Right-click on one of the highlighted photos and select Copy.
- Paste the photos into a new folder on the laptop labeled with the survey days date.
- Open the C: drive (if prompted, choose to open with Internet Explorer) on the laptop and locate the folder named "FMCdatalog."
- Right-click on the FMCdatalog folder, select Copy, and then Paste the folder into the survey day's photo folder.
- Attach a thumb drive to the computer via USB connection. Drag the survey day's photo folder onto the thumb drive. The photos and FMCdatalog folder will be copied onto the thumb drive.
- Attach a mass external hard drive to the computer via USB/USB cable. Drag the survey day's photo folder onto the WD external hard drive. The photos and FMCdatalog folder will be copied onto the hard drive.
- The day's photos and FMCdatalog folder should now be archived to three locations (laptop, thumb drive, and external hard drive).
- Open all photo locations to ensure that the photos and FMCdatalog folder are properly saved.
- Power OFF the camera system and charge the 28V Milwaukee battery.
- Contact the regional data coordinator to coordinate the shipment of data
- Mail data frequently to ensure quick processing time.

Mail data to: Ryan Howe Address TBD

West Coast Aerial Sardine Survey 2011

Transect Flight Log Form

Date:__________ **Set:**_________ **Pilot:**__________ **Observer:**_____________ **Plane:**_______________

Transect No.	Time	Start Photo No.	Latitude/Longitude	Altitude (ft)	Species Observed	Est. Tonnage (mt)	End Photo No.

Cloud Cover code	Glare code	Beaufort Wind Scale

Comments: ____________________

Transect No.	Time	Start Photo No.	Latitude/Longitude	Altitude (ft)	Species Observed	Est. Tonnage (mt)	End Photo No.

Cloud Cover code	Glare code	Beaufort Wind Scale

Comments: ____________________

Transect No.	Time	Start Photo No.	Latitude/Longitude	Altitude (ft)	Species Observed	Est. Tonnage (mt)	End Photo No.

Cloud Cover code	Glare code	Beaufort Wind Scale

Comments: ____________________

Transect No.	Time	Start Photo No.	Latitude/Longitude	Altitude (ft)	Species Observed	Est. Tonnage (mt)	End Photo No.

Cloud Cover code	Glare code	Beaufort Wind Scale

Comments: ____________________

Cloud Cover code: **1**- Clear, **2**- Cloud Coverage <50%, **3**- Cloud Coverage >50%, **4**- No Visibility

Glare code: **1**- No glare, **2**- glare <50%, **3**- glare >50%, **4**- Cloud shadows <50%, **5**- Cloud shadows >50%, **6**- No visibility

Beaufort Wind Scale: Refer to attached Beaufort Wind Scale (0-12) to quantify sea state

West Coast Aerial Sardine Survey 2011

Biological Sampling Form

Date Landed:__________ Vessel:_______________________ Sample No.___________ Point Set No.__________

Date Sampled:_________ Sampler:_____________________ Processor:___________ Sample Wt (kg):_______

Fish No.	Weight (g)	Std. Length (mm)	Sex (M/F)	Maturity Code	Otolith Vial No.
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					

Fish No.	Weight (g)	Std. Length (mm)	Sex (M/F)	Maturity Code	Otolith Vial No.
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					
46					
47					
48					
49					
50					

Comments:

West Coast Aerial Sardine Survey 2011

Point Set Flight Log Form

Date:________________ Pilot:________________________ Plane:_______________________

Processor:________________________ Observer:_____________________

Point Set No.	Time	Photo No.	Latitude/Longitude	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments:

Point Set No.	Time	Photo No.	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments:

Point Set No.	Time	Photo No.	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments

Point Set No.	Time	Photo No.	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments:

Point Set No.	Time	Photo No.	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments:

Point Set No.	Time	Photo No.	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)

Comments:

West Coast Aerial Sardine Survey 2011

Vessel Point Set Log

Date:____________________________ **Captain:**____________________________

Vessel:____________________________ **Processor:**____________________________

Hydroacoustic Gear

Type	Manufact.	Model	Frequency
Sounder			
Sonar			

Net Dimensions

Net Length (fath)	Net Depth (fath)	Mesh Size

School and Ocean Data

Point Set No.	Time	Latitude	Longitude	Depth to Top of School (fath)	Depth to Bottom of School (fath)	Ocean Depth (fath)	Temp.	Weather Condition

Captains Estimate and Delivery Information / **Office Use Only**

Point Set No.	Species Observed	% of school captured	Est. School Tonnage (mt)	Fish Hold (FP, FS, MP, MS, AP, AS)	Other Vessel utilized: Name, est. weight, fish hold	*Delivered Weight (mt)	*Fish Ticket Number

Comments: ____

West Coast Aerial Sardine Survey 2011

Survey Data Form Overview

The purpose of this document is to help guide us through each of the 2011 sardine survey data forms. If you are still unclear of what a field within a form is asking, please contact Mr. Ryan Howe for further clarification. Please have all survey forms completed and submitted to Mr. Howe by the end of each survey day.

Transect Flight Log Form

Aerial survey pilots will complete the Transect Flight Log Forms for each transect flown for each survey day. The information recorded on this form will help the photo analyst identify fish schools during the transect survey photo processing period, so be as detailed as possible while recording notes. *If a transect is skipped or aborted due to poor visibility or some other factor, please make a note of it on the Transect Flight Log Form and also let Mr. Howe know as early as possible.

Heading Information

- **Transect No.** – Record the transect number that is flown
- **Date** – Record the date that the transect is flown
- **Pilot** – Name of pilot flying the transect
- **Observer** – Name of observer on board if any
- **Plane** – Type of aircraft flying the transect
- **Transect Aborted** – If a survey transect is aborted or cut short of being completed, give the reason why i.e. fog, low cloud ceiling, ocean conditions and contact the regional field coordinator when time allows. Use the comments section for additional writing space.

Transect Data

- **Time** – Pilots are asked to log the time a fish school is observed along the survey transect
- **Photo #** - Pilots are asked to log the photo number that corresponds with the school identified on that transect.
- **Latitude/Longitude** – Record the latitude and longitude of the school observed while flying the survey transect.
- **Altitude (ft)** – Record the altitude of the plane as it passes over the school observed
- **Species Observed** – Record the species observed on each transect. Use comments section for additional writing space as needed.
- **Estimated School Tonnage (mt)** – Pilots are to estimate the observed tonnage of fish schools identified along the survey transect. If there are too many schools to estimate tonnage for each individual school, estimate the schools as a whole.

- **Cloud Cover/Glare/Beaufort Wind Scale** – Use the appropriate codes (given at the bottom of the form) to log these weather conditions.
- **Comments** – Please write any additional information or notes in this section

Biological Sampling Form

During the 2011 West Coast Aerial Sardine Survey, biological samples will be taken from landed point sets to collect individual fish data. This form is to be filled out by the person/s working up the biological sample. Please contact Mr. Howe with any questions or for further clarification.

Heading Information

- **Date Landed**– Record the date the point set was landed at the processing plant
- **Date Sampled** – Record the date the biological sample was worked up
- **Vessel** – Record the vessel name that delivered the point set catch
- **Sample No.** – Record the sample number consecutively as they occur during the 2010 season
- **Point Set No.** – Record the point set number that the biological sample corresponds to
- **Sampler** – Record the name of the person/s processing the biological sample
- **Processor** – Name of the fish processing plant the sample was collected at
- **Sample Wt. (kg)** – Record the total biological sample weight in kilograms

Biological Data

- **Weight (g)** – Record the individual fish weights using an electronic scale accurate to 0.5 gm
- **Standard (Std.) Length (mm)** – Record the length of each individual fish. Standard length is measured from the tip of fish snout to last vertebrae in millimeters.
- **Sex** – Record the sex of each individual fish (M = male ; F = female)
- **Maturity Code** – Record the maturity code that closely matches the maturity of the fish. Refer to Table. 3 of the Operational Plan for detailed sardine maturity codes.
- **Otolith vial #** - The otolith vial number is determined by the following information: the point set number, fish number and the year date the otolith was collected. This information allows for easy reference to the individual fish information as needed.
  Example: Point set number 23 is being offloaded. You collect your biological sample from the processing plant. You have already determined which fish will be the otolith fish. It is a good idea to pre-label the capsules before working up the sample. So our otolith capsule would read **PS23F37-11** which again refers to **P**oint **S**et **23** and **F**ish number **37** of 50 collected in 20**11**.
- **Comments** – Please write any additional information or notes in this section.

Point Set Flight Log Form

During the 2011 West Coast Aerial Sardine Survey, pilots are asked to record important point set information that will be used in the photo enhancement process. Each pilot is asked to fill out a new Point Set Flight Log Form each day point sets are attempted. The Point Set Flight Log Form allows for six point sets to be recorded on each form. Use additional Point Set Flight Log Forms as needed. Also on the form is a comments section for the pilot to include any other important details or notes.

Heading Information

- **Date** – Record the date the point sets are completed
- **Pilot** – Name of pilot the setting the vessel for point sets
- **Plane** – Type of aircraft flying for point sets
- **Observer** – Name of observer onboard airplane if any
- **Processor** – Name of the fish processing plant that the catch will be delivered to

Point Set Flight Log Data

- **Point Set Number** – Number the point sets consecutively as they occur during the 2010 season
- **Time** – Record the time when the point set is attempted
- **Photo #** - Pilots are asked to log the photo number that corresponds with the point set school that is identified and being targeted
- **Position (Latitude/Longitude)** - Record the latitude and longitude of the school being targeted for the point set
- **Altitude(ft)** – Record the altitude of the airplane for which species identification was made
- **Vessel** – Record the name of the vessel being set during each point set
- **Species Observed** – Record the species observed for each point set. Use comment section for additional writing space
- **% of School Captured** – Pilots are to estimate a percentage of point set school capture. Pilots estimated percent capture should be independent of captain's vessel estimate.
- **Estimated School Tonnage (mt)** – Pilots are to estimate the tonnage of the targeted fish school prior to setting on it.
- **Comments** – Please write any additional information or notes in this section.

Fisherman's Log Form

During the 2011 West Coast Aerial Sardine Survey, vessel captains participating in the capture of point sets are asked to record important fish school data, ocean data, catch estimates and delivery information. Additional vessels may be utilized during point set operations, so be sure to include this information in the '**Other Vessel utilized**' field under the Captains Estimate and Delivery Information heading. If additional vessels are used to land a point set, please contact Mr. Howe.

Heading Information

- **Date** – Record the date the point set is completed
- **Vessel** – Name of the vessel participating in the point set operations (also include any additional vessels that were utilized during a point set landing)
- **Captain** – Name of the person operating the vessel

- **Processor** –Name of the processing plant the point set catch will be delivered to

Fisherman's Log Data

Hydro acoustic Gear

- **Manufacturer –** Record the manufacturer name of the sounder and sonar being used during point set operations
- **Model –** Record the model number or series number of the sounder and sonar being used during point set operations
- **Frequency –** Record the frequency used for both the sounder and sonar during point-set operations

Net Dimensions

- **Net Length –** Record the length of the net (in fathoms) being used during point set operations
- **Net Depth –** Record the depth of the net (in fathoms) being used during point set operations
- **Mesh size –** Record the size of the net mesh (in inches) being used during point set operations

School and Ocean Data

- **Point Set Number –** Number the point sets consecutively as they occur during the 2010 season
- **Time –** Record the time the skiff was deployed from the vessel for point set capture
- **Latitude/Longitude –**Record the positional information related to the targeted point set school
- **Depth to Top of School (fath) –** Record the distance from the water surface to the top of the targeted point set school
- **Depth to Bottom of School (fath) –** Record the distance from the water surface to the bottom of the targeted point set school
- **Ocean Depth (fath) –** Record the ocean depth at which the point set occurred
- **Temperature –** Record the temperature of the water that the point set occurred in
- **Weather Condition –** Refer to the key at the bottom of the Fisherman's Log form for weather codes (Weather Codes: 1=calm, clear; 2=light wind, good visibility; 3=moderate wind, fair visibility; 4=poor fishing conditions)

Captains Estimate and Delivery Information

- **Species Observed** – Record the species observed for each point set
- **% of School captured** – Record the percentage of school captured. The captain's estimate will be independent of the pilot's estimated percent capture.
- **Estimated School Tonnage (mt)** – Record the estimated landed weight (mt)of the targeted point set
- **Fish Hold** – Record the fish hold that the point set is being held in for delivery. Below are abbreviations to be used for identifying which hold a specific point set is being held. Of course not all vessels will have six fish holds, use the fish hold code that best represents your vessels.

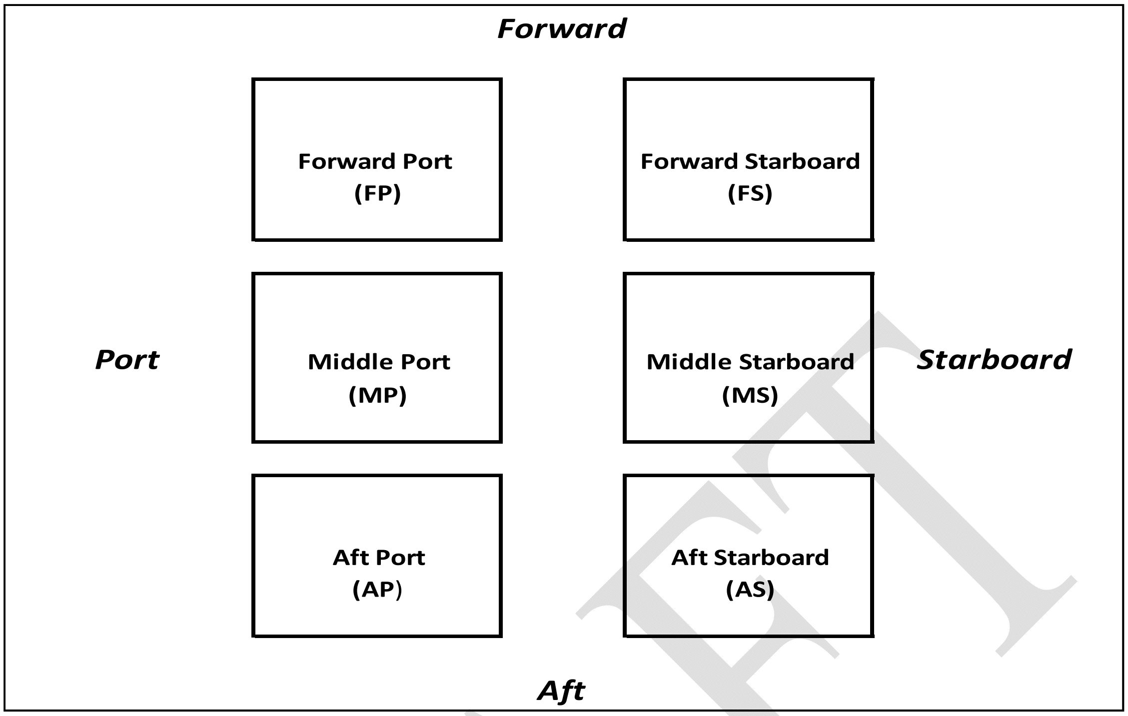


Diagram of fish hold abbreviations to be used on Fisherman's Log Form

- **Other Vessel utilized** – If an additional vessel is utilized to land a point set school, record the vessels name, estimated weight (mt) and in what holds the fish are being held. Use the comments section at the bottom of the form to report any additional information.
- ***Delivered Weight** (Office Use Only) – Leave this field blank. After the delivery is completed, the regional field coordinators will acquire this information from the processing plant manager.
- ***Fish Ticket Number** (Office Use Only) – Leave this field blank. The regional field coordinator will acquire this information from the processing plant manager.
- **Comments** – Please write any additional information or notes in this section.

Appendix I, Adjunct 3. Identification and gear configuration of participating vessels

A draft vessel list is provided below. An updated vessel list will be forthcoming when available. Due to the expected brevity of the season and the low quota, some vessels are still working on their 2011 business plans; this could mean that some boats that have historically fished sardine in the Pacific Northwest may chose not to participate in the sardine fishery in 2011.

Vessel Name	Skipper	Owner	USGS/OR Reg#	CPS/Sardine Permit #	Length	GRT	Holds	Capacity (Tons)
Pacific Pursuit	Keith Omey	Pacific Pursuit, LLC	OR873ABY	30920	73'	86	4	80
Lauren L. Kapp	Ryan Kapp	Daryll Kapp	OR072ACX	57008	72'	74	4	60
3rd vessel: TBD								
4th vessel: TBD								

Appendix I, Adjunct 3a. Identification of participating sardine processors

In Washington and Oregon, participating fish processors will be established by a bid process using the same procedure as in 2010. At this writing, the bid process has not been completed. Likely processors for 2011 may include Ocean Gold, Astoria Pacific, Astoria Holdings, and/or potentially others.

Appendix I, Adjunct 4. Aerial Survey Point Set Protocol

1) Sardine schools to be captured for point sets will first be selected by the spotter pilot and photographed at the nominal survey altitude of 4,000 ft. After selection, the pilot may descend to a lower altitude to continue photographing the school and setting the fishing vessel.
2) It is essential that any school selected for a point set is a discrete school and is of a size that can be captured in its entirety by the purse seine vessel; point set schools may not be a portion of a larger aggregation of fish.
3) To ensure standardization of methodology, the first set of point sets taken by each participating pilot will be reviewed to ascertain that they meet specified requirements. From that point forward, point set photos will be reviewed routinely to ensure that requirements are met.
4) A continuous series of photographs will be taken before and during the vessels approach to the school to document changes in school surface area before and during the process of point set capture. The photographs will be collected automatically by the camera set at 60% overlap.
5) Each school selected by the spotter pilot and photographed for a potential point set will be logged on the spotter pilots' Point Set Flight Log Form. The species identification of the selected school will be verified by the Captain of the purse seine vessel conducting the point set, and will be logged on the Fishermans' Log Form. These records will be used to determine the rate of school mis-identification by spotter pilots in the field and by analysts viewing photographs taken at the nominal survey altitude of 4,000 ft.
6) The purse seine vessel will wrap and fully capture the school selected by the spotter pilot for the point set. Any schools not "fully" captured will not be considered a valid point set for analysis.
7) If a school is judged to be "nearly completely" captured (i.e. over 90% captured), it will be noted as such and will be included for analysis. Both the spotter pilot and the purse seine vessel captain will independently make note of the "percent captured" on their survey log forms for this purpose.
8) Upon capture, sardine point sets will be held in separate holds for separate weighing and biological sampling at the dock.
9) Biological samples of individual point sets will be collected at fish processing plants upon landing. Samples will be collected from the unsorted catch while being pumped from the vessels. Fish will be systematically taken at the start, middle, and end of a delivery as it is pumped. The three samples will then be combined and a random subsample of fish will be taken. The sample size will be n = 50 fish for each point set haul.
10) Length, weight, maturity, and age structures will be sampled for each point set haul and will be documented on the Biological Sampling Form. Sardine weights will be taken using an electronic scale accurate to 0.5 gm. Sardine lengths will be taken using a millimeter length strip provided attached to a measuring board. Standard length will be determined by measuring from sardine snout to the last vertebrae. Sardine maturity will be established by referencing maturity codes (female- 4 point scale, male- 3 point scale). Otolith samples will be collected from n = 25 fish selected at random from each n = 50 fish point set sample for future age reading analysis. Alternatively, the 25 fish subsample

may be frozen (with individual fish identified as to sample number, point set, vessel and location captured, to link back to biological data) and sampled for otoliths at a later date.

11) School height will be measured for each point set. This may be obtained by using either the purse seine or other participating research vessels' hydroacoustic gear. The school height measurements to be recorded on the Fishermans' Log Form are: 1) depth in the water column of the top of the school, and 2) depth in the water column of the bottom of the school. Simrad ES-60 sounders will be installed on two purse seine vessels. Data collected by the ES-60 sounders will be backed-up daily and archived onshore.
12) Point sets will be conducted for a range of school sizes. Point sets will be targeted working in general from the smallest size category to the largest. The field director will oversee the gathering of point set landing data and will update the list of point sets needed (by size) daily for use by the spotter pilot. Each day, the spotter pilot will operate with an updated list of remaining school sizes needed for analysis. The spotter pilot will use his experience to judge the surface area of sardine schools from the air, and will direct the purse seine vessel to capture schools of the appropriate size. Following landing of the point sets at the dock, the actual school weights will be determined and the list of remaining school sizes needed will be updated accordingly for the next day of fishing. If schools are not available in the designated size range, point sets will be conducted on schools as close to the designated range as possible. Pumping large sets onto more than one vessel should be avoided, and should only be done in the accidental event that school size was grossly underestimated.
13) The Scientific Field Project Leader will also oversee the spatial distribution of point set sampling, to ensure adequate dispersal of point set data collection.
14) Photographs and FMCdatalogs of point sets will be forwarded from the field to Mr. Howe daily.
15) The total landed weight of point sets taken will not exceed the EFP allotment.
16) The following criteria will be used to exclude point sets from the density analysis (reasons used to deem a point set "unacceptable"). Mr. Howe will make the final determination of point set acceptability in the lab. A preliminary judgment will be made in the field, generally at the end of each day (or sooner), to ensure ongoing sampling is being properly accomplished.

1	Percent captured	School is judged to be less than 90% captured
2	No photograph -1	No photograph of vessel was documented (camera off)
3	No photograph -2	No photograph of vessel was documented (camera on)
4	No photograph -3	Photograph available, but late (vessel is already pursing the catch)
5	School not discrete	Sardine captured was only a portion of a larger school ("cookie cutter")
6	Mixed hauls	Multiple point sets were mixed in one hold

Appendix II

NMFS Guidelines: Coastal Pelagic Species Exempted Fishing Permit (EFP)

Aerial Sardine Survey

Application/Proposal Contents:

1. EFP application must contain sufficient information to determine that:

   a. There is adequate justification for an exemption to the regulations;

   Under this EFP, the West Coast Sardine Survey (a consortium of sardine industry participants) will perform a synoptic survey of the sardine biomass off the U.S. West Coast using aerial survey data in conjunction with fishing vessel observation data. This survey will continue the time series of data collection started in 2009 that provided information used in the PFMC Pacific sardine stock assessment. The PFMC has indicated support for the further development of this work, and has voted to set-aside a research allocation for the project.

   b. The potential impacts of the exempted activity have been adequately identified;

   Because the fishing, fishing locations, and quantities of fish requested in this EFP are addressed as part of the 2011 sardine harvest guideline as provided for in the CPS FMP, no additional unforeseen impacts are expected from this activity.

   c. The exempted activity would be expected to provide information useful to management and use of CPS fishery resources.

   <See: Introduction section of the Main Document>

2. Applicants must submit a completed application in writing that includes, but is not limited to, the following information:

   a. Date of application;

   [TBD]

   b. Applicant's names, mailing addresses, and telephone numbers;

   <See: Survey Logistics; Project Personnel: Roles and Responsibilities (Page 9 of Main Document) >

   c. A statement of the purpose and goals of the experiment for which an EFP is needed, including a general description of the arrangements for the disposition of all species harvested under the EFP;

<See Introduction (Page 2 of Main Document); Survey Logistics; Disposition of fish harvested under the EFP (Page 9 of Main Document)>

d. Identify a single project manager (the point of contact person responsible for overall coordination of the project from beginning to end), and other staff or organizations necessary to complete the project, including specific responsibilities related to technical, analytical, and management roles. Provide evidence that the work proposed is appropriate for the experience of the investigators.

To ensure clear communications among participants and other interested parties, the single point of contact person during 2011 survey field work will be Mr. Chris Cearns (NWSS).

<See also: 1) Survey Logistics; Project Personnel: Roles and Responsibilities (Page 7 and 8 of Main Document) and 2) Appendix II, Adjunct 2; Scientific Advisors: Resumes and Curriculums Vitae>

e. Valid justification explaining why issuance of an EFP is warranted;

In 2008, pilot work began in the Northwest to evaluate the quantitative aerial survey method with point sets collected during the summer period of open fishing. It was very difficult to collect the data in a deliberate, methodical manner during the frenetic pace that typically accompanies a derby-style fishery opening. The issuance of an EFP allows for a more controlled sampling process with the focus on research and data quality, and will help to ensure better and more complete study results while using industry resources. This approach worked well in 2009 and 2010.

f. A statement of whether the proposed experimental fishing has broader significance than the applicant's individual goals;

The research to be conducted under this EFP will further continue the time series of a new, scientifically rigorous survey of the Pacific sardine resource, and will again provide valuable Pacific sardine stock assessment data to the Council and to NOAA Fisheries. This information is considered a high priority research and data need by NOAA Fisheries. This survey methodology has been recommended by the Council and its sub-panels for use as an index of abundance in the PFMC Pacific sardine stock assessment.

g. An expected total duration of the EFP;

This EFP will be valid for one year, allowing for catching of Pacific sardine during the closed period between the second and third allocation periods in the 2011 season.

h. Number of vessels covered under the EFP as well as vessel names, skipper names, and vessel ID numbers and permit numbers;

<See: Appendix I, Adjunct 3; Identification and Gear Configuration of Participating EFP Vessels>

i. A description of the species (target and incidental) to be harvested under the EFP and quantitative justification for the amount(s) of such harvest necessary to conduct the experiment; this description should include harvest estimates of overfished species and protected species;

Under this EFP, participating vessels will target Pacific sardine exclusively. NWSS is proposing to the PFMC that 2,700 mt of Pacific sardine be deducted from the 2011 Harvest Guideline prior to allocation and set aside for the dedicated sardine research to be conducted under this EFP. If approved, the harvested quantity under this EFP will be limited to this Council recommended 2,700 mt set-aside.

Bycatch is generally low in CPS fisheries because most CPS vessels fish with roundhaul gear, which encircles schools of fish with nets. This gear targets specific schools, which usually contain only one species. The most common incidental catches in the CPS fishery are other CPS species; Pacific mackerel, jack mackerel, market squid, and northern anchovy, may be encountered in small numbers and will be retained if captured. Quantities of these other coastal pelagics species are expected to be nominal, and within the harvest guidelines for those species. Few other species are expected to be encountered or harvested under this EFP.

A quantitative analysis of sample size requirements was conducted in 2010 to justify the amount of sardine needed to accomplish the survey objectives (See: Sardine EFP Application for 2010 (WCSS 2010): Pages 11, and Appendix III.

j. A description of a mechanism, such as at-sea or dockside fishery monitoring, to ensure that the harvest limits for targeted and incidental species are not exceeded and are accurately accounted for, and reported;

Under this EFP, participating vessels will deliver all species harvested to participating processing/freezing facilities within the survey area. Each participating vessel and participating processing/freezing facility will be responsible for collecting and recording catch data for each species delivered. Each participant will be responsible for the issuing and reporting of fish tickets to State authorities, as required by law.

Each participant will also be required to report all catch and fish ticket data to the survey Scientific Field Project Leader on a daily basis. Daily reporting is necessary to achieve the project objectives as specified in the Survey Design section of the main document. Individual point set catches will be kept in separate vessel holds and will be individually weighed at the dock upon landing. These individual point set catch weights will be tallied by the Scientific Field Project Leader to monitor the attainment of the project sample size goals, which specify that point sets are to be collected in specific size categories (small and large) required under the survey design . This detailed accounting of daily catch will allow for a likewise detailed reporting to NMFS authorities and will ensure that the total sardine set aside amount of 2,700 mt will not be exceeded.

Any bycatch of other CPS species will be retained and a tally of the catch by species will be maintained by the Scientific Field Project Leader and reported to NMFS authorities on a daily basis to ensure that the harvest guidelines of incidental species taken are not exceeded. We do not expect more than a nominal amount of incidental species to be taken.

The PFMC website notes that, according to NMFS Biological Opinion, "… fishing activities conducted under the CPS FMP are not likely to jeopardize the continued existence of any endangered or threatened species." It is not expected that any fishing under this EFP would have any effect on any endangered or threatened species.

k. A description of the proposed data collection methods including procedures to ensure and evaluate data quality during the experiment and data analysis methodology and time line of stages through completion;

<See: 1) Survey Design and Survey Logistics sections of the Main Document, and 2) Appendix I: Field Operational Plan>

l. A description of how vessels were chosen to participate in the EFP;

<See: Page 8 of Main Document; EFP Purse Seine Vessel Selection>

m. For each vessel covered by the EFP, the approximate time(s) and place(s) fishing will take place, and the type, size, and amount of gear to be used;

The three vessels operating will have the option to operate throughout the entire range of the survey region (from Cape Flattery, WA to the Oregon/California border).

<See: Appendix I, Adjunct 3: Identification and configuration of participating vessels>

n. Identify potential benefits to fisheries management and coastal communities;

Sardine industry participants assert, based on the observations of fishing vessels and spotter pilots, that the survey to be conducted under this EFP will show a significantly greater Pacific sardine biomass than has been estimated under previous stock assessment models. If this assertion is proven to be true, the Pacific sardine HG may be expected to increase over that called for under the current stock assessment model. In any event this survey methodology has been demonstrated to be a valuable second index of abundance to expand understanding of the Pacific sardine resource.

A greater HG would provide benefits to all Pacific sardine and other CPS fisheries industry participants, including the fishermen, processers, spotter pilots, and all those employed by them, as well as to the coastal communities that support these industries. Due to the reduced HG in 2008, fishing was limited to 135 days in the first seasonal allocation period, 38 days in the second seasonal allocation period, and 7 days in the third seasonal allocation period, resulting in 185 lost fishing days. Fishing seasons were further limited in 2009, [50 fishing days in the first period, 17 days in the second period, 8 days in the third period, and total prohibition on sardine retention on December 23, virtually eliminating fishing on the CPS complex including market squid]. Fishing was further limited in 2010. These closures precipitated even greater socio-economic impacts on communities. These lost fishing days mean reduced employment for fishing vessel and processing plant crews, and reduced income for coastal communities.

o. Discuss compatibility with existing seasons and other test fisheries, potential difficulties with processors or dealers, additional enforcement requirements, and potential negative impacts of the study (e.g., species listed under the Endangered Species Act, allocation shifts, shortened allocation periods, etc.);

The research set-aside for the aerial sardine survey is supported enthusiastically by the west coast sardine industry. Processors and dealers are supportive of this EFP; they are contributing a significant in-kind contribution to the research by processing the fish at cost and contributing the profit from the fish to the research. This EFP research set aside is part of the harvest guideline, and daily reports will be supplied to NMFS detailing the vessels fishing, their landing port(s) and amount of fish caught; no additional enforcement costs should be accrued.

p. Discuss ability to conduct proposed research - Identify the total costs (including collection of samples, data analysis, etc) associated with the research and sources of funding; identify any existing commitments for participation in, or funding of the project;

<See: Appendix II, Adjunct 2; Estimated Project Budget>

q. The signature of the applicant(s);

<See cover page>

Thomas H. Jagielo

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Email: TomJagielo@msn.com

Employment

[2008-Present] Tom Jagielo, Consulting Seattle, WA

Fisheries Science Consultant *Recent Projects include:*

- Design and execution of an aerial survey to estimate West Coast sardine abundance (Washington-Oregon–California) *for the* Pacific Fishery Management Council.
- Represent Oregon Department of Fish and Wildlife on the Scientific and Statistical Committee of the Pacific Fishery Management Council.
- Review and Evaluation of Annual Catch Limits and Accountability Measures proposed by Western Pacific Fishery Management Council *for the* National Marine Fisheries Service Pacific Islands Regional Office, Honolulu, Hawaii.
- Literature review and evaluation of West Coast Spatial groundfish management *for the* Environmental Defense Fund.

[1984-2008] Washington Dept. of Fish and Wildlife Olympia, WA

Senior Research Scientist

- Developed stock assessments and rebuilding analyses used by Pacific Fishery Management Council; Designed surveys and conducted undersea manned submersible research; Investigated groundfish movement, survival, and abundance.

[1979-1984] University of Washington Fish. Res. Institute Seattle, WA

Biologist

- Various projects including: *Japanese Foreign Fisheries Observer* (On Bering Sea for 6 months); *Limnology of Lake Roosevelt*; *Toutle River salmon survival* - following Mt. St. Helens volcanic eruption.

Education

[1988-1992] University of Washington Seattle, WA

Post MS Graduate Study

- Fishery Population Dynamics, Statistical Sampling and Estimation

[1986-1988] University of Washington Seattle, WA

Master of Science

- MS in Fisheries – Limnology of Lake Roosevelt, WA.

[1974-1977] Pennsylvania State University University Park, PA

Bachelor of Science

- BS in Biology and Marine Science

Scientific Committees

- Pacific Fishery Management Council Scientific and Statistical Committee: Chairman (2002-2003); Vice Chairman (2000-2001); Member: (1992-2008); (2009-Present).
- US/Canada Groundfish Technical Subcommittee: Chairman (2003, 1987-1988); Member 1986-2008.
- PaCOOS – Pacific Coast Ocean Observation System: WDFW representative (2006-2008).

Selected Publications

Jagielo, T.H. 1988. The spatial, temporal, and bathymetric distribution of coastal lingcod trawl landings and effort in 1986. State of Wa. Dept. of Fish. Prog. Rept. No. 268. June 1988. 46 pp.

Jagielo, T.H. 1990. Movement of tagged lingcod, (*Ophiodon elongatus*), at Neah Bay, Washington. Fish. Bull. 88:815-820.

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Ryan A. Howe

Ryanhowe9@yahoo.com · (989) 941-2241 · 7215 NE Siskiyou St. Portland, OR 97232

Objective: To further my experience in the fisheries field while working with government agencies as well as public and private stakeholders.

Education: University of Alaska: Anchorage, AK
North Pacific Groundfish Observer Program
Level 1 Observer (October 2006)
Level 2 Observer (March 2008)

Michigan State University: East Lansing, MI
Bachelor's of Science Degree (August 2006): Fisheries and Wildlife

Work Experience:

Scientific Field Lead, Northern region
West Coast Aerial Sardine Survey: WA and OR *July 2008 – Present*

- Coordinate coast wide data collection of aerial sardine survey
- Interaction with state and federal agencies as well as public and private stakeholders
- Collect biological information routinely of Pacific sardine (i.e. otolith, sex/length/weight, maturity)
- Daily analysis and archiving of photographic and biological data
- Enhancement and analysis of digital photos using Adobe Photoshop CS3 and Adobe Lightroom 2
- Oversee the aerial sardine survey photo analyst staff
- Experience with Simrad ES60 hydro acoustics echo sounder
- Experience with Canon EOS 1Ds camera in an Aerial Imaging Solutions FMC mount system

Fisheries Technician
Pacific Whiting Conservation Cooperative: Seattle, WA *May 2008 - Present*

- Collect biological information daily of Pacific Whiting and other species (i.e. species I.D., length/weight, species retention and storage)
- Record raw data on deck forms and enter in Microsoft Excel daily
- Assist in Seabird CTD operations (conductivity, temperature, depth)
- Work with vessel operator and crew to accomplish project tasks

North Pacific Fisheries Observer
TechSea International Inc.: Seattle, WA *September 2006 – March 2008*

- Collect biological information for NMFS (i.e. otolith, scale, s/l/w, tissue samples, species id, species retention)
- Collect and record catch and positional information on fishing vessels within the Bering Sea and Gulf of Alaska
- Interaction with state and federal agencies as well as public and private stakeholders

Fisheries Technician
Michigan State University: East Lansing, MI *June 2006 – August 2006*

- Electro-shocked streams in Northwestern and Southwestern Ontario, Canada for a Ph.D. candidates Sea Lamprey research project.
- Maintained electro-shocking equipment and USGS vehicle provided for project
- Recorded biological, positional and catch information of sampled transects.

Fisheries Technician
Michigan State University: East Lansing, MI *Fall 2005*

- Aided in electro-shocking of streams across southern lower Michigan to capture mottled sculpin for an undergraduate research project
- Gained teamwork skills by working with other technicians to accomplish the project goals

Fisheries Technician
Michigan State University: East Lansing, MI *Fall 2005*

- Gained communication skills through interaction with hatchery biologists of the Michigan Department of Natural Resources
- Collect biological samples (i.e. kidney, liver, spleen, heart and gonads) of over 100 Chinook Salmon for future genetic analysis and to check for the presence of bacterial kidney disease (BKD).

Appendix II, Adjunct 2.

Estimated NWSS EFP Project Budget - 2011 Draft 2-17-2011

REVENUES:								Extension
Estimated Revenue/mt (FOB container yard):	$ 675.00							
Estimated EFP sardine available (mt):	2,700							
Estimated project revenue:								$ 1,822,500
EXPENSES:								
Aerial Transects	# Transects	Hrs/transect	$/hr	Total/Set	Replicates	Weather contingency	Total	
Flying the transects	41	3	$500	$61,500	4	1.25	$307,500	
Processing transect images	41	8	$25	$8,200	4		$32,800	
Point Sets	# Point sets	#Sets/day	$/Day	# Days				
Fishing Point sets on schools	56	2	$12,500	28			$350,000	
	Hours		$/Hr					
Flying the point sets	112		$300				$33,600	($723,900)
Scientific support costs:								
Science Oversight and Staff - compensation							$200,000	
Science Oversight and Staff - expenses							$35,000	
								($235,000)
Supplies and Equipment							$7,000	
								($7,000)
Accounting/bookkeeping							$5,000	
								($5,000)
10% contingency on operations							$96,590	
								($96,590)
PROJECT SUBTOTAL								**$755,010**
Estimated Processing Costs								
Estimated processing Cost/mt:	$ 300.00							**($810,000)**
NET Proceeds								**($54,990)**

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON EXEMPTED FISHING PERMIT (EFP) FOR 2011 NORTHWEST AERIAL SURVEY

The Coastal Pelagic Species Advisory Subpanel (CPSAS) reviewed the revised West Coast Aerial Sardine Survey (NWSS) application for an exempted fishing permit (EFP), and fully supports the proposal to utilize up to 2700 mt of the EFP set aside for aerial survey research. The proposal was revised after the March Council meeting, and addresses several comments made by the Coastal Pelagic Species Management Team, CPSAS, and the Scientific and Statistical Committee. Most notably, the proposal requests 2700 mt, which is 600 mt more than the March draft. The additional 600 mt became available mainly because the 2011 survey will not include the southern portion (i.e., California) this year, due to logistical and budget constraints. The requested additional tonnage will allow the NWSS to add more transects and point sets, thereby decreasing variance and increasing confidence in biomass estimates. The methods for the summer research will be similar to those carried out in 2010. While the NWSS may independently collaborate with Canadian researchers, they will prioritize the domestic portion of the survey.

The CPSAS expresses appreciation to industry for taking the initiative to develop the sardine research program. The CPSAS fully supports the NWSS aerial survey, as described in the EFP proposal, and recommends the Council convey its approval to National Marine Fisheries Service. The CPSAS also supports the request for an additional 600 mt, bringing the total EFP request to 2700 mt.

PFMC
04/08/11

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON EXEMPTED FISHING PERMITS FOR 2011 NORTHWEST AERIAL SURVEY

The Coastal Pelagic Species Management Team (CPSMT) reviewed a revised version of the West Coast Aerial Sardine Survey 2011 Application for Exempted Fishing Permit (EFP) submitted by the Northwest Sardine Survey (NWSS) (Agenda Item C.2.a, Attachment 1). In the March 2011 CPSMT statement (March 2011 Agenda Item C.1.b, Supplemental CPSMT Report), the CPSMT requested that multiple revisions be made to the EFP application. The Council supported most of the CPSMT recommendations, and asked the NWSS to revise the proposal based on those recommendations.

The NWSS incorporated the majority of the revisions requested by the Council, but did not include a general schedule of planned field activities (#1 in the March CPSMT statement). The CPSMT also notes a discrepancy in the number of point sets in Appendix 1, Table 2 (76 point sets) and the budgeted (Appendix II, Adjunct 2) number of point sets (56). The CPSMT alerted the applicants to this discrepancy via Council staff to provide the applicants the opportunity to amend their budget prior to the April Council meeting.

At the March 2011 Council meeting, the Council did not approve request #6 in the CPSMT statement. The CPSMT, however, still recommends that the Council direct the NWSS to revise the "Point Set Sampling" design to address the inadequacies in the spatial distribution of point sets in the past. Specifically, NWSS should develop what they feel to be a realistic plan to meet the suggestions made previously by the SSC and CPSMT during the April 2010 and March 2011 Council meetings (April 2010: 'Agenda Item F.1.b Supplemental SSC Report' and 'Agenda Item F.1.b, Supplemental CPSMT Report'; March 2011: 'Agenda Item C.1.b, Supplemental SSC Report' and 'Agenda Item C.1.b, Supplemental CPSMT Report'). The applicants have noted several challenges in making offshore point sets in the past. The applicants should develop a logistically feasible specific protocol for ensuring that the distribution of point set samples is more representative of the biomass observed from aerial photographs. Such a plan will help ensure that aerial survey data can be utilized in the next stock assessment. Inadequate spatial coverage prevented use of portions of the aerial survey data in the last stock assessment.

The revised version of the EFP Application contains a modification to the original (March 2011 Agenda Item C.1.a, Attachment 1) amount requested for the EFP. The NWSS initially requested 2,100 mt, and the revised tonnage request is 2,700 mt. The CPSMT supports the request for additional tonnage. However, for future requests for EFP set asides, the CPSMT recommends that a statistical analysis is provided, which includes a range of desired variance values with corresponding sample sizes, to illustrate the actual tonnage needed to reduce variance. Such an analysis will allow the CPSMT to make recommendations on tonnage amounts for a sufficient research set aside, while maximizing the portion of the harvest guideline available for the directed fishery allocation.

The CPSMT supports the revised EFP application and commends the applicants on their continuing efforts in quantifying the biomass of Pacific sardine and to improve aerial survey techniques.

PFMC 04/08/11

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON EXEMPTED FISHING PERMIT (EFP) FOR 2011 NORTHWEST AERIAL SURVEY

The Scientific and Statistical Committee (SSC) discussed the West Coast Aerial Sardine Survey Exempted Fishing Permit (EFP) application (Agenda Item C.2.a, Attachment 1) for 2011. The SSC reviewed an earlier draft of the EFP application in March 2011. SSC discussion at the current meeting focused on the EFP modifications made since March, and to what extent the March SSC recommendations have been incorporated. Mr. Tom Jagielo and Mr. Mike Okoniewski of the Northwest Sardine Survey (NWSS) briefed the SSC on the revised EFP. Ms. Brianna Brady (California Department of Fish and Game, Coastal Pelagic Species Management Team (CPSMT) Vice-Chair) and Mr. Kerry Griffin (Council Staff) summarized the ongoing CPSMT discussions on the EFP.

The EFP would continue research conducted in 2009 and 2010 (and a non-EFP pilot project in 2008). The proposed survey follows essentially the same methodology as in previous years. The survey area is reduced in extent from the 2009 and 2010 surveys, covering the region off the coasts of Washington and Oregon, but not extending into California. The key revisions to the EFP (from that proposed in March) included: (i) an increase in the allocation from 2,100 to 2,700 mt; and (ii) an increase in the number of point sets from 56 to 76. Although not formally a part of the EFP, the NWSS representatives informed the SSC of their intent to improve point set sampling north of the Columbia River by landing part of the catch in Westport, Washington.

In March 2011 and in earlier reviews, the SSC raised concerns about the lack of explicit protocols for the spatial distribution of point sets, which are needed to address the concern that the sets tended to be geographically clustered in the 2009 and 2010 surveys, and therefore might not have captured possible spatial variability in the relationship between school size and biomass. Since length composition and other biological data are also collected from the point sets, spatial variation in the biological characteristics might also have been missed. The SSC further notes that a substantial portion of the available point set data was not used in the last stock assessment because of the spatial mismatch between many point set locations and the key areas of sardine abundance (as inferred from the transects).

The SSC notes that the non-EFP pilot project was reviewed by a Stock Assessment Review panel and the SSC in 2009. Those reviews of the aerial survey were generally positive, based on the results from the pilot year, and the SSC recommended going forward with EFPs in the subsequent years. However, the 2009 review also recommended a series of analyses and re-evaluation of issues that could only be addressed once a sufficient number of years of data had been collected, e.g. "double reads" of estimates of surface area of schools from the point sets; calculation of measurement error from these double reads; tradeoffs between the number of transects vs. the number of point sets; etc. Upon completion of the 2011 field season and sardine assessment, it would be advisable to carry out this work and have it reviewed by a Council methodology review panel.

The EFP proposal has been improved but it has not been modified sufficiently to address the earlier SSC concerns about the spatial distribution of pointsets. The potential cost of not updating the design is twofold: (i) as with the 2010 stock assessment, a good deal of the point set data collected via the 2011 EFP may not be used in the 2011 assessment because of a mismatch between abundance and point set locations; or (ii) if the mismatch is severe, the aerial survey may not used at all in the 2011 assessment.

Although there have been implementation issues and cost-based limitations, there is a sufficiently strong scientific basis for the EFP proposal. The continuation of the time series and an additional year of data should contribute to the upcoming and future sardine stock assessments. Notwithstanding these concerns, the SSC endorses the EFP proposal for implementation in 2011.

PFMC
04/09/2011

COASTAL PELAGIC SPECIES SURVEY METHODOLOGY REVIEW

Full assessments for Pacific sardine and Pacific mackerel typically occur every third year, although in recent years they have occurred more frequently. Survey methods new to Pacific coastal pelagic species (CPS) assessments may be peer-reviewed prior to use in an assessment, and the 2006 Reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) provides a process by which regional fishery management councils can establish peer review procedures. The Council approved Terms of Reference (TOR) in September, 2010, to guide such processes.

In November, 2010, the Council considered three methodologies not previously used in Pacific CPS stock surveys and assessments, and recommended that these methodologies be peer-reviewed, per the methodology TOR. Two of these methods were subsequently withdrawn from consideration, leaving only the Southwest Fisheries Science Center's (SWFSC) acoustic-trawl methodology as a new candidate to be reviewed and potentially used in 2011 CPS stock assessments.

In response to the Council's recommendation, Council staff and the SWFSC convened a panel of experts (Panel), made up of two Scientific and Statistical Committee members and three from the Council of Independent Experts. The Panel was charged with investigating the technical merits of the methodology, and to make recommendations for improvement, if warranted. The TOR allows for two Advisors who were also present during the Panel meeting; one from the CPS Advisory Subpanel and one from the CPS Management Team.

The Panel considered the acoustic-trawl methodology in early February, 2011, at the SWFSC in La Jolla, California. The Panel generally gave a positive review of the methodology, and provided a report with several recommendations to be implemented prior to use of the methodology in a stock assessment (Agenda Item C.3.a Attachment 1). The primary documents describing the methodology are attached as Agenda Item C.3.a Attachments 2 and 3.

The Council is tasked with considering the Panel's report and any supplemental information; and providing guidance to CPS stock assessment teams, for using the new methodology.

Council Action:

Approve acoustic-trawl methodology for potential use in CPS assessments

Reference Materials:

1. Agenda Item C.3.a, Attachment 1: Acoustic-Trawl Survey Method for Coastal Pelagic Species; Report of Methodology Review Panel Meeting
2. Agenda Item C.3.a Attachment 2: Zwolinski et al. *Acoustic-trawl surveys of Pacific sardine Part I* (electronic only)
3. Agenda Item C.3.a Attachment 3: Demer et al. *Acoustic-trawl surveys of Pacific sardine Part II* (electronic only)
4. Agenda Item C.3.a Attachment 4: Simmonds independent report (electronic only)
5. Agenda Item C.3.a Attachment 5: Godo independent report (electronic only)
6. Agenda Item C.3.a Attachment 6: Gerlotto independent report (electronic only)

Agenda Order:

a. Agenda Item Overview Kerry Griffin
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action**: Approve New Survey Methodology for use in 2011

PFMC
03/22/11

Pacific Fishery Management Council

Acoustic-Trawl Survey Method for Coastal Pelagic Species

Report of Methodology Review Panel Meeting

National Marine Fisheries Service (NMFS)
Southwest Fisheries Science Center (SWFSC)
La Jolla, California
3-5 February 2011

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

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

Acoustic-Trawl Method Technical Team:
David Demer, NMFS, SWFSC
Kyle Byers, NMFS, SWFSC
George Cutter, NMFS, SWFSC
Josiah Renfree, NMFS, SWFSC
Juan Zwolinski, NMFS, SWFSC

OVERVIEW

A review of the acoustic-trawl method, developed by the Southwest Fisheries Science Center (SWFSC) for surveying coastal pelagic finfish species (CPS) off the west coast of the United States of America, including Pacific sardine, jack mackerel, Pacific mackerel, and northern anchovy, was conducted by a Methodology Review Panel (Panel), at the SWFSC Torrey Pines Court Laboratory, La Jolla, CA, from 3-5 February 2011. The Panel followed the Terms of Reference for Stock Assessment Methodology Reviews (November 2010).

The meeting began with a welcome by Dr Francisco Werner, Director of the SWFSC. The Chair then identified six key issues which provided a focus for discussions during the review: (a) design of the acoustic and trawl sampling, including the representativeness of the data for the four CPS species; (b) analysis of the survey data for estimating CPS abundances; (c) evaluation of potential biases in sampling design and analysis; (d) characterization of uncertainty in estimates of CPS biomass; (e) decision if acoustic-trawl estimates of CPS biomass can be used in stock assessments and management advice for Pacific sardine, jack mackerel, Pacific mackerel, and northern anchovy; and (f) guidance for future research. Dr Kevin Hill, SWFSC, then gave a brief presentation of the most recent Pacific sardine stock assessment to orient the Panel on important issues for CPS assessments and management. Dr David Demer, Leader of the Advanced Survey Technologies Program, SWFSC, gave a presentation on the acoustic-trawl method for assessing CPS, and this was followed by responses to several requests by the Panel for additional information.

This report first summarizes the Panel's requests to the acoustic-trawl survey team (henceforth "Team"); then summarizes discussions related to the six key issues and the key unresolved problems, then summarizes comments by CPSAS representative, and concludes with a list of research recommendations. Appendix 1 lists the participants and their affiliations. Appendix 2 includes short biographies for the Panel. Appendix 3 includes a list of the primary background documents which were provided to the Panel in advance of the meeting, via email and on an ftp site. These documents included descriptions of the acoustic-trawl method; example applications of the method for acoustically estimating the distributions and abundances of Pacific sardine and other CPS from data collected in spring 2006, 2008, and 2010, and summer 2008 ('present surveys'); and four supporting references. Wireless access to the FTP site functioned intermittently during the meeting.

Considerable information was provided by the Team. This information was made available in the papers and presentations provided to the Panel, and is not repeated here. The acoustic-trawl surveys also have the potential to provide estimates of fish distribution and behavior, as well as information for ecosystem-based fishery management. The review was, however, focused on the provision of abundance estimates and this report reflects that focus.

The Panel **commends** the Team for their thorough presentation, detailed background material, and willingness to respond to the Panel requests. Although the review focused on the areas of potential concern with the acoustic-trawl estimates of abundance, the Panel wishes to emphasize that the Team had already identified most of the issues identified by the Panel and had prepared information pertinent to these which helped to Panel in its deliberations. The work related to avoidance of CPS to vessels was particularly helpful, allowing the Panel to draw conclusions related to whether avoidance, or at least its effects on the acoustic-trawl survey results, is likely substantial.

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.

The Chair thanked SWFSC for hosting the meeting and the participants for the excellent and constructive atmosphere during the review, the results of which should help inform the Council and its advisory bodies determine the best available science for the management of CPS. He specifically thanked the primary rapporteur (Dr Martin Dorn) for composing a substantial report in a very short period.

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

A: Map the backscatter excluded by the final VMR filter in the spring 2008 survey.

Rationale: The first stage Multifrequency VRM filter worked well in the northern areas. However, the final stage VMR filtering algorithm was needed to deal with layers of backscatter which were prevalent in the south. The Panel wished to evaluate the impact of this final stage on the selection of CPS.

Response: Results were presented for the spring 2008 survey which included extensive layers of diffuse, low-level backscatter, passing, in the absence of final stage VMR filter, for CPS backscatter. More backscatter was filtered by the final stage VMR filter in the southern part of the survey. The Panel **agrees** that the excluded backscatter was unlikely to be from CPS as the morphology of the scattering did not appear to be representative of a characteristic CPS school. Furthermore since there was no direct sampling of the layer, it was appropriate to exclude it. The Panel deemed the filtering approach appropriate. However, it **cautions** that the filtering algorithms must be checked every survey to ensure their effectiveness under changing conditions. Furthermore, backscattering spectra with unknown origin should be identified using net sampling.

B: Graph the autocorrelations of transect-densities for the spring 2006, 2008, and 2010, and summer 2008 surveys.

Rationale: The bootstrap procedure to estimate variance is only valid if the transects are spatially uncorrelated.

Response: Graphs were presented which indicated that the spatial correlations of the transects within strata were uniformly low, indicating that the bootstrap method for variance estimation was appropriate. While spatial correlation did not appear to be significant, the power to detect statistically-significant correlation was low due to the small number of transects sampled per stratum. It was noted that CPS habitat is almost certainly spatially coherent, suggesting that correlation is very likely to be present in the CPS distribution, even if it cannot be quantified. It was also noted that the post-stratification of the transects likely served to reduce the effect of any inter-transect correlation on the estimation of variance.

C: Repeat the bootstrap variance estimation procedure for the summer 2008 survey except: (a) remove the jackknife procedure for resampling trawls; and (b) remove the bootstrap procedure for resampling the transect densities.
Rationale: One of these two elements may contribute most to the total sampling variance.
Response: Results were presented for estimates of sardine biomass for all surveys and strata. As expected, the sampling variance due to inter-transect variability dominated the overall sampling variance in nearly all cases. The Team clarified that the stratum area included the area bounded by the western ends of the transects, the coastline, and one-half transect spacing beyond the most northern and southern transects. It was noted that this area included the unsurveyed area between the eastern ends of the transects and the coastline.

D: Provide tables of catch in numbers and weight for CPS and other species in all surveys split into northern and southern areas.
Rationale: Are there other species in the surveyed volume, particularly that occupied by CPS, that are important to consider?
Response: The Panel was referred to cruise reports of the Daily Egg Production Method (DEPM) and California Current Ecosystem surveys for this information (these reports had not been made available to the Panel). CPS are usually the dominant species in the trawl catches. It was noted that this information should also be included in the reports of the acoustic-trawl surveys. It was noted that catches in general were very small, with the associated uncertainty in catching what is actually there (see also Section 2.1.7).

E: Compare the distributions of CPS backscatter versus distance below the surface for different survey vessels.
Rationale: This may allow some evaluation of vessel avoidance.
Response: A plot was presented which showed that the distribution peaked slightly shallower for measurements of mean nautical-area backscattering coefficient (m^2 nmi^{-2}) values made from *F/V Frosti* compared to the other survey vessels. However, statistical evaluation of this potential difference was not possible without information about measurement and sampling uncertainties. Regarding sampling uncertainty, it was noted that each survey vessel operated in a different geographic area and at different times of the year, so diel-vertical and seasonal migration behaviors could easily obfuscate detection of any avoidance behavior. Consequently, different methods are needed to investigate fish reactions to different survey vessels, and such studies were considered beyond the scope of the review meeting. See Section 2.2.4 for further discussion of avoidance.

F. Provide an estimate of the area between the eastern ends of the transects and the coastline, by survey and strata.
Rationale: The CPS density in this area may not be represented accurately by the mean transect densities.
Response: A table was presented which showed that the mean distance to the shoreline was 12 km north of Cape Mendocino, and the inshore area was 4.4% of the total area. CPS density tends to increase towards the inshore end of the transects for the summer 2008 survey (**Fig. 1**). A sensitivity analysis indicated that if this higher density was used for the unsurveyed nearshore area, the estimate of total abundance for this survey would increase by about 15 % (see Sections 2.2.1 and 2.3 for further details related to spatial coverage).

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

2.1 Design of the acoustic and trawl sampling

The Panel reviewed the available information to evaluate the acoustic-trawl method and the results of present surveys for estimating the distributions and abundances of Pacific sardine, jack mackerel, Pacific mackerel, and northern anchovy. Ideally, the surveys should cover the geographic extents of all four species, and the acoustic and trawl samples should be representative of the stocks within the survey area. The Panel recognized the added complexity in meeting the ideal design requirements for surveys of an ecosystem with large natural fluctuations, and that, pragmatically, setting priorities by species inherently influences survey design and ultimately, will likely result in less (and less precise) information for one or more of the target species within the overall assemblage.

2.1.1 Are the acoustic-trawl surveys representative of the distribution of CPS species?

Appendix 4 provides a summary of the distributions of CPS in the California Current, compiled by a group of meeting participants at the request of the Chair.

2.1.1.1 Pacific sardine

One sampling strategy of the acoustic-trawl method is to survey along transects until the density of CPS is essentially zero. The Panel **supports** this approach. However, it **agrees** that the evidence available suggests that some Pacific sardine may have been outside of the area surveyed (e.g., the high densities at the western ends of the transects in spring 2006). The proportion of the population outside of the survey area (north of the northernmost transect, south of the southernmost transect, further offshore than the western ends of the transects and inshore of the eastern ends of the transects) will likely differ between spring and summer, and among years. In order to address these spatial distribution issues and noting the concerns expressed by the CPSAS representative the Panel **recommends** that analyses be conducted using auxiliary information (e.g., trends in biomass density estimated along transects; information from ichthyoplankton surveys south of the survey area; and fishery-catch information) to provide best estimates for the biomass outside of the survey area at the time of the survey, as well as ranges of possible total biomass. The estimates of the biomass outside of the survey area should be included in the estimates of biomass on which the assessment of Pacific sardine is based and form the basis for sensitivity tests.

2.1.1.2 Jack mackerel

Less is known about the distribution in CCE of jack mackerel than of Pacific sardine. However, the Panel **agrees** that the available evidence suggests that jack mackerel are also found outside of survey area, though perhaps to a lesser extent during the summer than the spring surveys.

2.1.1.3 Pacific mackerel

The primary concern regarding the distribution of Pacific mackerel in relation to the acoustic-trawl surveys is that a large, but unknown, fraction of the population is likely south of the survey area in any year, particularly during spring.

2.1.1.4 Northern anchovy

The distribution of northern anchovy appears to be more nearshore than that of Pacific sardine, and the biomasses of the sub-populations within the survey area appear to be very low.

2.1.2 Transect design and stratification

The current approach utilizes the design for the egg surveys on which the DEPM indices are based for both spatial coverage and trawl data. Thus, the design has not been chosen explicitly to conduct an acoustic-trawl survey. Nevertheless, the transect design in the present surveys is close to regular, but with higher effort, closer transects, in areas of expected high abundance. The Panel **agrees** that while not necessarily optimized, the current approach is adequate. A design with parallel-transects normal to the coastline, and uniform transect spacing within any identified strata, will allow reliable abundance estimates and is preferred over any randomization of transect spacing. Formally, if the survey is to provide an 'absolute estimate', a random starting point is required to allow a possibility that samples can be obtained from all locations, i.e., meet probability sampling criteria for unbiased abundance estimation. If for logistical reasons a random start is not possible, the fish locations must be assumed to be unrelated to geographical features on the scale of one transect spacing. For an index, a fixed starting point is sufficient. The Panel was not concerned with a fixed starting point for the acoustic surveys, except for the small localised populations of northern anchovy.

The potential for using stratification of effort to obtain improved estimates of Pacific sardine abundance is clearly demonstrated (Zwolinski *et al*., in press). Such an approach would improve the precision of the estimates of abundance for Pacific sardine, although this may lead to poorer estimates for the other species. Stratification would need to be based on estimations of habitat that would be specific to season and year. Habitat information can be derived from satellite-sensed oceanographic conditions (Zwolinski *et al*., in press) prior to the survey, and can potentially be refined during the survey using direct oceanographic samples.

The Panel **recommends** that prior to modifying (e.g., optimizing) the present survey design, it will be necessary for the survey objectives to be clearly identified and agreed (e.g., primarily for Pacific sardine or adequate for all CPS species). The design would clearly need to be changed if useable estimates of abundance for northern anchovy or Pacific herring, or both, are needed, given the current population sizes and distributions of these species. The Panel **emphasizes** that the abundances of CPS species fluctuate over time and that the optimal survey design may change over time, for example if anchovy were to increase substantially in abundance. If the survey is for multiple species, or has an ecosystem emphasis, further work may be required to estimate the utility of stratified versus uniformly-distributed sampling effort.

2.1.3 Trawl sampling

The current survey design utilizes trawl samples obtained during the egg surveys to provide species proportions and length distributions. Trawls generally occur at night on dispersed fish at predetermined, well-spaced stations, with the addition of a few *ad hoc*, target trawls. The data are used to apportion the CPS backscatter to species and estimate target strength (TS; dB re 1 m^2) values for estimating abundances.

A potential concern with the trawl sampling is that there may be species selectivity; selectivity for size is less likely, except for 0-group animals. There appears to be considerable spatial separation among CPS species, especially during the summer survey, indicating that species proportions are relatively well established. Although nighttime catches are not coincident with daytime acoustic observations, the Panel considered this to be a minor issue for Pacific sardine and jack mackerel because the areas occupied by these species are generally homogeneous. Increased effort will be required in areas dominated by the less abundant species, if useable estimates of abundance are needed for the full range of all species.

If estimates of species selectivity were required, the Panel notes that the effects of 'gross' species selectivity may be detectable by comparing the ratios of mean catch rates and acoustically-estimated densities where single species dominate. If the ratios were similar this would indicate that catch rates were similar (assuming TS is correct). In contrast, if there were significant differences, this would indicate the potential for species selectivity, but not identify its cause. In the long-term, efforts should be made to evaluate if different fishing practices or gears, or both, would facilitate daytime fishing on target fish schools for improved species identification and TS estimation.

2.1.4 Allocation of effort between trawl and transect data collection

The balance of time spent sampling acoustically along transects and with trawls at stations is currently based on the needs of the DEPM surveys. This balance appears to be adequate at present, although a different balance may be optimal. The current variance estimation procedure could be utilized to investigate an optimal sampling strategy in terms of variance in the estimated biomass. However, some studies (e.g., Simmonds and MacLennan, 2005; Simmonds *et al.*, 2009) suggest that a broad range of time allocations lead to similar overall variance estimates, which indicates that optimization of the time allocation may not be a critical issue.

2.1.5 Multi ship issues

The use of multiple vessels in standard assessment surveys may add complexity to the interaction between the observer and the observed. The present surveys were conducted using four vessels ranging from 41 to 65 m in length, with displacements ranging at least two fold. Such differences require consideration of the following issues:

- Vessel noise may potentially affect fish behavior during surveys. Fish may avoid the sound source, either by diving or moving to the side, or both. Such behavior may lead to reduced fish density under the transducer during the moment of recording. Furthermore, TS might change as a result of changing fish tilt angle during the avoidance response, thus impacting, in most cases reducing, estimates of density. Some studies (e.g. Dagorn *et al.*, 2001; Røstad *et al.*, 2006) suggest that vessels may attract fish, thus increasing densities measured by acoustics. The International Council for the Exploration of the

Seas (ICES) has therefore recommended using noise-reduced vessels to reduce these potential impacts.

- Other parts of the sound spectrum, particularly infrasound, also appear to be responsible for changes in fish behavior in response to survey vessels (Ona *et al*., 2007; Sand *et al*., 2008). This implies that noise as measured by the ICES standard (Mitson, 1995) does not necessarily reflect the strength of the vessel's avoidance stimulus. Rather, the stimulus may be more associated with the size of the vessel and its displacement than the noise emission.
- Visual stimuli may attract fish similarly to a Fish Aggregating Device and will affect observations in shallow water and at short distances from the vessel.

Further complexity in potential fish behavior is caused by interactions among the above sources. This is reflected in the literature as large variability in the observed responses of fish to survey vessels. In the present case, the vessels vary substantially in size and horse power and have different propulsion and noise-reducing arrangements. The potential exists for vessel-specific impacts on the survey results if the target species are sensitive to any of the stimuli described above (Hjellvik *et al*., 2008). As an example, the FV *Frosti*, which is considered a noisy vessel by the Team, recorded fish closer to the surface than the other vessels. If vessel noise represents the stimulus, it could signify a vessel avoidance effect. On the other hand, *FV Frosti* is the smallest ship (least displacement) and the vessel difference could be due to infrasound impacts from the larger vessels (Ona *et al*., 2007; Sand *et al*., 2008).

The issue of avoidance is discussed further in Section 2.2.4.

2.1.6 Timing of acoustic and trawl sampling

Pelagic species have diel and seasonal behavioral characteristics which can have large impacts on survey results. These characteristics may influence the results due to variations in the availability of the fish to acoustic sampling as a result of their vertical and horizontal movements. The acoustic sampling occurs during the day when the CPS are typically aggregated deeper, and trawling occurs at night when the CPS are typically dispersed near the surface. The current trawl and vessel configurations have been generally unsuccessful catching schooling fish during the day. The Panel **agrees** that conducting acoustic sampling during the day and trawling at night is a reasonable approach because the available effort is used efficiently. Nevertheless, validation of CPS backscatter to species and size should be improved through target-trawl sampling.

The Panel also notes that the trawl catches are small compared to those in other acoustic-trawl surveys, which emphasizes the question whether trawl catches are representative of the populations. It **recommends** further investigation of how trawls are allocated to acoustic signals, for example by conducting sensitivity tests in which stations are pooled and allocated to acoustic values over a larger area.

In the longer-term, a goal is to have a trawl and vessel configuration that can support target-trawl sampling. This would increase the number of samples, and enhance the representativeness of the trawl samples to species and their sizes in the populations sampled acoustically. Also, repeated trawl sampling experiments could lead to a better understanding of small-scale variability and could help improve the sampling design.

2.1.7 Trawl design and operation

Appendix 5 outlines the design of the Nordic trawl used during the trawls. Trawl efficiency depends on the interaction between trawl design and use and fish behavior. This may cause size- and species-selectivity due to: (a) fish avoiding the trawl before entering the net; (b) fish escaping through the meshes near the mouth of the net; and (c) fish escaping through the meshes in front of the codend. The latter problem is particularly probable if there is a large change in mesh size from the trawl to the codend and the net is towed at a high speed. If pelagic species exhibit schooling rather than individual behavior, these problems may be minor. However, the low trawl catches may indicate individual behaviors of the fish during the trawls, which could influence species and size selection. Concerning species-selection, there are normally species-related behavioral characteristics that influence trawl selectivity and may affect estimates of species proportions in areas where the species are mixed. This may be the case here, but selectivity is not limited to this particular trawl design. For the survey and sampling design used here, the trawl appears to be adequate, but the small catches call for further studies, likely leading to improvements to the trawl sampling.

The Panel **recommends** that experts in trawl design should be consulted to evaluate the gear and fishing protocols in relation to the survey objectives. The available drawings (Appendix 5) indicate that the small-mesh codend is very short and the change in mesh size from the codend to the trawl is large. This could cause the so-called “bucket effect”. This is partly documented and partly anecdotal information about a large loss of fish in front of the codend due to a combination of trawl design and trawling speed. In such cases, fish might swim in the transition zone between the codend and the trawl, and escape through the trawl meshes, and cause size- and species-selection (see e.g. http://www.worldfishing.net/features101/product-library/fish-catching/trawling/increasing-efficiency-in-pelagicsemi-pelagic-trawling; Fernoe and Olsen, 1994; Wardle *et al*., 1986). Simple adjustments, e.g., increasing total length and mesh size of the codend and the extension piece, could mitigate this potential problem

Over long-term, the efficiency and selectivity of the trawl could be tested by comparing samples from same area taken with the survey trawl and a purse seine. Further, state-of-the-art acoustic and optic technology allows direct observation of trawl efficiency by observing fish behavior and escapement at various critical positions of the trawl. The panel **recommends** that such approaches be pursued and that, in the long-term, trawl and vessel configurations be used that enable direct sampling of pelagic schools.

2.1.8 Acoustic equipment specifications

The acoustic data collected depends on the type of equipment installed and the settings decided at the start of the survey. For vertical echosounders, several issues should be considered in relation to these settings:

- Choice of frequencies. Each group of species is better observed by a given set of frequencies (e.g., plankton, small and big fish, fish with and without swimbladders, and squids). Multiple frequencies allow for group differentiation.
- ‘VRM extraction process and overall threshold’. This may lead to exclusion of some of the total biomass (mostly plankton, but also small non-schooling fish), and must consequently be set given the survey objectives. This is especially important for visual analysis of the echograms.

- Ping rate. The ping rate will affect the description of small spatial structures (e.g., schools). A too low ping rate results in a loss of information about these structures, while a too high rate will lead to redundant data. The use of multiple acoustic devices may impose a certain ping rate, but this may affect the precision of the results or their use for some particular research topics, principally studies on school structure and behavior
- Transducer location. The choice between a fixed and a towed transducer depends on the location of the target species (e.g., shallow versus deep).
- Complementary sensors. Use of additional acoustic devices (e.g., multibeam and short-range and long-range scanning sonar may be used for behavior and avoidance observations; an ADCP may be used for measuring vertical stratification of the seawater and for describing habitat features) can add information, but this may affect fish behavior (e.g., the sonar signal may affect schools) or the transmission rates of other devices.

In relation to these considerations, the acoustic-trawl surveys have been conducted with four to five frequencies (typically 18, 38, 70, 120, and 200 kHz). The use of a vertical echo sounder is appropriate for assessing fish distribution and estimating abundance. Multiple-frequency data are likely to permit automatic group recognition (e.g., plankton versus fish versus invertebrates) and potentially species identification. Multiple-frequency methods were applied for apportioning the acoustic backscatter to CPS (e.g., Demer *et al*., 2009) as detailed in Demer *et al.* (background document).

The transducer is mounted on a blister or keel extending from the vessel hull, precluding observation of animals present nominally 10 m below the surface. The vertical echosounder is unable to provide information about organisms residing near the surface, particularly at night. However, this is not a concern for abundance estimation because the acoustic observations contributing to the biomass estimates are made during the day. The pulse-repetition interval is, in general, 0.5 seconds, or one ping each 2.5 m at 10 knots. This may be low for observing small, near-surface schools close to the vessel, but is adequate for estimating biomass.

The Panel **agrees** that the acoustic specification is appropriate for abundance estimation, noting that a layer near the surface is not sampled (see also Section 2.2.3 on avoidance). However, the acoustic sampling may not be adequate for research on school characteristics and a description of the global pelagic ecosystem.

The Panel **recommends** that the team continues to: (a) consider other existing methods (e.g. Lawson *et al*., 2001; Haralabous and Georgakarakos, 1996; Kloser *et al.* 2002; Lebourges-Dhaussy and Fernandes, 2010) for species identification; (b) evaluate the potential use of non-vertical echosounders; (c) develop methods that categorize the acoustic record and thus support automatic species identification, and (d) work on definition and precision of the VMR process.

2.2 Analysis of the survey data for estimating CPS abundances

2.2.1 Filtering Algorithm

The method most commonly used elsewhere to identify acoustic backscatter from a target species is to conduct trawls on various types of backscatter. Once the sources of the various types of backscatter have been identified, the backscatter is classified using a rather laborious process, relying heavily on expert judgement. A different approach is used for the acoustic-trawl surveys of CPS. A series of filters, including those based on the variance to mean ratios (VMR;

Demer *et al*., 2009) and differences in volume backscattering strength measured at multiple frequencies, are used to apportion the backscatter to CPS and other organisms. Although the initial development of the filtering algorithm was based on nighttime tows and expert judgement (without the benefit of daytime target tows), application of algorithm is a completely numerical process. The Panel **accepts** the filtering approach as being appropriate, but **recommends** that it is checked every year to ensure that it remains effective under changing conditions. Furthermore, tows on various kinds of backscatter should be added to routine survey operations to assure that the filtering algorithm accurately identifies backscatter from CPS, as intended.

2.2.1 Target strength

No TS measurements are available for *in situ* CPS from the CCE. Used instead are published TS versus length relationships for the same or similar species in other ecosystems. While this substitution is not ideal, the Panel **agrees** that such TS estimates likely do not have a large impact on abundance estimates (probably less than 5 %). The largest error may result from the use of Chilean jack mackerel TS for Pacific mackerel. TS measurements of *in situ* CPS are difficult to obtain, but the effort should be made to do so in future CPS acoustic-trawl surveys. Alternative approaches such as school capture with purse seine, inference from models, and multi-frequency observations of *ex-situ* fish could be explored if it is considered that TS measurements of *in situ* CPS are not feasible.

2.2.2 Abundance estimation

The surveys are post-stratified into strata which exclude, in most cases, a region of contiguous survey transects where no CPS were detected. The approach for estimating abundance is then to sum over strata the area of each stratum multiplied by the mean transect density. This is a standard approach, and the Panel **agrees** that it is appropriate. The Panel notes that some of the strata do not have uniform transect coverage, which could be a problem, but **agrees** that this is relatively inconsequential for abundance estimation. (If this becomes an issue, transect estimates can be weighted by their inter-transect spacing.) CPS backscatter is assigned to species based on the species composition of the nearest trawl, which is a reasonable approach, but this relies on the untested assumption that species composition in the trawl is representative of the fish sampled acoustically. While this assumption can be questioned, it is fairly standard when analysing data from acoustic-trawl surveys. The Panel would have liked to have seen a more rigorous comparison of the CPS catch in the trawls with the backscatter attributed to CPS along the transects, but did not have a good idea about how to do this. In addition, the Panel discussed alternative approaches for ascribing the acoustic backscatter into the different species using the trawl data. These issues need to be explored further (see also Section 2.1.7).

2.2.3 Avoidance

Fish response to vessel passage has been documented for small pelagic species in other areas (e.g. Freon and Misund, 1999). There is a potential for bias in abundance estimates from acoustic surveys if vessel passage causes fish to change their orientation in the water column, or exhibit some kind of consistent movement, either avoidance or attraction. Echosounders used in the CPS acoustic-trawl survey are mounted approximately 3.75 to 7.5 m deep. Sardine, in particular, are often found near the surface at least at some times of the year, and fishermen have noted strong avoidance responses to vessel passage. This is a critical issue to address when deciding how or whether to use the abundance estimates based on acoustic-trawl data for stock assessment. The Panel consequently spent considerable time discussing the issue of avoidance.

The influence of fish avoidance has been investigated using two approaches: (a) the distribution under and to the side of the vessel was examined using multibeam sonar, and (b) volume backscattering (S_v; dB re 1 m^{-1}) of fish schools observed in successive pings was examined to test the hypothesis that a vessel impact would lead to a reduction in S_v and an increasing average depth during passage. Studies with similar equipment on European pilchard in the Mediterranean Sea show increased schools off track (Soria *et al*., 1996), while Chilean sardine in contrast showed no increase in schools off track (Gerlotto *et al*., 2004). Results from the first study indicated that CPS school counts peaked sharply under the vessel, and declined steadily with distance away from the vessel track and depth, suggesting no increase in schools off track, as might be expected if there is lateral movement in response to the vessel. Results from the second study indicated that in most cases for CPS in the CCE there was little evidence for differences in depth or backscatter from the front to the end of schools, suggesting that any diving behavior takes place before the school passes through the acoustic beam, although a minor diving apparently was noted when schools were shallow. The Panel did not consider this very strong evidence for lack of avoidance, since other interpretations are possible, but definitely useful information which should be considered when drawing conclusions during the review

The Panel **concludes** that, based on the information presented during the meeting, vessel-induced behavior, including vessel-specific behavior, although clearly demonstrated vertically, appears unlikely to have a substantial effect on the estimates of CPS biomass during the present surveys. However, the Panel notes that the results related to the potential for lateral avoidance are somewhat difficult to interpret without reference to expected patterns under alternative hypotheses of fish response. Nevertheless, they do not appear to be suggestive of large avoidance effects.

Although the Panel concluded that vessel avoidance has been studied using appropriate methods and there was no evidence for substantial avoidance effects, the issue warrants further study. For example, variation in vessel size (41m – 65m) and survey speed (11-14 knots) calls for further follow up studies. 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.

2.2.4 Characterization of uncertainty

Uncertainty is characterized using a Monte Carlo approach. Specifically, a bootstrap resampling approach is used to characterize between-transect variance and a jacknife-like approach (removing one trawl for each Monte Carlo replicate) is used to quantify uncertainty due to trawl location. The Panel **agrees** that the bootstrap approach for estimating transect density variation is appropriate given the lack of autocorrelation. However, the jackknife, which attempts to characterize a potentially important source of uncertainty in a pragmatic manner, would lead to negatively-based estimates of uncertainty, although the magnitude cannot be evaluated. The Panel discussed alternative approaches to characterizing trawl uncertainty, but all were considerably more complex than the approach used. The Panel thought that a simple solution would be preferable, and **recommends** further work on this issue before estimates of abundance based on the acoustic-trawl surveys are used in assessments.

The Panel considered other potential sources of uncertainty in the abundance estimates, such as TS and the parameters of the filtering algorithm. The Panel **concludes** that uncertainty in TS is unlikely to be large compared to those due to trawl location and particularly between-transect variation in density to be worth quantifying at present. Uncertainty in the filtering algorithm is difficult to evaluate, but is certainly present. However this kind of uncertainty is seldom quantified in acoustic surveys, so the CPS surveys follow conventional procedures in this regard.

2.3 Use of acoustic-trawl survey data in stock assessments

The Panel evaluated how the acoustic-trawl data could be used in PFMC assessment and management for each of the four finfish CPS species, noting that the information available differs markedly among these species and that the basis for the management advice differs between monitored and actively managed species. The focus for Panel discussions was Pacific sardine which is currently the CPS species with the largest biomass. Not unexpectedly, there was less information for the other species and the Panel is unable to make as definitive conclusions for jack mackerel, Pacific mackerel, and northern anchovy as for Pacific sardine.

2.3.1 *Pacific Sardine*

Pacific sardine are an actively-managed CPS species with an SS3-based stock assessment. Estimates of abundance based on acoustic-trawl data can be included in this stock assessment as absolute estimates of abundance or as relative indices of abundance. Given the relatively short time-series of abundance estimates, including the acoustic-trawl data as relative indices of 1+ biomass would likely not impact the assessment results substantially (but this should be examined in the assessment). The major potential sources of uncertainty related to using the acoustic-trawl data as estimates of absolute abundance identified during the review were:

- The relationship between TS and length are not based on measurements of *it situ* CPS from the CCE.
- Sardine may avoid the vessel to some extent.
- A proportion of the sardine stock may reside outside of the area covered by the acoustic transects, with the proportion depending on season as well as environmental conditions.

In relation to the first and second of these sources of uncertainty, information presented to the Panel suggests that they are unlikely to be substantial (see Sections 2.2.1 and 2.2.4 above). In contrast, Fig. 1 suggests that an inshore correction (in summer survey) of up to 15 % of the total abundance estimate may be needed.

Given current information, the Panel **agrees** that the acoustic-trawl surveys can be considered to provide estimates of absolute abundance for the survey area with the associated length-composition, and the assessment author should consider the use of these data in the September 2011 sardine assessment. It **recommends** that prior to the September 2011 assessment, 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 range of possible biomass levels. In addition, the CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data (see Section 2.2.4).

The Panel **recommends** that the assessment should: (a) examine the sensitivity of the results to alternative acoustic-trawl abundance estimates; (b) determine if use of the acoustic-trawl results as absolute estimates of abundance leads to patterns in the residuals; (c) examine the implications of ignoring some or all of the acoustic trawl estimates [e.g., the estimates from the summer 2008 and spring 2006 surveys], and (d) treating these estimates as relative indices of biomass. Treating any survey estimate as an absolute estimate of abundance is a strong constraint in stock assessment models, and the appropriateness of that assumption can only be evaluated in the context of the other information available for the assessment.

The Panel **recommends** that future STAR Panels review any research conducted in relation to acoustic-trawl surveys, and how these data are used to estimate absolute abundances of CPS.

2.3.2 *Jack mackerel*

Jack mackerel are a monitored CPS species. There are few recent data on which to base estimates of abundance and distribution for this species. The acoustic-trawl survey data are the only scientific information on abundance for the area surveyed. The Panel **agrees** that even though less information is available for this species than for Pacific sardine on the key uncertainties, the 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 catchability for jack mackerel may not be the same as that for Pacific sardine. The estimate for summer may therefore be more reliable as the various CPS are more separated at that time.

2.3.3 *Pacific mackerel*

While there is no reason why the acoustic-trawl surveys cannot be used to provide estimates of abundance for Pacific mackerel, the estimates of abundance for Pacific mackerel are more uncertain as measures of absolute abundance than for jack mackerel or Pacific sardine. This is reflected by very high CVs for the spring surveys. A major concern for this species is that a sizable (currently unknown) fraction of the stock is outside of the survey area. While the estimates for survey area are valid, if the acoustic-trawl data are to be used to provide estimates of total stock biomass, auxiliary information will be needed to estimate the annually-varying proportion of the whole stock in the survey area.

2.3.4 *Northern anchovy*

There is also no reason why acoustic-trawl surveys cannot be used to estimate abundance for northern anchovy. However, the perceived current size of the population, along with its more inshore distribution, means that the present survey data cannot be used to provide estimates of relative or absolute abundance for northern anchovy. A few northern anchovy were sampled nearshore, mostly off Oregon and Washington (2006, 2008, and 2010), north of Monterey Bay (2006) and in the Southern California Bight (2006 and 2008). Apart from the occasional large catches (~ 300kg) off the mouth of the Columbia River and other locations such as off Santa Barbara and Monterey Bay, anchovy were scarce in these surveys, even off southern California where they once were the most abundant species. The sampling scheme would need to be modified (more transects and trawls in the areas where northern anchovy are found) if estimates of abundance of northern anchovy are needed given its current abundance.

3. AREAS OF DISAGREEMENT REGARDING PANEL RECOMMENDATIONS

There were no major disagreements between the Panel and the Team or among Panel members.

4. UNRESOLVED PROBLEMS AND MAJOR UNCERTAINTIES

The CCE has seen major changes in CPS abundance historically, and there should be little doubt that similar changes will occur in the future. Any long-term survey program for CPS should be designed to respond adaptively to changing conditions. Monitoring increases and declines of CPS is likely to present difficulties if range expansion and contraction occurs at the same time that abundance changes. In addition, changes in abundance and range may affect species mixing and overlap and thus increase uncertainty due to trawl sampling given the existing sampling strategy. Although precise estimates of abundance of monitored species (northern anchovy and jack mackerel) are not presently required by the management system, some ability to track the abundance of these species is desirable. For northern anchovy, abundance estimates using the current layout of transects is not feasible, and consideration should be given to a periodic focus on this species for baseline monitoring.

5. MANAGEMENT, DATA OR FISHERY ISSUES RAISED BY THE PUBLIC AND CPSMT AND CPSAS REPRENTATIVES

The following issues were presented by the CPSAS representative as issues of concern:

- Spatial range of survey
- Survey timing
- Vessel avoidance

Appendix 6 includes a statement provided to the Panel by the CPSAS Advisor, further elucidating his concerns.

6. RECOMMENDATIONS FOR FUTURE FOR FUTURE RESEARCH AND DATA COLLECTIONS

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, catch information) to provide best estimates for the biomass outside of the survey area as well as the range of possible biomass levels.

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

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.
b. Compare total CPS backscatter along transects to trawl catch rates using statistical techniques.
c. Conduct sensitivity tests in which stations are pooled and allocated to acoustic values over a larger area.
d. Consult experts in trawl design to evaluate the current trawl design in relation to the survey objectives
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
f. Evaluate the potential use of the echosounder in a non-vertical position.
g. Check the filtering algorithm every year to ensure that it is still suitable under changing conditions.
h. Study trends in frequency response over depth strata in schools.
i. Compare results from the 18 kHz and other transducers to examine possible avoidance reactions.
j. Continue to consider the advantages and disadvantages of conducting acoustic-trawls surveys at different times of the year.
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.
l. Conduct standard (ICES) vessel noise measurements for all vessels.

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.
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.
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.

Although the review focused on abundance estimation, the Panel recognised that acoustic-trawl data could be used in ecosystem studies and for ecosystem based fishery management. Recommendations about this broader use of acoustic-trawl data are:

- estimate plankton biomass;
- describe the vertical habitat (e.g. thermocline, oxycline, currents, and plankton); and
- estimate school characteristics which may provide information on species and on possible changes in the fish behavior due to environmental variations.

Other References

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Table 1: Relative merits of spring and summer surveys for Pacific sardine.

Factor	Spring	Summer
North/South geographic coverage	Stock may extend into Mexico.	Stock may extend into Canada.
Onshore/offshore coverage	Stock mostly offshore, but distribution is more extensive.	Stock mostly inshore; fishing regularly inshore of current survey lines.
Migrating at time of survey	Potentially.	Potentially.
Species separation	More mixed-species samples.	Species more geographically segregated.
Sampling precision (per transect mile)	Lower, with current survey design, due to distributed spawning-stock distribution.	Higher, with current survey design, due to greater east-west concentration of the stock.
Hours of daylight	Lower, allowing more time for species-identification samples.	Higher, allowing more time to for acoustic sampling along transects.

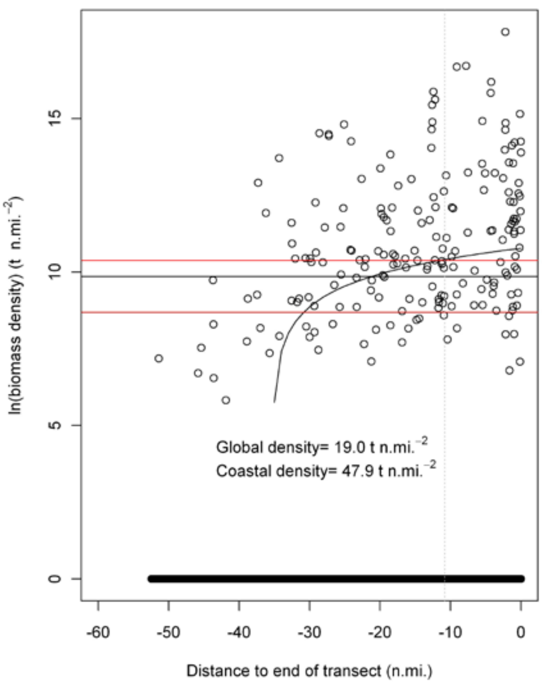

Figure 1. Relationship between biomass density and distance to the eastern end of a transect, based on the summer 2010 survey.

Appendix 1: List of Participants

Methodology Review Panel Members:

André Punt (Chair), University of Washington, Scientific and Statistical Committee (SSC)
Martin Dorn, National Marine Fisheries Service (NMFS), Alaska Fisheries Science Center, SSC
François Gerlotto, IRD, Center for Independent Experts (CIE)
John Simmonds, European Commission Joint Research Centre, CIE
Olav Rune Godø, Institute of Marine Research, CIE

Pacific Fishery Management Council (Council) Representatives:

Greg Krutzikowsky, Oregon Department of Fish and Wildlife, Coastal Pelagic Species Management Team (CPSMT)
Mike Okoniewski, Pacific Seafood, Coastal Pelagic Species Advisory Subpanel (CPSAS)
Kerry Griffin, Council Staff

Acoustic-Trawl Survey Technical Team:

David Demer, NMFS, Southwest Fisheries Science Center (SWFSC)
Kyle Byers, NMFS, SWFSC
George Cutter, NMFS, SWFSC
Josiah Renfree, NMFS, SWFSC
Juan Zwolinski, NMFS, SWFSC

Others in Attendance

Briana Brady, California Department of Fish and Game (CDFG), CPSMT
Ray Conser, NMFS, SWFSC, SSC
Ken Cooke, Department of Fisheries and Oceans, Canada
Paul Crone, NMFS, SWFSC, CPSMT
Emmanis Dorval, NMFS, SWFSC
Sam Herrick, NMFS, SWFSC, CPSMT
Roger Hewitt, NMFS, SWFSC
Kevin Hill, NMFS, SWFSC
Josh Lindsay, NMFS, Southwest Regional Office
Nancy Lo, NMFS, SWFSC
Sam McClatchie, NMFS, SWFSC
Beverly Macewicz, NMFS, SWFSC
Bill Michaels, NMFS, Science and Technology
Dianne Pleschner-Steele, California Wetfish Producers Association, CPSAS
Sarah Shoffler, NMFS, SWFSC
Dale Sweetnam, CDFG, CPSMT
Russ Vetter, NMFS, SWFSC
Cisco Werner, NMFS, SWFSC

Appendix 2: Panel Biographical Summaries

André E. Punt is a Professor of Aquatic and Fishery Sciences at the University Washington, Seattle. He received his B.Sc, M.Sc and Ph.D. degrees in Applied Mathematics at the University of Cape Town, South Africa. Before joining the University of Washington, André 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 170 papers in the peer-reviewed literature, along with over 400 technical reports. André is currently a member of the Scientific and Statistical Committee (SSC) of the Pacific Fishery Management Council and chair of its Coastal Pelagic Species subcommittee, the Crab PLAN Team of the North Pacific Fishery Management Council, and the Scientific Committee of the International Whaling Commission.

Martin Dorn is a Fisheries Research Biologist at the Alaska Fisheries Science Center, NOAA Fisheries, in Seattle, USA. He holds a M.Sc. in Biomathematics and a Ph.D. in Fisheries from the University of Washington. Martin has been involved in research on management strategy evaluations to evaluate impacts of climate and ecosystem change, modelling fishing behavior, and applying Bayesian methods to resource management problems. His current research focuses on the Bayesian meta-analysis of fish populations, and the development of cooperative research programs to address fisheries management issues. Martin leads the stock assessment team for walleye pollock in the Gulf of Alaska. He has been a member of the ICES working group on the ecosystem effects of fishing activities (WGECO) and the ICES study group on the use of acoustics on fishing vessels. He is Chair of Scientific and Statistical Committee (SSC) of the Pacific Fisheries Management Council and is an Affiliate Associate Professor at the School of Aquatic and Fishery Sciences at the University of Washington, Seattle.

Dr François Gerlotto (PhD, HDR, *Directeur de Recherches de 1ère Classe*) is a fisheries ecologist who specializes in pelagic fish behavior, particularly schooling. He has expertise and extensive experience using underwater acoustics for direct observations of animals in pelagic ecosystems and has coordinated several EU projects in this field. He was Chair of the ICES Working Group on Fisheries Acoustics Science and Technology (1997-2000), and the ICES Fisheries Technology Committee (2005-2007), and is currently the Chair of the ICES Study Group on fish avoidance to research vessels (see www.ices.dk). He was Convenor of the steering committee of the ICES Symposium on Fisheries Acoustics, in Montpellier, 2002. As an IRD scientist, he has worked for 20 years in/with South American and Caribbean countries as director of a partner's fisheries department (FLASA, Venezuela), Director of ORSTOM/IRD research units (1994-2004), coordinator of international networks (Caribbean Acoustic Network, 1991-2001, ECHOSPACE, 1991-1993), and as a scientist in several IRD projects. He is presently a member of the inter-institute research unit (UMR) EME n° 212 (Exploited Marine Ecosystems) in Sète, France, and Chairman of the IRD Scientific Commission CGRA1 (2008-2011: see www.ird.fr).

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. 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 a Senior Fisheries Scientist at the European Commission Joint Research Centre, Ispra, Italy. He obtained BSc and MSc. degrees in Electronics and Underwater Acoustics in the UK. Before joining JRC he worked in fisheries research for 37 years at the FRS Marine Laboratory, Aberdeen, Scotland. He has worked with acoustic surveys of pelagic species for more than 30 years, and assessments involving acoustic, trawl, and egg surveys for more than 15 years. He is the author of a books on Fisheries Acoustics (1991 and 2nd Edition 2005), and has been responsible for developing approaches for combining acoustic, trawl, and ichthyoplankton surveys in assessments for North Sea herring. He has worked on absolute assessments using TAEP methods for North Eastern Atlantic mackerel and has developed extensive experience of fish stock assessment and fisheries management, chairing, among other groups, the herring survey planning group 1991-95, the ICES Fisheries Acoustics WG 1993-96, the ICES herring assessment working group 1998-2000, and the ICES study group on Management Strategies 2004-2009. He currently chairs the STECF group that prepares evaluations of the 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

1. Demer, D.A, Zwolinski, J.P., Byers, K.A., Cutter, G.R., Renfee, J.S., Sessions, T.S. and B.J. Macewicz. Acoustic-trawl surveys of Pacific sardine (*Sardinops sagax*) and other pelagic fishes in the California Current ecosystem: Part 1, Methods and an example application
2. Zwolinski, J.P., Byers, K.A., Cutter, G.R., Renfee, J.S., Sessions, T.S., Macewicz, B.J. and D.A. Demer. Acoustic-trawl surveys of Pacific sardine (*Sardinops sagax*) and other pelagic fishes in the California Current ecosystem: Part 2, Estimates of distributions and abundances in spring 2006, 2008, and 2010

Other primary documents

1. Barange, M., Hampton, I. and M. Soule. 1996. Empirical determination of *in situ* target strengths of three loosely aggregated pelagic fish species. ICES Journal of Marine Science, 53: 225–232.
2. Conti, S.G. and D.A. Demer. 2003. Wide-bandwidth acoustical characterization of anchovy and sardine from reverberation measurements in an echoic tank. ICES Journal of Marine Science, 60: 617–624.
3. Cutter, G.R. and D.A. Demer. 2007. Accounting for scattering directivity and fish behaviour in multibeam-echosounder surveys. ICES Journal of Marine Science, 64: 1664–1674.
4. Demer, D.A., Cutter, G R., Renfree, J.S. and J.L. Butler. 2009. A statistical-spectral method for echo classification. ICES Journal of Marine Science, 66: 1081–1090.
5. Zwolinski, J.P., Emmett, R.L. and D.A. Demer. In press. Predicting habitat to optimize sampling of 5 Pacific sardine (*Sardinops sagax*). ICES Journal of Marine Science, 68: 000–000.

Appendix 4: Summary of information on the distribution of CPS species

Gregory Krutzikowsky (Chair), Ken Cooke, Nancy Lo, Mike Okoniewski

Background

The CPS Fishery Management Plan (FMP) is an outgrowth of the Northern Anchovy Fishery Management Plan and work began on incorporating other CPS into the Plan with Amendment 8 in June 1997. This summary draws from that work and references cited in that Amendment are not generally repeated here. Essential Fish Habitat for CPS has been defined as waters with SST 10 - 26ºC to the depth of thermocline, and a recent review of Essential Fish Habitat (EFH) confirmed this designation. It was noted that EFH for CPS changes seasonally and EFH may not encompass the entire range of these species. Life history and distribution of CPS are provided in Section 1 of Appendix A to Amendment 8 and details of the analysis, available data, and discussion of the management issues for harvest levels for US fisheries with these transboundary finfish stocks can be found in Section 4.1.3 of Appendix B to Amendment 8 with literature cited given in Appendix E (PFMC 1998). The best estimates of the portion of CPS stocks available in US waters were derived from CalCOFI egg and larvae collections (1951-1984) (Moser *et al*., 1993) and aerial fish spotter data (1964-1992). It was recognized that these stocks did not reside entirely in US waters so a distribution term was utilized to account for the portion available to US fisheries. The estimates represent an average of CalCOFI data for spring and summer and fish spotter data from summer through winter. The best estimate for the average annual distribution for Pacific sardine in US waters was 87% and that for the average annual distribution for Pacific mackerel in US waters was 70%. Best estimates for the average distribution in US waters for monitored stocks of jack mackerel and the central subpopulation of northern anchovy were 65% and 82%, respectively. Information available at that time suggested that a higher proportion of each stock was in US waters during Summer-Fall than in Winter-Spring. It was noted that it was unlikely that these estimates could be updated frequently, but that these estimates should be updated and refined if additional data became available, fishery conditions changed, and/or significant changes in stock biomass occurred. The spatial coverage of data collected did not allow for any distribution or seasonal estimates for the northern supbpopulation of northern anchovy in US waters.

It should be noted that the relative biomass of CPS species has changed substantially since those data were collected. The biomass of Pacific sardine has substantially increased and the range of habitat occupied has increased as well. Pacific sardine supported an important fishery in the Pacific Northwest (PNW) during the 1930s and 1940s. Sardines were rarely observed in waters off the PNW after the population crashed in the mid-1950s. Pacific sardine resumed migrating into PNW waters during the 1990s (Emmett et al. 2005). With the increase in Pacific sardine, northern anchovy as well as other species now make up a smaller percentage of the biomass of CPS in the California Current Ecosystem (CCE) than they did when those distribution and seasonal data were collected. More recent information on seasonal distribution comes from both fishery-independent surveys and fishery data. Surveys have concentrated their efforts in spring and summer and have rarely gone more than 200 nm from shore. Fishery effort appears to be concentrated relatively close to ports with processing capabilities, and also depends on the presence of CPS, fishery regulations and markets for fish.

Pacific sardine

The northern subpopulation of Pacific sardine ranges from the waters off northern Baja California, Mexico northward to southeastern Alaska, and as far as 300 nm offshore. The main spawning biomass is thought to be south of San Francisco within 150 nm offshore from late March to May. Pacific sardine moving northward start arriving in waters off Oregon and Washington in late May where they are thought to concentrate within 50 nm of the coast in recent years (Emmett *et al*., 2005). However, in the mid-1990's sardine eggs were observed as far as 200 nm off shore (Bentley *et al*., 1996).. It is also worth noting that young of the year Pacific sardine have been captured in fishery-independent surveys off Oregon and Washington in some years, suggesting successful reproduction in northern waters (Emmett et al. 2005). Fishery data indicate that there has been successful fishery effort from February to December and inside of 3 nm off Oregon, but Washington prohibits commercial fishing for sardine until April 1 and within 3 nm of its shoreline. Data from British Columbia, Canada indicate that Pacific sardine can be found in those waters from July through December. Anecdotal information from Canadian fishermen suggests that sardines are found in commercially harvestable quantities in the inlets of Vancouver Island, areas where fishery-independent surveys have not occurred. Fishery landings and effort in early spring, late fall, and winter months in the PNW, including British Columbia, are limited and factors such as inclement weather, the acceptability of the fish for market purposes, and regulatory closures in US waters in recent years may all contribute to this fact. Sardine were apparently absent from Oregon to British Columbia during the period of low sardine abundance, suggesting that the extent of migratory behaviour may become significant only during periods of relatively high abundance. These observations argue against having a too tidy conceptual model of Pacific sardine seasonal migration and the need to reconcile these observations of uncertain density varying among years with the information on potential habitat and survey observations of CPS density.

Jack mackerel

Jack mackerel range from the southern tip of Baja California, Mexico and the Gulf of California to 160^{o} W in the Gulf of Alaska, offshore up to 500 nm (Blunt 1969, Mac Call 1983). Egg distribution from the DEPM and CalCOFI surveys suggests that jack mackerel have a more offshore distribution than Pacific sardine. Commercial landings of jack mackerel occur all year in California, with the highest catches in Monterey from March through May and the highest catches in Southern California from September through May. Commercial landings of jack mackerel in the PNW occur in the summer months. There is presently no targeted fishery for jack mackerel and landings occur as incidental catch primarily in the sardine fishery. Fishery-independent data in the PNW suggest that jack mackerel are caught in higher densities in summer than in spring, with the earliest catches in late May (Emmett et al. 2006).

Pacific Mackerel

Pacific mackerel range from Banderas Bay (Puerto Vallarta), Mexico, including the Gulf of California to southeast Alaska. They usually occur within 16 nm offshore, but have been captured more than 100 nm offshore. Data from US surveys indicate two spawning peaks in the survey area: Southern California in May and central Baja in August. There are fishery landings in California all year with the peak being from June to August. Pacific mackerel occur seasonally in the northern part of their range. Fishery-independent data from surveys conducted in Oregon and Washington waters off the Columbia River from late April to August out to 35 nm indicate that Pacific mackerel are caught in higher densities in summer than in spring, with the earliest catches in late May (Emmett et al. 2006). Landings in Oregon and Washington occur into October.

Northern anchovy

Unlike the other CPS finfish, northern anchovy are not thought to engage in strong seasonal migrations. They are, however, known to exhibit diel migrations. There are three subpopulations off the west coast of North America, two of which, the central and northern, are found in US waters. The distribution of northern anchovy appears to be more inshore than that for Pacific sardine. The central subpopulation is the most abundant of the three and is found from central Baja, Mexico to San Francisco, with the bulk of the population in the Southern California Bight. The northern subpopulation ranges from roughly Cape Mendocino in California to British Columbia. The spawning area for the northern subpopulation appears to be centered in the Columbia River plume in the summer months (Richardson, 1981, Emmett et al. 1997). Recent fishery-independent surveys utilizing surface trawls in waters off Oregon and Washington indicate that the northern subpopulation occupies waters to at least 35 nm offshore with higher catch densities closer to shore (Emmett et al. 2006, Litz et al. 2008) and fishery data indicate that this stock occupies very nearshore waters, including estuaries, in commercially harvestable quantities (pers com. L. Wargo, Washington Department of Fish and Wildlife). Data from fishery-independent surveys collecting egg and larvae conducted off California indicate that the spawning area for central subpopulation of northern anchovy has a generally more inshore distribution than Pacific sardine in recent years. Older data from CalCOFI cruises indicate distribution of eggs and larvae extended offshore to well beyond the 200 nm EEZ of the U.S. (Hewitt, 1980).

Appendix 5: Details of the Nordic 264 trawl

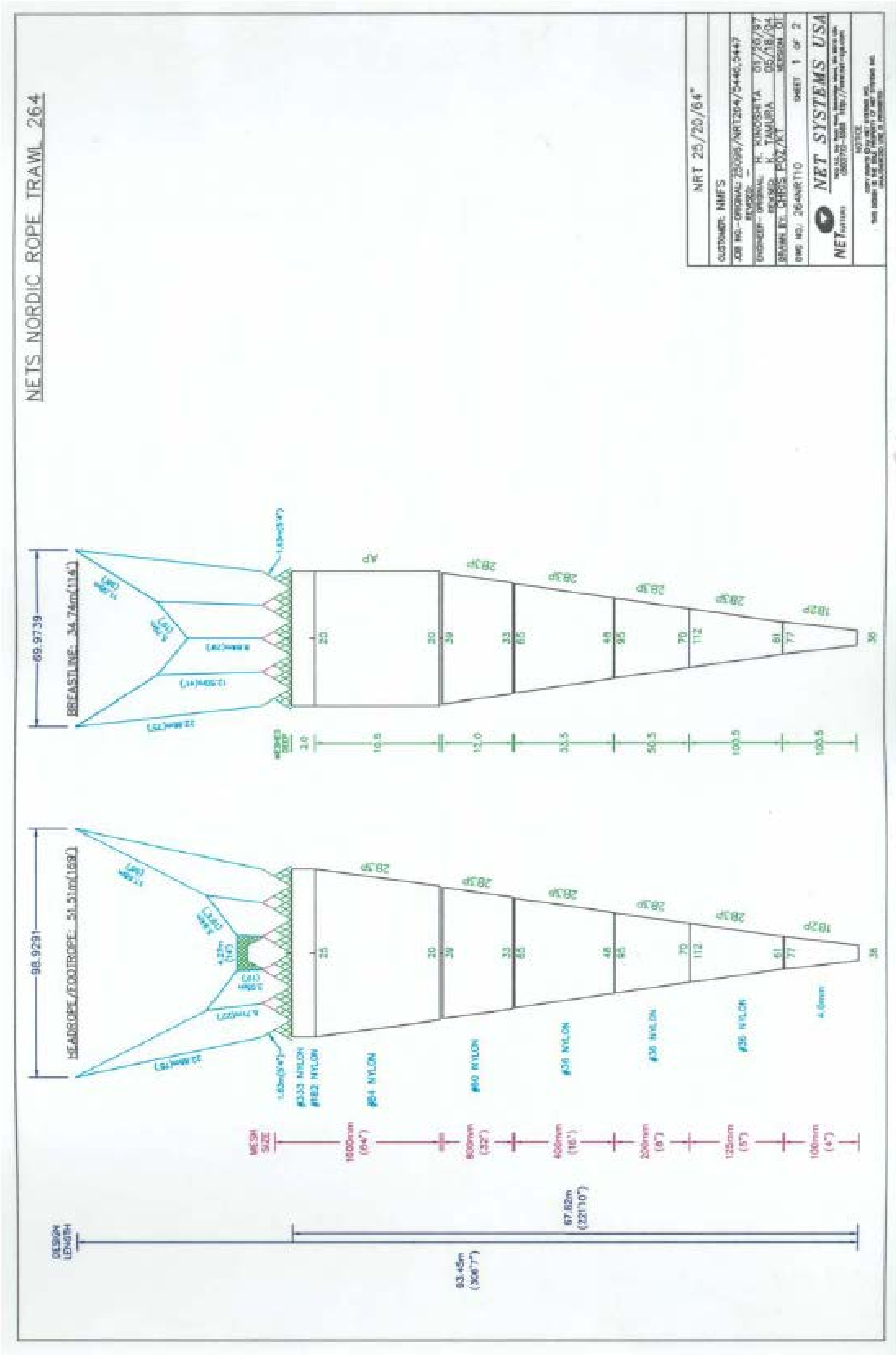

Figure 1. Details of the Nordic 264 trawl.

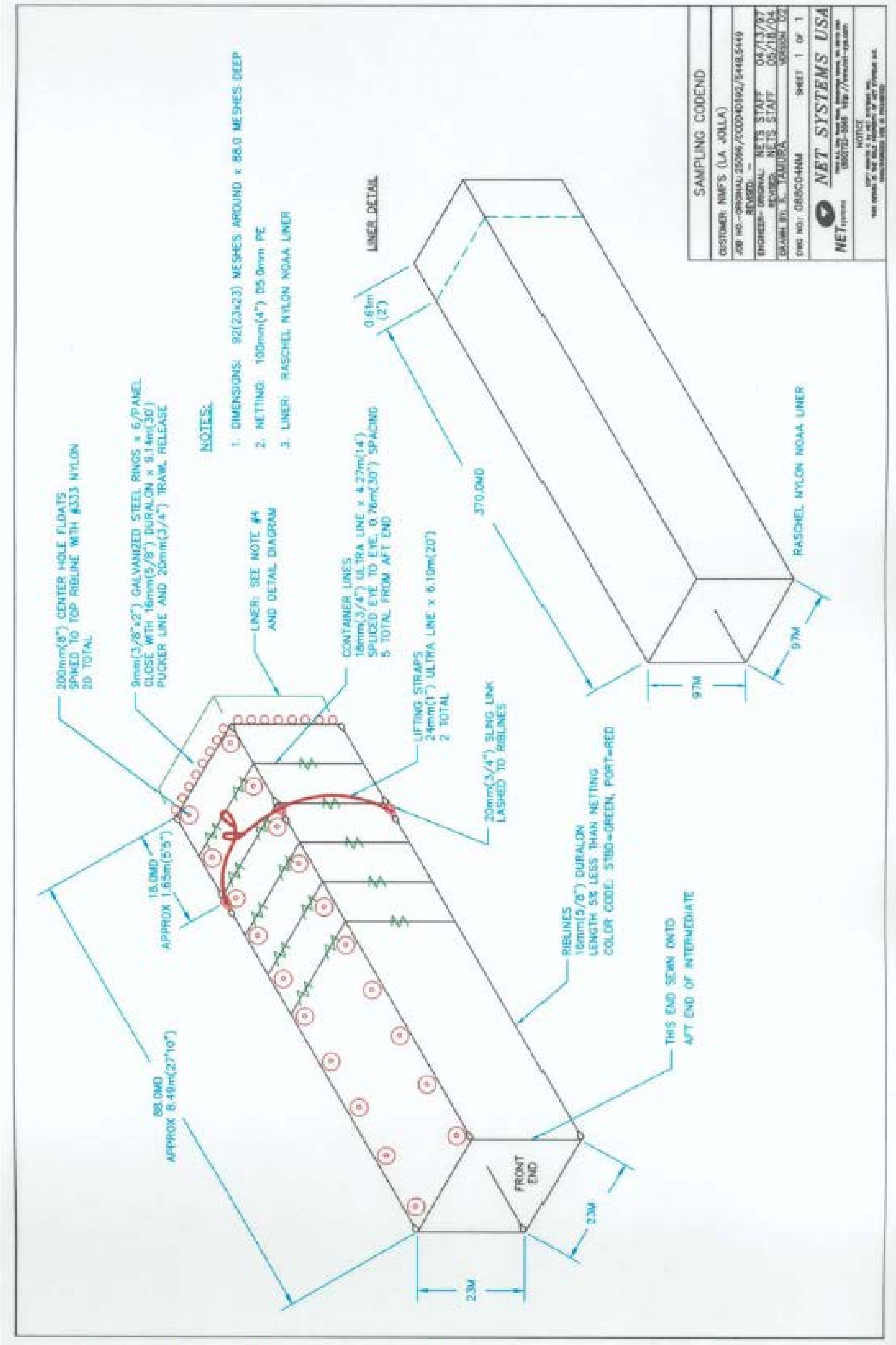

Figure 2. Details of the Nordic 264 codend.

Appendix 6: Statement of the CPSAS Advisor

First, I wish to applaud the SWFSC efforts to develop another survey that will inform the stock assessment model. While I have some specific issues with the acoustic-trawl surveys' measurement accuracy of the sardine populations in the Pacific Northwest (PNW), and lack of any survey work in Canada I believe this is an important step forward and commend Dave and his team for their work. There are 4 areas of concern I wish to address again: (a) northern and eastern range of the acoustic-trawl survey; (b) Timing of the survey in the PNW as it relates to habitat and migration theory utilized in the assessment; and (c) Vessel avoidance.

1. Range of survey: Ref: 2.2.1-2.1.2 & Appendix 5: 5-b (Dr. Cooke) The survey does not go into Canadian waters. The mean distance inshore for transects is approx. 10KM: Concerns: Canada harvest levels have risen in the last several years. DFO has done off shore swept trawl surveys with some estimates of abundance for the west side of Vancouver Island. Canadian fishermen anecdotal reports suggest there are heavy concentrations as far north as the Queen Charlottes. No effort is made in the US acoustic-trawl survey to measure this phenomenon. Per California (CA) fishermen the greatest amount of sardine harvest and concentration occurs within 3 miles of the shore. Per NW fishermen a great amount of the NW fishing effort and observed concentrations occur inshore of 10KM. It is worrisome to industry that the acoustic-trawl survey does not encompass the entire range of the population or go inshore in US waters in areas where fishermen see large aggregations of fish.
2. Acoustic-trawl survey timing: (no specific reference): Fishery data and anecdotal reports suggest that the greatest concentrations of fish are concurrently seen in both the PNW and Canada from early August/late September. CPUE rates support this time range. The acoustic-trawl survey relies heavily on habitat modelling and migration theory to support the idea that the A-T survey can successfully observe all fish by doing the survey in a June-July time frame before the fish theoretically migrate north into Canadian waters. Industry members wish to point out that the migration theory is based on tagging studies that occurred over 70 years ago. There is no conclusive evidence to suggest that the entire population migrated back to CA waters in the winter during the last expansion cycle or the current one. In fact there has been anecdotal evidence that at least a portion of the population over-winters in Canada and off the NW. To some extent this has been reinforced by fisheries data from landings in Canada in December and in NW landings that have occurred in every month except January.
3. Vessel Avoidance: Ref: 2.2.4: This topic was debated at length by the Panel: It was concluded that "there was no evidence for substantial avoidance effects." This is a point that industry is not willing to concede on a wholesale basis. Fishing vessels employing both fishing caliber sonar and echo sounding equipment simultaneously have reported that often they will observe sardines with the sonar but see nothing in the echo-sounders. This is by no means conclusive, but the prevailing consensus amongst NW and Canadian fishermen is that most often schooling sardines move laterally away from the vessel and not below it. This has been supplemented from a report and colored sonar recording graphs at the last sardine Tri National.

Conclusions: The CPSAS representative believes that the use of the acoustic-trawl survey represents an important step forward and that the Team has done an amazing amount of work in development of this survey. I believe the Panel has done an excellent job identifying and elucidating the issues.

CPSAS Future Recommendations:

1. Change timing of the survey to early August.
2. Extend the survey inshore and into Canada.
3. Use of sonar to better document vessel avoidance issues.
4. Use of Northwest Sardine Survey airplanes and cameras to do over-flights when acoustic-trawl survey vessels are doing transects in NW (Canadian?) waters.
5. Use of fishery data and fishermen knowledge to better understand whether sardines are behaving in accordance with migration and habitat theories.
6. Reevaluation of trawl equipment and technique.

Final question: Should the survey be used to formulate a relative or absolute measure of sardine abundance? I do not have the expertise to argue this question but I do have concern that the acoustic-trawl survey at this level of development is not observing all areas where there are substantial amounts of fish and that fish avoidance behavior may not be adequately understood.

Acoustic-trawl surveys of Pacific sardine (*Sardinops sagax*) and other pelagic fishes in the California Current ecosystem: Part 1, Methods and an example application

David A. Demer, Juan P. Zwolinski, Kyle A. Byers, George R. Cutter, Josiah S. Renfree, Thomas S. Sessions, and Beverly J. Macewicz

Abstract

Pacific sardine (*Sardinops sagax*) and other coastal pelagic fish species (CPS) have long been surveyed off the west coast of the United States of America using combined echosounder and trawl sampling. The challenges of the acoustic-trawl method are to first estimate and survey the potential habitat; identify the contribution of target species to the total acoustic backscatter; estimate the mean acoustic backscatter per individual fish of each target species, and combine this information to estimate their biomass densities, total biomasses, and geographic distributions. Total uncertainty, including random and systematic components of measurement and sampling error, is then estimated. Using equipment and methods resulting from over fifty years of technological maturation, the total biomass of sardine in the northern sub-population was estimated from the summer 2008 acoustic-trawl survey data as 0.679 Mt (CV = 30.9 %), compared to 0.7 Mt from an assessment model. Biomass estimates of jack mackerel (*Trachurus symetricus*) and Pacific mackerel (*Scomber japonicus*) were estimated from the survey as 0.448 Mt (35.7 %), and 0.055 Mt (53.3%), respectively. The distribution of acoustically-mapped CPS matched the distribution of trawl catches with CPS. The sardine biomass was located mostly off the coasts of Oregon, and Washington as predicted by a generalized additive model (GAM) of potential sardine habitat. For future surveys, the GAM also indicates that acoustic-trawl surveys of sardine in the northern sub-population may be most efficiently conducted during the months of June and July, when the habitat is compressed along the coasts of Oregon and Washington and the fish are generally north of Point Conception and south of the Strait of Juan de Fuca. Also during this period, daytime survey effort is maximum and the survey analysis can be augmented with fishery catch data from the same general time and place.

Keywords: Acoustic, trawl, survey, sardine, anchovy, mackerel, herring, coastal pelagic fishes.

Running Heads: Acoustic-trawl surveys of coastal pelagic fishes

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Introduction

Coastal pelagic fishes

Around the globe, stocks of coastal pelagic fish species (CPS) are highly variable and widely distributed, creating challenges for the fishing industry and management (Fréon *et al.*, 2005;Chavez *et al.*, 2003; Fréon *et al*., 2009; Mason, 1991; Mason, 2004). In the California Current Ecosystem (CCE), the dominant CPS biomass has shifted between Pacific sardine (*Sardinops sagax*), hereafter sardine; Pacific mackerel (*Scomber japonicus*); jack mackerel (*Trachurus symetricus*); and northern anchovy (*Engraulis mordax*), hereafter anchovy; and these dynamics have strongly impacted the fisheries off the west coast of North America (Mason, 2004). These alternations may be the result of both overfishing and changes in large-scale atmospheric and oceanographic conditions which favour one species at a time (Chavez *et al.*, 2003; Radovich, 1982).

From approximately 1900 to 1940, the abundance of sardine in the CCE reached 3.6 Mt (MacCall, 1979), making it the most abundant CPS in the region (Radovich, 1982). In the 1940's, the sardine stock, and thus the fishery, collapsed. During the subsequent fifty years of low abundance, the few remaining sardine schools concentrated in the coastal region off southern California. Between the 1950's and the 1980's, the fishing industry began targeting jack mackerel, anchovy, and then Pacific mackerel, which had begun to thrive (Mason, 2004; Smith and Moser, 2003). During that period, however, there was a lower demand for CPS and their catches remained low relative to the earlier catches of sardine (Mason, 2004). With the gradual recovery of the stock in the late 1980s (Jacobson and Maccall, 1995; Wolf, 1992), perhaps due to the combination of conservation measures and favourable environmental conditions, sardine in the CCE expanded their biomass and distribution and resumed their seasonal migration between southern California and Canada (McFarlane and Beamish, 2001). In the 1990's, Pacific mackerel had become scarce and the fishery shifted back to sardine (Mason, 2004).

Presently, sardine and Pacific mackerel are the only CPS which are actively managed by the Pacific Fishery Management Council (PFMC) through fishing quotas based on annual assessment of their stocks (Crone *et al.*, 2009; Hill *et al.*, 2009). Recent assessments of sardine biomass ranged from 1.3 Mt in 2006 to 0.7 Mt in 2008 (Hill *et al.*, 2009). The combined landings of sardine off the west coasts of Mexico, the United States of America (US), and Canada peaked at 0.12 Mt in 2007, driven mostly by the re-opening of the fishery in the northeast Pacific (Hill *et al.*, 2009). Following a decline of sardine abundance, which began in 2006, and associated reductions in the harvest guidelines (HG), the sardine catches receded to 0.08 Mt in 2009. Meanwhile, the US landings of Pacific mackerel were less than 10 000 t annually (Crone *et al.*, 2009), only about 20 % of their HG.

Anchovy and jack mackerel are monitored species, so there are neither federal fishery controls nor annual assessments of their populations (PFMC, 2009). The latest assessment of anchovy dates to 1995 (Jacobson *et al.*, 1995), so their current biomass is unknown. In recent years, anchovy landings in the US totalled less than 10 000 t, and most were caught near Monterey Bay (PFMC, 2009). Currently, landings of jack mackerel are only incidental to catches of sardine and Pacific mackerel (Mason, 2004).

CPS surveys

Periodic assessments of CPS rely on, to varying extents, fisheries-independent estimates of abundance from the Daily-Egg-Production Method (DEPM; Hampton, 1996; Lo *et al.*, 2009; Stratoudakis *et al.*, 2006) aerial-purse-seine surveys (Squire, 1972); and acoustic-trawl surveys (Hampton, 1996). While the principal objectives of these surveys are to estimate the geographic distributions and biomasses of CPS, additional survey objectives may include, for example, investigations of: causal relationships between targets and their biotic and abiotic environments; predator-prey interactions; and vertical distributions.

Acoustic-trawl surveys

Acoustic-trawl methods have been used to survey sardine off the west coast of the US, within the CCE, for more than a half century. Beginning with 'sonar mapping' in the 1950s (Smith, 1978), and single-frequency echo-sounding in the 1960s (Mais, 1977), the acoustic survey equipment and methods evolved to broad-bandwidth resonance scattering in the 1970s (Holliday, 1972, 1977), and now to a combination of scientific multiple-frequency echosounders and multibeam sonars (e.g., Cutter and Demer, 2008).

Multi-frequency echosounders are used to record acoustic backscatter data beneath the survey vessel and along parallel-line transects spanning the sardine habitat (**Fig. 1**). Net-catch information is used to ascribe these data to the variety of sound scatterers present in the CCE, e.g., 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 estimated by multiplying their mean biomass density by the survey area.

Total uncertainty, including random and systematic components of measurement and sampling error, is then estimated using bootstrapping procedures and experimentation. Random error is typically dominated by random sampling error (Petitgas *et al.*, 2003; Demer, 2004). Random sampling error can be minimized by increasing sampling effort, or, in cases where the areas of highest densities are known a priori, most effort can be allocated to these regions (Jolly and Hampton, 1990).

Systematic sampling and measurement error can result from temporally- and spatially-varying biases associated with the sampling design, fish behaviour (e.g., geographic and diel vertical migrations), species identification, and estimation of the mean backscatter from an individual animal of the target species. Temporally- and spatially-varying biases in acoustic biomass estimates can confound observations of change in abundance. Quantifying these biases usually requires additional experimentation. For example, multibeam sonars may be used to estimate sampling bias due to potential reactions of the epipelagic schools to the survey vessel (Gerlotto et al., 2004; Cutter and Demer, 2008).

Methods

Survey design

The dominant CPS in the CCE are broadly distributed (**Table 1**). Their biomass is patchy and most of it is aggregated in dense schools (Cutter and Demer, 2008; McClatchie, 2009). Sampling of such skewed distributions is often the dominant component of variance in acoustic surveys (Demer, 2004). Acoustic sampling is therefore conducted along parallel-line transects which span the anticipated fish habitat (**Fig. 1**). Trawl sampling is conducted periodically along the same transects. The current survey design ensures that the mean acoustic backscatter is independent between transects, which permits statistically-unbiased estimations of mean biomass densities and sampling variances for target species (Jolly and Hampton, 1990; Simmonds *et al.*, 2009).

Trawl sampling

Trawl sampling for identifying species and their sizes is performed at night, either at uniformly or randomly distributed, pre-assigned or *ad-hoc* stations along the transects. The trawl used is a Nordic 264 rope trawl with an opening of 600 m^2. The headrope is rigged with floats for towing at the surface at a speed of nominally 3.5 kts. Up to four trawls are performed every night. The catch is sorted by species and weighed. From the catches with CPS, up to 50 fish from the target species are randomly selected. These are weighed (g), and measured (mm), either in standard length (*SL*) for sardine, anchovy, and herring, or fork length (*FL*) for jack mackerel and Pacific mackerel.

The length distributions of the sampled populations are estimated using weighted averages of the length distributions from the trawls. The length data are first combined by transect, weighted by the acoustically-estimated mean densities closest to each trawl. Next, the transect-weighted lengths are combined, weighted by the acoustically-estimated mean densities for each transect.

Acoustic sampling

System calibration

Prior to the survey, each echosounder system is tested, and calibrated using the standard sphere technique (Foote *et al.*, 1987). First, the sound speed (m s^{-1}), and the absorption coefficients (dB m^{-1}) are calculated from measurements of sea-surface temperature and salinity obtained from the vessel's thermosalinograph, input to the echosounders, and held constant for the duration of the calibration and survey. Next, impedance measurements are made of each transducer quadrant and of the four quadrants connected in parallel using an impedance analyzer (Agilent 4294A). Then, a 38.1 mm diameter sphere made from tungsten carbide with 6 % cobalt binder material (WC) is used as a reference target. It is positioned nominally 20 m from the transducers and moved systematically throughout the acoustic beams to measure and adjust the on-axis system gains.

Acoustic system and measurements

Measurements of volume acoustic backscatter are made using calibrated, multi-frequency (typically 18, 38, 70, 120, and 200 kHz) echosounders (Simrad EK60) configured with split-beam transducers (typically Simrad ES18-11, ES38B, ES70-7C, ES120-7C, and

ES200-7C, respectively). Throughout the survey, the echosounders synchronously transmit 1024-µs pulses every 0.5 s, to allow multiple insonifications of small fish schools at the nominal survey speed of 10 kts. The transmit powers are 2000, 2000, 1000, 500, and 100 W at 18, 38, 70, 120, and 200 kHz, respectively. Following each transmission, the echo-power data are recorded for periods corresponding to an observational depth of 250 m. These acoustic data are indexed by time and geographic position using navigational data from a GPS receiver input to the echosounder software (Simrad ER60 V. 2.2.1). The survey-depth range accommodates the maximum of the expected sardine-depth distribution (70 m depth), and that of other CPS (**Table 1**).

Using post-processing software (Myriax Echoview), the echo-power values are compensated for propagation losses (spherical spreading and attenuation) and system parameters (transmit wavelength, pulse duration, and power; and transducer gain and equivalent two-way beam angle), and converted to estimates of target strength (*TS*; dB re 1 m^2), volume backscattering coefficient (s_v; m^{-1}), and volume backscattering strength (S_v = 10 log (s_v); dB re 1 m^{-1}). The latter is plotted versus depth and trackline distance, an 'echogram', to provide high-resolution imagery of backscatter density and depth distribution.

Data Analysis

Target identification

In addition to echoes from sardine, there are potentially echoes resulting from other CPS such as jack mackerel, Pacific mackerel, anchovy, Pacific herring (*Clupea pallasi*), and Pacific saury (*Cololabis saira*); semi-demersal fish such as Pacific hake (*Merlucius productus*) and rockfishes (*Sebastes* spp.); and krill (principally *Euphausia pacifica* and *Thysanoessa spinifera*). When analyzing the acoustic-survey data, it is therefore necessary to objectively filter 'acoustic by-catch', backscatter not from the target species. **Table 1** summarizes some relevant features of by-catch candidates, with attention to their geographic and depth distributions, maximum lengths, schooling and diel vertical migration behaviours, and food preferences. More detail regarding the principal target, sardine, is provided in the **Appendix**.

Objective identification of echoes from CPS, i.e., epi-pelagic fishes with swimbladders, is performed using a semi-automated data-processing algorithm (detailed below and illustrated in **Fig. 2)**. First, background noise is estimated for each echosounder frequency and subtracted from the respective echograms of S_v. Portions of the 'noise-reduced' echograms are designated 'bad data' if the associated vessel speed is below a threshold, 5 kts, indicating it was 'on station' or otherwise 'off effort'.

Next, the S_v values in these 'speed-filtered' echograms are preliminarily identified as echoes from fish with swim bladders if their variance-to-mean-ratio (Demer *et al.*, 2009) is within a certain range, -60 dB ≤ *VMR* < -16 dB. The S_v values outside this *VMR* range are set to -999 dB (practically zero).

The '*VMR*-filtered' echograms (**Fig. 3a)** are gridded into ten-sample-deep by three-transmission-long bins. The S_v values within each depth-distance window are replaced by the median value of the S_v ensemble. This procedure reduces the variance of the data and allows comparisons of the median-S_v values with expected ranges of values for the target species. The 'median-filtered' echograms (**Fig. 3b**) are compared to predictions of backscattering spectra for CPS, their backscatter versus frequency. The echograms are ultimately apportioned to CPS, and all else, using the following ranges of S_v differences:

$-12 \leq S_{v18\text{ kHz}} - S_{v38\text{ kHz}} \leq 20.5$;

$-17 \leq S_{v70\text{ kHz}} - S_{v38\text{ kHz}} \leq 10$;

$-17 \leq S_{v120\text{ kHz}} - S_{v38\text{ kHz}} \leq 14$; and

$-14 \leq S_{v200\text{ kHz}} - S_{v38\text{ kHz}} \leq 5$ dB,

and a requirement that the maximum S_v at 38 kHz in 5-m deep by 100-m distance cells must exceed -43 dB. For grid cells which do not meet all these criteria, their corresponding S_v values in the noise-free echograms are set to -999 dB. The resulting 'CPS' echograms (**Fig. 3c)** are thresholded below S_v = -60 dB, which corresponds to a density of approximately 2 fish•100 m^{-3}, in the case of 20-cm-long sardine. The s_v values are then summed and averaged within each 5-m depth by 100-m distance cell between an observational range of 10 and 70 m depth (**Fig. 3d**), or, if the seabed is shallower, to 3 m above the estimated dead zone (Demer *et al.*, 2009):

$$s_A = 4\pi(1852)^2 \int_{10}^{70} sv\, dz\,. \qquad (1)$$

The resulting s_A values (m^{-2} $n.mi.^{-2}$), attributed to CPS, are then apportioned to the epipelagic-fish species using trawl data. However, consideration is given to the time-of-day the acoustic samples were taken.

Most CPS exhibit diel vertical migrations (**Table 1**); they school at depth during day and ascend to the surface to feed during night (Mais, 1974). Consequently, the probability of detecting echoes from CPS at night is low using echosounders with downward-projecting hull-mounted transducers. The night-time data is negatively biased (Cutter and Demer, 2008). Therefore, only the s_A values from the daytime portions of the surveys, the period between nautical twilights, are used to estimate the distributions and abundances of sardine and other CPS.

Target strength estimation

The daytime-s_A values corresponding to CPS ($s_{A_{CPS}}$) are apportioned to the j species present using the catch mixtures in the nearest (space and time) trawl samples (Nakken and Dommasnes, 1975):

$$s_{A_i} = \frac{w_i \times 10^{\left(\langle TS_i \rangle /10\right)}}{\sum_j w_i \times 10^{\left(\langle TS_i \rangle /10\right)}} s_{A_{CPS}} \tag{2}$$

where w_i is the proportion of the mass of the catch (kg) for the i-th species, and $<TS_i>$ is its length-weighted mean target strength (TS; dB re 1 $m^2 \cdot kg^{-1}$). In other words, each $<TS_i>$ is a mean TS weighted by the distribution of total lengths (TL) of the sampled fish of that species. The TS relationships employed are:

$$TS = -14.90 \times \log(TL) - 13.21, \text{ for sardine;} \tag{3}$$

$$TS = -12.15 \times \log(TL) - 21.12, \text{ for anchovy; and} \tag{4}$$

$$TS = -15.44 \times \log(TL) - 7.75, \text{ for jack and Pacific mackerel,} \tag{5}$$

where TL is in cm. These relationships were originally estimated for anchovy (*Engraulis capensis*), sardine (*Sardinops ocellatus* = *Sardinops sagax*), and horse mackerel (*Trachurus trachurus*), based on the combination of backscatter-versus-length and mass-versus-length measurements of *in situ* fish (Barange *et al.*, 1996). Because jack mackerel and Pacific mackerel have similar TS (Peña, 2008), eq. (5) is used for both of these species. TL values of fish are derived from their measured SL or FL values using relationships derived from measurements of California Current specimens (*unpublished SWFSC data*).

Biomass and uncertainty estimation

The s_A values are converted to fish-biomass density for the i species (ρ_i; kg·n.mi.$^{-2}$) using:

$$\rho_i = \frac{s_{A_i}}{4\pi 10^{(\langle TS_i \rangle /10)}}\,. \qquad (6)$$

Total biomass is calculated, by species, for strata having similar biomass densities and transect spacing. The mean biomass density of each stratum is calculated by a transect-length weighted average of the transect mean densities (Jolly and Hampton, 1990).

The sampling variances are estimated using bootstrapping procedures (Efron, 1981) that provide better statistical inference than traditional methods (Jolly and Hampton, 1990) for unknown statistical distributions. Confidence intervals for the mean biomass densities are estimated by constructing 1,000 bootstrap samples (sets of equal size as the original set and resampled with replacement) of the transects and calculating the respective survey means (weighted averages using transect lengths as weights). To include the sampling error due to species classification and *TS*-estimation in the variance estimates, the trawl samples with CPS are subjected to jackknife resampling prior to the bootstrapping of the transects. Each time a trawl is removed from the set, the biomass densities of each target species in the 100-m distance cells are re-calculated taking into consideration the new nearest-neighbour configuration (**Fig. 4**). The confidence intervals for the survey mean are estimated as the 2.5 and 97.5 percentiles of the bootstrap-survey-mean distribution. The standard error is given by the standard deviation of the bootstrap means. The coefficient of variation (CV) is estimated by dividing the standard error by the mean of the bootstrap survey means (Efron, 1981).

Results

Echo energy from CPS exhibited a strong diel cycle (**Fig. 5**), confirming that only daytime data should be used for estimating CPS biomasses. The automated algorithm for ascribing echoes to CPS and other sources was apparently effective as the distributions of acoustic- and trawl-sampled CPS are well matched (**Fig. 6**). Sardine were the most abundant species in terms of the mass of their total-catch, and their occurrences in catches with CPS (**Table 2**). The next most abundant species was jack mackerel. Anchovy and Pacific mackerel were caught in roughly the same proportions, although the mass of the total catch of Pacific mackerel was roughly one tenth of that for anchovy.

The species-apportioned biomass densities reflect the distributions of the species in the trawl catches (**Figs. 6 and 7**). Most of the sardine biomass was located in the northern portion of the study area, off Oregon and Washington, while jack mackerel was found mainly off central California. Pacific mackerel were more scattered than sardine and jack mackerel (**Fig. 7**). Too few trawls included anchovy and herring in the catch to allow evaluation of their distributions and abundances. The biomass densities of each evaluated species were independent between transects (not shown), enabling the bootstrap procedure to estimate the random sampling error.

Summing the biomass of the strata in the sampling region (**Fig. 7**), the total biomass of sardine from San Diego to the Strait of Juan de Fuca was estimated to be 0.679 Mt with a CV of 30.9 %, compared to 0.7 Mt from the 2008 assessment (Hill *et al.*, 2009). The stock of jack mackerel was estimated to be 0.448 Mt with a CV of 35.7 %. The stock of Pacific mackerel was estimated to be 0.055 Mt with a CV of 53.3 %, compared to 0.275 Mt from the 2009 assessment (Crone *et al.*, 2009).

The CV values reflect the combined random sampling error of the acoustic and trawl sampling. For sardine and jack mackerel, these values may be sufficiently small to allow the results to be used in assessments. However, the proportion of the jack mackerel stock present in the sampling area is unknown. The much larger CV for Pacific mackerel was the result of a lower, patchy distribution and too few trawl catches (**Table 3**).

Discussion

Target detection

The range of the acoustic sampling for CPS (10 m - 70 m) encompasses the daytime vertical extent of the CPS in the CCE (**Fig. 5**), particularly for sardine, jack mackerel, and Pacific mackerel (Hill *et al.*, 2009; Squire, 1972) and it is shallow enough to mostly exclude hake (Dorn *et al.*, 1994) and rockfishes (Butler *et al.*, 2003). In fact, the vertical distribution of the CPS backscatter sampled during the summer 2008 survey (**Fig. 5**) indicates that most of the CPS reside in the upper 40 m, which is consistent with early acoustic observations of CPS in the Southern California Bight (Holliday and Larsen, 1979). Although it is likely that the stocks of sardine, jack mackerel, and Pacific mackerel were effectively sampled shallower than 70 m, other CPS species may be currently under-sampled. For example, anchovy may reside in depths to 95 m, during the day, off southern California (Mais, 1974; Robinson *et al.*, 1995); and, depending on their reproductive condition, Pacific herring may reside in very shallow inshore and inland waters or may migrate offshore and to depths of 200 m (Lassuy, 1989).

Fish may react to an approaching vessel (Ona *et al.*, 2007), or not (Fernandes *et al.*, 2000), and they may react more to a large quiet vessel than to a smaller noisy vessel (Ona *et al.*, 2007). Fish behaviour varies among species and many other factors (Vabø *et al.*, 2002), such as ontogeny, time of day, season, region, sampling platform, and stimuli. In the CCE, a significant proportion of CPS schools reside near the sea surface (Holliday and Larsen, 1979; Mais, 1974). However, while schools of epipelagic fish may dive in response to a survey vessel, perhaps altering their *TS*, (Holliday and Larsen, 1979; Gerlotto and Freon, 1992; Patel and Ona, 2009; Vabø *et al.*, 2002), this behaviour may position them deeper and allow their detection with down-looking echosounders. For example, schools of Spanish sardine (*Sardinella aurita*) located in the path of the vessel, initially in the upper 20 m, invariably descended a few meters prior to the passage of the survey vessel; the effect diminished with school depth, and the lateral movements were negligible (Gerlotto and Fréon, 1992). If this behaviour is consistent for CPS in the CCE surveyed with down-looking echosounders from NOAA ships, the sampling bias due to this factor may be negligible.

To investigate this hypothesis, measurements were made of CPS schools during a 2006 survey of CPS using a side-looking multibeam echosounder, pole-mounted on *David Starr Jordan* (Cutter and Demer, 2008). Results supported earlier observations that near-surface fish dove beneath the vessel, well in advance of its arrival (Gerlotto and Fréon, 1992; Ona *et al.*, 2007). Moreover, the distributions of acoustically-detected CPS matched the distributions of the trawl catches well; and the sardine biomass estimated from the acoustic-trawl survey matched the assessment well.

Species identification and *TS* estimation

The echo energy was apportioned to species using an objective algorithm which assumes that: 1) echoes from fish schooling in the upper 70 m during the day can be identified as CPS by their backscattering spectra; and 2) a representative portion of those CPS are sampled with the surface trawl at night. The proportions of the various CPS in the catches were used to apportion the nearby CPS echoes to species, considering their *TS*. Because the distributions of the CPS echoes matched those of the CPS caught in the trawl, these assumptions appear to be valid.

Where CPS were acoustically mapped, CPS were caught in the trawls; where CPS were not acoustically observed, CPS were absent from the catches (**Fig. 6**), in general. Furthermore, the distributions of catches show some degree of segregation among the various species, which supports the method of ascribing CPS backscatter to species based on their proportions in the nearest catches.

Fish behaviour can affect trawl sampling. If certain species or sizes avoid capture, 'net selectivity' causes a variable sampling bias. In the acoustic-trawl method, it is currently assumed that the net samples are unbiased and therefore the proportions of CPS in the catch, and their length distributions, are representative of their respective stocks. However, there may be some net selectivity which will affect the species identifications and *TS* estimations, and cause variable sampling biases in the biomass estimates.

In the absence of *TS* models for the target species in the populations and conditions under study, the biomass estimates were computed using *TS*-to-biomass relationships derived for related species in similar systems (Barange *et al.*, 1996). The *TS* of swimbladdered fish are intrinsically variable, depending mainly on the acoustic frequency and the swim bladder size and orientation relative to the incident sound wave (Foote, 1980). The swim bladder size and orientation are related to the fish anatomy, physiology, behaviour, and ontogeny (Ona, 1990). Consequently, the *TS*-to-biomass relationships should ultimately be derived from measurements of target fish in the conditions which they are sampled (Fässler *et al*., 2008). Future studies should evaluate uncertainty in the *TS* models used and new relationships should be tailored for the populations in the CCE. For example, high-resolution images using X-rays (e.g., Conti and Demer, 2003; Renfree *et al*., 2009) or magnetic resonance (e.g., Peña and Foote, 2008) can be used to parameterize scattering models and better predict *TS* as a function of frequency and orientation (e.g., Horne, 2003, Cutter and Demer, 2007; Cutter *et al*., 2009). The frequency response of single- and mixed-species aggregations can then be simulated by summing the responses of fish varying in number and orientation.

Future surveys

Potential sardine habitat

To minimize uncertainties in estimates of sardine biomass, irrespective of the survey technique, the sampling effort must be optimally allocated to only the region containing the stock. Based on water temperatures associated with spawning activity and evidence that sardine might be food limited above 16.5°C, potential spawning-sardine habitat has been described as seawater with temperatures from 13.5 to 16.5 °C (Agostini, 2005), 14 to 16°C (Jacobson *et al.*, 2005), and 12 to 15 °C (Reiss *et al.*, 2008). Notwithstanding these observed associations, accurate predictions of sardine distributions and densities have been elusive, until recently. Zwolinski *et al.* (in-press) demonstrated accurate predictions of potential sardine habitat and the dynamics of its spatio-temporal distribution.

Based on a 12-year dataset including samples of sardine eggs and concomitant remotely-sensed oceanographic conditions, a probabilistic, generalized-additive model was developed which predicts the distributions of habitat for the northern stock of sardine. Significant relationships were identified between sardine eggs and sea-surface temperature, chlorophyll-a concentration, and the gradient of the sea-surface altitude. The model describes and accurately predicts the potential habitat and seasonal migration pattern of sardine, whether or not they are spawning (**Fig. 8**). The model predictions of potential habitat were extensively validated by fishery landing data from Oregon, Washington, and British Columbia, and scientific net sample data collected near the Columbia River mouth. The predicted habitat can be used to optimize the times and locations of DEPM, acoustic-trawl, and aerial surveys of sardine. Averaged over twelve years, 92 % of the biomass was sampled using 64 % of the original survey effort. That is, habitat predictions could have allowed approximately 36 % of the survey effort to be reallocated to potential habitat, likely reducing the sampling error.

Temporal sampling

Traditionally, DEPM surveys of CPS have been performed in the spring, during the peak of the spawning season (Lo *et al*., 2009). At that time, CPS mostly aggregate offshore of central and southern California, with some species, particularly Pacific herring and anchovy, located in a few coastal areas further north. However, Zwolinski *et al*. (in-press) concluded that acoustic-trawl surveys of sardine may be most efficiently conducted during the months of June and July, when the habitat is compressed along the coasts of Oregon and Washington (**Fig. 9**), the fish are generally north of Point Conception and south of the Strait of Juan de Fuca, the days are longest and thus daytime sampling is maximized, and the survey can be augmented with fishery catch data from the same general time and place. Incidentally, the results of the summer 2008 acoustic-trawl survey are in agreement with these model predictions; the sardine biomass was located mostly off the coasts of Oregon and Washington (**Fig. 7**).

The modeled predictions of potential sardine habitat could be used to optimally plan both DEPM and acoustic-trawl surveys, saving valuable time to increase sampling effort in areas of expected sardine presence. This strategy could potentially lower the variance and increase the accuracy of the estimates, or allow better sampling of the distribution of the less abundant species such as anchovy and Pacific mackerel. When acoustic-trawl surveys are performed during spring, the sampling should extend to the southern limit of the potential sardine habitat, perhaps south of the US-Mexican border (Félix-Uraga *et al.*, 2004). When acoustic-trawl surveys are performed during summer, attention should be paid to the northern limit of the potential sardine habitat, perhaps north of the US-Canadian border (Ware, 1999).

Conclusion

Acoustic-trawl surveys can provide high-resolution, quantitative information about the biomasses, and geographic and vertical distributions of multiple species and trophic levels. Acoustic-trawl methods can be employed concurrently with other survey methods and can enable investigations of animal interactions, with each other and their environments.

The principal challenges of acoustic-trawl surveys of sardine are to: estimate and survey the potential sardine habitat (habitat estimation); identify the contribution of sardine backscatter to the total acoustic backscatter (species identification); and to estimate the mean acoustic backscatter per average-individual sardine (target strength estimation). Reduced uncertainty in the survey results will likely result from more optimal allocation of sampling effort; increased net sampling; and refinements to acoustic-target identification and target strength estimation.

Improvements to survey variance may result from further constraining the survey to areas containing fish using model predictions of potential sardine habitat. While CUFES surveys of sardine may be best conducted off Southern California during spring, acoustic-trawl surveys of sardine may be most efficiently conducted nearshore, off northern California, Oregon, and Washington during the months of June and July.

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Tables

Table 1. Geographic and depth distributions, maximum total length (*TL*), diel vertical migratory (DVM) and schooling behaviours, and food preferences for CPS in the CCE.

Species	South-north distribution	East-west distribution	Depth distribution	DVM	Schooling	Max. *TL*	Prey	References
Jack mackerel	Baja California to the Gulf of Alaska	Coastal and oceanic; larger fish to 1000 n.mi. offshore	0 - 300m (commonly 0 - 50 m)	Strong	Dense schools and solitary	60 cm	Large zooplankton, small fish, and squid	(MacCall and Stauffer, 1983; Mais, 1974)
Northern anchovy	Baja California to Canada (discrete locations)	Coastal	0 – 200 m	Strong	Dense schools	25 cm	Phyto- and zooplankton, (typically larger than sardine prey)	(Mais, 1974; Miller and Lea, 1972)
Pacific hake	Baja California to the Gulf of Alaska	Coastal and oceanic; larger fish further offshore	0 - 600 m	Weak	Diffuse aggregatio ns	90 cm	Large zooplankton and small fish	(Alverson and Larkins, 1969; Mais, 1974; Quirollo, 1992)
Pacific herring	Northern Baja California to Alaska (discrete locations)	Neritic and coastal	0 – 200 m	Strong	Dense schools and solitary	30 cm	Zooplankton	(Lassuy, 1989)
Pacific mackerel	Baja California to the Gulf of Alaska	Coastal and oceanic	0 – 300 m (commonly 0 - 50 m)	Strong	Dense schools	40 cm	Large zooplankton and small fish	(Fitch, 1958; Gluyas-Millán and Quiñonez-Velázquez, 1997)
Pacific sardine	Gulf of California to the Gulf of Alaska	Coastal and oceanic; larger fish to 300 n.mi. offshore	0 - 100 m (commonly 0 - 50 m)	Strong	Dense schools	30 cm	Phyto- and zooplankton	(Blaxter and Hunter, 1982; Mais, 1974)
Pacific saury	Central and Northern California	Oceanic	0 - 250m	Strong	Dense schools	30 cm	Zooplankton	(Mais, 1974)

Table 2. Species prevalence, the fraction of CPS catches which included the species; the total catch of the species; the fraction of the total CPS catch attributed to the species; and the ranges, means, and standard deviations of fork (*FL*) or standard length (*SL*) values.

Species	**Pacific sardine**	**Jack mackerel**	**Pacific mackerel**	**Northern anchovy**	**Pacific herring**
Prevalence (%)	60	58	38	22	11
Total catch (kg)	2587	507	42	364	82
Catch fraction (%)	72	14	1	10	2
Length range (cm)	$8.5 \leq SL \leq 25.7$	$6.0 \leq FL \leq 61.0$	$20.0 \leq FL \leq 37.0$	$8.6 \leq SL \leq 16.1$	$15.0 \leq SL \leq 18.0$
Length mean (s.d.) (cm)	20.5 (2.2)	44.4 (8)	30.8 (3.5)	12.6 (1.2)	16.8 (0.7)

Table 3. CPS Biomass estimates (Mt), their coefficients of variation (CV), and 95 % confidence intervals (CI_{95}) in the CCE during the 2008 survey. The total biomass values are apportioned two strata as defined in **Figs. 3-5**. Catches of other CPS were too few to enable estimations of their biomasses.

Species	**Stratum 1**		**Stratum 2**		**Total**		**CI_{95}**
	Biomass (Mt)	CV (%)	Biomass (Mt)	CV (%)	Biomass (Mt)	CV (%)	Biomass (Mt)
Pacific sardine	0.630	32.6	0.049	88.5	0.679	30.9	0.303 - 1.098
Jack Mackerel	0.027	56.7	0.421	37.6	0.448	35.7	0.161 – 0.781
Pacific Mackerel	0.055	53.3	-	-	0.055	53.3	0.016 – 0.126

Figures

Figure 1. Sampling design for a six-week acoustic-trawl survey of CPS in the CCE between Mexico and Canada.

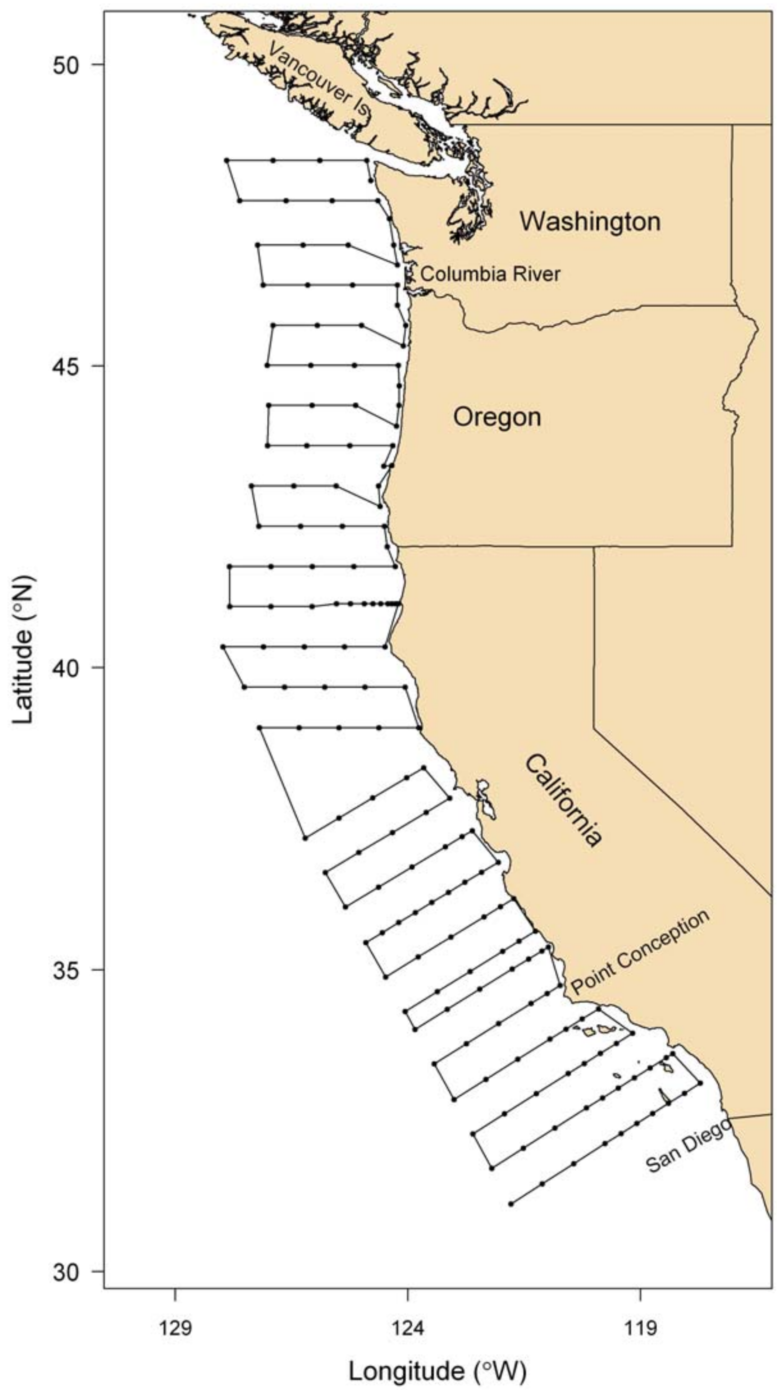


Figure 2. Flow chart of the acoustic processing algorithm.

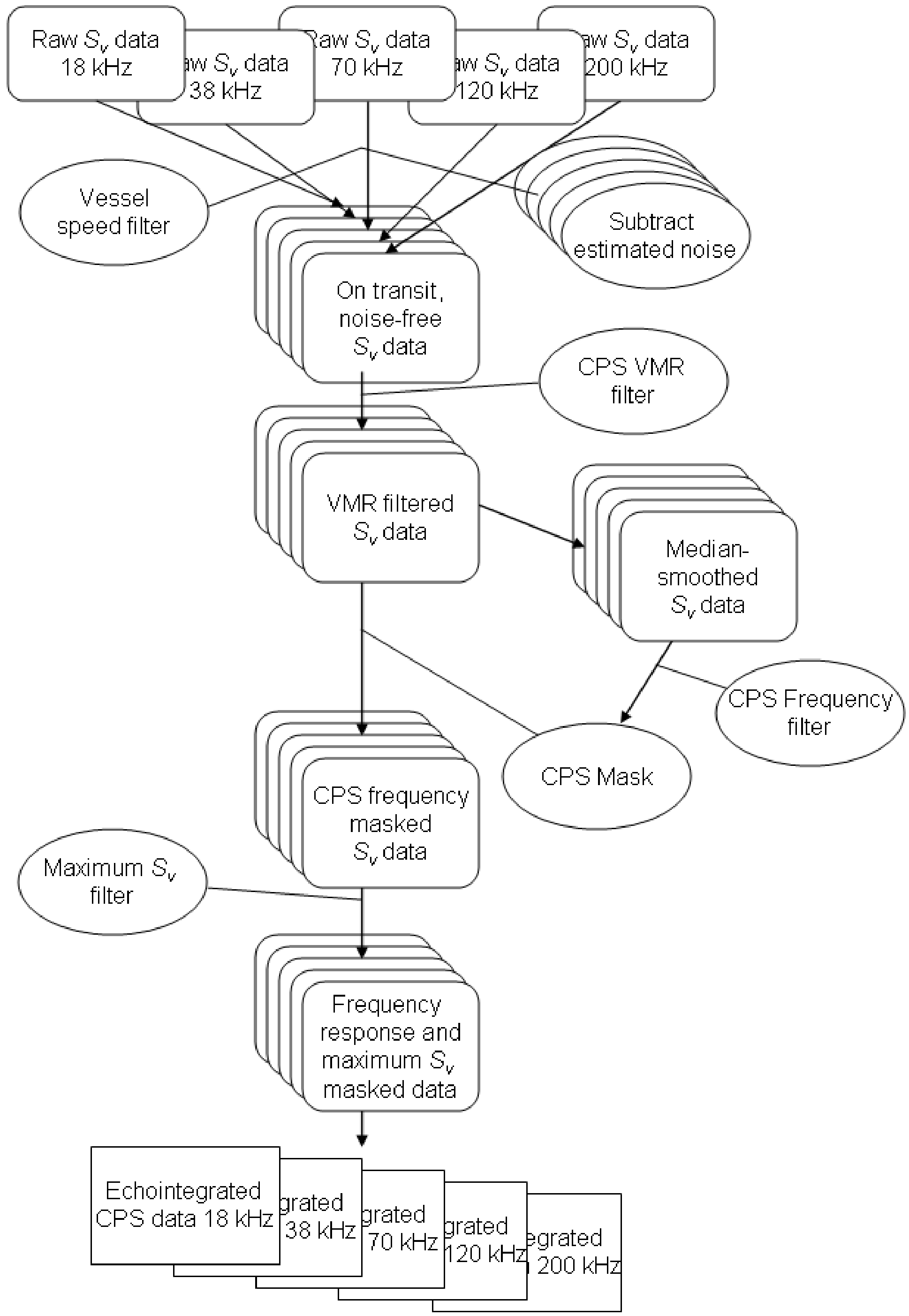


Figure 3. Echograms of 38 kHz S_v (dB re 1 m^{-1}), spanning 0 to 250 m depth and 1 km distance, illustrating parts of the algorithm for identification and integration of echoes from CPS: (**a**) *VMR*-filtered; (**b**) median-filtered; (**c**) candidate CPS from multifrequency spectra; and (**d**) candidate CPS shallower than 70 m depth with 5-m depth by 100-m distance cells filtered by maximum S_v in each cell thresholded at – 60 dB. The s_v (m^2·n.mi.$^{-2}$) attributed to epi-pelagic CPS are integrated for each cell and apportioned to species using trawl-catch data.

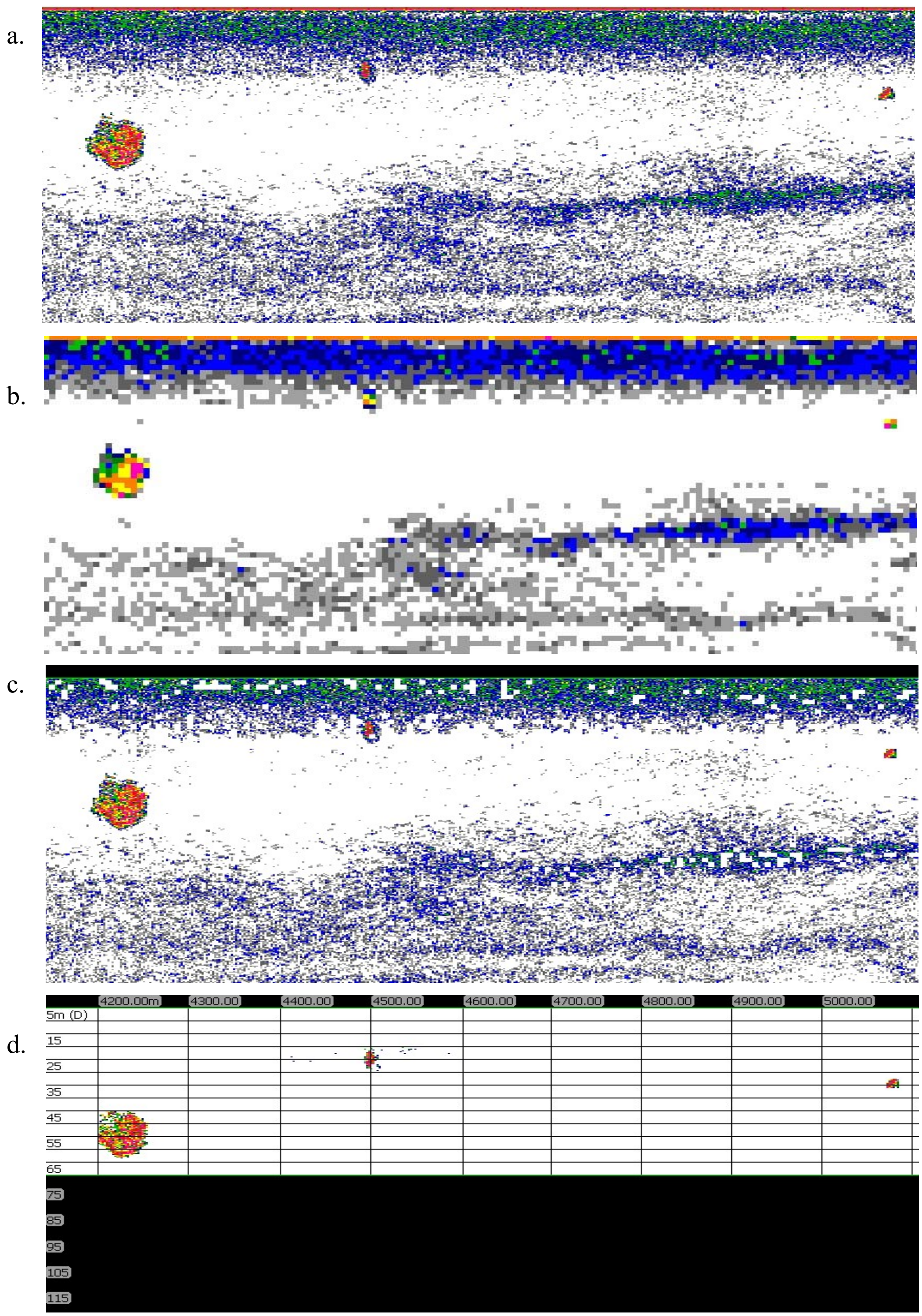


Figure 4. Flow chart of the procedure to obtain estimates of CPS abundances and estimates of random sampling error.

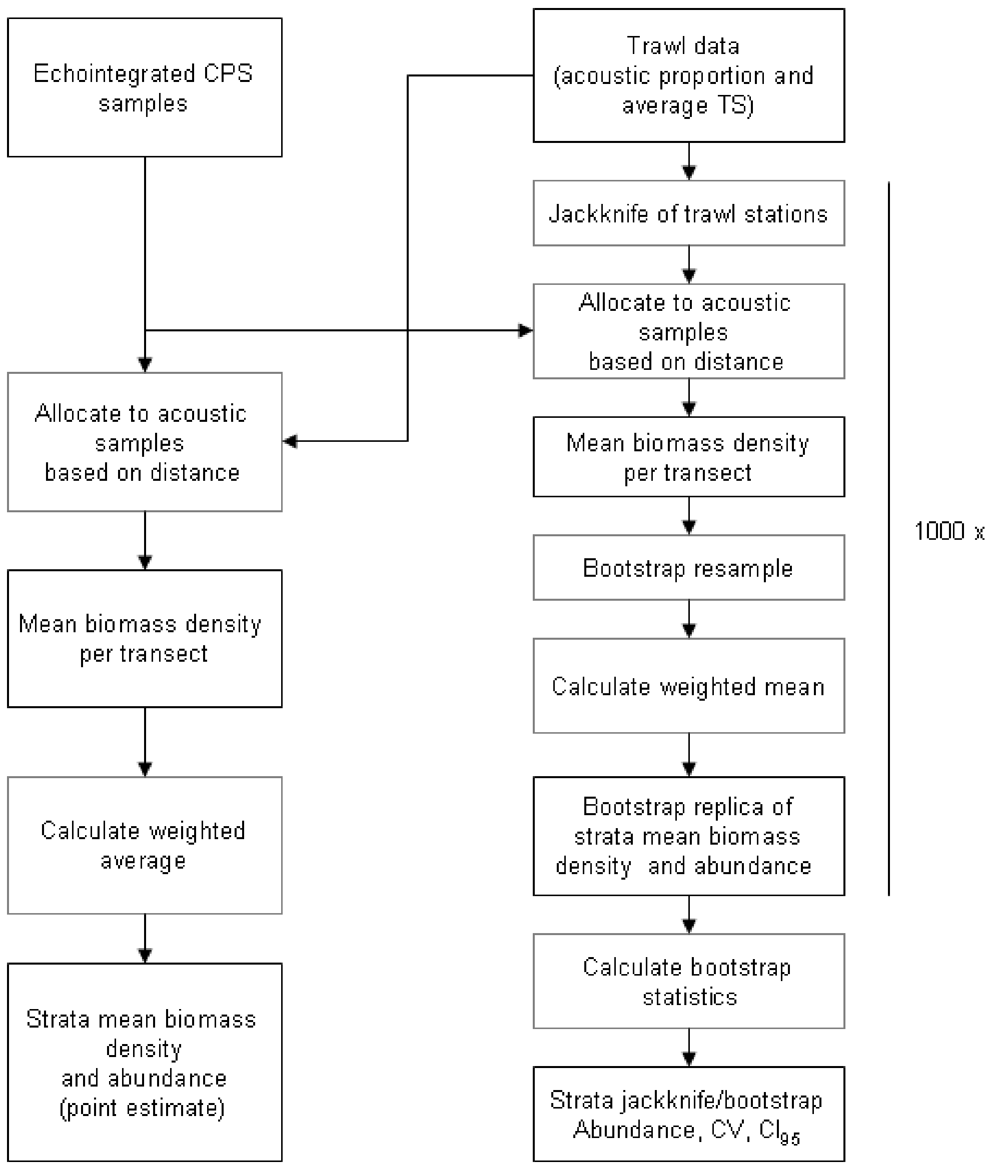


Figure 5. Vertical distribution of the acoustic backscatter attributed to CPS, averaged by depth (5 m bins) and time (1 hour intervals) (upper-left). Sums of these data across depth (lower) show that the probability of detecting CPS drops precipitously during night-time hours. Approximate times of local apparent sunrise and sunset are indicated (vertical lines ca. 0430 and 2200). Sums of these data across time (right), show that CPS in the CCE are detected mainly in the upper 40 m during daytime.

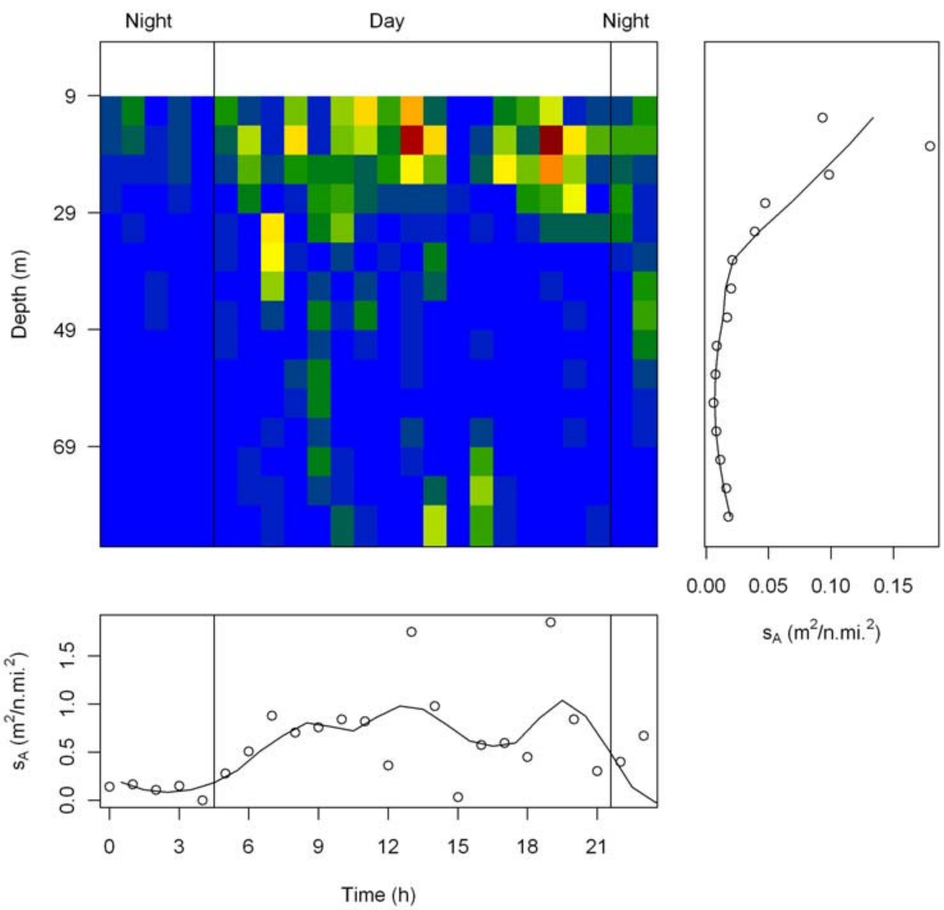


Figure 6. Acoustically detected CPS biomass densities (sampling unit = 10 - 70 m depth by 2 km trackline distance); and trawl catches including at least one CPS specimen (positive trawl) and no CPS (negative trawl). For each positive trawl, the proportion of each CPS is represented by the proportion of the area in the circle.

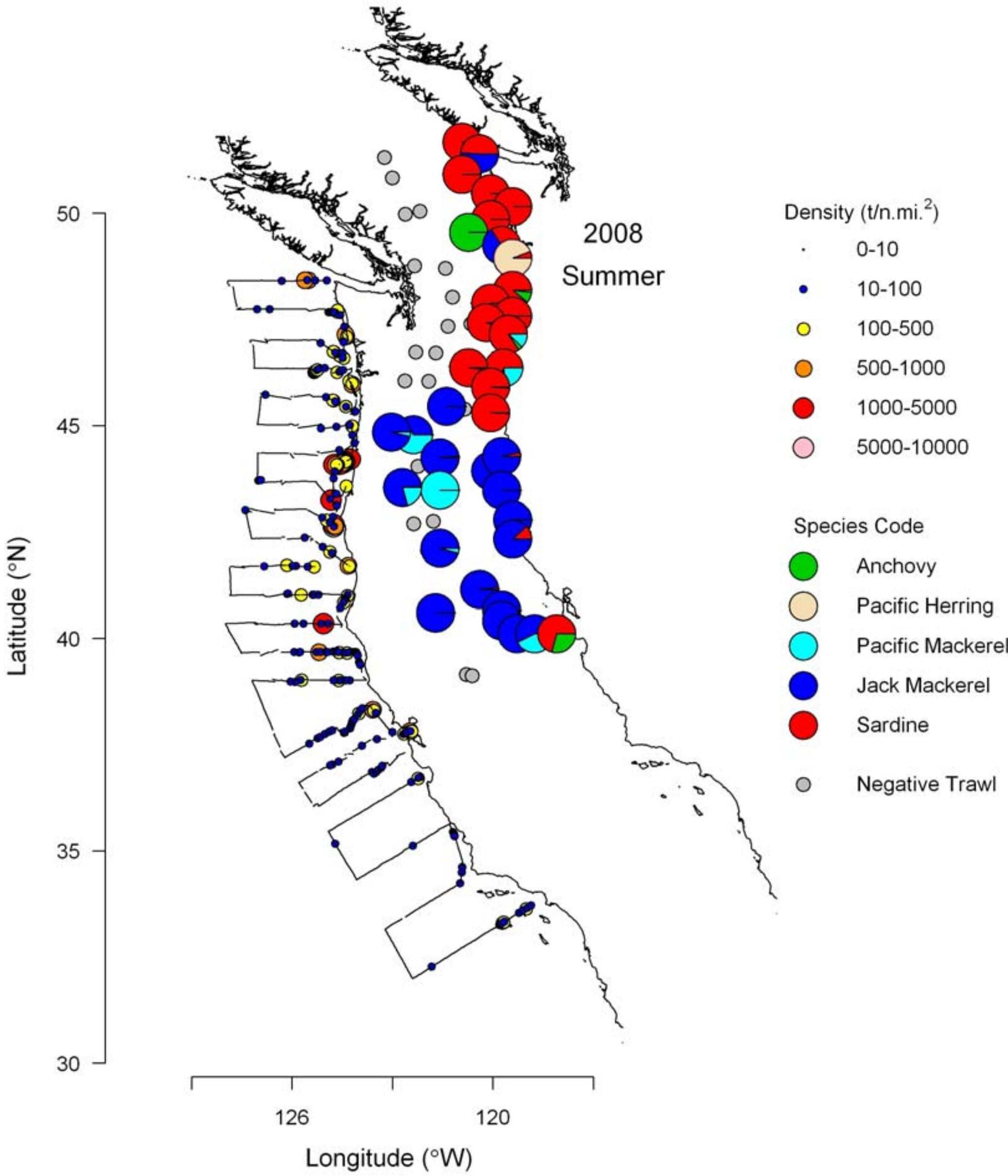


Figure 7. Spatial distribution of biomass densities estimated for sardine (left), jack mackerel (middle), and Pacific mackerel (right). The estimates are based on the s_v integrated from 10 - 70 m depth; the acoustic composition of the nearest trawl; and the average *TS* of each species. Strata (dashed lines) were created post-cruise. Pacific herring, anchovy, and other epipelagic CPS are not included due to their low biomasses and high sampling uncertainties.

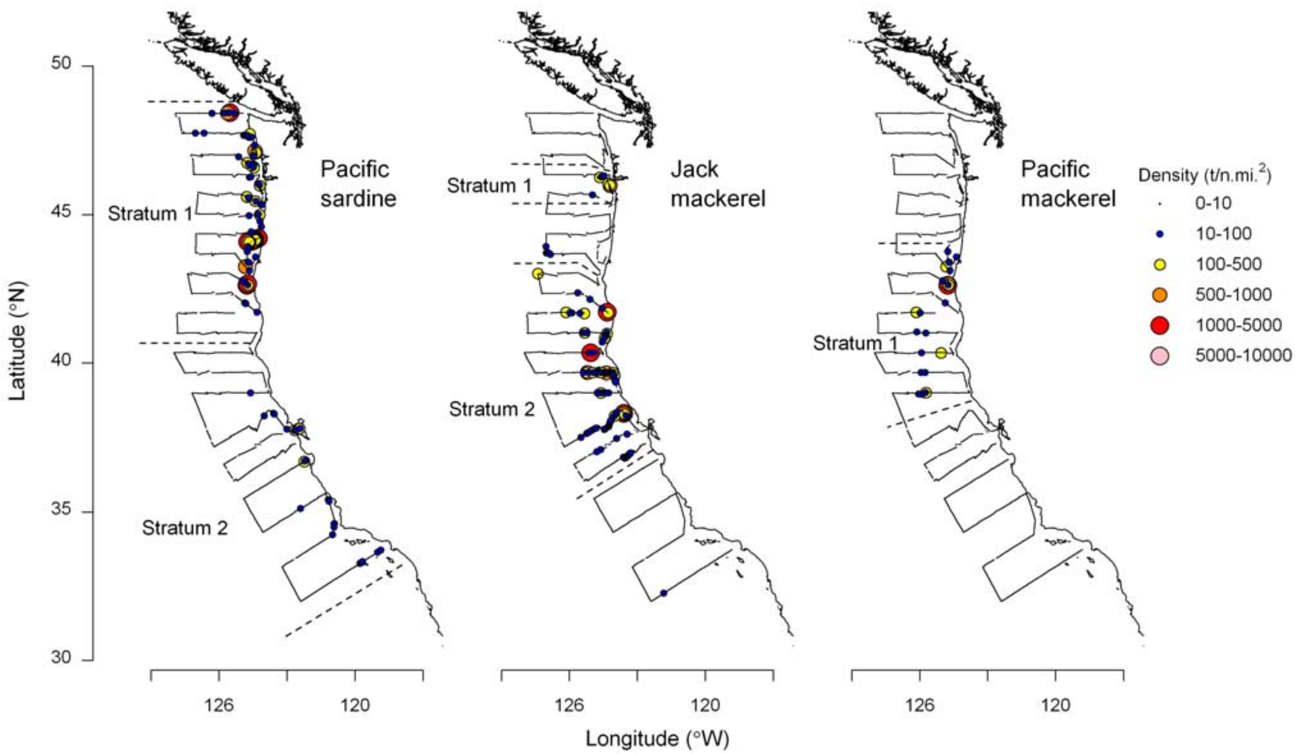
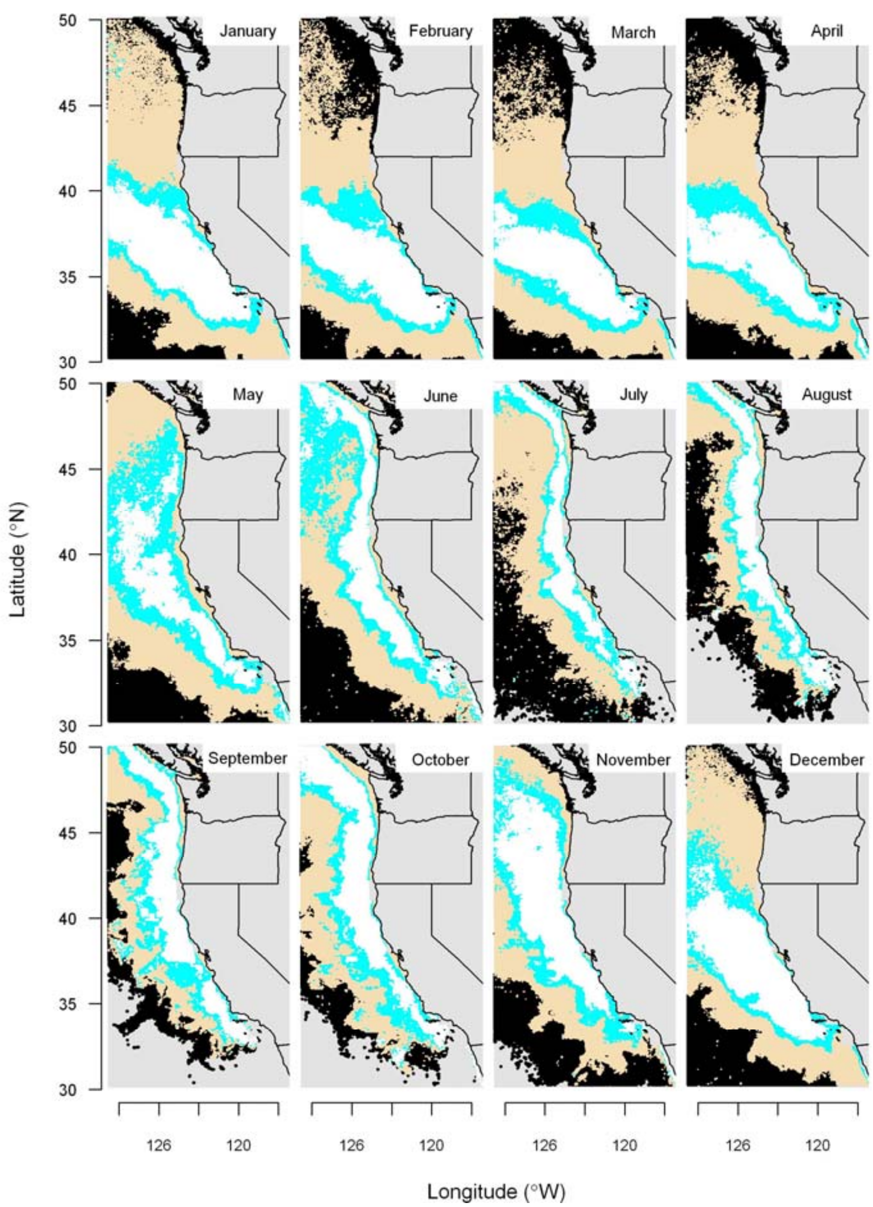


Figure 8. Average monthly distribution of the potential habitat of adult sardine in the CCE (Zwolinski *et al*., in-press). Optimal habitat (white) includes 80 % of the positive samples during the 1998 to 2009 surveys. Good habitat (blue) plus optimal includes 90 % of the positive samples; bad habitat (tan) plus good plus optimal includes 99 % of the positive samples; and unsuitable habitat (black) includes < 1 % of the total positive samples not included in the other classes. There are no data (grey) in other areas. The model accurately predicts the habitat of sardine, irrespective of their spawning condition. In the spring, the habitat is located offshore of southern California. In the summer, the habitat is compressed along the coasts of Oregon, Washington, and Vancouver Island.



Appendix

The following is a primer on Pacific sardine in the California Current Ecosystem, relevant to acoustic-trawl surveys.

Distribution

There are two sardine stocks in the CCE, a northern and southern stock, distinguishable using serological techniques (Vrooman, 1964), water temperature (Félix -Uraga *et al.*, 2004, 2005), population dynamics, and spawning grounds (Smith, 2005). These two stocks do not overlap substantially, and are managed separately. The northern stock is the principal target of the US, and Canadian fisheries, and is thus the focus of the US stock assessment and the surveys described here.

During the late winter through early spring, the northern stock aggregates to spawn in the coastal region between Ensenada and Point Conception (Smith, 2005), typically off the continental shelf where micro and meso-zooplankton abundance are maximum (Lynn, 2003). During late spring and summer, the stock migrates north to the coastal feeding grounds, older fish migrating further north (Emmett *et al.*, 2005), and returns south offshore in the late fall (Zwolinski *et al.*, in-press). Age-one sardine may not migrate, instead residing year-round in coastal waters where they were recruited (Emmett *et al.*, 2005).

As in other eastern-boundary currents (Barange *et al.*, 2009), sardine in the CCE are highly mobile and adapted to the large ranges of temperatures and salinities associated with variable coastal upwelling. They are most prominent in the neritic and coastal regions, but seasonally exhibit excursions to 300 nautical miles offshore (Macewicz and Abramenkoff, 1993). Larger sardine tend to reside further offshore. Sardine and other clupeoids respond to oceanographic conditions, and, in the absence of predators and competitors, tend to aggregate near their prey in mono-specific, epipelagic (ca. 0 - 70 m depth) schools (Robinson *et al.*, 1995), comprised of similar-sized fish. Nevertheless, mixed-species schools are not uncommon (Gerlotto, 1993; Fréon and Misund, 1999).

Feeding

Sardine can filter-feed on phytoplankton and small zooplankton (Van der Lingen, 1994;) ranging in size from tens of μm (Garrido *et al.*, 2007) to a few mm (Emmett, 2005).

Although lacking teeth, they can also particulate-feed on larger prey, depending on their densities and types (Garrido *et al*., 2007; van der Lingen, 1994). However, because their gill rakers are not completely developed until they reach total lengths of approximately 100 mm (Scofield, 1932), small and large sardine generally feed on different prey.

Spawning

Sardine, like most CPS, are batch spawners and their eggs are fertilized in the water column (Blaxter and Hunter, 1982). Their fecundity is high, e.g., spawning more than 300 eggs per gram of female mass (Lo *et al*., 2009), and each individual produces several egg batches throughout a usually extensive spawning season.

Sardine spawning appears to coincide with times and locations with low upwelling, and associated seawater temperatures ranging from 13.5 to 16.5 °C (Zwolinski *et al*., in press). These areas and conditions provide adequate food supplies for adult sardine (Aceves-Medina *et al*., 2009) and their larvae (Lynn, 2003), and are conducive to nearshore retention of their eggs and larvae (Parrish *et al*., 1981). The peak spawning period is in spring, April and May, off southern California, but can occur from January until August, and in higher water temperatures. The extent of the spawning season appears to be related to the food available to the adults, both prior to and during the spawning season (Aceves-Medina *et al*., 2009; Garrido *et al*., 2008; Somarakis *et al*., 2006).

Sardine spawning aggregations persist for a few hours and are comprised of actively spawning females and a larger proportion of actively spawning males in advanced spawning conditions (Ganias, 2008; Zwolinski *et al*., 2006). Their eggs are positively buoyant and planktonic, but can take several hours to ascend near to the sea-surface. Sardine eggs hatch within 2-5 days, depending on the seawater temperature (Lo, 1986), producing juvenile sardine within two to three months.

The success of a reproductive season appears to be related to the joint contribution of three physical processes: enrichment, concentration, and retention (Bakun, 1996). Enrichment refers to high primary productivity. Concentration allows efficient consumption by the larvae. Retention keeps the larvae from being advected to open ocean where the food supply, and thus the probability of surviving, is low. Intense upwelling, although nurturing primary productivity, can result in sub-optimal feeding conditions

(Uehara *et al*., 2005). A moderately stable water column is thus needed for concentration of the food and successful development of larvae (Lasker, 1981). Sardine recruitment improves in warm periods, characterized by an expansion of their habitat (Lluch-Belda *et al*., 1992; Jacobson *et al*., 1995), low-intensity-coastal upwelling, and increased wind-stress-curl upwelling (Rykaczewski and Checkley, 2008).

Sizes

Sardine exhibit rapid growth and early maturation (Blaxter and Hunter, 1982), becoming mature during their first or second year of life. Increased maturity is associated with lower water temperature and higher latitude and population size. Sardine grow to standard lengths (*SL*) of 30 cm, and normally live for as many as 8 years (Butler *et al*., 1996).

Physiology

Sardine and anchovy are physostomous, possessing a swimbladder with a pneumatic duct to the stomach and an anal duct to the cloaca (Whitehead and Blaxter, 1989; Conti and Demer, 2003). Like other clupeoids, sardine inflate their swimbladders by swallowing air at the surface and by forcing it from the stomach through the pneumatic duct into the swimbladder (Whitehead and Blaxter, 1989). These swimbladder features allow them to perform rapid vertical migrations, typically rising to the sea-surface to feed at night (Cutter and Demer, 2008), and predominantly contribute to their high acoustic backscatter (Foote, 1980a).

Acoustic-trawl surveys of Pacific sardine (*Sardinops sagax*) and other pelagic fishes in the California Current ecosystem: Part 2, Estimates of distributions and abundances in spring 2006, 2008, and 2010

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Abstract

The abundances and distributions of epipelagic fish species in the California Current Ecosystem (CCE), from San Diego to Southern Vancouver Island, were estimated from combined acoustic and trawl surveys conducted in the springs of 2006, 2008, and 2010. Pacific sardine, jack mackerel, and Pacific mackerel were the dominant coastal pelagic species (CPS). Northern anchovy and Pacific herring were sampled only sporadically, rendering their estimates unreliable, but their biomasses were likely much lower. The estimates of Pacific sardine biomass compared well to those of the annual model-based assessments, confirming that the stock has been declining since 2006. During the same period, the biomass of jack mackerel has been stable or increasing; the uncertainty is mostly due to random sampling error. The estimated biomasses of Pacific mackerel in the study area were relatively low and variable. Future surveys of CPS in the CCE should benefit from: adaptive sampling based on modeled habitat; increased acoustic and trawl sampling, particularly of species with patchy and nearshore distributions and low biomasses; and directed-trawl sampling for improved species identification and target strength estimation.

Keywords: Acoustic, trawl, survey, sardine, anchovy, mackerel, herring, coastal pelagic species, euphausiids, krill.

Running Heads: Acoustic-trawl surveys of coastal pelagic species

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Introduction

The California Current Ecosystem (CCE) spans the west coast of North America. As in most upwelling ecosystems, the CCE has high primary and secondary productivity and consequently high biomasses of lower- and middle-trophic-level species. Four coastal pelagic fish species (CPS) appeared to sequentially dominate the epipelagic-fish biomass in the CCE: Pacific sardine (*Sardinops sagax*), hereafter sardine; Pacific mackerel (*Scomber scombrus*); jack mackerel (*Trachurus trachurus*); and northern anchovy (E*ngraulis mordax*) (Mason, 2004). Sardine dominated in the first half of the 20th century, then declined precipitously and the stock and the fishery collapsed. Jack mackerel were abundant for the next decade, followed by northern anchovy for about two decades, then Pacific mackerel for a decade. Sardine returned to dominance during the most recent two decades (PFMC, 2009). These alternations are driven by natural cycles in the climate and ocean conditions (Chavez *et al.* 2003), perhaps accentuated by fishing pressure (Radovich, 1982).

Fisheries-landing statistics may suggest changes in the structure of the CPS community, but they are not unbiased indicators of the state of the CCE (Cotter *et al.*, 2009; Pennington and Stromme, 1998). This is because landing data are affected by both natural variability and the market (Mason, 2004). For example, fishing effort is concentrated close to ports and the landing statistics are not necessarily representative of the CPS community in other areas. Consequently, the stocks of sardine and Pacific mackerel in the CCE are managed using single-species assessment models. Inputs to these models include catch-at-age statistics and data from fisheries-independent surveys utilizing the daily-egg-production method (DEPM), aerial, trawl, and larval sampling (Crone *et al.*, 2009; Hill *et al.*, 2009). To improve the sardine assessments, managers called for additional fisheries-independent abundance estimates to include in the model (Hill *et al.*, 2006). In response, an acoustic-trawl method was developed and used to survey the abundances and distributions of the dominant CPS in the CCE (Demer *et al*., this issue).

Acoustic-trawl surveys, conducted periodically and synoptically over the scales of the stocks, can simultaneously provide biomass estimates of multiple managed and monitored species. Data from these multi-species surveys could facilitate tracking of the community structure and allow a precautionary (FAO, 2003), ecosystem approach to fisheries management (Rice *et al.*, 2005). See Demer *et al.* (this volume) for the technical details of acoustic-trawl surveys in the CCE, and an example application during summer 2008. This paper includes the results of three additional acoustic-trawl surveys conducted in the springs of 2006, 2008, and 2010; and a discussion regarding apparent trends in the estimated abundances and distributions of the currently most abundant CPS.

Methods

Three acoustic-trawl surveys of CPS were conducted off the west coast of the United States of America (US) in the springs of 2006, 2008, and 2010. The surveys were conducted from NOAA survey vessels *Oscar Dyson* (2006), *David Starr Jordan* (2008), and *Miller Freeman* (2010), and a contracted fishing vessel *Frosti* (2010). The surveys extended south to the Mexican border, and north to the westernmost part of Vancouver Island, Canada, in 2006, and to the Strait of Juan de Fuca in 2008 and 2010. The transects extended to 250 n.mi. offshore, south of Point Conception, and to 140 n.mi. offshore, further north. Transect spacings varied between 40 and 80 n.mi., with denser sampling off southern California, the area of higher expected biomass (Zwolinski *et al.*, in press). See Fig. 1 in Demer *et al.* (this volume) to view the generic survey design.

Acoustic sampling

Measurements of volume backscattering strength (S_v; dB re 1 m^{-1}) and target strength (TS; dB re 1 m^2) were made using calibrated echosounders (Simrad EK60) configured with split-beam transducers, and operating at 38, 70, 120, and 200 kHz (*Jordan* and *Frosti*), 18, 38, 70, 120, and 200 kHz (*Dyson*), and 18, 38, 120, and 200 kHz (*Freeman*). The echosounder systems were calibrated immediately prior to the surveys using a 38.1 mm diameter sphere made from tungsten carbide with 6 % cobalt binder material (Foote, 1983). Throughout the surveys, pulses of 1024 μs were transmitted at least every two seconds (every 0.5 s in 2006). Transmit powers were 2000, 2000, 1000, 500, and 100 W at 18, 38, 70, 120, and 200 kHz, respectively. Received powers were sampled every 256 μs, indexed by time and geographic positions, and recorded in .raw format, to at least 250 m range (500 m in 2006). The daytime data attributed to CPS were mapped (**Fig. 1**). Further details of the acoustic sampling are provided in Demer *et al.* (this issue).

Trawl sampling

Each night during the survey, beginning 30 to 60 minutes following sunset, as many as four surface trawls were set to sample CPS for the purposes of estimating species and length compositions. The trawl, a Nordic 264 with floats on the head rope, was towed at a nominal speed of 3.5 kts. The trawl catches were mapped (**Fig. 1**). On four occasions during the 2010 survey aboard *Frosti*, the floats were removed and the net was set on midwater targets. The net was directed to the depth of schools with the aid of a Scanmar "Trawleye" and a net sounder. Further details of the biological sampling are provided in Demer *et al.* (this issue).

Data analysis

The integrated volume backscattering coefficients (s_A; m^2 n.mi.$^{-2}$), sampled during the daytime and attributed to CPS (see Demer *et al.*, this issue), were apportioned to each target species based on the proportion and sizes of the species in the nearest trawl (**Fig. 1**). For each target species, the survey area was post-stratified into one or two regions with similar biomass density and transect spacing. The strata were bounded in the north and south by lines parallel to the transects (**Figs. 2-4**). The strata were bounded in the west and east by the offshore limits of the transects and by the coast-line, respectively. The large inter-transect distances ensured that the mean biomasses estimated for each transect were uncorrelated and could be considered as independent measures of the biomass in each strata. This independence was confirmed through an analysis of cross-correlation (not shown).

Only daytime acoustic samples contributed to the biomass estimates, as the nighttime data were considered negatively biased for CPS. Confidence intervals (CI) and coefficients of variation (CV) were estimated from boostrap and jackknife resampling of both the acoustic and trawl data. Further details of the acoustic-data processing are provided in Demer *et al.* (this issue).

For use in the assessment models, the biomass estimates for each survey are accompanied by the relevant fish-length distributions (**Fig. 5**). These were estimated by averaging the length distributions from the individual trawl-length distributions. The length data were first averaged by transect, with each trawl being weighted by the proximate acoustically-estimated mean densities. Next, the transect-averaged length-distributions were averaged, using as weights the acoustically estimated mean densities for each transect.

Results

The spatial distributions of echoes attributed to CPS were similar to those of CPS caught in the trawls (**Fig. 1**). In all three surveys, sardine were the most prevalent species in catches containing CPS, the most commonly caught CPS, and they were the most abundant CPS in terms of catch weight (**Table 1**). Jack mackerel were the second most prevalent, followed by Pacific mackerel. The prevalence and abundance of Pacific mackerel were only about half and one-tenth of those for jack mackerel. Anchovy had low prevalence and abundance, except for one catch of more than 300 kg in 2008. Pacific herring were only caught in 2008, and then at low densities. The standard length (*SL*) for sardine ranged between the 11 and 27 cm and averaged approximately 21 cm. Anchovy were considerably smaller than sardine, while jack mackerel and Pacific mackerel were substantially larger (**Table 2**).

Occasionally, a few echoes classified as CPS were observed in the absence of positive CPS trawls. These echoes were generally semi-demersal, often in contact to the bottom, or in regions with unsuitable conditions for CPS and were assumed to be from other swimbladdered species such as hake (*Merlucius productus*) or rockfishes (*Sebastes* spp), which tend to inhabit deeper waters during the day. Daytime trawling samples directed at echoes in the upper water column were unsuccessful as fish avoided the gear.

The catches of sardine and jack mackerel were spatially correlated (**Fig. 1**). In contrast to their distribution during the summer of 2008 (Demer *et al.*, this issue), the sardine were located offshore of central and southern California in the spring. A few anchovy were sampled nearshore, mostly off Oregon and Washington (2006, 2008, and 2010), north of Monterey Bay (2006) and in the Southern California Bight (2006 and 2008). Pacific mackerel were found mixed with sardine and jack mackerel, mainly off southern and central California. Pacific herring were found nearshore, off Oregon, in 2008.

The biomasses of sardine and jack mackerel were estimated using a single stratum in 2006 and 2010, and two strata in 2008. Both species were widely distributed in the southern half of the survey area, and overlapped some. Compared to sardine or jack mackerel, Pacific mackerel were much less abundant and their distributions were much smaller. Pacific mackerel were caught in small numbers (**Table 1**) and they were only caught with sardine, jack mackerel, or both (**Fig. 1**). Their biomasses were estimated using a single stratum each year. Only a few trawl catches included Northern anchovy and Pacific herring (**Fig. 1**).

Sardine was the most abundant epipelagic CPS, and its biomass declined monotonically by 80 % between 2006 and 2010 (**Table 3**). This downward trend was corroborated by the model-based assessments (**Fig. 6**). Although the two time-series differ in the rate of decline, the confidence intervals for the acoustic-trawl estimates encompassed the assessment estimates.

Jack mackerel was the second most abundant species, but its biomass either increased or remained stable during the study period. Smaller confidence intervals and CV values are needed to be more certain of a change. Compared to both sardine and jack mackerel, the estimated biomasses of Pacific mackerel were much smaller and their CV values were larger. The prevalence of northern anchovy and Pacific herring in the catches was too low to allow reliable estimations of their biomasses (**Table 1**; **Fig. 1**). Nevertheless, based on the low prevalence in net catches, their biomasses were likely much lower than those of sardine, Pacific mackerel, and jack mackerel.

For sardine and jack mackerel, the large spatial coherence of the species proportions in the trawl catches made the random error due to trawl sampling negligible compared to that for the acoustic sampling. In other words, nearby trawl catches were likely to have similar species proportions, while the cumulative biomass densities were independent between transects. For Pacific mackerel however, the inconsistency of the trawl catches made the random error due to trawl sampling more important. For all species, the CV values were not clearly related to the number of trawls or the total length of the transects, but the sample size was too small (not shown).

Sardine exhibited a seasonal distributional pattern (**Fig. 2**), located to the south of Cape Mendocino and both onshore and offshore in the springs of 2006, 2008, and 2010, and to the north of this point and very close to shore in the summer of 2008 (Demer *et al.*, this issue). Similar to sardine, the distributions of jack mackerel suggest a seasonal migration. They are located primarily off the coast of California during spring (2006, 2008, and 2010) and north of San Francisco during the summer (2008). However, relative to sardine, jack mackerel were located close to shore in the spring and further offshore in the summer (**Fig. 3; see also Fig. 6 in Demer *et al.*, this volume**). As their biomass densities increased, so did their distributions. Pacific mackerel were located of central California in each survey (**Fig. 4**).

The sardine-length distributions were void of age-1 fish, less than 15 cm in *SL,* and the modal lengths increased throughout the time-series (**Fig. 5**). Both the aging population and the decreasing biomass (**Fig. 6**) are indicative of successive poor recruitments.

Discussion

The acoustic-trawl surveys indicated that sardine and jack mackerel were the most abundant species in the CCE during the period from 2006 to 2010. In the springs of 2006, 2008, and 2010 (this study), the sardine were located primarily offshore of southern California. In contrast, during the summer (Demer *et al*., this volume), they were compressed along the coast from northern California to Washington. These findings are consistent with the predictions of seasonal changes in potential sardine habitat in the CCE (Zwolinski *et al*, in press). Moreover, the seasonal dynamics of potential sardine habitat appears to be related to the migration of jack mackerel, which were mapped in the warmer margins of sardine potential habitat, as it is recurrently depicted from the egg distributions observed during the CalCOFI spring surveys.

The CV values for the estimates of sardine biomass varied between 22 and 44 %, followed by jack mackerel that were typically about 40 %, and by Pacific mackerel with values of up to 100 %. Sardine had the lowest CV values, indicating they were more homogeneously distributed than jack mackerel and Pacific mackerel. The low biomass values and the large patchiness of their distribution explains the high CVs of Pacific mackerel. The current data provides no general relation between the degree of coverage, both in terms of trawls or transect length per unit area and the precision of the survey estimates. Optimization of future surveys for a desired precision would thus require simulation studies of various biomass levels, possible distributions, and sampling strategies (Simmonds and Fryer, 1996), constrained with information from a larger time series (see Simmonds *et al*., 2009).

The confidence intervals for the acoustic estimates of sardine encompass the estimates from the annual assessments (Hill *et al*., 2009). Both sets of estimates show that the sardine biomass has declined since 2006. The gradient is steeper for the acoustic estimates, versus the assessment estimates, but it is plausible considering annual natural mortality rates between 0.3 and 0.5 (Hill *et al*., 2009).

Jack mackerel were mapped to the south of, or in the same areas as sardine. This pattern is similar to that observed in spring surveys of fish eggs (http://swfsc.noaa.gov/textblock.aspx?Division=FRD&id=16135). Since 2006, the jack mackerel population appears to have remained constant or has grown slightly, but there are no independent measurements for comparison. If the biomass of jack mackerel is increasing while that of sardine is decreasing, the stock dynamics in the CCE may be mimicking those in the early 1950s (Mason, 2004; Smith and Moser, 2003). It is premature to claim an inverse relationship between the abundances of these two species, but attention should nevertheless be paid to this hypothesis. Jack mackerel are omnivorous feeders, and sardine eggs, larvae, and small juveniles can be part of their diet (Emmett and Krutzikowsky, 2008). Therefore, it is important to continue monitoring CPS in the CCE, and to conduct a comprehensive trophodynamic study of the epipelagic community in the CCE.

The biomass estimates for Pacific mackerel were highly variable and typically less than 50 000 t, while the current total-stock biomass is estimated in excess of 280 000 t (Crone *et al*., 2009). This discrepancy is because the majority of the Pacific mackerel stock likely resides south of the survey area, as far south as Cabo San Lucas (Crone *et al*., 2009). The acoustic estimates of biomass for the portion of the Pacific mackerel stock located off the

US coast are plausible given recent catches of less than 8,000 t annually (Crone *et al.*, 2009). The large CV values are indicative of patchiness. Therefore, to reduce both random and systematic error, the sampling effort should be increased, and the survey area should be extended farther south, and also more nearshore, particularly off southern California (Crone *et al.*, 2009; Moser *et al.*, 2001).

Northern anchovy were caught in a few trawls in each survey. Apart from the occasional large catches (~ 300kg) off the mouth of the Columbia River and other likely locations such as off Santa Barbara and Monterey Bay (Mais, 1974; Moser *et al.*, 2001), anchovy were scarce, even off southern California where they once were the most abundant species (Mais, 1974; Mason, 2004). Anchovy is currently a monitored species with a residual fishery and unknown abundance (PFMC, 2009). Similar to Pacific mackerel, the northern anchovy stock is likely small, but concentrated nearshore and not adequately sampled. To better sample the entire pelagic community, sampling should be increased over the continental shelf, where juvenile sardine, northern anchovy, jack mackerel, Pacific mackerel, and herring may coexist (Mais, 1974).

The alternations of dominance between sardine and northern anchovy have been linked to conditions in the CCE resulting from larger-scale meteorological and oceanographic phenomena (Chavez *et al.* 2003). An environmental regime initiated in 1989 (Hare and Mantua, 2000), may have allowed the resurgence of sardine in the 1990s (McFarlane *et al.*, 2000), while limiting the population of northern anchovy. For the past two decades, the conditions were stable enough to allow a large sardine population, and the fishery, to persist and expand throughout its historical geographic range. In recent years, however, the sardine biomass has again decreased precipitously (Hill *et al.*, 2009; this study). Changes in the abundances of pelagic fish occur rapidly and cyclically, so vigilance and rapid response are prudent actions for successful management (Radovich, 1982).

Relative to sardine and northern anchovy, little is known about the temporal and spatial dynamics of jack and Pacific mackerel biomasses and their roles in the CCE. This information gap can be filled with periodic, large-scale, quasi-synoptic, fisheries-independent, acoustic-trawl surveys. Time series for the biomasses of multiple species comprising the epipelagic community could facilitate an ecosystem approach to fisheries management in the CCE (Rice *et al.*, 2005). They could provide a scientific foundation for important management decisions, particularly during periods of increased environmental instability (FAO, 2003), such as now in the northern Pacific (Overland *et al.*, 2008).

Conclusion

This work provides, for the first time, fisheries-independent estimates of the abundances and distributions of multiple epipelagic CPS in the CCE. The results emphasize the value of acoustic-trawl surveys for the monitoring of CPS communities. The time series of sardine abundance, and perhaps jack mackerel, could be used in the annual assessments of the stocks (Hill *et al.*, 2006). Also, the estimated distributions and abundances of other CPS could be used to transition from single-species assessments to an ecosystem approach to fisheries management (Rice *et al.*, 2005). Future work should be done to reduce uncertainty associated with species identification, target-strength estimation, fish avoidance, net selectivity, and sampling time and location. Immediately, the survey design could be optimized to improve sampling, particularly of species with low abundances and located partially outside of the current survey area.

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Tables

Table 1. Species prevalence (ratio between the number of positive trawls for the species and the total number of positive trawls for all CPS); and species abundance (total cumulative catch weight for the species (kg), and the fraction of the combined CPS catch weight).

Year	Northern anchovy		Pacific sardine		Jack mackerel		Pacific mackerel		Pacific herring	
	Prev.	**Weight (fraction)**	**Prev.**	**Weight (fraction)**	**Prev.**	**Weight (fraction)**	**Prev.**	**Weight (fraction)**	**Prev.**	**Weight (fraction)**
2006	0.43	5 (0.08)	0.71	44 (0.68)	0.36	9 (0.14)	0.21	7 (0.11)	0	0 (0)
2008	0.18	532 (0.75)	0.59	103.4 (0.15)	0.23	61 (0.09)	0.23	3 (0.004)	0.09	6 (0.009)
2010	0.04	1 (0.00)	0.73	276 (0.54)	0.58	217 (0.43)	0.27	13 (0.03)	0	0 (0)

Table 2. Ranges, means, and standard deviations (sd) of fork (Pacific and jack mackerel) or standard (other species) lengths (cm) of the sampled fish.

Year	Northern anchovy		Pacific sardine		Jack mackerel		Pacific mackerel		Pacific herring	
	Range	Mean (sd)	Range	Mean (sd)	Range	Mean (sd)	Range	Mean (sd)	Range	Mean (sd)
2006	6.9 – 16.1	10.9 (2.4)	11.1 – 26.8	18.9 (1.8)	7.7 – 36.0	28.1 (5.3)	20.0 – 28.0	22.08 (1.6)	18	18 (0)
2008	10.7 – 14.8	12.5 (0.9)	16.3 – 25.9	21.2 (1.5)	28.0 – 58.0	39.6 (4.7)	27.5 – 34.7	31.9 (2.3)	16 – 18	17 (1.4)
2010	12.2 – 15.3	13.7 (0.8)	11.6 – 26.5	22.0 (1.5)	19.8 – 44.0	37.0 (4.3)	20.8 - 36.6	31.8 (3.2)	NA	NA

Table 3. Estimates of biomass for sardine, jack mackerel, and Pacific mackerel, and their coefficients of variation (CV) and 95 % confidence intervals (CI_{95}) versus survey year and stratum (see **Figs. 2 - 4**).

Species	Spring surveys	Stratum	Biomass (Mt)		CV (%)	CI_{95} (Mt)
Pacific Sardine	**2006**	1		1.947	32.6	0.780 – 3.205
	2008	1	0.047		47.0	0.015 – 0.098
		2	0.704		23.5	0.046 – 1.136
		1+2		0.751	22.3	0.501 – 1.183
	2010	1		0.357	44.4	0.097 – 0.694
Jack Mackerel	**2006**	1		0.285	44.3	0.055 – 0.416
	2008	1	0.078		33.1	0.034 – 0.135
		2	0.069		74.6	0.000 – 0.208
		1+2		0.147	41.0	0.054 – 0.303
	2010	1		0.323	40. 3	0.113 – 0.605
Pacific Mackerel	**2006**	1		0.047	100.0	0.003 – 0.229
	2008	1		0.018	63.6	0.003– 0.049
	2010	1		0.018	68.7	0.004 – 0.043

Figures

Figure 1. Acoustically detected CPS biomass densities (sampling unit = 10 - 70 m depth by 2 km trackline distance); and trawl catches including at least one CPS specimen (positive trawl) and no CPS (negative trawl). For each positive trawl, the proportion of each CPS is represented by the proportion of the area in the circle.

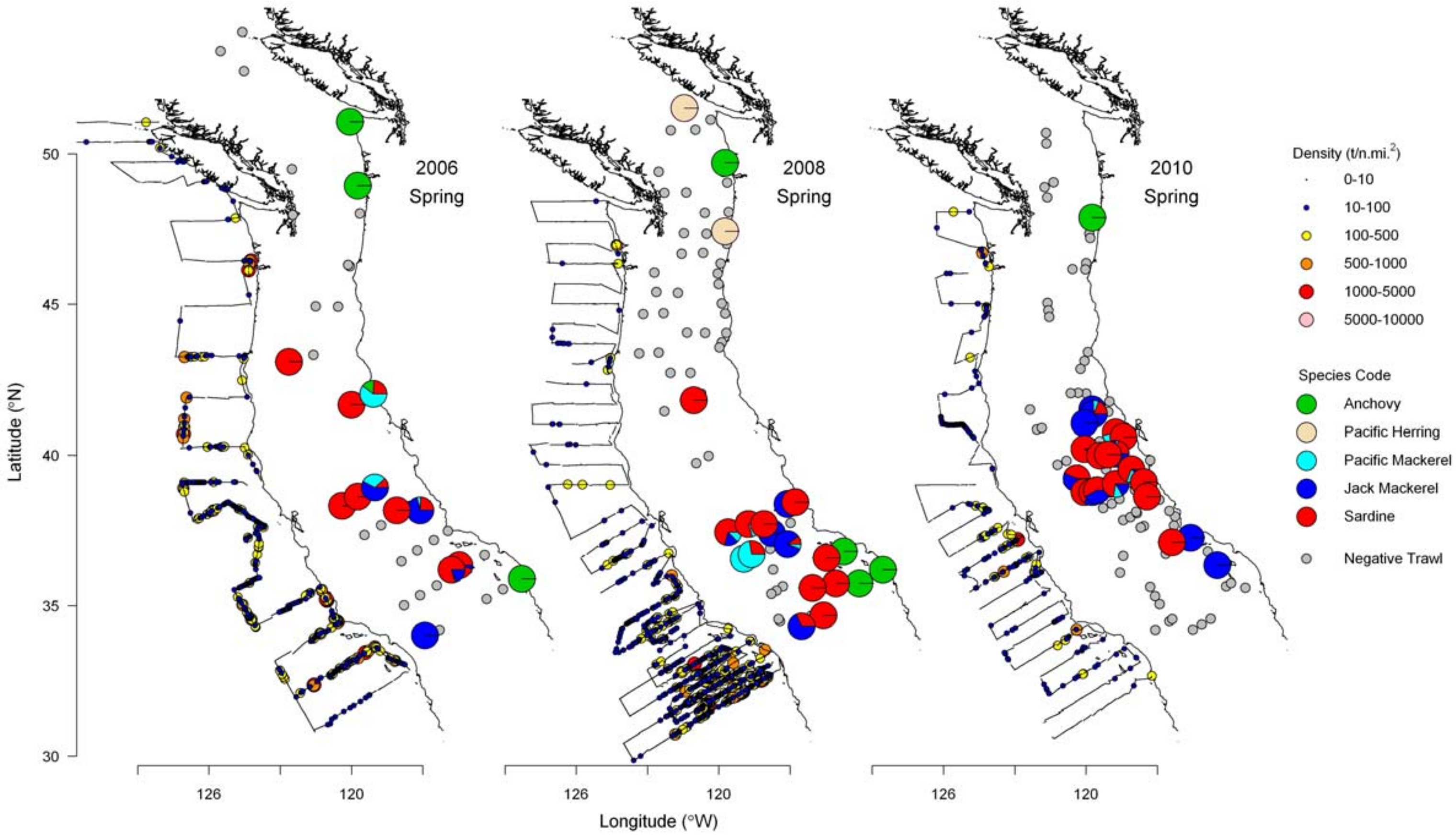


Figure 2. Sardine biomass densities estimated by combining the acoustic and trawl samples. The northern and southern boundaries of the strata are shown (dotted lines).

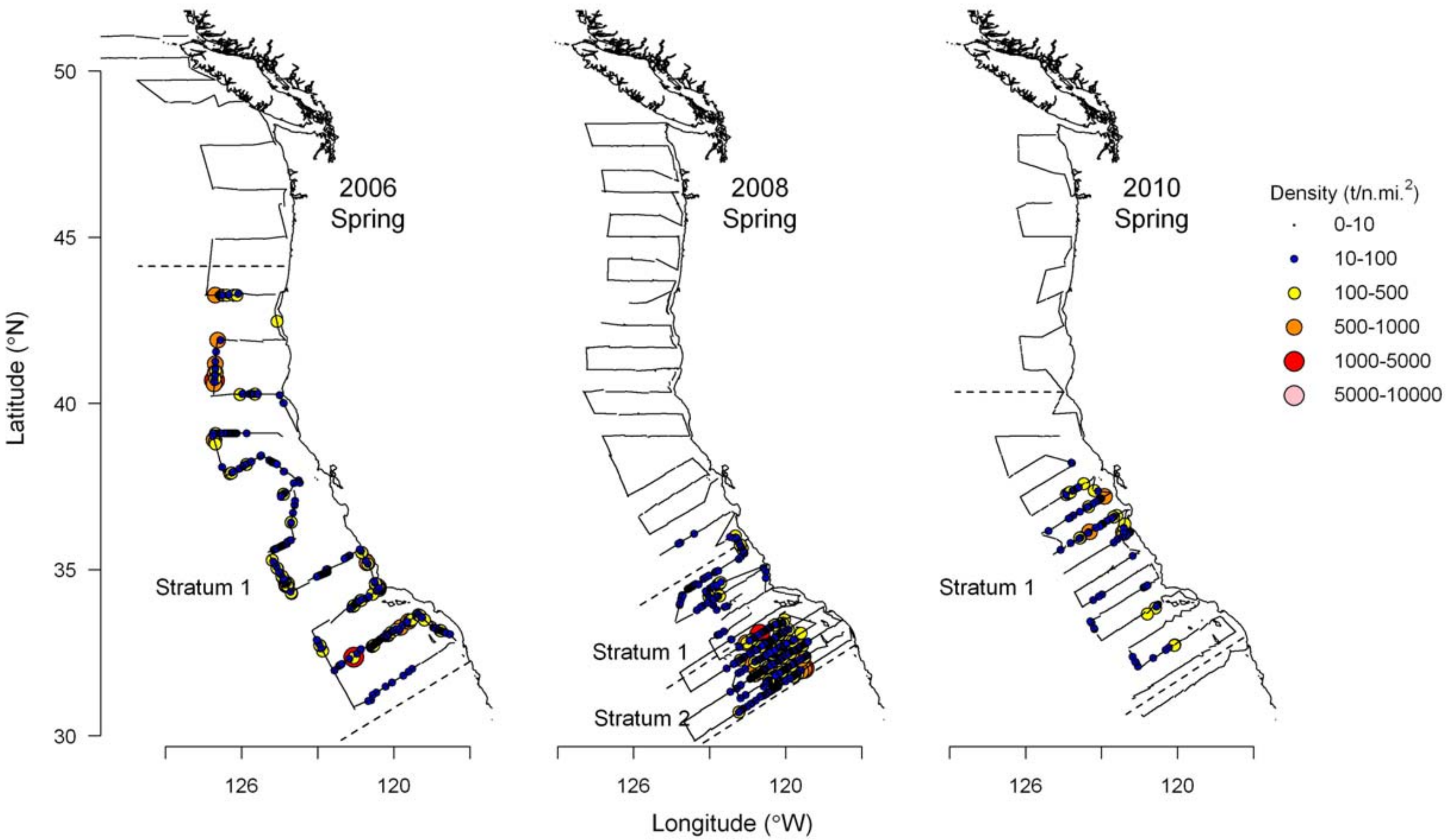


Figure 3. Jack mackerel biomass densities estimated by combining the acoustic and trawl samples. The northern and southern boundaries of the strata are shown (dotted lines).

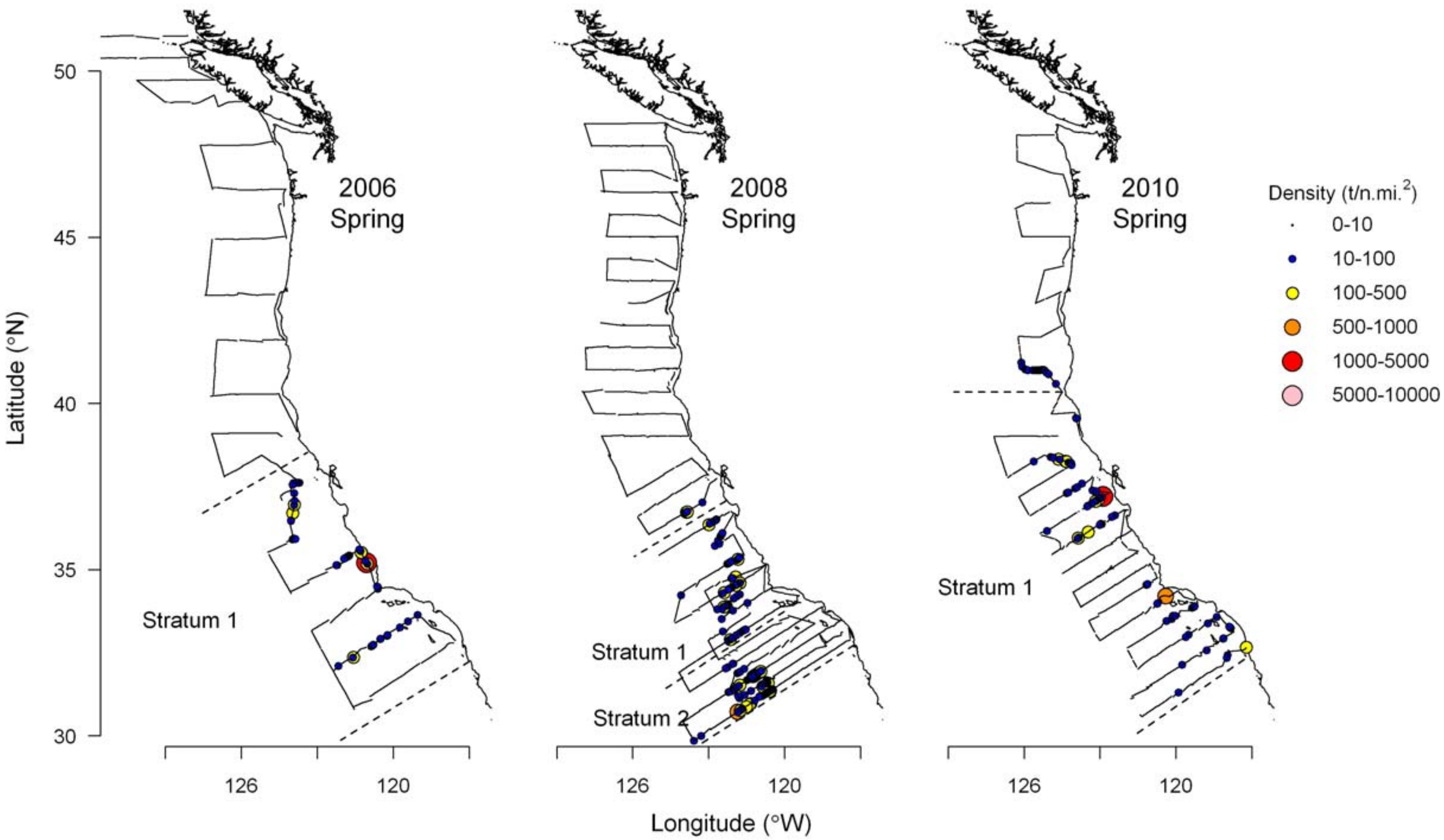


Figure 4. Pacific mackerel biomass densities estimated by combining the acoustic and trawl samples. The northern and southern boundaries of the strata are shown (dotted lines).

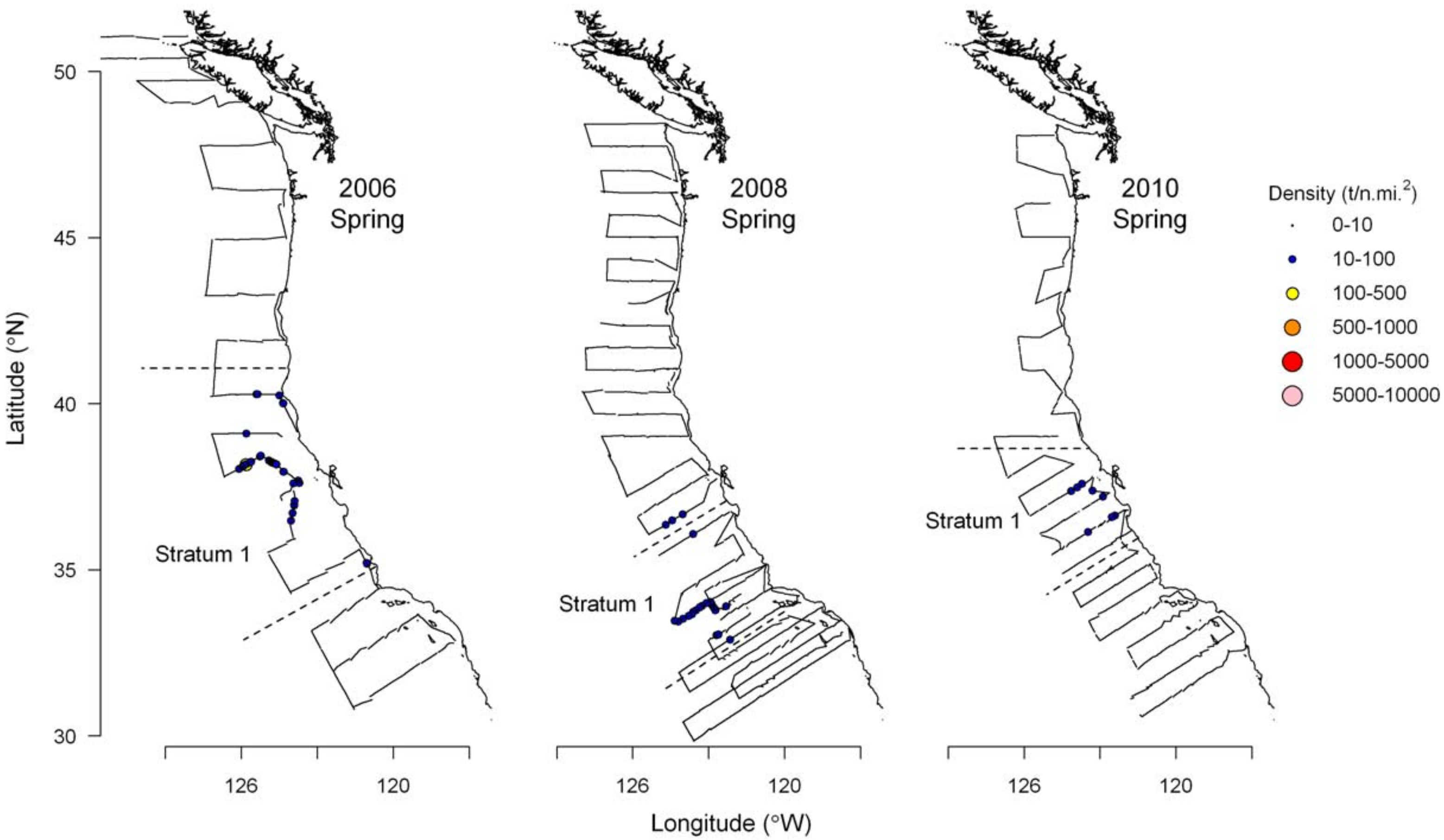


Figure 5. Estimated length distributions for the 'northern' stock of sardine in the CCE during the spring 2006, 2008, and 2010 surveys.

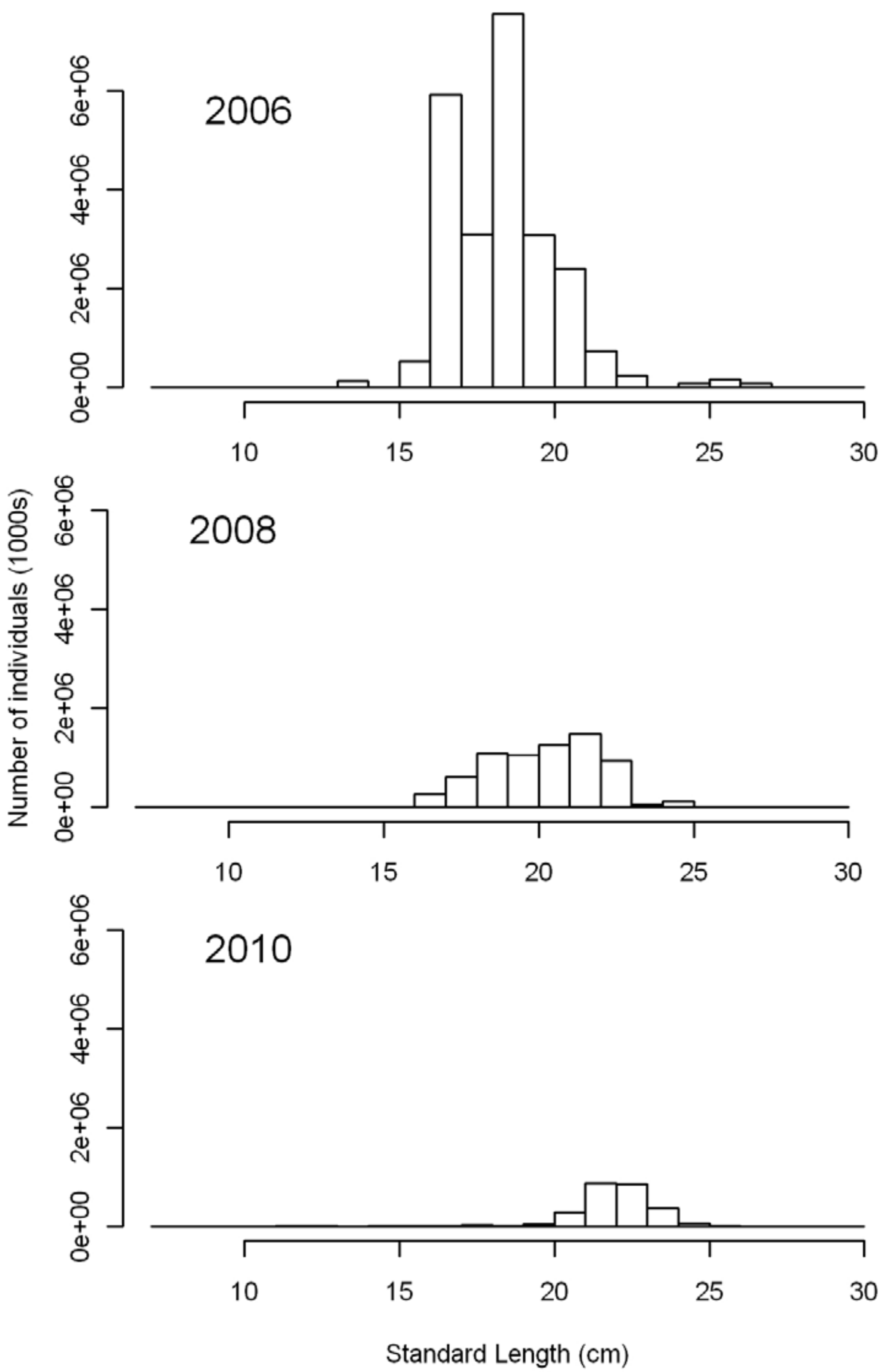
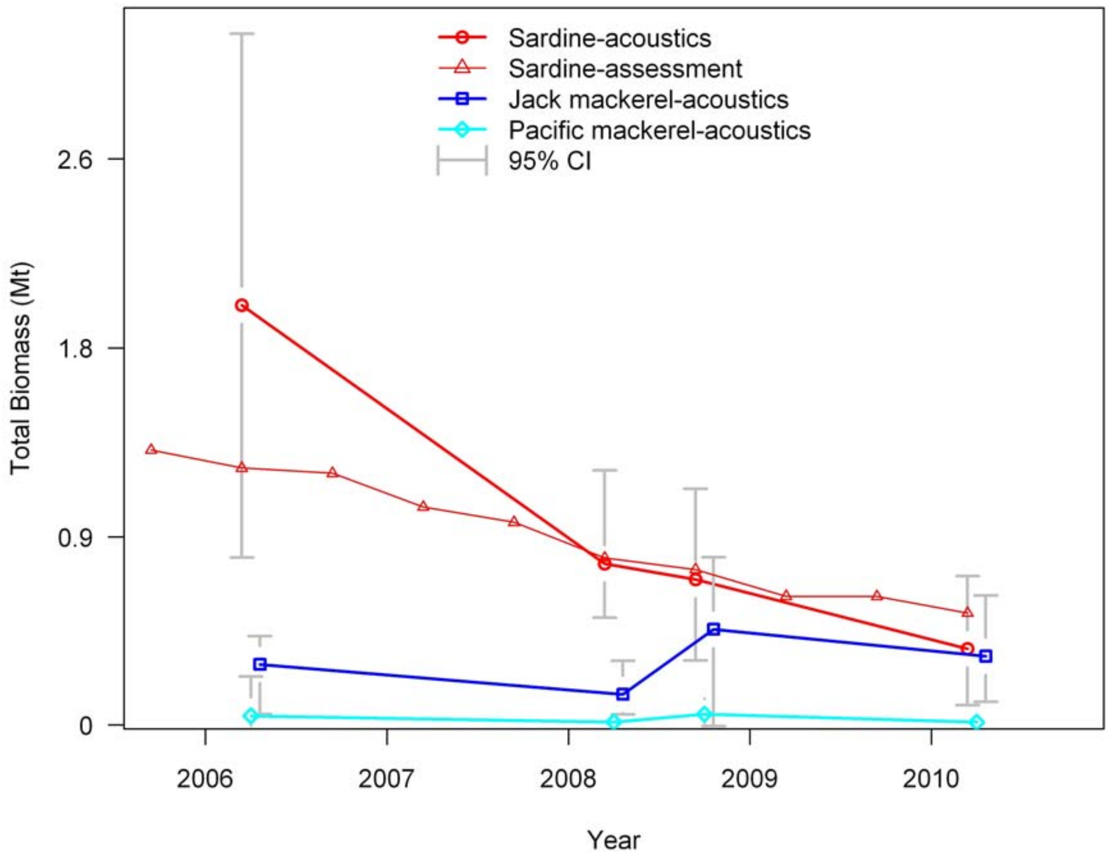


Figure 6. Evolution of the biomasses (Mt) of the most abundant epipelagic CPS in the CCE, estimated using the acoustic-trawl method, in spring 2006, 2008, and 2010 (this study), and summer 2008 (Demer *et al.*, this volume). The 95 % confidence intervals (95 % CI) are indicated. Superimposed are the estimates of total sardine biomass from the 2009 assessment (Hill *et al.*, 2009). The biomass estimates from the Pacific mackerel assessment were not included because the stock distribution greatly exceeds the sampling area, and estimates for the relevant sub-population were not available.



Center for Independent Experts (CIE) Independent Peer Review Report of Acoustic-Trawl Method Pertaining to Surveys of Coastal Pelagic Fish Species in the California Current Ecosystem.

NOAA / Southwest Fisheries Science Center
La Jolla, California
February 2-5, 2011

E J Simmonds

1. Executive Summary

The Chair identified six aspects that provided a focus for discussions during the review:

i. design of the acoustic and trawl sampling, representativeness of the data for the four CPS species;
ii. analysis of the survey data for estimating CPS abundances;
iii. evaluation of potential biases in sampling design and analysis;
iv. characterization of uncertainty in estimates of CPS biomass;
v. decision if acoustic-trawl estimates of CPS biomass can be used in stock assessments and management advice for Pacific sardine, jack mackerel, Pacific mackerel, and northern anchovy; and
vi. guidance for future research.

For orientation Dr Kevin Hill, SWFSC, gave a brief presentation of the most recent Pacific sardine stock assessment and management. Dr David Demer, Leader of the Advanced Survey Technologies Program (ASTP), SWFSC, gave a presentation of the acoustic-trawl method for assessing CPS, and this was followed by responses to several requests by the Panel for additional information.

The acoustic-trawl surveys also have the potential to provide estimates of fish distribution and behavior, as well as information for ecosystem-based fishery management. The review was, however, focused on the provision of abundance estimates and this report reflects that focus.

The ASTP prepared a thorough presentation, provided detailed background material, and were willing to respond to the Panel requests. They provided a highly competent review and presented information on all substantive aspects that required discussion.

In conclusion it is considered 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 acoustic-trawl surveys can be included in the 2011 Pacific sardine stock assessments as 'absolute estimates', contingent on the completion of two tasks; and estimates of jack mackerel and Pacific mackerel may also be useful in stock assessments and management. However, given the current size and abundance of the northern anchovy stock(s), the present surveys with fixed starting point and sparse transects cannot provide estimates of their abundance(s) for use in management.

2. Background

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. A Statement of Work (Annex 2) is established by the NMFS Project Contact and Contracting Officer's Technical Representative, and reviewed by the CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee. Further information on the CIE process can be obtained from www.ciereviews.org.

This independent reviewer was requested to participate in a panel-review meeting to conduct independent peer reviews of the acoustic-trawl method as it pertains to surveys of coastal pelagic fish species (CPS) in the California Current Ecosystem (CCE). The principal species for consideration is Pacific sardine, but the potential for also including jack mackerel, Pacific mackerel, and northern anchovy, depending on their biomasses and distributions, and the sampling effort afforded, was also to be considered. The survey area is the CCE off the west coast of the United States of America (US), generally between the Mexico-US and the US-Canadian borders. The latitudinal and offshore extents of the surveys are seasonal, extending further north in the summer and further offshore in the spring. Survey estimates are to include absolute biomasses, and their total random sampling errors, and spatial distributions. The review solely concerns technical aspects of the survey design, method, analysis, and results.

3. Description of the Reviewer's Role in the Review Activities

I am an expert in fisheries acoustics, assessment for pelagic stocks and their use in fish stock management. My background is that of a senior fisheries scientist working at European Commission Joint Research Centre (JRC), Ispra, Italy. I obtained BSc. and MSc. degrees in Electronics and Underwater Acoustics in UK. Before joining JRC I had worked in fisheries research for 37 years at FRS Marine Laboratory Aberdeen in

Scotland. I have worked with acoustic 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. I am author of a books on Fisheries Acoustics (1991 and 2nd Edition 2005). I have been responsible for developing approaches for combining acoustic-trawl, trawl and ichthyoplankton surveys in assessments for North Sea herring. I have worked on absolute assessments based on Total Annual Egg Production methods for North Eastern Atlantic mackerel. I have 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 I have 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 WG 1993-96, the ICES herring assessment working group 1998-2000, and the ICES study group on Management Strategies from 2004-2009. I currently chair the STECF group that prepares evaluations of historic performance of management plans and the impact assessments for new multi-annual fisheries management plans.

I participated in all aspects of the review, paying particular attention to survey design and effort allocation, calculations of total biomass and its variance, and the utility of the results as an absolute estimate or relative index of abundance within the current SS3 assessment for Pacific sardine.

4. Findings by ToR

4.1. ToR 1- Reporting

Review documents detailing acoustic-trawl survey and data analysis methods and results according to the PFMC's ToR for CPS Stock Assessment Methodology Reviews. Document the meeting discussions. Evaluate if the documented and presented information is sufficiently complete and represents the best scientific information available.

Two primary documents were provided; a) Acoustic-trawl survey and data analysis methods and b) Acoustic survey result. In addition, 22 papers or reports (listed in Annex 2) were provided as background for the work. The presentations commenced with background information from Dr. Kevin Hill and then the rest of the day was occupied with a detailed presentation by Dr. David Demer on the survey work. This occupied the full day during which several aspects were identified for further investigation and presentations. These additional aspects were prepared by the survey group and presented during the remaining two days.

From the evidence provided it is clear that the project team is of high quality and can be relied upon to carry out work to high standards. The two main documents are substantively complete and provide a good basis for evaluating the conduct and results of the surveys. The presentations were of a very high standard and substantively cover the work. The team responded to all questions in a helpful and highly competent manner.

There are a number of areas, given below, where increased detail could be provided both in the methods and the survey results reports. These suggestions should not be taken as substantive criticism of the standard of reports, rather there are a few points that would allow the work to be verified more quickly and to support the assertion that they are being conducted well should any challenge to the methodology occur.

4.1.1. Methods report

Separation of reporting into a standard methods document and an individual survey report provides a good basis for documentation. The methods part forms a formal document which provides the standards to which the survey is being conducted and the details of the methodology. Having a single complete document of this type provides an efficient and effective way to both define the way work is carried out and support its validity. Such an archive should not be regarded as a fixed document, rather the record of the current approach so that others may continue the work if the current staff move on or are redeployed. Thus keeping it up to date is an essential part of good survey practice. Within the current version there are a number of areas where more information would be beneficial.

Flow diagrams give a good basis for understanding the process. Some elements of these flow charts, such as density estimation, are explicitly documented with formulas, others do not have that clear documentation need to be expanded.

The description of the identification of CPS using the VMR, frequency ranges, and Sv range is complete but difficult to follow and needed quite a long explanation, The fact that this is used as a classifier for selecting S_v values at 38kHz (and other frequencies) could be stated explicitly. It could be improved by numbering processing boxes in the flow chart and giving numbered paragraphs and equations.

There is a need to explicitly provide the equations for variance estimation for clarify what is considered a 'sample' for both jackknife and bootstrap estimation methods. This would help to clearly show that it is collapse transect values that are used, and that between transect segments are excluded.

The TS equations and sources are stated as TS (biomass) versus length. The measurements imply a specific weight/length equation and thus condition factor (which is effectively reported in the cited paper) through TS/individual equations. It is necessary to check if this condition factor (which may change seasonally) is appropriate, and to decide which is invariate TS/kg or TS/individual given length.

An additional rather trivial aspect (not discussed) regards Echo-view processing. From the documentation the 'bad data' methodology in Echoview is used. The exact numerical treatment of 'bad data' is not fully documented, the methodology in Echoview implies the need for slightly differing approaches depending on the basis for bad data classification. i.e. whether 'bad data' samples are classed as 'taken = zero' or 'taken unknown' or 'not taken'. In this case the classification appears to be 'not taken', while Echoview treatment is 'taken = zero'. This aspect just needs clarification, but its impact on the results is thought to be negligible.

4.1.2. Survey results report

These reports provide a very good report of the surveys, tables and plots are sufficient to document the results for biomass. There are a number of minor additions that should be included.

Length: The original reports did not contain length distributions by number or biomass. These should be supplied. Currently this is probably the method by which acoustic results may best be related to the assessed population.

Calibration results: The survey reports should include calibration values and comparison with previous years

Correlation analysis: A representation of correlation of acoustic data should be plotted.

4.1.3. Conclusions to reporting

The reports and presentations provide an excellent basis to evaluate the performance of the acoustic-trawl survey. They are of a high standard and require only minor improvements which are detailed above.

4.2. ToR 2 –Evaluation

Evaluate and provide recommendations on the survey method used to estimate the abundances and distributions of Pacific sardine and other CPS, and associated sources of uncertainty. Recommend alternative methods or modifications to the proposed methods, or both, during the Panel meeting. Recommendations and requests to FRD for additional or revised analyses during the Panel meeting must be clear, explicit, and in writing. Comment on the degree to which the survey results describe and quantify the distributions and abundances of CPS, in particular Pacific sardine, and the uncertainty in those estimates. Confidence intervals of survey estimates could affect management decisions, and should be considered in the report.

4.2.1. Stratification / Transect design

The issue: does the current survey design and allocation of sampling effort spatially meet the objectives of the survey. Sampling must be designed to give representative information (acoustic and trawl) from which total abundance can be estimated.

Current approach: utilizes existing egg surveys designs for both spatial coverage and trawl data. Thus the design is not been chosen explicitly to carry out just an acoustic survey. The survey transect design is close to regular, but with higher effort, reduced transect spacing, in some areas of expected high abundance. Abundance is estimated by equal weight of transect abundances within strata and variance by bootstrap.

Comment: here I address estimation within the area surveyed, and the issue of selection of limits to the area is discussed below.

Abundance estimation: An equal spaced parallel transect design normal to the line of the coast with uniform spacing within any prior identified strata will give good abundance estimates and is preferred over any randomization of transect spacing. The rate of change of expected density might be expected to be greatest normal to the coast line, with generally greater continuity in the along coast direction. Thus sampling with the highest sample rate (along track) is expected to yield best results if the track is normal to the coast. Formally if the survey is to provide an 'absolute estimate' a random starting point is required (to give a probability that samples can be obtained from all locations). If for logistic reasons a random start is not possible, then there is a necessary condition: fish location must be assumed to be unrelated to geographical features on the scale of one transect spacing. This condition is probably an acceptable assumption for sardine and jack mackerel as the populations are extensive in geographical extent and mobile seasonally. However, given the sparsity of transects and small scale of coastally located stocks of Northern anchovy, I think this would not be case for this species. If an absolute estimate of Northern anchovy were required, either effort in those areas should increased (which could be considered anyway for other reasons) or for the current distribution of effort a random start would be required, though at this level of coverage the variance would be expected to be high. In order to provide an index of abundance, a fixed starting point for the grid is sufficient.

Variance estimation: for the transect sampling can be obtained via a variety of methods. As acoustic sampling for density is almost exhaustive along the transect (at 0.5 s per transmission and 10knots samples overlap by about 25m depth) a collapsed transect method that assumes measurements along the transect are effectively without error is an acceptable assumption. As the sampling is regular (non random transect placement) variance estimation requires checking for or including the effects of autocorrelation in the data. As an echosounder is capable of delivering independent samples on adjacent transmissions, an autocorrelation can be considered as a property of the fish stocks. In this case observed autocorrelation would indicate that the spatial structure of the stock was being well captured, however, simple treatment of variance calculation would overestimate the variability. The current approach is to identify one or two strata that form the main region of the distribution, check for significant autocorrelation and when it is found to be non significant, to use a classical variance estimator. This post stratification has a small influence on the variance estimation, formally for the classical estimator it would result in underestimation of variance, as placement of strata boundaries depend on observations, however, without the strata is likely that correlation would be significant and an appropriate variance estimator, such as kriging estimation variance, would be lower than the classical estimator. Overall the approach is an acceptable approximation.

Conclusion: I consider that the current spatial allocation of transects allows abundance of CPS and variance of spatial sampling to be estimated. While not necessarily optimized, the current approach is adequate for estimation of sardine in the area surveyed, but not all of the species in the CPS can be estimated to the same quality. The survey is currently able to provide estimates of Pacific sardine and jack mackerel for the area covered. Rather imprecise estimates of Pacific mackerel are also possible; estimates of Northern anchovy and Pacific herring (not included in the review but included in the reports) should be treated with caution.

Improvement: For the survey design to be improved in the short term there is a need to determine if the survey objectives should include the full set of main CPS species or concentrate primarily on sardine. If there is a requirement to obtain abundance estimates of Northern anchovy and Pacific herring, some change of design is required.

The potential for using stratification of effort to obtain improved estimates of Pacific sardine is clearly demonstrated in the documents provided. Such an approach would have benefits in improving the precision of the sardine estimates, though this may have costs for the evaluation of other species. Stratification would need to be based on estimations of habitat that would be specific to season and year. There is evidence to suggest that some of this could be derived from data sources, such as satellite data, prior to the survey, but potentially could also be adapted during the survey from water mass observation during the survey.

If the survey is to be multispecies or ecosystem based, further work would be required to determine if stratification would be successful, or if a uniform spatial distribution of effort is optimal for a diverse range of objectives.

If the survey can be directed at a smaller area there is potential for increased sampling effort to reduce variance (auto correlation will also increase); however, this will require more complex variance estimation.

Currently I expect the transect design to deliver a good estimate of the abundance, however, its formal basis is not clearly defined and adequate variance estimate. It the reports reference is made to methods in Jolly and Hampton (1990), Petigas *et al.* (2003), Demer, (2004) and Simmonds *et al.*, 2009. However, these publications have a different statistical basis in their treatment of spatial autocorrelation, thus it is not fully clear what process is being followed. The report states that, “The current survey design ensures that the mean acoustic backscatter is independent between transects, which permits statistically-unbiased estimations of mean biomass densities and sampling variances for target species.” However independence between transects is not a precondition of unbiased estimation, or sampling variance, though it will affect the method of variance calculation. There is no suggestion that the estimation process is wrong. Correlation between transects is beneficial to the precision of the survey and it is something to aspire to, not attempt to show is not present. Accepting that the CPS distribution is spatially correlated is an explicit requirement for stratification and the advantage of regular transect designs. It would be preferable to fully embrace this aspect in the thinking as this will bring you a coherence of approach which is currently lacking.

4.2.2. Trawl sampling

The issue: do the current trawl samples provide information on species composition, size and weight as need for TS, abundance and biomass estimation.

The current approach: utilizes trawls obtained during the egg surveys to provide species proportions, length distributions, and weight at length. Trawls are generally on predetermined well spaced stations with the addition of some directed stations. The data is utilized to give species proportions that are applied to acoustic records of CPS, length and weight data to give TS and size information for calculating total abundance by size. The allocation method is through nearest neighbor method and variance uses jackknife.

Parameter Estimates: The results suggest that the region has considerable separation between species, particularly in summer, indicating that species proportions are relatively well established. Although nighttime catch rates may not fully match daytime observations this is considered to be a minor issue for Pacific sardine and jack mackerel because the areas occupied by these species are generally homogeneous, particularly in the summer survey. Though there are some concerns that in the minority parts of the area where mixtures are observed species selectivity of the gear may be an issue. There are potentially issues for size selectivity in the small parts of the areas where 'O' group sardine are caught.

In the short term if estimation of the full range of species is required, increased trawl effort will be required in areas dominated by minority species. It may be possible to identify if there are gross 'species selectivity' issues for the major species by comparing the ration of catch rates and acoustic abundance in areas where single species dominate.

Sampling for size and weight is limited to a maximum of 50 per species per haul. Reports indicate that even for sardine the numbers of individuals measured and used to estimate length can be quite low. The analysis procedure uses nearest neighbor allocation; this approach implies that within station sampling error is low or negligible, given that some positive hauls can have very few fish this may not be an appropriate assumption. It may be preferable to use weighted averages from several hauls to account for numbers of fish.

Variance estimation for trawl sampling is obtained through the use of a jackknife procedure, hauls taken are removed one at a time and the survey recalculated with the remaining set allocated to their area of influence accounting for the missing haul. This procedure mimics the concept that a haul in a location may or may not be taken. It intuitively represents the right kind of sampling uncertainty. However, for a single removal jackknife there is a requirement to inflate the variance to account for the number of stations. This has not been done and it is not immediately obvious that this inflation can be fitted neatly into the integrated variance procedure due to the complex interaction of different factors. Thus the current method underestimates the variability associated with hauls. A number of potential approaches could be considered.

1. The most complex: Fit a multivariate surface for TS and length distribution; calculate the residuals; bootstrap these residuals over the surface
2. Move from nearest neighbor to weighed averages within a zone of influence, bootstrap the observations (multiple draws of same haul changes weighting).
3. Determine the number of hauls (n) to be removed randomly in the jackknife in order that variance inflation is not required. Check if the procedure can cause problems if mostly adjacent hauls are removed simultaneously, if so remove the n hauls from within n equally sized latitudinal groups.

The first of these is formally the best but the most complex and dependent on the model fit. The other two are simpler and probably adequate for what is thought to be a minor source of variance. Option 2 would be selected if the nearest neighbor method is replaced with an area influence weighting method. Option 3 would be appropriate if the current nearest neighbor method is found to be appropriate. There may be other methods not noted here.

Conclusion: The estimates are considered to be an acceptable method for estimating biological parameters, some exploration of other options and increased numbers of fish sample could be explored. An alternative variance estimation method is required.

4.2.3. Allocation of effort between trawl and transect data collection

Issue: Is the allocation of vessel time between trawl and transect data collection optimal.

The current approach: Currently the balance of time allocated to transect or trawl data collection is based on the needs of the egg surveys.

Comment: Currently the balance appears adequate to give useful results, though there may be potential for optimization in order to best meet the main objectives once they are specified. The current variance estimation could be utilized to obtain minimum variance estimates based on variance/effort relationships/assumptions. Some studies (Simmonds 1995, Simmonds 2009, Simmonds and Maclennan 2005) suggest that relating overall variance to effort reallocation between trawl and transect allocation results in a rather flat broad range of options with rather similar variance. This is because CV is follows a dependence on $1/\sqrt{n}$ giving a relatively shallow response curve for the two main sources of effort, and the minimum formed as effort is exchanged between them is not that sensitive to the choice. This suggests that optimization may not be a very critical issue.

4.2.4. Area coverage

Issue: Is the area (volume) covered by the survey correctly located and sufficiently large to substantively cover the distribution of the stocks of interest.

The current approach: The area evaluated is bounded vertically by the minimum depth limit of the acoustic system, and a maximum of 70m, latitudinally by ½ transect spacing to the north and south of the survey area and longitudinally by the coast and the outer limit of the transects.

Comment: this issue is addressed in three aspects: the vertical extent, latitudinal range (along coast), and longitudinal extent (both onshore and off shore limits).

Vertical extent: The upper limit is defined by the minimum range available from a 38kHz sounder mounted on a vessel. The evidence presented suggests the upper limit is appropriate, given the discussion of avoidance given below. The sounder systems used are capable of much greater ranges than the 70m maximum defined in the analysis, this appears to be appropriate and could easily be extended if required.

latitudinal range (along coast): Both surveys appear to cover the majority of the latitudinal extent of the distribution of sardine, anchovy, and jack mackerel, but evidence presented suggests this is not the case for Pacific mackerel. However, there is evidence of suitable habitat for sardine and some fisheries to the south and north that may be occupied, and there is also evidence of fisheries in these areas. The extent of potential habitat should be evaluated (by year) and compared with fisheries to try to determine how sensitive the results are to area boundaries. This is a necessary study to conduct before accepting the estimates can be accepted as absolute.

Longitudinal extend (on and offshore): From the information presented the offshore extent for spring surveys 2008 and 2010 appears to be appropriate for sardine and jack mackerel and anchovy, though there is some doubt concerning the 2006 survey for sardine. Currently estimates of the small section of the area between the transect ends and the coast are obtained from the transect means, however, evidence was presented (on request) concerning the abundance with off shore distance. This suggests rising densities of sardine towards the coast that might in some cases give 15% higher biomass. This aspect needs further exploitation. Although the distance from the cost is much less than a half transect spacing, the potential area estimated by transect ends, the existence of trend implies a need to evaluate this accounting for trend. Among others several options are possible:

- Develop a GLM (or GAM) to characterize trends and to use this to extrapolate the small missing segment.
- Krig the along transect data including data from the transect ends (Rivoirard *et al.,* 2000). Set the area boundaries into the area required, compare estimates for area bounded by transect ends with extended area (the advantage of this method is

it can potentially give an appropriate increase in variance accounting for sample locations via the geostatistical estimation variance).

- If the missing segment is very short an approximation would be to include the appropriate extra distance of track from the between transect values. This is the nearest available additional data.

The observations on distribution are supported by information provided from fisheries and some survey data from Canada. In addition information was provided by CPSAS representative regarding location an season of fisheries. Taking all of this into account the SWFSC group should evaluate the data in more detail and propose a method for inshore and seasonally related latitudinal extensions to the area of occupancy for Pacific sardine. The magnitude of the extrapolation by survey should be evaluated and presented separately, so its contribution to the absolute estimate can be checked.

4.2.5. Prescreening algorithms for extracting school data

The issue: The choice of method for the extraction of CPS echoes for the acoustic records.

The current approach: Utilizes variance mean ratio among several frequencies at fine scale and with 38kHz at a broader scale to separate CPS from other acoustic scatters, mostly plankton. The basis of this is the different pdf expected echoes from larger gas bearing targets from other non gas bearing or very much smaller organisms.

Comment: The general principle of extracting objects from daytime records and assigning these to individual or groups of species is a very well established approach for acoustic surveys. This is done manually by some practitioners (see PGHERS reports ICES 2007 and earlier) by directly picking out schools in a region or numerically using threshold and spatial continuity (Barange *et al.,* 1994) observed frequency response (Korneliussen and Ona, 2003). The current method utilizes the functionality of Echoview (Higgingbottom *et al.,* 2000). The method used here is based on a more formal approach, in terms of frequency ranges, though the spatial averaging at different stages is selected to match local situations. It appears to work well. As for most practitioners, variance estimation is not included.

4.2.6. Timing (day/night, school makeup)

The issue: Do the night trawl samples adequately provide information on species composition to be applied to daytime estimates of biomass.

The current approach: Samples from night trawls from predefined stations (with some additional stations) are used to obtained species proportions that are allocated through the nearest neighbor method to assign species proportions to schools extracted from the daytime acoustic records.

Comment: The use of night hauls to estimate species parameters for daytime observation on schools is not ideal. This method (day transect, night haul) is used elsewhere, for example in the eastern section of NS herring survey (ICES 2007 and earlier PGHERS repots). For other areas of the NS herring, fishing is on directed daytime hauls. This combined survey utilizing both methods is used in the ICES assessment of North Sea herring (Simmonds 2009).

The documentation shows that where CPS were acoustically mapped, and trawls were carried out CPS were caught in the trawls; where CPS were not acoustically observed, and trawls were carried out, CPS were absent from the catches. This is supportive of night catches being indicative of CPS.

Compared with directed fishing on schools in the daytime, there are some advantages and disadvantages to this approach.

Disadvantages of current method	Advantages of current method
1. Schools are not explicitly identified 2. If species distribute outside the fishing layer at night they may be missed, without this being apparent.	1. Mixed layers at night may contain more homogeneous species proportions, than individual schools 2. Catching at night may be more representative of size range as it involves less avoidance as fish don't see the net until it is very close 3. Catching at night may involve less species selection as fish don't see the net until it is very close; thus catches are less selective. 4. Catching success or probability during the day may be species specific so missed trawls may be species dependent, giving biased results.

In this particular situation, the key point is that the resulting species proportions obtained here show rather homogeneous areas with a single dominant species, which indicates that the species separation is particularly clear spatially so the allocation by species is rather precise. Acceptance that this approach is useful is highly dependent on the species separation that allows that conclusion. If the area were, in the future, to become occupied by multi species schools or more likely single species schools of different species, the use of this approach would need more attention. Under such circumstances, daytime fishing and school identification to species level might be required.

Improvement: In the longer term efforts should be made to evaluate if a change in fishing practices / gears would be beneficial. The objective would be to deploy a gear with the potential for daytime fishing. This would allow direct species identification to school level and could be supported acoustic identification to species level.

4.2.7. Trawl design-net, tow speed, etc

A rope trawl at 3.5knots which may have been the gear of choice on the older vessels now going out of service may not be the optimal choice for the new research vessels coming into service over the next few years. There are other options and some studies of pelagic fish capture; see, for example, Suuronen *et al.* (1997), McClatchie, *et al.* (2000).

4.2.8. Acoustic Equipment Specifications

The Simrad EK echosounder systems deployed to give primary abundance estimation are the scientific standard for marine acoustic surveys. A variety of sonars and multibeam scanners have been deployed to evaluate avoidance. There is no particular reason to prefer one over another except that simultaneous observation below and to the side of the vessel is required. There is a tradeoff in frequency; high frequency scanners provide better angular resolution giving improved spatial resolution but they are also more sensitive to fish directivity, making inference on relative fish abundance at angle more difficult to evaluate. It is very important to continue to collect data of fish distribution/ avoidance of the vessel.

4.2.9. Vessel avoidance

The issue: Do the CPS avoid the vessel and if so do the results of from vertical sounders give a biased estimate that is known to be to high or too low.

The current approach: A series of evaluations extensive of using scanning sonars have been carried out during the surveys. The results of these were presented. It was identified that avoidance occurs, fish schools are observed at deeper depths under the survey vessel than those seen to the side. That fish schools occur at shallower depths than those observed by the vertical sounder is in agreement with some observations by fishermen provided by the CPSAS representative.

Comment: Fish response to vessel passage has been documented for CPS found in other areas. If vessel passage causes fish to change their orientation in the water column, or exhibit some kind of consistent movement (avoidance or attraction), there is a potential for bias in abundance estimates from acoustic survey. Echosounders used in the CPS acoustic-trawl survey are mounted in or near the center of vessel and evaluations start at deeper than approximately 10 m. Sardines in particular are often found near the surface at least at some time of the year, and fishermen in the Northwest have noted strong avoidance responses. This is a critical issue to address when deciding how or whether to use the abundance estimates for stock assessment. The Panel considered the following information:

There is clear evidence that schools seen on the surface dive to at least 10m (Cutter and Demer 2007). This gives rise to concern that the abundance may not be correctly recorded. The technical team presented results from a number of studies using multibeam sonar mount sideways or downwards. Two aspects were studied, the distribution of schools and distribution of backscatter underneath and to the side of the vessel. Counts of presence/absence showed a sharp peak under the vessel, and a steady reduction with distance away from the vessel tract and depth, suggesting no increase in schools off track. Other studies with similar equipment on Mediterranean sardine increased schools off track (Soria *et al*., 1996). In contrast, Chilean sardine (Gerlotto *et al*., 2004) show no increase in school off track. The distribution of backscatter to the side of the vessel shows a similar pattern, but without the sharp peak directly under the transducer. The technical team also presented results from a study of schools passing through the echosounder that did not find evidence of differences in depth or backscatter from the front end of the school to the rear end of the school.

Based on these results it was concluded that there is no strong evidence of bias due to vessel avoidance; however, these results are not definitive and continued monitoring and analysis is critical to provide verification of validity of the survey.

4.2.10. Target strength

The issue: Do the target strength formulas used give a sufficiently accurate TS value that mean biomass will be unbiased.

The current approach: Three formulas coming from peer-reviewed papers are used to give TS – length relationships. The values used are standardized to 20 log slope, and use weight at length conversion to biomass

Comment: The published values are for the same species for sardine and should be a good starting point. There is less good data on some other species and there may be small differences. The use of a common function for Pacific mackerel and jack mackerel is of some concern. The reports quoted (Peña, 2008) are published but don't contain strong evidence for the similarity between these species. Some species of mackerel (*Scomber*) are very different from jack/horse mackerel (*Trachurus)* thus there is some basis for concern, in contrast both these species have swimbladders, and their body forms are more similar than for some others members of the same genus, supporting the use of same TS. However some non peer reviewed studies off the African coast have suggested differences between these species. The authors are encouraged to investigate TS values locally and particularly for pacific mackerel if this is to be used as an absolute estimate.

4.2.11. Hydrography

A very minor point: changes in hydrography occur throughout the area during the survey. The documentation suggests a fixed sound velocity and absorption used throughout the area, though the latitudinal extent of the area is extensive and has upwelling, these two suggest some variability. However, the dominant stock is shown to be close to the transducer and in a limited range of water type, thus implying less of an issue. It would be good to document the range of sound velocity (and absorption) to show this has been checked to have low impact in the context of range or equivalent beam angle dependence.

4.3. ToR 3

Evaluate and provide recommendations for the application of these methods for their utility in stock assessment models and for their ability to monitor trends at the population level for Pacific sardine and other CPS. Survey methods or results that have a flawed technical basis, or are questionable on other grounds, should be identified so they may be excluded from the set upon which stock assessments and other management advice is to be developed.

Use of acoustic-trawl survey data in stock assessments

This question is addressed specifically in the context of perceptions of the data already used in the SS3 assessment and the model formulation. Thus the recommendations are conditional on these aspects. Given a different model or other competing data sources the conclusion might be the same or different.

The acoustic-trawl data was considered for each of the four CPS species separately, noting that the information available differs markedly among these species and that the basis for the management advice differs between monitored and managed species. The focus for discussions was Pacific sardine, which is currently the species with the largest biomass. Not unexpectedly, there was less information for the other species and it is not possible to give such clear recommendations for jack mackerel, Pacific mackerel and Northern anchovy as it was for Pacific sardine.

The practice of using acoustic surveys as absolute estimates of abundance is different in areas. These differences depend both on the surveys and the other data in the assessment. In Europe the assessments are often hampered by uncertain historic catches (due to IUU fishing or discarding and slipping practices). These assessments are used primarily to advise on more on catch rates, quoting biomasses, but managing on F and 'virtual populations'. In these circumstances acoustic surveys for pelagic species such as herring are used as indices to tune VPA style assessments. Thus the survey might be absolute but the assessment is not. Using them as absolute might give poorer advice if historic catches are uncertain. Here the assessment requires some information on the absolute abundance, and inferring this directly from catch is difficult given the relatively low exploitation rate (~0.1), and the natural mortality (0.4). If an index is to be used the coefficient of proportionality (Q) for that series must be estimated in the model; for a short timeseries such as the Pacific sardine acoustic-trawl survey presented here, the power to estimate that Q will be low. The other data in the assessment do not come from very accurate measures of absolute abundance. As a series becomes longer the power to estimate Q will increase and it may be possible to clearly identify if Q=1 is appropriate. It is against this set of information that consideration of the use of the survey as absolute or relative is considered.

Pacific Sardine

Pacific sardine are an actively managed CPS species with an SS3-based stock assessment. Estimates of abundance based on acoustic-trawl data can be included in this stock assessment as absolute estimates of abundance or as relative indices of abundance.

For the survey method, the main area conclusions for are:

- The survey method is substantively sound.
- The variance estimate for the major source of uncertainty (transect data) is correct.
- The variance using jackknife estimator for trawl data needs revision (see above).

The major potential sources of uncertainty related to using the acoustic-trawl data are estimates of absolute abundance identified during the review were:

- The relationship between target strength and length are based on it situ measurements, but are taken from a different area.
- Sardine may avoid the vessel to some extent.
- Sardine are found outside of the area covered by the acoustic transects (north, south, offshore and inshore), with the proportion of the stock outside this area depending on season as well as environmental conditions.

Given the information provided, the first and second of these three sources of uncertainty are considered likely to be relatively minor (see Sections 4.2.9,10). Item three needs further evaluation (See Section 4.2.4).

Also, given current information, it is determined that the acoustic-trawl surveys can be considered estimates of absolute abundance for the survey area, and the assessment author should consider the use of these data in the September 2011 sardine assessment. Prior to the September 2011 assessment, analyses should be conducted using auxiliary information to provide best estimates for the biomass outside of the survey area as well as range of possible biomass levels. In addition, the CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.

Within this recommendation for use in the assessment, the following should be considered: (a) examine the sensitivity of the results to alternative acoustic-trawl abundance estimates, (b) determine whether assuming that the acoustic trawl indices are absolute indices of abundance lead to patterns in the residuals, (c) examine the implications of ignoring some or all of the acoustic trawl indices [e.g., the summer 2008 and spring 2006 surveys], and (d) treat these indices as relative measures of biomass.

In future STAR Panels, review any research conducted in relation to acoustic trawl surveys, and evaluate how these data are used to estimate absolute abundance, in the same way as is done for other indices.

Jack mackerel
Jack mackerel are a monitored CPS species. There are few recent data on which base estimates of abundance and distribution for this species. The acoustic-trawl survey data are the only scientific information on abundance for the area surveyed. Though there is less information available for this species than for Pacific sardine on the key uncertainties, the estimates of absolute abundance for the survey area can be used as estimates of the biomass of jack mackerel in US waters. The catchability for jack mackerel may not be the same as that for Pacific sardine. The estimate for summer may therefore be more reliable as the various CPS are more separated at that time.

Pacific mackerel
While there is no reason why the acoustic-trawl surveys cannot be used to provide estimates of abundance for Pacific mackerel, the estimates of abundance for Pacific mackerel are more uncertain as measures of absolute abundance than for jack mackerel or Pacific sardine. This is reflected by very high CVs for the spring surveys. A major concern for this species is that a sizable (currently unknown) fraction of the stock is outside of the survey area. While the estimates for survey area are valid, if the acoustic-trawl data are to be used to provide estimates of stock biomass, auxiliary information will be needed to estimate the annually varying proportion of the whole stock in the survey area.

Northern anchovy
There is also no reason why an acoustic-trawl survey cannot be used to estimate abundance for Northern anchovy. However, the current size of the population, along with its more inshore distribution, means that the present survey data cannot be used to provide estimate of relative or absolute abundance for Northern anchovy. A few Northern anchovy were sampled nearshore, mostly off Oregon and Washington (2006, 2008, and 2010), north of Monterey Bay (2006) and in the Southern California Bight (2006 and 2008). Apart from the occasional large catches (~ 300kg) off the mouth of the Columbia River and other likely locations such as off Santa Barbara and Monterey Bay, anchovy were scarce in these surveys, even off southern California where they once were the most abundant species. The sampling scheme would need to be modified (more transects and trawls in the areas where Northern anchovy are found) if estimates of abundance of Northern anchovy are needed given its current abundance.

4.4. ToR 4

Evaluate the effectiveness of the survey methods for detecting the appropriate spatial scale and seasonal timing for annually estimating stock abundances.

Pacific Sardine
Given current information, it is considered that the acoustic-trawl surveys can be considered estimates of distribution of abundance for the survey area. It is expected that the area survey covers the vast majority of Pacific sardine at the time when the surveys are conducted. There is a need for a number of analyses to be conducted using auxiliary information to provide best estimates for the biomass outside of the survey area as well as

range of possible biomass levels. In addition, the CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.

Jack mackerel

Jack mackerel are a monitored CPS species. The acoustic-trawl survey data are the only scientific information on abundance for the area surveyed. Even though less information is available for this species than for Pacific sardine on the key uncertainties, the estimates distribution by the survey area can be used for jack mackerel in US waters. The estimate for summer may be more reliable as the various CPS are more separated at that time.

Pacific mackerel

A major concern for this species is that a sizable (currently unknown) fraction of the stock is outside of the survey area. While the estimates for survey area are valid, and some information on distribution is available, if the acoustic-trawl data are to be used to provide estimates of stock biomass, auxiliary information will be needed to estimate the annually-varying proportion of the whole stock in the survey area.

Northern anchovy

The current size of the population, along with its more inshore distribution means that the present survey data cannot be used to provide estimate of relative or absolute abundance or distribution for northern anchovy. A few Northern anchovy were sampled nearshore, mostly off Oregon and Washington (2006, 2008, and 2010), north of Monterey Bay (2006) and in the Southern California Bight (2006 and 2008). Apart from the occasional large catches (~ 300kg) off the mouth of the Columbia River and other likely locations such as off Santa Barbara and Monterey Bay, anchovy were scarce in these surveys, even off southern California where they once were the most abundant species. The sampling scheme would need to be modified (more transects and trawls in the areas where Northern anchovy are found) if estimates of distribution of Northern anchovy were required.

4.5. ToR 5

Decide through Panel discussions if the ToRs and goals of the peer review have been achieved. If agreement cannot be reached, or if any ToR cannot be accomplished for any reason, then the nature of the disagreement or the reason for not meeting all the ToR must be described in the Summary and Reviewer's report. Describe the strengths and weaknesses of the review process and Panel recommendations.

The goals of the review have been substantively reached, and recommendations or answers have been made for each ToR. There was discussion on a number of important points. Had the reviewers operated separately they might have come to different conclusions; but with a discussion, the panel reached agreement, though there might remain some small differences between perceptions held by different members.

I found the review process generally of a high standard. It was important that the process included a meeting where initial differing opinions could be raised, discussed, and a consensus reached. I would particularly like to commend the chairman for very clear view of needs which focused the meeting well and the balanced way he summarized the views.

All the documentation required was provided. The performance of the Acoustic-Trawl Survey Technical Team was of a particularly high standard, providing good documentation, which was well presented and explained. Where additional studies were requested these were provided efficiently and presented professionally.

It is perhaps necessary to recognize an aspect of the review process. The Acoustic-Trawl Survey Technical Team provided information of a high standard, and all information presented was based on data collected and published methods mainly from peer reviewed material. This is as it should be. However, some participants gave opinions or made assertions without the same level of verification and references required of the Technical Team. This is the nature of the review process, in that the forum involves non-experts and non-scientific members on the committee. I do not find this a problem, nor to I think it can or should be changed, but it does need to be recognized that different actors participating in the process are subject to different requirements. Provided this is clearly understood by those who read the review, it does not constitute a problem.

While generally the meeting facilities were good, two aspects presented a problem. First, access to the meeting room on Saturday was not fully supported by the institute, and this led to problems for at least one person (observer) who missed a session. Second, there were considerable technical difficulties with the network access provided by SWFSC, as this was barely functional, requiring additional printing and making exchange of documents difficult.

I was impressed overall with the quality of this review and all who participated in it, and I would like to thank all involved for their efforts. In particular, I would like to thank the Chairman for his hard work guiding the review and both he and the rapporteur are to be acknowledged for their hard work assembling and editing the Panel report.

5. Recommendations

Pacific Sardine: It is recommended that the acoustic-trawl surveys be considered estimates of distribution of abundance for the survey area.

It is recommended that a number of analyses be conducted using auxiliary information to provide best estimates for the biomass outside of the survey area, as well as range of possible biomass levels. In addition, the CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.

Jack mackerel: Even though less information is available for this species than for Pacific sardine on the key uncertainties, it recommended that the distribution estimates by the survey area can be used for jack mackerel in US waters.

Northern anchovy: It is recommended that if estimates were required, the sampling scheme would need to be modified.

There are a series of specific aspects detailed below:

1. Immediate (prior to the next stock assessments)

a. Analyses should conducted using auxiliary information (e.g. trends in density along transects, information from ichythoplankton surveys south of the survey area, catch information) to provide best estimates for the biomass outside of the survey area as well as the range of possible biomass levels.
b. The CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.

2. Short-term

a. Investigate 'gross' species selectivity effects by comparing the ratio of catch rates and acoustic density in areas where single species dominate.
b. Conduct sensitivity tests in which stations are pooled and allocated to acoustic values over a larger area.
c. Consult experts in trawl design to evaluate the current trawl design in relation to the survey objectives
d. 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 and check the performance of the selection process on each survey.
e. Develop further studies on effect of avoidance: study trends in frequency response over depth strata in schools, compare results from the 18 kHz and other transducers to examine possible avoidance reactions.
f. Continue to consider the advantages and disadvantages of conducting acoustic-trawls surveys at different times of the year and extending the survey into Canadian and Mexican waters.
g. 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.

3. Long-term

a. Evaluate if differing fishing trawling practices / gears would be beneficial.
b. Use a trawl/vessel configuration that can support directed trawl sampling.
c. Conduct repeated trawl sampling experiments to obtain better understanding of small-scale variability.
d. Test the efficiency and selectivity of the trawl by comparing samples from same area taken with the survey trawl and purse seine.
e. Apply state-of-the-art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl.
f. Conduct validation tows on various kinds of backscatter to assure that the filtering algorithm is performing as intended to separate out CPS.

g. Make efforts to obtain *in situ* target strength measurements for CPS species in California Current Ecosystem.

6. Conclusion

The reports and presentations provide an excellent basis to evaluate the performance of the acoustic-trawl survey. They are of a high standard and require only minor improvements that are detailed above.

The acoustic-trawl surveys should be considered estimates of distribution of abundance of Pacific Sardine for the survey area, conditional on a number of analyses to be conducted using auxiliary information to provide best estimates for the biomass outside of the survey area as well as range of possible biomass levels. In addition, the CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.

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Appendix 1: Bibliography of materials provided for review

Primary Documents

David A. Demer, Juan P. Zwolinski, Kyle A. Byers, George R. Cutter, Josiah S. Renfree, Thomas S. Sessions, and Beverly J. Macewicz 2011 Acoustic-trawl surveys of Pacific sardine (Sardinops sagax) and other pelagic fishes in the California Current ecosystem: Part 1, Methods and an example application.

Juan P. Zwolinski, Kyle, A. Byers, George R. Cutter, Josiah S. Renfree, Thomas, S. Sessions, Beverly J. Macewicz, and David A. Demer 2011 Acoustic-trawl surveys of Pacific sardine (Sardinops sagax) and other pelagic fishes in the California Current ecosystem: Part 2, Estimates of distributions and abundances in spring 2006, 2008, and 2010

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Appendix 2: Statement of Work for John Simmonds

External Independent Peer Review by the Center for Independent Experts

Panel Review of an Acoustic-Trawl Method for Surveying CPS

3-5 February 2011

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by the CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The Pacific Fishery Management Council (PFMC) uses information from surveys to make decisions related to harvest guidelines for managed coastal pelagic species (CPS) (i.e., Pacific sardine and Pacific mackerel) and Overfishing Levels (OFLs) / Acceptable Biological Catches (ABCs) for monitored CPS (i.e., northern anchovy, jack mackerel and market squid). The current assessments for Pacific sardine and Pacific mackerel are based on the 'Stock Synthesis' framework. The assessment for Pacific sardine uses age- and length-composition data from four fisheries, the results from an aerial survey, and measures of female spawning biomass and total egg production (DEPM) from combined trawl and egg surveys, to estimate the parameters of a population-dynamics model. The survey outcomes and hence model-derived estimates of Pacific sardine spawning-stock biomass (SSB) have recently decreased, resulting in dramatically lower harvest guidelines for 2008 and 2009. The Southwest Fisheries Science Center's (SWFSC's) current standard survey covers the 'core' spring-spawning area between San Diego and San Francisco. The exploited stock ('northern subpopulation') is believed to migrate seasonally, potentially from northern Baja California, Mexico in the spring to British Columbia, Canada in the summer. The DEPM is an indirect measure of fish distribution and abundance. As the sardine population recovered from historic lows and recently reoccupied its former historic range, migrating as far north as Canada in the summer, multiple types and more direct estimates of CPS biomass, particularly sardine biomass, may be needed to improve stock assessments.

Three CIE reviewers will serve on a Panel to evaluate an acoustic-trawl method for surveying CPS. The SWFSC's Fisheries Resources Division (FRD) has explored the use of acoustic-trawl methods, which are commonly used by other regions and countries to estimate the abundances and distributions of CPS. Acoustic-trawl methods may provide a more robust (i.e., accurate and precise) and efficient means to routinely survey the Pacific sardine populations as well as the populations of jack mackerel, Pacific mackerel, and northern anchovy. In spring 2006, 2008, and 2010, and summer 2008, FRD conducted acoustic-trawl surveys off the U.S. west coast, from the Mexican to Canadian borders, and developed methods for estimating the abundances and distributions of CPS from these data. The Panel will review the acoustic-trawl survey design and analysis methods, documents, and any other pertinent information for acoustic-trawl surveys of Pacific sardine, Pacific mackerel, jack mackerel, and northern anchovy.

The Panel report will be used to guide improvements to the acoustic-trawl survey and analysis methods, the resulting time series of estimates of abundance and distribution for CPS species, and estimates of their uncertainty. The report will also be used to evaluate the appropriateness of using the results from the survey as inputs to the assessment model for Pacific sardine and Pacific mackerel. The assessment models for Pacific sardine and Pacific mackerel will be reviewed by separate Stock Assessment Review (STAR) Panels. However, the report of this Methods Review Panel will be considered by the assessment analysts and STAR Panels.

An overview of the ToRs for the Panel are attached in **Annex 2**. The tentative agenda of the Panel review meeting is attached in **Annex 3**. Finally, an outline of the summary report of the Panel is attached as **Annex 4**.

Requirements for CIE Reviewer: Three CIE reviewers shall participate in the Panel and conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. Three CIE reviewers shall have expertise and work experience in the design and execution of fisheries-independent acoustic-trawl surveys for estimating the abundance of coastal pelagic fish species, and expertise with sardines is desirable. The CIE reviewers shall have knowledge of the life history strategies and population dynamics of coastal pelagic fish species.

Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location/Date of Peer Review: The CIE reviewers shall participate as independent peer reviewers during the panel review meeting at NOAA Fisheries, Southwest Fisheries Science Center, 3333 North Torrey Pines Court, La Jolla, California, 92037-1023, during 3-5 February 2011 in accordance with the agenda (Annex 3).

Statement of Tasks: The CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Following the CIE reviewer selections by the CIE Steering committee, the CIE shall provide the CIE reviewers' information (name, affiliation, and contact details) to the Contracting Officer's Technical Representative (COTR), who will forward this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers (reviewer hereafter). The Project Contact is responsible for providing the reviewer with the background documents, reports, foreign national security clearance, and information concerning other pertinent meeting arrangements. The Project Contact is also responsible for providing the Panel Chair (Chair hereafter) a copy of the SoW in advance of the Panel. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When a reviewer who is a non-US citizen participates in a panel review meeting at a government facility, the Project Contact is responsible for obtaining a Foreign National Security Clearance for the CIE reviewers. For the purpose of their security clearance, each reviewer shall provide requested information (e.g., name, contact information, birthdate, passport number, travel dates, and country of origin) to the Project Contact at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations (available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/sponsor.html).

Pre-review Background Documents: Two weeks before the review, the Project Contact will electronically send to each reviewer, by email or FTP, all necessary background information and reports for the review. If the documents must be mailed, the Project Contact will consult with the CIE on where to send the documents. The CIE reviewers shall read all documents in preparation for the review, for example:

- documents on current survey methods, in particular, related to DEPM and aerial surveys of sardine and other CPS;
- document on SWFSC acoustic-trawl surveys conducted between 2006 and 2010;
- documents from past Panels; and
- miscellaneous documents, such as the ToR, SoW, agenda, schedule of milestones, deliverables, logistical considerations, and PFMC's ToR for CPS Stock Assessment Methodology Reviews.

The CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. Any delays in submission of pre-review documents for the CIE review will result in delays with the CIE review process, including a SoW modification to the schedule of milestones and deliverables.

Panel Review Meeting: Each CIE reviewer shall participate in the Panel and conduct an independent review in accordance with the SoW and ToRs. **Modifications to the SoW and ToR cannot be made during the review, and any SoW or ToR modification prior to the review shall be approved by the COTR and CIE Lead Coordinator.** Each reviewer shall actively participate in a professional and respectful manner as a member of the Panel, and their review tasks shall be focused on the ToRs as specified in the contract SoW.

Respective roles of the CIE reviewers and Chair are the PFMC's ToR for CPS Stock Assessment Methodology Review (see p. 6-8). The CIE reviewers will serve a role that is equivalent to the other panelists, differing only in the fact that they are considered 'external' members (i.e., outside the PFMC's membership and not involved in management or assessment of west coast CPS, particularly sardine). The reviewers will serve at the behest of the Chair, adhering to all aspects of the PFMC's ToR as described in Annex 2. The Chair is responsible for: 1) developing an agenda; 2) ensuring that Panel members (including the Reviewers) and those being reviewed (the "proponents") follow the ToR; 3) participating in the review of the methods (along with the Reviewers); and 4) guiding the Panel (including the Reviewers), FRD, and NWSS to mutually agreeable solutions.

The Project Contact is responsible for any facility arrangements (e.g., conference room for Panel meetings or teleconference arrangements). The CIE Lead Coordinator can contact the Project Contact to confirm any meeting facility arrangements.

<u>Contract Deliverables - Independent CIE Peer Review Reports</u>: In addition to participating in the Panel, each CIE reviewer shall also complete an independent-review report in accordance with the SoW, i.e., in the required format as described in Annex 1; and addressing each ToR as described in Annex 2.

<u>Other Tasks – Contribution to Summary Report</u>: Reviewers will assist the Chair with contributions to the Summary Report. The Panel is not required to reach a consensus and, therefore, the reviewers should provide a brief summary of their views on the findings and conclusion reached by the Panel in accordance with the ToRs (format defined in Annex 1).

Specific Tasks for CIE Reviewer: The following chronological list of tasks shall be completed by the CIE reviewers in a timely manner, as specified in the **Schedule of Milestones and Deliverables**:

1) prepare for the review by thoroughly reading the documents provided by the Project Contact;
2) participate in the panel review meeting in La Jolla, CA during 3-5 February 2011 as indicated in the SoW, and conduct an independent review in accordance with the ToRs (Annex 2); and
3) write an independent-review report, addressed to the "Center for Independent Experts," and submit it to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and CIE Regional Coordinator, via email to David Die ddie@rsmas.miami.edu, no later than 17 March 2011 indicated in the SoW. The report shall be written using the format and content requirements specified in Annex 1, and address each ToR in Annex 2.

Schedule of Milestones and Deliverables: The CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

28 December 2011	The CIE sends the CIE reviewers' contact information to the COTR, who forwards it to the Project Contact.
10 January 2011	The Project Contact sends the pre-review documents to the CIE reviewers.
3-5 February 2011	The CIE reviewers participate in the Panel review meeting and conducts an independent review.
3 March 2011	The CIE reviewers submit their reports to the CIE Lead Coordinator and CIE Regional Coordinator for final review and revisions.
17 March 2011	The CIE submits independent peer review reports to the COTR for contractual compliance.
24March 2011	The COTR distributes the final reports to the Project Contact and the regional Center Director.

Modifications to the Statement of Work: Requests to modify this SoW must be made through the COTR who submits the modification for approval to the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the CIE within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToR of the SoW as long as the role and ability of the Reviewer to complete the SoW deliverable in accordance with the ToRs and the deliverable schedule is not adversely impacted. The SoW and ToRs cannot be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, the reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via email the contract deliverables (the CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards: (1) the CIE report shall have the format and content in accordance with Annex 1; (2) the CIE report shall address each ToR as specified in Annex 2; and (3) the CIE report shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon notification of acceptance by the COTR, the CIE Lead Coordinator shall send via email the final CIE reports in pdf format to the COTR. The COTR will distribute the approved CIE reports to the Project Coordinator, the regional Center Director, and the PFMC.

Key Personnel:

William Michaels, Program Manager, COTR
NMFS Office of Science and Technology
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NMFS Project Contact:

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Dr. David Demer, FRD
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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations.

2. The main body of the Reviewer's report shall consist of the following sections, in accordance with the ToRs: Background, Description of the Reviewer's Role in the Review Activities, Summary of Findings for each ToR, and Recommendations and Conclusion.

   a. The Reviewer should describe in their own words the review activities completed during the panel meeting, including providing a detailed summary of findings, recommendations, and conclusion.

   b. The Reviewer should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where they were divergent.

   c. The Reviewer should elaborate on any points raised in the Summary Report that might require clarification.

   d. The Reviewer shall provide a critique of the review process, including suggestions for improving both the process and products.

   e. The CIE report shall be a stand-alone document for others to understand the proceedings and findings of the meeting without having to read the Panel report. The report shall be an independent review of each ToR, and shall not simply repeat the contents of the Panel report.

3. The Reviewer's report shall include the following separate appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: The CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the review meeting.

Annex 2: Terms of reference (ToRs) for the peer review of the acoustic-trawl method for surveying Pacific sardine and other CPS

The CIE reviewers will participate in the panel-review meeting to conduct independent peer reviews of the acoustic-trawl method as it pertains to surveys of coastal pelagic fish species (CPS) in the California Current Ecosystem (CCE), principally Pacific sardine, but potentially also including jack mackerel, Pacific mackerel, and northern anchovy, depending on their biomasses and distributions, and the sampling effort afforded. The survey area is the CCE off the west coast of the United States of America (US), generally between the Mexico-US and the US-Canadian borders. The latitudinal and offshore extents of the surveys are seasonal, extending further north in the summer and further offshore in the spring. Survey estimates are to include absolute biomasses, and their total random sampling errors, and spatial distributions. The review solely concerns technical aspects of the survey design, method, analysis, and results, and addresses the following ToR:

ToR 1 – Review documents detailing acoustic-trawl survey and data analysis methods and results according to the PFMC's ToR for CPS Stock Assessment Methodology Reviews. Document the meeting discussions. Evaluate if the documented and presented information is sufficiently complete and represents the best scientific information available.

ToR 2 – Evaluate and provide recommendations on the survey method used to estimate the abundances and distributions of Pacific sardine and other CPS, and associated sources of uncertainty. Recommend alternative methods or modifications to the proposed methods, or both, during the Panel meeting. Recommendations and requests to FRD for additional or revised analyses during the Panel meeting must be clear, explicit, and in writing. Comment on the degree to which the survey results describe and quantify the distributions and abundances of CPS, in particular Pacific sardine, and the uncertainty in those estimates. Confidence intervals of survey estimates could affect management decisions, and should be considered in the report.

ToR 3 – Evaluate and provide recommendations for the application of these methods for their utility in stock assessment models and for their ability to monitor trends at the population level for Pacific sardine and other CPS. Survey methods or results that have a flawed technical basis, or are questionable on other grounds, should be identified so they may be excluded from the set upon which stock assessments and other management advice is to be developed.

ToR 4 – Evaluate the effectiveness of the survey methods for detecting the appropriate spatial scale and seasonal timing for annually estimating stock abundances.

ToR 5 – Decide through Panel discussions if the ToRs and goals of the peer review have been achieved. If agreement cannot be reached, or if any ToR cannot be accomplished for any reason, then the nature of the disagreement or the reason for not meeting all the ToR must be described in the Summary and Reviewer's report. Describe the strengths and weaknesses of the review process and Panel recommendations.

The Reviewer’s report should be completed, at least in draft form, prior to the end of the meeting.

Annex 3: Participants and Agenda

Participants

Methodology Review Panel Members:
Martin Dorn, SSC, NMFS, Alaska Fisheries Science Center
François Gerlotto, Center for Independent Experts (CIE)
Olav Rune Godø, Center for Independent Experts (CIE)
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
John Simmonds, Center for Independent Experts (CIE)

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

Acoustic-Trawl Survey Technical Team:
Kyle, A. Byers, NMFS, Southwest Fisheries Science Center
George R. Cutter, NMFS, Southwest Fisheries Science Center
David Demer, NMFS, Southwest Fisheries Science Center
Josiah Renfree, NMFS, Southwest Fisheries Science Center
Beverly J. Macewicz, NMFS, Southwest Fisheries Science Center
Juan P. Zwolinski, NMFS, Southwest Fisheries Science Center

THURSDAY, FEBRUARY 3, 2011 – 8:00 A.M.

A. Call to Order, Introductions, Approval of Agenda, and Appointment of Rapporteurs
B. Terms of Reference for the CPS Methodology Reviews
(8:30 a.m., 0.5 hour)
C. Presentation on the acoustic-trawl survey David Demer
(9:00 a.m., 1.5 hours)

BREAK

C. Presentation on the acoustic-trawl survey (Continued) David Demer
(11 a.m., 1 hour)

LUNCH

C. Presentation on the acoustic-trawl survey (Continued) David Demer
(1 p.m., 1.5 hours)

D. Panel discussion Panel
(2.30 p.m., 1 hour)

BREAK

E. Requests to FRD Panel
(4.00 p.m., 1 hour)

FRIDAY, FEBRUARY 4, 2010 – 8:30 A.M.

F. Responses to Panel Requests (FRD) David Demer
(8.30 a.m., 2 hours)

BREAK

G. Panel discussion Panel
(11 p.m., 1 hour)

LUNCH

H. Requests to the FRD Panel
(1 p.m., 1 hour)

I. Report drafting Panel
(2.30pm, 1 hours)

BREAK

J. Responses to Panel Requests (FRD) David Demer
(4 p.m., 0.5 hours)

K. Requests to FRD Panel
(4.30 p.m., 0.5 hours)

SATURDAY, FEBRUARY 5, 2010 – 8:30 A.M.

K. Responses to Panel Requests (FRD) David Demer
(8.30 a.m., 1.5 hours)

BREAK

L. Report Drafting Panel
(11am , 1 hours)

LUNCH

M. Report review Panel
(1 p.m+)

Annex 4: Panel Summary Report (Template)

- Names and affiliations of Panel members
- List of analyses requested by the Panel, the rationale for each request, and a brief summary of the proponent's responses to each request.
- Comments on the technical merits and/or deficiencies in the assessment and recommendations for remedies.
- Explanation of areas of disagreement regarding Panel recommendations:
  - among Panel members; and
  - between the Panel and the proponents
- Unresolved problems and major uncertainties, e.g., any special issues that complicate survey estimates, estimates of their uncertainty, and their use in stock assessment models.
- Management, data, or fishery issues raised the public (i.e., non-Panel and proponent participants) at the Panel meetings.
- Prioritized recommendations for future research, and data collections and analyses.

Appendix 3: Panel Membership or other pertinent information from the review meeting.

Andre Punt (PFMC, Chair),	aepunt@u.washington.edu
Martin Dorn (AFSC),	Martin.Dorn@noaa.gov
François Gerlotto (CIE),	francois.gerlotto@ird.fr
Olav Rune Godø (CIE),	olav.rune.godoe@imr.no
John Simmonds (CIE),	ejsimmonds@googlemail.com
M. Okoniewski (CPSAS),	mokoniewski@pacseafood.com
G. Krutzikowsky (CPSMT),	Greg.Krutzikowsky@state.or.us
Kerry Griffin (PFMC),	Kerry.Griffin@noaa.gov
Mike Burner (PFMC),	Mike.Burner@noaa.gov
observers, and SWFC/FRD.	

Bill Michaels <William.Michaels@noaa.gov>,
Vetter Russ Russ.Vetter@noaa.gov

External Independent Peer Review by the Center for Independent Experts

Panel Review of an Acoustic-Trawl Method for Surveying CPS
Southwest Fisheries Science Center
La Jolla California
February 2-5, 2011

Report by Olav Rune Godø

1. Executive Summary

The Chair initiated the panel discussion by identifying six key issues that provided a focus for discussion during the review:

(a) design of the acoustic and trawl sampling, including the representativeness of the data for the four coastal pelagic species (CPS);

(b) analysis of the survey data for estimating CPS abundances;

(c) evaluation of potential biases in sampling design and analysis;

(d) characterization of uncertainty in estimates of CPS biomass;

(e) decision if acoustic-trawl estimates of CPS biomass can be used in stock assessments and management advice for Pacific sardine, jack mackerel, Pacific mackerel, and northern anchovy, and;

(f) guidance for future research.

Dr Kevin Hill, SWFSC, presented the most recent Pacific sardine stock assessment, and thus updated the Panel on important issues for CPS assessments and management. Dr David Demer, Leader of the Advanced Survey Technologies Program (ASTP), SWFSC, gave a presentation of the acoustic-trawl method for assessing CPS, and this was followed by responses to several requests by the Panel for additional information.

The collected data from the survey also provide useful information on ecosystem properties as well as fish behaviour. In a dynamic system like the California current, ecosystem and fish behaviour properties information is important for understanding shifts in species composition and relations among species that are recorded in the surveys.

The ASTP provided detailed background material with a very competent evaluation of methodologies and results. Further, their willingness and capability to respond to the Panel requests enhanced the efficiency of the Panel. It became clear that the ASTP team had already identified most of the issues identified by the Panel and had prepared information pertinent to these, which helped the Panel in its deliberations. The work related to avoidance of CPS to vessels was particularly helpful for drawing conclusions related to whether avoidance, or at least its effects on the acoustic-trawl survey results, is likely substantial.

In summary, the acoustic-trawl surveys, as well as the methods of data collection and analysis, are adequate for the provision of advice on the abundance of 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. Most importantly, the estimates from the acoustic-trawl surveys can be included in the 2011 Pacific sardine stock assessments as 'absolute estimates', contingent on the completion of two tasks, and estimates of jack mackerel and Pacific mackerel may also be useful in stock assessments and management. However, given the current size and abundance of the northern anchovy stock(s), the present surveys cannot provide estimates of their abundance(s) for use in management. The acoustic-trawl method could potentially be applied to survey CPS currently in low abundances, e.g., northern anchovy and Pacific herring, but only if the sampling design take into account the distinctiveness of these stocks' distribution and biology. In particular it should be noted that the survey effectiveness could change considerably if/when the species composition among the CPS changes. A strategic interaction between the ongoing aerial survey and the acoustic-trawl survey could potentially facilitate a monitoring less sensitive to the impacts of the environment on distribution and abundance of the CPS.

2. Background

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. A Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by the CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. As a CIE reviewer I am contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report. Further information on the CIE process can be obtained from www.ciereviews.org.

As an expert in acoustic-trawl survey methodologies, I was selected to serve on a Panel to evaluate an acoustic-trawl method for surveying coastal pelagic species (CPS). The SWFSC's Fisheries Resources Division (FRD) has explored the use of acoustic-trawl methods, which are commonly used by other regions and countries to estimate the abundances and distributions of CPS in Californian waters. Acoustic-trawl methods may provide a more robust (i.e., accurate and precise) and efficient means to routinely survey the Pacific sardine populations as well as the populations of jack mackerel, Pacific mackerel, and northern anchovy. FRD has conducted acoustic-trawl surveys off the U.S. west coast, from the Mexican to Canadian borders, and developed methods for estimating the abundances and distributions of CPS from these data. The data are used in analytical stock assessment. This review covers the acoustic-trawl survey design and analysis methods, documents, and other pertinent information for acoustic-trawl surveys of Pacific sardine, Pacific mackerel, jack mackerel, and northern anchovy. The confinement of the stocks within the survey area compared to inshore-offshore areas, as well as north into Canada and south into Mexican waters, are important design issues. Trawl sampling and the evaluation of uncertainty including behavioural aspects impact on survey results are important issues of the review.

3. Description of the Reviewer's Role in the Review Activities

My focus of research is presently related to acoustic- trawl survey methodologies. Behavioural impacts on assessments of fish stocks from surveys, acoustic as well as trawl surveys, have been an important part of my experience. My practical experience comes from assessment surveys, stock assessment working groups, and the responsibility of a large number of experiments for assessing quality of scientific surveys. I have field experience from European coastal waters as well as from deep waters in the mid-Atlantic and in the Vietnam-Thailand-Malaysia area. I have worked at the demersal fish department at the Institute of Marine Research, and served as section head at the pelagic fish department. In 2002 I started building a new research group in survey methodology. Presently I am chairing a new international initiative in marine ecosystem acoustics. My main research interests include acoustic-trawl survey methodology, fish behaviour, biophysical interaction, and fisheries induced evolutionary changes. My work has been presented in about 70 publications in peer-reviewed journals, and, in addition, several book chapters and a number of technical papers and reports. I have served on the board of four research programs of the Research Council of Norway, have been a member of the scientific steering committee of Census of Marine Life and have also been a member of a SCORE WG in observation methods. I have also been a member of several working groups under the International Council of the Exploration of the Sea.

Prior to the review meeting, I responded on requests from the CIE office. I had access to most of the review material and prepared for the meeting by reading the material. The main activity was participation in the panel meeting and the associated discussions and reporting. After the meeting, I repeatedly read and commented on the panel chair's updated versions of the panel review report. My particular emphasis was on impacts on behavioural aspects on survey results. This includes aspects of the survey design (coverage), species compositions, trawl sampling and fish avoidance. Final activity included the preparation of this report.

4. Summary of Findings

4.1 ToR 1 – Review of reports

Review documents detailing acoustic-trawl survey and data analysis methods and results according to the PFMC's ToR for CPS Stock Assessment Methodology Reviews. Document the meeting discussions. Evaluate if the documented and presented information is sufficiently complete and represents the best scientific information available.

There were two prime documents available for review before the meeting started: 1) Acoustic-trawl survey --- methods and examples, and 2) Acoustic-trawl survey --- Estimation of distribution and abundance in the spring. In addition, 22 other papers and reports were provided as background information (all documentation is listed in Appendix 1).

The presentations at the meeting started with Dr Kevin Hill, SWFSC, who gave a brief summary of the most recent Pacific sardine stock assessment to orient the Panel on important issues for CPS assessments and management. Dr David Demer, Leader of the

Advanced Survey Technologies Program, SWFSC, gave a presentation on the acoustic-trawl method for assessing CPS, and this was followed by responses to several requests by the Panel for additional information. The primary papers along with the presentations gave an informative documentation of the survey methods along with the traditional assessment of the stocks in question. Further, information on the environmental and ecological background of the area and the challenges associated to the acoustic-trawl assessment was provided. The papers and presentation also highlighted the dynamics of the ecosystem that may involve change of species dominance over relatively short periods of time.

The presentation and the responses to questions and request for further analysis were impressive and revealed a team with high scientific standards and demonstrated a thorough preparation for the review. After the presentation the panel put forward a number of questions that either was clarified directly or specified for further analysis. These requests were answered the next day.

Survey reports:
The methods reporting was split in a survey method report (Part 1) and a report on experience (Part 2). This separation was a useful way of giving insight in the basic methodologies and how it can be applied.

The methods report (Part 1) gives a solid documentation of the work done to secure good practice in a routine survey. This is particularly valid for the acoustic evaluation where the authors document routines for objective evaluation of the acoustic records (VMR filtering). Some specific comments on the documentation of some key issues that could have been improved:

1. TS – in lack of *in situ* TS measurements, available measurements from similar species in other areas are used. Changes in TS due to depth, season and condition (Ona, 2003) are not considered.
2. The documentation of sampling gear and its efficiency is limited. As sampling has a crucial impact on the abundance estimates documentation, e.g. as trawl drawing and rigging should be provided as an appendix.

The experience report (Part 2) provides a pertinent overview of results when applying the methods described in Part 1. The figures and table present the essential information for evaluating the results. Some important details seem to be lacking, and this has an impact on the evaluation of the results:

1. The length compositions are not included but the reader is referred to another report. Length information should be available as it has a crucial impact on the results.
2. As vessel avoidance is a much debated issue, the results might be affected by the fact that many vessels are involved in the surveys. Noise measurements or some kind of intercalibration would be preferable. The reader has no way of evaluating the vessel effect. At least vessel sizes and horse powers should be specified.
3. Calibration results should be presented in a way that allows for a comparison among surveys.

Of the additional reports presented I would like to mention the aerial survey (Jagielo *et al.,* 2009, background information) demonstrating that visual techniques may provide useful information about the CPS. As this survey method collected data that are complementary to the acoustic-trawl survey, it produces an important source of information that might shed light on, even in quantitative terms, vessel avoidance and availability issues.

In conclusion, the acoustic-trawl survey reports are well prepared and the competent presentation gave an excellent background for the discussion of the quality and performance of the acoustic – trawl survey.

4.2 ToR 2 – Evaluate and provide recommendations on survey methods

Evaluate and provide recommendations on the survey method used to estimate the abundances and distributions of Pacific sardine and other CPS, and associated sources of uncertainty. Recommend alternative methods or modifications to the proposed methods, or both, during the Panel meeting. Recommendations and requests to FRD for additional or revised analyses during the Panel meeting must be clear, explicit, and in writing. Comment on the degree to which the survey results describe and quantify the distributions and abundances of CPS, in particular Pacific sardine, and the uncertainty in those estimates. Confidence intervals of survey estimates could affect management decisions, and should be considered in the report.

4.2.1 Survey design and area coverage

Surveying dynamic pelagic stocks in a dynamic ocean environment requires a survey and sampling design that takes appropriately into account the distribution and migration patterns. Ideally, the surveys should cover the entire ranges of all four species, and sampling should be designed to provide representative information (acoustic and trawl) within the surveyed area. In practical terms compromises have to be made. The issue here is if the current survey design and allocation of sampling effort spatially meet the objectives of the survey.

The design utilizes the existing egg surveys for both spatial coverage and collection of trawl data. Thus, there is no explicit design to meet the acoustic-trawl survey. As the survey transects are more or less regularly spaced, the design meets normal standards for such surveys. Also, some adjustments are done in areas according to expected abundance. Abundance is estimated by equal weight of transect abundances within strata and variance by bootstrap.

The design assumes distribution of fish within 70 m depth and presumes that the major part of the biomass is deeper than the transducer depth. The survey vessels run transducers with different depth. This might introduce a vessel effect. Although there is no information indicating a large impact of vertical distribution on the available survey results, annual changes in vertical distribution could introduce both a vessel bias and an overall underestimate of abundance.

Some selected aspects are discussed in the following:

The design and approach take for the CPS survey seem appropriate and at present there exists enough evidence to state that some fish, but not a critical amount, are located outside the survey area. The preferred habitat method should be further explored to ascertain its validity for stratification of the survey effort over time. Further, other information, including information from the commercial fisheries, should be studied in an effort to enhance the use of the limited survey effort. The design would clearly need to be changed if useable estimates of abundance for northern anchovy (and Pacific herring) are needed, given the current size and distribution of these species. The abundance of CPS species fluctuates over time and that the optimal survey design may need to change over time (e.g. if anchovy should increase substantially in abundance). Further work would be required to determine if stratification would be successful, or if a uniform spatial distribution of effort is required. The whole issue is determined by the objectives - if the survey is to be single species, multispecies or to have an ecosystem focus. A dynamic and variable distribution by the various species will also affect impact of distribution outside the area covered by the present survey. Will the survey design be able to pick up this variability? We were informed that transects were continued, when possible, to the zero distribution line offshore. The analyses of the potential biases caused by lacking or variable coverage seem appropriate and should be continued. Prediction of preferred habitat (Zwolinski *et al*., 2011, background information) demonstrates a way of enhancing/optimizing survey design. The robustness of the survey design and habitat prediction method for substantial changes in abundance and distribution is still unknown. I think that there are good reasons to believe that the properties and relationships, including preferred habitat, estimated during this study period might change periodically similarly to what is seen in other large pelagic stocks (see e.g. Holst *et al.,* 2006). Particularly, such changes will probably take place when the substantial changes in the CPS species' compositions and abundance take place and the need for reliable survey results are highest.

Recommendations: Further development of the habitat prediction approach and use of auxiliary information, e.g. distribution from an aerial survey could enhance efficiency of the survey design and minimize impact of temporal changes in distribution (vertical and horizontal) and migration patterns.

4.2.2 Trawl sampling

The acoustic-trawl survey utilizes trawl samples designed for the simultaneous egg survey. These samples are needed for species and size compositions in the estimation of TS, abundance and biomass. The approach is contrasted with a most common approach which applies targeted sampling on recorded echo traces.

The strategy as presently applied works well under homogenous situations. The problem with the current approach might occur when the survey area has many species with different acoustic properties, inhomogeneous distribution and varying behavioural characteristics. The problem might affect estimation of **stock properties** and **estimates of uncertainty.**

The CPS survey covers several pelagic species which demonstrate large variability in abundance and distribution over time. A potential concern with the trawl sampling is that there may be species and size selectivity. At present, there appears to be considerable spatial separation among CPS species, especially during the summer survey, indicating that species proportions are relatively well established. Although night time catch rates may not fully match daytime observations, it might be considered a minor issue for Pacific sardine and jack mackerel because the areas occupied by these species are generally homogeneous. Size separation by depth is not studied and this could complicate the sampling issue and comparability day/night. There is a need to test the assumption of spatial homogeneity.

Recommendations: Increased effort will be required in areas dominated by the less abundant species if useable estimates of abundance are needed for the full range of all species. It is possible to study species selectivity effects by comparing the ratio of catch rates and acoustic abundance in areas where single species dominate. To clarify size composition issues depth stratified sampling could be conducted. In the longer term, efforts should be made to evaluate if different fishing practices / gears would be beneficial. The objective would be to deploy a gear with the potential for daytime fishing and direct species identification of schools to support acoustic identification to the species level.

4.2.3 Allocation of effort between trawl and transect data collection

Balancing effort in biological and acoustic sampling is a critical issue for survey assessment quality. In this case, the balance is determined by the needs of the simultaneous egg survey. Although this balance appears to be adequate at present, the design is rigid and does not allow needed flexibility for biological sampling. The current variance estimation procedure could be utilized to investigate an optimal sampling strategy in terms of variance in the estimated biomass. Some studies (e.g. Simmonds and MacLennan, 2005; Simmonds *et al*., 2009) suggest that a broad range of time allocations lead to similar overall variance estimates, which indicates that optimization of the time allocation may not be a critical issue.

Recommendations: Allocation of effort is probably fine. Flexibility in sampling, allowing opportunistic sampling according to acoustic registration, is, in most acoustic surveys, an important practice to detect changes in distribution patterns by size or species and should be aimed for in CPS surveys in the future.

4.2.4 Multiple vessel

The use of multiple vessels in standard assessment surveys may add complexity to the interaction between the observer and the observed. Current surveys were conducted using four vessels ranging from 41 to 65 m in length, with displacements ranging at least two fold. Such differences require consideration of the following issues:

- Vessel noise may potentially affect fish behaviour during surveys. Fish may avoid the sound source, either by diving or moving to the side, or both. Such behaviour may lead to reduced fish density under the transducer during the moment of recording. Furthermore, TS might change as a result of changing fish tilt angle during the avoidance response, thus impacting, in most cases reducing, estimates of density. Some studies (e.g. Dagorn *et al*., 2001; Røstad *et al*., 2006) suggested that vessels may attract fish, thus increasing densities measured by acoustics. The International Council for the Exploration of the Seas (ICES) has therefore recommended using noise-reduced vessels to reduce these potential impacts.
- Other parts of the sound spectrum, particularly infrasound, also appear to be responsible for changes in fish behaviour in response to survey vessels. This implies that noise as measured by the ICES standard (Mitson, 1995) does not necessarily reflect the strength of the vessel's avoidance stimulus. Rather, the

stimulus may be more associated with the size of the vessel and its displacement than the noise emission.
- Visual stimuli may attract fish similarly to a FAD (Fish Aggregating Device) and will affect observations in shallow water and at short distances from the vessel.

Further complexity in potential fish behaviour is caused by interactions among the above sources. This is reflected in the literature as large variability in the observed responses of fish to survey vessels. In the present case, the vessels vary substantially in size and horse power and have different propulsion and noise-reducing arrangements. The potential exists for vessel-specific impacts on the survey results if the target species are sensitive to any of the stimuli described above (Hjellvik *et al*., 2008). As an example, the FV *Frosti*, which is considered a noisy vessel by the Team, recorded fish closer to the surface than the other vessels. If vessel noise represents the stimulus, it could signify a vessel avoidance effect. On the other hand, *FV Frosti* is the smallest ship (least displacement) and the vessel difference could be due to infrasound impacts from the larger vessels (Ona *et al*., 2007; Sand *et al*., 2008).

Recommendations: To avoid vessel effects it is an obvious advantage and a general recommendation to use same vessels over time. Appropriate noise measurements and intercalibration are recommended when various vessels are used, as in the present case. Dedicated studies of avoidance behaviour should be carried out (see 4.2.8).

4.2.5 Timing of acoustic and trawl sampling

Pelagic species are known to have diel and seasonal behavioural characteristics which can have large impacts on survey results. These characteristics may influence the results due to variations in the availability of the fish to acoustic sampling as a result of their vertical and horizontal movement. The acoustic sampling occurs during the day when the CPS are typically aggregated deeper, and trawling occurs at night when the CPS are typically dispersed near the surface. The current trawl and vessel configurations have been generally unsuccessful catching schooling fish during the day. Conducting acoustic sampling during the day and trawling at night is a reasonable approach because the available effort is used efficiently, and available analyses comparing distributions of CPS backscatter with length and species distributions from the trawls indicate that present procedures produce estimates that reflect the true properties of the stocks. Nevertheless, validation of CPS backscatter to species and size should be improved through targeted trawl sampling.

It is particularly noted that the trawl catches are small compared to those in many other acoustic-trawl surveys, which raises the question whether trawl catches are representative of the populations. I, therefore, recommend further investigation of how trawls are allocated to acoustic signals, for example, by conducting sensitivity tests in which stations are pooled and allocated to acoustic values over a larger area.

Recommendations: In the longer-term, it is ideal to have a trawl and vessel configuration that can support targeted trawl sampling. This would increase the number of samples, and enhance the representativeness of the trawl samples to species and their sizes in the populations sampled acoustically. Also, repeated trawl sampling experiments could lead to a better understanding of small-scale variability and could improve the sampling design as well as enhance understanding of the uncertainty in the survey estimates.

4.2.6 Trawl design and operation

Trawl efficiency depends on the interaction between trawl design and fish behaviour. This causes size- and species-selectivity due to: (a) fish avoiding the trawl before entering the net (potentially size- and species-dependent); (b) fish escaping through the meshes near the mouth of the net; and (c) fish escaping through the meshes in front of the codend. The latter problem is particularly probable if there is a large change in mesh size from the trawl to the codend and the net is towed at a high speed. If pelagic species exhibit schooling rather than individual behaviour, these problems may not be significant. However, the low trawl catches may indicate individual behaviours of the fish during the trawls, which could influence species and size selection. Species-related behavioural characteristics influence trawl selectivity and may affect estimates of species proportions in areas where they are mixed. This is a problem for trawl sampling in general. For the survey and sampling design used here, the available information indicates the trawl to be adequate, but the small catches call for further studies, likely leading to improvements to the trawl sampling.

The available drawings of the Nordic trawl indicate that it is used with a small-mesh and short codend, and the change in mesh size from the codend to the trawl is large. This could cause the so-called "bucket effect". This is partly documented and partly anecdotal information and concerns the heavy loss of fish in front of the codend due to combination of trawl design and trawling speed. In such cases, fish might swim in the transition zone between the codend and the trawl, and escape through the trawl meshes, and cause size and species selection (see e.g. http://www.worldfishing.net/features101/product-library/fish-catching/trawling/increasing-efficiency-in-pelagicsemi-pelagic-trawling; Wardle *et al.*, 1986; Fernoe and Olsen, 1994).

Recommendations: There is a need to have the design evaluated by experts in trawl design to make sure that the gear and fishing protocols are aligned with the survey objectives. Simple adjustments, e.g., increasing total length and mesh size of the codend and the extension piece could mitigate the identified potential problems. Over the long-term, the efficiency and selectivity of the trawl could be tested by comparing samples from same area taken with the survey trawl and a purse seine. Further, state-of-the-art acoustic and optic technology allows direct observation of trawl efficiency by observing fish behaviour and escapement at various critical positions of the trawl. Thus, I recommend that such approaches should be pursued and that, in the long-term, trawl and vessel configurations be used that enable direct sampling of pelagic schools.

4.2.7 Acoustic equipment specifications

The survey applies state of the art echosounding technology with multiple frequencies Simrad EK 60 as the main tool. The survey team has developed new innovative filtering routines utilising the multiple frequency system, and much work has already been done on utilising the variation in backscattering by frequency, and there is still further potential in this technique. This avenue need to be pursued further.

Due to the fact that fish are distributed close to the vessel, a higher ping rate than the one applied might have given better resolution of schools for the characterisation of distributional, ecological and behavioural properties important to the survey results.

Complementary sensors were used for behavioural studies including multibeam systems. Such instrumentation is useful for studying avoidance reactions to vessel and trawl (Ona *et al.,* 2007). Behaviour of fish in relation to water currents could be obtained from data produced by ADCP. We were informed that new advanced sonars (Simrad MS/ME 70) will be available in the near future. These will give new opportunities to study fish in the upper part of the water column.

The acoustic specification is appropriate for abundance estimation, noting that a layer near the surface is not sampled. However, the acoustic sampling may not be adequate for research on school characteristics and a description of the global pelagic ecosystem.

Recommendations: The following should be considered: (a) develop routines for using new sonar technology (MS/ME 70) when these become available to quantify abundance and vessel-induced behavioural effects of near surface fish; (b) continue to work on definition and precision of the VMR process; (c) use a higher pingrate to improve resolution of fish close to the vessel; and (d) continue development of methods that categorize the acoustic records and thus support automatic species identification, following existing methodologies (e.g. Haralabous and Georgakarakos, 1996; Korneliussen and Ona 2000; Lawson *et al*., 2001; Kloser *et al.* 2002).

4.2.8 Vessel avoidance

Fish response to vessel passage has been documented for small pelagic species in other areas (e.g. Freon and Misund, 1999). There is a potential for bias in abundance estimates from acoustic surveys if vessel passage causes fish to change their orientation in the water column, or exhibit some kind of consistent movement, either avoidance or attraction. Echosounders used in the CPS acoustic-trawl survey are mounted in the centre of vessel and are effectively deeper than approximately 3.75 m and extend to 10 m. Sardine, in particular, are often found near the surface at least at some times of the year, and fishermen have noted strong avoidance responses to vessel passage. This is a critical issue to address when deciding how or whether to use the abundance estimates based on acoustic-trawl data for stock assessment.

The influence of fish avoidance has been investigated using two approaches: (a) the distribution under and to the side of the vessel was examined using multibeam sonar, and (b) volume backscattering (S_v; dB re 1 m^{-1}) of fish schools observed in successive pings was examined to test the hypothesis that a vessel impact would lead to a reduction in S_v and an increasing average depth during passage. Studies with similar equipment on European pilchard in the Mediterranean Sea show increased schools off track (Soria *et al*., 1996), while Chilean sardine in contrast showed no increase in schools off track (Gerlotto *et al*., 2004). In most cases for CPS in the CCE there was little evidence for differences in depth or backscatter from the front to the end of schools, suggesting that any diving behaviour takes place before the school passes through the acoustic beam, although a minor diving apparently was noted when schools were shallow. There is limited evidence for avoidance. School counts showed a sharp peak under the vessel, and a steady reduction with distance away from the vessel track and depth, suggesting no increase in schools off track, as might be expected if there were lateral movement in response to the vessel. Additionally, the maps of CPS observed acoustically and caught in trawls were qualitatively in agreement. The contrasting evidence of strong avoidance experienced by fishermen might be caused by learning; fish being hunted are more reactive than those not.

It is concluded that, based on the information presented during the meeting, vessel-induced behaviour, including vessel-specific behaviour, appears unlikely to have a substantial effect on the estimates of CPS biomass during the current surveys. However, it is noted that the results related to the potential for lateral avoidance are somewhat difficult to interpret without reference to expected patterns under alternative hypotheses of fish response. Nevertheless, they do not suggest large avoidance effects.

Recommendations: Although vessel avoidance has been studied using adequate methods and there was no evidence for substantial avoidance effects, the issue warrants further study. For example, variation in vessel size (41m – 65m) and survey speed (11-14 knots) calls for further, follow-up studies. Future studies should resolve the information by species and address the possibility of spatial and temporal variability in vessel effects.

- The frequency response of schools should be studied for trends versus depth 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 behaviour 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. Over the long term, vessel by vessel studies following the model of the Bering Sea comparative studies, should be conducted.

The sophisticated multibeam systems (Simrad MS70 and ME70) (Ona *et al.,* 2006) will be available on the new SWFSC vessel in near future. This represents state-of-the-art instrumentation to clarify issues related to school behaviour 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.

4.2.9 Target strength

Target strength is a key property in acoustic-trawl surveys, but is the basic formula used here appropriate for giving reliable survey estimates?

No, *in situ* target strength measurements are available for CPS in the CCE. Used instead are published TS versus length relationships for the same or similar species in other ecosystems. While this substitution is not ideal, such TS estimates likely do not have a large impact on abundance estimates. The largest error may result from the use of

Chilean jack mackerel, with specific swimbladder properties (Peña 2008), as TS for Pacific mackerel.

Recommendations: *In situ* CPS TS measurements are difficult to obtain, but effort should be made in future CPS acoustic-trawl surveys; for example, using alternative platforms (Johansen *et al.,* 2009). Alternative approaches such as school capture with purse seine, inference from models and multi-frequency observations or *ex-situ* methods should be explored. The impact of errors in the TS could be elevated and become detrimental to assessment if distribution patterns of the various species change with higher degree of mixing. It is also known that TS might vary by season, depth and condition. Modelling TS taking this into account should be a goal for the future (see Ona, 2003).

4.3 ToR 3 – Evaluate and provide recommendations for the application of these methods

Evaluate and provide recommendations for the application of these methods for their utility in stock assessment models and for their ability to monitor trends at the population level for Pacific sardine and other CPS. Survey methods or results that have a flawed technical basis, or are questionable on other grounds, should be identified so they may be excluded from the set upon which stock assessments and other management advice is to be developed.

Application of the acoustic – trawl survey in stock assessment

The applicability of the survey data in assessment is totally dependent on its quality (as discussed above) and consistency over time and among species. I concur with the rest of the panel on the quality of the survey methods and the collected data. When it comes to consistency of the data over time, the time-series are short and are difficult to evaluate. Often, inconsistency in time series becomes apparent when stocks are passing through recruitment cycles or other natural variability. My limited experience with the stock assessment model used in this case prevents me from giving specific comments directly related to assessment models.

The most apparent finding is the discrepancy among the involved species. The focus of the survey has been on Pacific sardine, and the quality and appropriateness for the other species are limited by their geographical distribution or variability. Not unexpectedly, there was less information for the other species; hence, in contrast to Pacific sardine, it was more difficult to reach definitive conclusions for jack mackerel, Pacific mackerel and northern anchovy

Pacific Sardine

Pacific sardine are an actively-managed CPS species. Given the relatively short time-series of abundance estimates, inclusion of the acoustic-trawl data as relative indices of 1+ biomass would likely not impact the assessment results substantially (but this should be examined in the assessment). The low fishing mortality increases demand for fisheries independent data. I consent that including the sardine estimate as an absolute estimate is appropriate for the upcoming stock assessment in September 2011. The major potential sources of uncertainty related to using the acoustic-trawl data as estimates of absolute abundance identified during the review are:

- The relationship between TS and length are not based on *it situ* measurements, but are taken from a different area.
- Sardine may avoid the vessel to some extent.
- Sardine are found outside of the area covered by the acoustic transects (north, south, offshore and inshore), with the proportion of the stock outside this area depending on season as well as environmental conditions.

Although these uncertainties seem limited at the time being, these are all reasons to closely follow up each of the issues to secure stability over time. In particular, all effort should be taken to minimize the impact of fish distributed outside the survey area by reanalyzing the auxiliary information (e.g., trends in density along transects, information from ichythoplankton surveys south of the survey area, and catch information).

Jack mackerel
Jack mackerel are a monitored CPS species. This is a data poor stock and the survey information is thus an important source. Being of limited abundance compared to sardine creates additional uncertainty of larger importance to jack mackerel than for sardine. Particularly, the catchability of jack mackerel could be considerably different from sardine. This suggests that the summer survey might be the most appropriate as this is the time with the highest degree of separation. To conclude, as the survey estimates are the only relevant estimate, the estimates should be considered as estimates of absolute abundance and biomass of jack mackerel for the survey area in US waters (and the estimate for summer may therefore be more reliable).

Pacific mackerel
High variability (CV) and unknown and variable amount of fish outside the survey area suggest that these data should be used with great caution. At present, the Pacific mackerel data appears inappropriate to be included in a stock assessment model.

Northern anchovy
This species has another distribution and behaviour compared to the other CPS. This should not prevent the acoustic – trawling survey method from being adequate for giving reliable estimation of abundance. As the stock is small and fragmented in inshore areas, it is not properly covered by the present survey design. The available information is not recommended to be used in stock assessment models.

4.4 ToR 4 – Evaluate the effectiveness of the survey methods
Evaluate the effectiveness of the survey methods for detecting the appropriate spatial scale and seasonal timing for annually estimating stock abundances.

Pacific Sardine
Anecdotal and fisheries information indicates that Pacific sardines are distributed outside the survey area. This is documented by the Mexican and the Canadian surveys. Also, Canadian fishermen claim that large catches are taken outside the Canadian survey area (in the inlets). Available analyses indicate that the problem is small but in some surveys possibly substantial. This issue needs substantial attention as it might change from year to year. It is recommended that analyses using auxiliary information, including data from fishermen, are intensified. If possible, systematic collection of such information about distribution both outside and during the time of the survey should be done. At present, it is reasonable to state that the acoustic-trawl surveys can be

considered as providing estimates of distribution of abundance for the survey area. To conclude, it is expected that the area surveyed covers the majority of sardine at the time of the survey. The distribution dynamics over time and space, as described in the primary documents, suggest that analysis of distribution changes and survey coverage should be routinely done as a part of the survey stock assessment.

Jack mackerel
The jack mackerel acoustic-trawl survey estimates are the only quantitative scientific information about this stock. A major part of the uncertainty of this stock arises probably due to distributional uncertainty. Even though less information is available for jack mackerel, the geographical information obtained from the survey is important. Over the years, the spatial and temporal distribution might give a more comprehensive understanding of the true distribution pattern. This might also enhance the applicability of the data in stock assessment models.

Pacific mackerel
It is a general concern for this species that a considerable, but still unknown, part of the stock is found outside the survey area. The distribution pattern of the stock within the survey area is probably well reflected. Thus, survey estimates given for the survey are considered valid, but how big the fraction of the stock is remains unknown and might vary from year to year.

Northern anchovy
The anchovy population is currently small and distributed inshore, often in areas not properly covered by the survey. The survey is thus neither expected to reflect the distribution nor the abundance. A few northern anchovy were sampled nearshore, mostly off Oregon and Washington (2006, 2008, and 2010), north of Monterey Bay (2006) and in the Southern California Bight (2006 and 2008). Apart from the occasional large catches (~ 300kg) off the mouth of the Columbia River and other likely locations such as off Santa Barbara and Monterey Bay, anchovy were scarce in these surveys, even off southern California where they once were the most abundant species. If the anchovy population should be properly covered, the sampling design would need to be considerably modified.

4.5 ToR 5 – Decide through Panel discussions if the ToRs and goals of the peer review have been achieved

Decide through Panel discussions if the ToRs and goals of the peer review have been achieved. If agreement cannot be reached, or if any ToR cannot be accomplished for any reason, then the nature of the disagreement or the reason for not meeting all the ToR must be described in the Summary and Reviewer's report. Describe the strengths and weaknesses of the review process and Panel recommendations.

The review was carried out efficiently with a strong focus on covering all the ToRs. As far as I can see, we went through materials that elucidated all ToRs and recommendations were developed for all of them. The atmosphere during the discussion was good and creative. Occasionally, when disagreement surfaced, we were given enough time to cover the subject to a point where agreement was obtained. This process was run efficiently so that momentum was maintained and progress was not lost in endless discussions.

It is unquestionable that the panel chair, being well prepared and able to separate the important and unimportant issues, should be paid tribute for an efficient meeting and a fruitful process. A second positive source was the Acoustic-Trawl Survey Technical Team, which gave a professional presentation and was very efficient and apt to respond to all requests.

During the preparation phase, I was guided through all the needed paperwork in an efficient way. We had the scientific documentation available in due time although there was some delay due to a misunderstanding regarding the background information on the ftp site.

In addition to the panel and the The Acoustic-Trawl Survey Technical Team, other observers were present, leading to a large number of attendees. This was mostly useful because more information was readily available when needed. On the other hand, some of these participants were not as prepared and focused as e.g. the The Acoustic-Trawl Survey Technical Team, making arguments, presenting opinions and information that were more difficult to interpret.

Altogether, the review was an exciting meeting with a focused discussion moving steadily towards the goal. This made it a nice and educating experience.

5. Recommendations

The recommendations with respect to utilization of survey results in stock assessment:

It is recommended that Pacific sardine acoustic – trawl survey estimates of abundance and biomass are used in the September stock assessment working group as estimates of absolute abundance/biomass

Jack mackerel data show high variability but provide useful information for assessment and monitoring purposes.

Pacific mackerel estimates should be considered valid within the survey area but uncertainty on the distribution and migration over seasons and years creates uncertainty about the representativity regarding the whole stock.

The Pacific anchovy is poorly covered and the data are not appropriate for stock assessment. Adjustment of survey design is needed to enhance geographical coverage.

Further recommendations are organised according to urgency:

1. Immediate (prior to the next stock assessments)

a. Analyses should be conducted using auxiliary information (e.g. trends in density along transects, information from ichythoplankton surveys south of the survey area, catch information) to provide best estimates for the biomass outside of the survey area as well as the range of possible biomass levels.
b. The CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.

2. Short-term

a. Investigate 'gross' species selectivity effects by comparing the ratio of catch rates. and acoustic density in areas where single species dominate.

b. Conduct sensitivity tests in which stations are pooled and allocated to acoustic values over a larger area.
c. Consult experts in trawl design to evaluate the current trawl design in relation to the survey objectives.
d. 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.
e. Check the filtering algorithm every year to ensure that it is still suitable under changing conditions.
f. Analyze existing data for vessel avoidance:
    a. trends in frequency response over depth strata in schools.
    b. comparing school depths from the 18 kHz and other transducers to examine possible avoidance reactions.
g. Continue to consider the advantages and disadvantages of conducting acoustic-trawls surveys at different times of the year.
h. 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.
i. Conduct standard (ICES) vessel noise measurements for all vessels.

3. Long-term

a. Evaluate if differ fishing trawling practices / gears would be beneficial
b. Use a trawl/vessel configuration that can support directed trawl sampling.
c. Conduct repeated trawl sampling experiments to obtain better understanding of small-scale variability.
d. Test the efficiency and selectivity of the trawl by comparing samples from same area taken with the survey trawl and purse seine.
e. Apply state-of-the-art acoustic and optic technology to investigate fish behaviour and escapement at various critical positions of the trawl.
f. Conduct validation tows on various kinds of backscatter to assure that the filtering algorithm is performing as intended to separate out CPS.
g. Make efforts to obtain *in situ* target strength measurements for CPS species in California Current Ecosystem.
h. Focus on utilising more advanced instrumentation and resource-demanding research for studying vessel impacts.

The survey data can be used for other purposes other than estimating stock properties for the assessment and management of the stock. For example, acoustic-trawl data could be used in ecosystem studies and for ecosystem based fishery management. Although this is beyond the scope of the review, the following suggestions can be useful:

- estimate plankton biomass;
- describe the vertical habitat (thermocline, oxycline, currents, plankton, etc.); and
- determine school characteristics (likely to provide information on species and on possible changes in the fish behavior due to environmental variations)
- Utilise the above to better understand and quantify annual changes in distribution patters that influence quality of survey estimates.

6. Conclusion

The review was carried out efficiently and in a productive and stimulating atmosphere.

The scientific information presented for the evaluation panel are of high scientific standard and indicate that the acoustic trawl survey and associated data analysis follow good practice for such surveys.

The survey results for Pacific sardine are adequate as data for the assessment as estimates of absolute of abundance. The survey also describes well the distribution of the stock, although there is a need to monitor changes in distribution that could impact the quality of data as input in assessment.

The results for the other stocks are more variable mainly due to distributional impacts, but the surveys are an important source of information for all due to the general lack of information.

In the background information and in the scientific literature, it is well known that the CPSs vary cyclically in abundance and distribution. I understand that a focused review of the acoustic-trawl survey methodology is needed, but think that the usefulness of the survey and its review in coming years will depend on the survey's ability to adjust design according to the likely changes in distribution and abundance. My personal opinion is that this issue should have been given attention in the ToR of the review. I think the available information could have given useful guidance for a systematic involvement of auxiliary information and active development and integration of other survey information, in particular the aerial survey. Such approaches could have strengthened the long term monitoring, assessment and management goals of the CPS.

Cited literature

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Appendix 2:

Statement of Work for Dr. Olav Rune Godø

External Independent Peer Review by the Center for Independent Experts

Panel Review of an Acoustic-Trawl Method for Surveying CPS

3-5 February 2011

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by the CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The Pacific Fishery Management Council (PFMC) uses information from surveys to make decisions related to harvest guidelines for managed coastal pelagic species (CPS) (i.e., Pacific sardine and Pacific mackerel) and Overfishing Levels (OFLs) / Acceptable Biological Catches (ABCs) for monitored CPS (i.e., northern anchovy, jack mackerel and market squid). The current assessments for Pacific sardine and Pacific mackerel are based on the 'Stock Synthesis' framework. The assessment for Pacific sardine uses age- and length-composition data from four fisheries, the results from an aerial survey, and measures of female spawning biomass and total egg production (DEPM) from combined trawl and egg surveys, to estimate the parameters of a population-dynamics model. The survey outcomes and hence model-derived estimates of Pacific sardine spawning-stock biomass (SSB) have recently decreased, resulting in dramatically lower harvest guidelines for 2008 and 2009. The Southwest Fisheries Science Center's (SWFSC's) current standard survey covers the 'core' spring-spawning area between San Diego and San Francisco. The exploited stock ('northern subpopulation') is believed to migrate seasonally, potentially from northern Baja California, Mexico in the spring to British Columbia, Canada in the summer. The DEPM is an indirect measure of fish distribution and abundance. As the sardine population recovered from historic lows and recently reoccupied its former historic range, migrating as far north as Canada in the summer, multiple types and more direct estimates of CPS biomass, particularly sardine biomass, may be needed to improve stock assessments.

Three CIE reviewers will serve on a Panel to evaluate an acoustic-trawl method for surveying CPS. The SWFSC's Fisheries Resources Division (FRD) has explored the use of acoustic-trawl methods, which are commonly used by other regions and countries to estimate the abundances and distributions of CPS. Acoustic-trawl methods may provide a more robust (i.e., accurate and precise) and efficient means to routinely survey the Pacific sardine populations as well as the populations of jack mackerel, Pacific mackerel, and northern anchovy. In spring 2006, 2008, and 2010, and summer 2008, FRD conducted acoustic-trawl surveys off the U.S. west coast, from the Mexican to Canadian borders, and developed methods for estimating the abundances and distributions of CPS from these data. The confinement of the stocks within the survey area, compared to inshore-offshore as well as north into Canada and south into Mexican waters is important design issues. Behavioural aspects are also raised as an important impact factor.

The Panel report will be used to guide improvements to the acoustic-trawl survey and analysis methods, the resulting time series of estimates of abundance and distribution for CPS species, and estimates of their uncertainty. The report will also be used to evaluate the appropriateness of using the results from the survey as inputs to the assessment model for Pacific sardine and Pacific mackerel. The assessment models for Pacific sardine and Pacific mackerel will be reviewed by separate Stock Assessment Review (STAR) Panels. However, the report of this Methods Review Panel will be considered by the assessment analysts and STAR Panels.

An overview of the ToRs for the Panel are attached in **Annex 2**. The tentative agenda of the Panel review meeting is attached in **Annex 3**. Finally, an outline of the summary report of the Panel is attached as **Annex 4**.

Requirements for CIE Reviewer: Three CIE reviewers shall participate in the Panel and conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. Three CIE reviewers shall have expertise and work experience in the design and execution of fisheries-independent acoustic-trawl surveys for estimating the abundance of coastal pelagic fish species, and expertise with sardines is desirable. The CIE reviewers shall have knowledge of the life history strategies and population dynamics of coastal pelagic fish species.

Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location/Date of Peer Review: The CIE reviewers shall participate as independent peer reviewers during the panel review meeting at NOAA Fisheries, Southwest Fisheries Science Center, 3333 North Torrey Pines Court, La Jolla, California, 92037-1023, during 3-5 February 2011 in accordance with the agenda (Annex 3).

Statement of Tasks: The CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

<u>Prior to the Peer Review</u>: Following the CIE reviewer selections by the CIE Steering committee, the CIE shall provide the CIE reviewers' information (name, affiliation, and contact details) to the Contracting Officer's Technical Representative (COTR), who will forward this information to the NMFS Project Contact no later the date specified in the

Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers (reviewer hereafter). The Project Contact is responsible for providing the reviewer with the background documents, reports, foreign national security clearance, and information concerning other pertinent meeting arrangements. The Project Contact is also responsible for providing the Panel Chair (Chair hereafter) a copy of the SoW in advance of the Panel. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When a reviewer who is a non-US citizen participates in a panel review meeting at a government facility, the Project Contact is responsible for obtaining a Foreign National Security Clearance for the CIE reviewers. For the purpose of their security clearance, each reviewer shall provide requested information (e.g., name, contact information, birthdate, passport number, travel dates, and country of origin) to the Project Contact at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations (available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/sponsor.html).

Pre-review Background Documents: Two weeks before the review, the Project Contact will electronically send to each reviewer, by email or FTP, all necessary background information and reports for the review. If the documents must be mailed, the Project Contact will consult with the CIE on where to send the documents. The CIE reviewers shall read all documents in preparation for the review, for example:

- documents on current survey methods, in particular, related to DEPM and aerial surveys of sardine and other CPS;
- document on SWFSC acoustic-trawl surveys conducted between 2006 and 2010;
- documents from past Panels; and
- miscellaneous documents, such as the ToR, SoW, agenda, schedule of milestones, deliverables, logistical considerations, and PFMC's ToR for CPS Stock Assessement Methodology Reviews.

The CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. Any delays in submission of pre-review documents for the CIE review will result in delays with the CIE review process, including a SoW modification to the schedule of milestones and deliverables.

Panel Review Meeting: Each CIE reviewer shall participate in the Panel and conduct an independent review in accordance with the SoW and ToRs. **Modifications to the SoW and ToR cannot be made during the review, and any SoW or ToR modification prior to the review shall be approved by the COTR and CIE Lead Coordinator.** Each reviewer shall actively participate in a professional and respectful manner as a member of the Panel, and their review tasks shall be focused on the ToRs as specified in the contract SoW.

Respective roles of the CIE reviewers and Chair are the PFMC's ToR for CPS Stock Assessment Methodology Review (see p. 6-8). The CIE reviewers will serve a role that is equivalent to the other panelists, differing only in the fact that they are considered 'external' members (i.e., outside the PFMC's membership and not involved in management or assessment of west coast CPS, particularly sardine). The reviewers will serve at the behest of the Chair, adhering to all aspects of the PFMC's ToR as described in Annex 2. The Chair is responsible for: 1) developing an agenda; 2) ensuring that Panel members (including the Reviewers) and those being reviewed (the "proponents") follow the ToR; 3) participating in the review of the methods (along with the Reviewers); and 4) guiding the Panel (including the Reviewers), FRD, and NWSS to mutually agreeable solutions.

The Project Contact is responsible for any facility arrangements (e.g., conference room for Panel meetings or teleconference arrangements). The CIE Lead Coordinator can contact the Project Contact to confirm any meeting facility arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: In addition to participating in the Panel, each CIE reviewer shall also complete an independent-review report in accordance with the SoW, i.e., in the required format as described in Annex 1; and addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: Reviewers will assist the Chair with contributions to the Summary Report. The Panel is not required to reach a consensus and, therefore, the reviewers should provide a brief summary of their views on the findings and conclusion reached by the Panel in accordance with the ToRs (format defined in Annex 1).

Specific Tasks for CIE Reviewer: The following chronological list of tasks shall be completed by the CIE reviewers in a timely manner, as specified in the **Schedule of Milestones and Deliverables**:

1) prepare for the review by thoroughly reading the documents provided by the Project Contact;
2) participate in the panel review meeting in La Jolla, CA during 3-5 February 2011 as indicated in the SoW, and conduct an independent review in accordance with the ToRs (Annex 2); and
3) write an independent-review report, addressed to the "Center for Independent Experts," and submit it to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to, and CIE Regional Coordinator, via email to David Die ddie@rsmas.miami.edu, no later than 17 March 2011 indicated in the SoW. The report shall be written using the format and content requirements specified in Annex 1, and address each ToR in Annex 2.

Schedule of Milestones and Deliverables: The CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

28 December 2011	The CIE sends the CIE reviewers' contact information to the COTR, who forwards it to the Project Contact.
10 January 2011	The Project Contact sends the pre-review documents to the CIE reviewers.
3-5 February 2011	The CIE reviewers participate in the Panel review meeting and conducts an independent review.
3 March 2011	The CIE reviewers submit their reports to the CIE Lead Coordinator and CIE Regional Coordinator for final review and revisions.
17 March 2011	The CIE submits independent peer review reports to the COTR for contractual compliance.
24March 2011	The COTR distributes the final reports to the Project Contact and the regional Center Director.

Modifications to the Statement of Work: Requests to modify this SoW must be made through the COTR who submits the modification for approval to the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the CIE within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToR of the SoW as long as the role and ability of the Reviewer to complete the SoW deliverable in accordance with the ToRs and the deliverable schedule is not adversely impacted. The SoW and ToRs cannot be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, the reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via email the contract deliverables (the CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards: (1) the CIE report shall have the format and content in accordance with Annex 1; (2) the CIE report shall address each ToR as specified in Annex 2; and (3) the CIE report shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon notification of acceptance by the COTR, the CIE Lead Coordinator shall send via email the final CIE reports in pdf format to the COTR. The COTR will distribute the approved CIE reports to the Project Coordinator, the regional Center Director, and the PFMC.

Key Personnel:

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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations.

2. The main body of the Reviewer's report shall consist of the following sections, in accordance with the ToRs: Background, Description of the Reviewer's Role in the Review Activities, Summary of Findings for each ToR, and Recommendations and Conclusion.

   a. The Reviewer should describe in their own words the review activities completed during the panel meeting, including providing a detailed summary of findings, recommendations, and conclusion.

   b. The Reviewer should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where they were divergent.

   c. The Reviewer should elaborate on any points raised in the Summary Report that might require clarification.

   d. The Reviewer shall provide a critique of the review process, including suggestions for improving both the process and products.

   e. The CIE report shall be a stand-alone document for others to understand the proceedings and findings of the meeting without having to read the Panel report. The report shall be an independent review of each ToR, and shall not simply repeat the contents of the Panel report.

3. The Reviewer's report shall include the following separate appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: The CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the review meeting.

Annex 2: Terms of reference (ToRs) for the peer review of the acoustic-trawl method for surveying Pacific sardine and other CPS

The CIE reviewers will participate in the panel-review meeting to conduct independent peer reviews of the acoustic-trawl method as it pertains to surveys of coastal pelagic fish species (CPS) in the California Current Ecosystem (CCE), principally Pacific sardine, but potentially also including jack mackerel, Pacific mackerel, and northern anchovy, depending on their biomasses and distributions, and the sampling effort afforded. The survey area is the CCE off the west coast of the United States of America (US), generally between the Mexico-US and the US-Canadian borders. The latitudinal and offshore extents of the surveys are seasonal, extending further north in the summer and further offshore in the spring. Survey estimates are to include absolute biomasses, and their total random sampling errors, and spatial distributions. The review solely concerns technical aspects of the survey design, method, analysis, and results, and addresses the following ToR:

ToR 1 – Review documents detailing acoustic-trawl survey and data analysis methods and results according to the PFMC's ToR for CPS Stock Assessement Methodology Reviews. Document the meeting discussions. Evaluate if the documented and presented information is sufficiently complete and represents the best scientific information available.

ToR 2 – Evaluate and provide recommendations on the survey method used to estimate the abundances and distributions of Pacific sardine and other CPS, and associated sources of uncertainty. Recommend alternative methods or modifications to the proposed methods, or both, during the Panel meeting. Recommendations and requests to FRD for additional or revised analyses during the Panel meeting must be clear, explicit, and in writing. Comment on the degree to which the survey results describe and quantify the distributions and abundances of CPS, in particular Pacific sardine, and the uncertainty in those estimates. Confidence intervals of survey estimates could affect management decisions, and should be considered in the report.

ToR 3 – Evaluate and provide recommendations for the application of these methods for their utility in stock assessment models and for their ability to monitor trends at the population level for Pacific sardine and other CPS. Survey methods or results that have a flawed technical basis, or are questionable on other grounds, should be identified so they may be excluded from the set upon which stock assessments and other management advice is to be developed.

ToR 4 – Evaluate the effectiveness of the survey methods for detecting the appropriate spatial scale and seasonal timing for annually estimating stock abundances.

ToR 5 – Decide through Panel discussions if the ToRs and goals of the peer review have been achieved. If agreement cannot be reached, or if any ToR cannot be accomplished for any reason, then the nature of the disagreement or the reason for not meeting all the ToR must be described in the Summary and Reviewer's report. Describe the strengths and weaknesses of the review process and Panel recommendations.

The Reviewer's report should be completed, at least in draft form, prior to the end of the meeting.

Annex 3: Tentative Agenda

<u>THURSDAY, FEBRUARY 3, 2011 – 8:00 A.M.</u>

A. Call to Order, Introductions, Approval of Agenda, and Appointment of Rapporteurs

B. Terms of Reference for the CPS Methodology Reviews
(8:30 a.m., 0.5 hour)

C. Presentation on the acoustic-trawl survey — David Demer
(9:00 a.m., 1.5 hours)

BREAK

C. Presentation on the acoustic-trawl survey (Continued) — David Demer
(11 a.m., 1 hour)

LUNCH

C. Presentation on the acoustic-trawl survey (Continued) — David Demer
(1 p.m., 1.5 hours)

D. Panel discussion — Panel
(2.30 p.m., 1 hour)

BREAK

E. Requests to FRD — Panel
(4.00 p.m., 1 hour)

<u>FRIDAY, FEBRUARY 4, 2010 – 8:30 A.M.</u>

F. Responses to Panel Requests (FRD) — David Demer
(8.30 a.m., 2 hours)

BREAK

G. Panel discussion — Panel
(11 p.m., 1 hour)

LUNCH

H. Requests to the FRD — Panel
(1 p.m., 1 hour)

I. Report drafting — Panel
(2.30pm, 1 hours)

BREAK

J. Responses to Panel Requests (FRD) — David Demer
(4 p.m., 0.5 hours)

K. Requests to FRD — Panel

(4.30 p.m., 0.5 hours)

SATURDAY, FEBRUARY 5, 2010 – 8:30 A.M.

K. Responses to Panel Requests (FRD) David Demer

(8.30 a.m., 1.5 hours)

BREAK

L. Report Drafting Panel

(11am , 1 hours)

LUNCH

M. Report review Panel

(1 p.m+)

Annex 4: Panel Summary Report (Template)

- Names and affiliations of Panel members

- List of analyses requested by the Panel, the rationale for each request, and a brief summary of the proponent's responses to each request.

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

- Explanation of areas of disagreement regarding Panel recommendations:
  - among Panel members; and
  - between the Panel and the proponents

- Unresolved problems and major uncertainties, e.g., any special issues that complicate survey estimates, estimates of their uncertainty, and their use in stock assessment models.

- Management, data, or fishery issues raised the public (i.e., non-Panel and proponent participants) at the Panel meetings.

- Prioritized recommendations for future research, and data collections and analyses.

Appendix 3: Panel Membership or other pertinent information from the review meeting.

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Center for Independent Experts (CIE) Independent Peer Review Report of:

Acoustic-trawl method as it pertains to surveys of coastal pelagic fish species in the California Current Ecosystem.

NOAA / Southwest Fisheries Science Center
La Jolla, California
February 2-5, 2011

F. GERLOTTO

1. Executive Summary

The Chair identified six aspects that provided a focus for discussions during the review:

i. design of the acoustic and trawl sampling, representativeness of the data for the four CPS species;
ii. analysis of the survey data for estimating CPS abundances;
iii. evaluation of potential biases in sampling design and analysis;
iv. characterization of uncertainty in estimates of CPS biomass;
v. decision if acoustic-trawl estimates of CPS biomass can be used in stock assessments and management advice for Pacific sardine, jack mackerel, Pacific mackerel, and northern anchovy; and
vi. guidance for future research.

Several presentations were given to the panel prior to the discussion of each one of these aspects, which allowed for a better understanding of the documents provided before the meeting and elucidated a number of points that needed to be discussed. Among these documents, some were of major importance and completed the two synthetic "primary documents" produced by Dr David Demer and his team (the Advanced Survey Technologies Program: ASTP). They also presented, in great detail, some innovative methods, especially using multibeam acoustic instruments and species identifications.

In general, there was consensus between the participants of the Panel, and the final report reflects correctly these discussions and conclusions.

The general conclusion of the review process is that the design of the surveys, the selection of instruments and methods and the general protocol are adequate. They produce an accurate abundance estimate of the major stock of California Pelagic Species (CPS), i.e. the Pacific sardine stock, and to a lesser level of the other stocks (jack mackerel, Pacific Mackerel). The limited and coastal distribution of the northern anchovy requires additional information, as the general survey designed primarily for sardine

cannot give a comprehensive overview of the distribution of this stock. The conclusion is that (1) the acoustic-trawl surveys can be included in the 2011 Pacific sardine stock assessments as 'absolute estimates'; (2) information on mackerel and jack mackerel are useful for stock analysis; (3) a specific survey design should be used for abundance estimates of anchovy.

2. Background

The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. A Statement of Work (Annex 2) is established by the NMFS Project Contact and Contracting Officer's Technical Representative, and reviewed by the CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee. Further information on the CIE process can be obtained from www.ciereviews.org.

The California Pelagic Species, and principally sardine, mackerel and jack mackerel are distributed along a general area along the California coast but the surveys concern principally the part of the area belonging to US coastal waters. Some information was collected from the Canadian fishery. The Mexican area in which the fish are found was not included in the survey. Surveys are mostly performed during spring (in the southern part of the area: 2006, 2008, 2010) and during some years in summer (central and northern part of the area: 2008). They are done together with eggs and larvae surveys. The review focused on survey design, including the acoustic and trawl sampling, the precision and accuracy of results and their potential use in stock assessment.

3. Description of the Reviewer's Role in the Review Activities

My background is on fisheries biology, with particular expertise in pelagic fish behaviour related to acoustic research and fisheries acoustics survey. My Institute (IRD, "*Institut de Recherches pour le Développement*", France) is specialized in co-operative research with developing countries, and in this framework my research during the last 3 decades concerned pelagic stocks in Africa (Ivory Coast, Senegal), Caribbean (Venezuela, Cuba, French West Indies) and South America (Chile and Peru), where I worked principally on Clupeids (ethmalose, sardine, sardinella), Engraulids (several species of anchovies) and Carangids (Chilean Jack Mackerel). I have also conducted research in acoustic survey design and acoustic methods. I have developed works on acoustic sonar, being pioneer in the adaptation and use of multibeam sonar for behavioural research on fish schools.

During this period, I have chaired several ICES groups (ICES Fisheries Acoustics WG 1997-2000, the ICES Fisheries Technology Committee 2005-2007, the ICES study group on Fish avoidance to research vessels 2007-2010) and international networks. In my Institute, I have been chair of several Research Units (from 1995 to 2004) and some EU projects (among which the AVITIS project, 1997-2000 focused on the design of multibeam sonar).

Due to my area of expertise, my major contribution was on fish avoidance, distribution and identification, and on the impact and measurement of fish behaviour related to acoustic estimates and survey methods. Within this area, I was especially interested in the methods designed by the team on measurement of fish avoidance using multibeam sonar, on the definition of the "potential habitat" for sardine, and on species identification using multifrequency methods.

4. Findings by ToR

4.1. ToR 1- Reporting

Review documents detailing acoustic-trawl survey and data analysis methods and results according to the PFMC's ToR for CPS Stock Assessment Methodology Reviews. Document the meeting discussions. Evaluate if the documented and presented information is sufficiently complete and represents the best scientific information available.

The reviewers received important material for supporting their reviews. The two primary documents from Demer et al., 2011, on "Methods and example application" and Zwolinski et al, 2011, on "Estimates of distributions and abundances in spring 2006, 2008, and 2010" were particularly useful in that they clearly present the whole procedure. The documents provide an extensive description of the survey design and acoustic methods applied. The figures and flow charts allow a good understanding of these methods and the protocols. Within the large amount of scientific papers (more than 20) that were made available, I was particularly interested in three of them that proved particularly useful for understanding the methods elaborated: Zwolinski et al (2010), on potential habitat; Cutter and Demer (2007), on fish behaviour observed through multibeam systems; and Demer et al (2009), on a statistical-spectral method for echo classification.

In general, the documentation distributed to the Panel was complete and of high scientific quality (unfortunately, that was not the case of the internet facilities). Most of the questions that I listed before the meeting were elucidated thanks to these documents and the answers of the team. The documentation demonstrates that the scientific skills of the team are extremely high and that the methodology in general is accurate. The comments and criticisms that were made during the meeting were mostly marginal, aiming to help the team to improve its methodology where it can be done, but my general conclusion was there are no weak areas and only a few specific points should be substantially improved in the future.

I fully agreed with the following statement from the Chair of the Panel: "*The Panel* ***commends*** *the Team for their thorough presentation, detailed background material, and willingness to respond to the Panel requests. Although the review focused on the areas of potential concern with the acoustic-trawl estimates of abundance, the Panel wishes to emphasize that the Team had already identified most of the issues identified by the Panel and had prepared information pertinent to these which helped to Panel in its deliberations. The work related to avoidance of CPS to vessels was particularly helpful, allowing the Panel to draw conclusions related to whether avoidance, or at least its effects on the acoustic-trawl survey results, is likely substantial* ".

4.1.1. ToR 1 Conclusions

The two primary documents represent an excellent synthesis and are quite helpful for the reviewers. Very few points remained unclear and these were clarified during the discussion. As a whole, the documents delivered before the meeting were of a very high standard and all the information needed was available. Overall, the quality of these reports and papers showed the high competence of the team in the field of acoustic surveys.

4.2. ToR 2 –Evaluation

Evaluate and provide recommendations on the survey method used to estimate the abundances and distributions of Pacific sardine and other CPS, and associated sources of uncertainty. Recommend alternative methods or modifications to the proposed methods, or both, during the Panel meeting. Recommendations and requests to FRD for additional or revised analyses during the Panel meeting must be clear, explicit, and in writing. Comment on the degree to which the survey results describe and quantify the distributions and abundances of CPS, in particular Pacific sardine, and the uncertainty in those estimates. Confidence intervals of survey estimates could affect management decisions, and should be considered in the report.

4.2.1. Stratification / Transect design

Sampling and stratification are defined in order to adapt to a particular case (in this case the sardine stock), but also to combine the requirement of different sampling methods (namely acoustics and CUFES (Continuous Underwater Fish Egg Survey). This implied some constraints for both methods, and particularly for acoustic design. The design is mostly based upon systematic sampling using parallel equidistant transects perpendicular to the coastline. This is acknowledged as the best compromise for pelagic stock surveys, and, in general, the biases and error are minimized when using this sampling strategy. Some adaptation in this general method has been made, particularly for inter-transect distances vary in some sectors and years, but the results (and the maps delivered) show that the sampling effort is sufficient to provide a good representation of the mean density (i.e. abundance) of sardine in the area covered. I agree with the statement that "*CPS habitat is almost certainly spatially coherent, suggesting that correlation is very likely to be present in the CPS distribution, even if it cannot be quantified.*" As far as I know about variance estimates, I agree with John Simmonds' statement: "*Overall the approach is an acceptable approximation*".

Representing a compromise between several and different (sometimes contradictory) needs, the transect design is not optimal for the anchovy stock estimate, as the inter-transect distance is too wide, and the transects do not get close enough to the shore. Therefore, the abundance estimate for this species is in large part a result of extrapolation hypotheses which prevents the results to be considered as absolute biomass measurements. For this particular stock, a dedicated sampling strategy and probably a specific survey have to be designed. Nevertheless, the possible risk of underestimation of the spring abundance must be taken into consideration. Surveys during different seasons and improvement of the potential habitat definition would resolve this problem.

The stratification/transect design is adequately defined for the sardine and in a lesser level to mackerel and jack mackerel (see remarks below) and should be able to provide correct estimates of abundance, especially for sardine. For the other CPS, more work and surveys are required before to declare that absolute abundance estimates for jack mackerel and mackerel are acceptable, and a different transect and stratification strategy, i.e. specific surveys are required for anchovy.

4.2.2. Trawl sampling

The trawl sampling strategy differs considerably from those used elsewhere in the world, mostly because of the egg surveys requirements. In this case, trawls are performed by night on predefined locations, while the most current method consists in deciding a trawl depending on the acoustic information collected: a trawl is then linked to a given concentration of fish. There are two major reasons for the ASTP to design this different sampling strategy: (a) the constraints of the egg surveys that require sampling in the area where eggs are found, and (b) the fish behaviour: by day fish are rather deep and form dense schools, while by night they are scattered and very shallow, i.e. out of reach of the echo sounders. Fish catchability is better by day for acoustics and by night for trawling. This has a drawback, that sampling is not related to dense concentrations. This may have negative effects when populations of fish are mixed. Fortunately, during some periods of the year the different populations of CPS are separated. Then this strategy imposed by the fish behavior is unlikely to produce biases in the evaluation of species proportion. I share Simmonds' comment that "*though there are some concerns that in the minority parts of the area where mixtures are observed species selectivity of the gear may be an issue*". One concern is that the catches are usually rather low (a few individuals), then risks of biases cannot be excluded. This would impose a higher effort in trawl sampling, especially in areas with multiple species. It would also require a particular effort in the selection of the most appropriate (the least selective) fishing gear as fish behaviour is known to impact trawl selectivity, and may affect estimates of species proportions in areas where the species are mixed. In particular, comparisons between trawling and purse seine catches in a given area could help to evaluate the risk of biases due to the gear and the method. It could also be recommended to develop particular experiments with observation tools (cameras, multibeam sonar, net sensors etc.), in order to evaluate the magnitude of fish avoidance and escapement from the net.

For the survey and sampling design used here, the trawl appears to be adequate, but the small catches call for further studies, likely leading to improvements to the trawl sampling. The present approach should be pursued and more research work and experiments on fishing selectivity should be done in order to evaluate the biases linked to trawl sampling. Clearly, an optimal solution would be to have direct sampling of pelagic schools.

4.2.3. Allocation of effort between trawl and transect data collection

Due to the particular strategy imposed by the egg survey requirements (see above), there is low flexibility in the allocation of time between transects and trawling. Nevertheless, the balance is likely to provide useful results. In general, this point is not a major issue in the acoustic surveys, and authors (e.g. Simmonds and MacLennan, 2005) have showed that changes in the allocation of effort does not significantly improve the results. In this particular case, the catch sampling effort is rather important and cannot be reduced. In any case, this point is probably not critical.

4.2.4. Area coverage

There are two major points related to area coverage: the latitudinal extension of the survey area, and the definition of the surveyed zone inside the latitude limits.

<u>Latitude.</u> One major issue for sardine evaluation is the fact that during a part of the year a consistent part of the population is present south of the US water limits. In my opinion, the major risk is linked to the fact that part of the population may be present outside the survey area when the stock is located in the south of the region (winter and part of spring), as the Mexican waters are not sampled. This is obviously the case in early spring, as shown by the CUFES results since 1989 (Zwolinski et al., 2010, fig 2). A way to evaluate this risk is to compare the results from spring surveys to those from summer surveys. The results presented show that there is a strong similarity in the results from summer and spring over the survey period; therefore it is unlikely that, at least in 2006-2010, a significant part of the southern Pacific Sardine stock was missed. Nevertheless, this possible risk of underestimation of the spring abundance must be taken into consideration. Surveys during different seasons and improvement of the potential habitat definition would resolve this problem. Obviously, the best solution would be to perform joint US-Mexican surveys. If this cannot be done, indirect methods for evaluate the southern part of the stock have to be applied (surveys during different seasons, improvement of the potential habitat concept, etc.). The northern limit of the stock (in Canadian waters) is not such an issue, since the sardines are concentrated in the south during spring and a limited part of the stock crosses the border. It may be that non-migrating elements of the stock remain permanently in the Canadian waters, as it appears

for other species and other areas (e.g. the Chilean jack mackerel, the west African Ethmalosa, etc.), but they are marginal compared to the magnitude of the main population.
Concerning the other CPS, although no complete information was given to the panel on their biology, considering the average behaviour of related species (e.g. Chilean Jack mackerel, European jack mackerel, etc.), it is likely that their areas of distribution are larger than the surveyed area; however, the extent of their distribution remains unclear. Therefore, if an absolute estimate can be provided for the observed area, no absolute estimate for the whole population can be done for these groups. Concerning the anchovy, the distribution area is entirely covered, but the sampling is not appropriate (see above).

Surveyed area. An interesting study conducted on the definition of the "potential habitat" (Zwolinski et al, 2010 allows a better allocation of sampling effort. The potential habitat is based on sea surface temperature, chlorophyll and altitude of the sea surface, where temperature is the major factor, and roughly limited by isotherms 11-16º for the maximum extension and 13-14º for the "optimal" zone (Zwolinski et al, 2011). This principle of defining a habitat is essential as it allows the delimitation of the maximum extension of the area to be sampled, and it puts forth the hypothesis that no sardine can be found outside this habitat. I had long and interesting discussions with the authors and I concluded that the "potential habitat" designation is an excellent first step. I encourage the ASTP to continue in this field, towards the description of the actual habitat (instead of the potential one). Indeed, sardine is not physiologically limited by the 11-16º surface temperature, as part of the species is observed along the coast of Baja California in warmer waters (e.g. Robinson et al., 2007). Potential habitat is still a statistical observation that can be found to be incorrect in a given year. Contrary to this observation, the potential habitat designation is much wider than the observed distribution area of the sardine, which shows that other factors are involved in the definition of the habitat (probably dissolved oxygen, e.g. Bertrand et al., 2010). In any case, the research developed in this area is extremely important and remarkable results have already been obtained that help dispel some potential risks of biases, such as presence of sardine outside the sampled area and especially in offshore waters.

Except for anchovy, the extension of the surveys towards the coast is probably not a major issue. Nevertheless, the extrapolation method should be evaluated. At present the method consists in applying the average density along the transect to the non-explored surface onshore. Some results presented show that there is a trend along the transects, with an increasing density when being closer to the coast. Obviously, such a trend is not necessarily representative of what occurs outside the surveyed area, but at least it shows that the average is probably not the most accurate approach. One usual solution is to use the inter-transect data as representative of the inshore area. Some experiments with small vessels going very close to the shore could give answers to this question. In any case, the relatively small surface that this unexplored area represents is unlikely to become a real issue.

I fully support J. Simmonds' conclusion in this field: "*The observations on distribution are supported by information provided from fisheries and some survey data from*

Canada. In addition information was provided by CPSAS representative regarding location an season of fisheries. Taking all of this into account the SWFSC group should evaluate the data in more detail and propose methods for inshore and seasonally related latitudinal extensions to the area of occupancy for Pacific sardine. The magnitude of the extrapolation by survey should be evaluated and presented separately, so its contribution to the absolute estimate can [be] checked."

4.2.5. Prescreening algorithms for extracting school data

The general principle of extracting objects from daytime records and assigning these to individual or groups of species is a well-established approach for acoustic surveys. The current method utilizes the functionality of Echoview (Higgingbottom et al 2000). The method used here is based on a more formal approach, in terms of frequency ranges, though the spatial averaging at different stages is selected to match local situations. The method is described in detail in the background documents and in some of the papers delivered to the Panel. It seems to provide excellent results.

As far as I understood, this work is mostly done by the ASTP to "remove" all the non-fish echoes, which are in some way considered as biological noise. If this is the case, I regret that no attention is paid on this part of the biomass in the pelagic ecosystem: there is a large amount of information that can be extracted from the plankton and micronekton present in the CPS area, and any ecosystem approach should take them into consideration. One example is the use of trophic models to evaluate the productivity of the area. Another more recent approach taking advantage of the zooplankton distribution has been given by Bertrand et al (2010) who use the vertical distribution of the plankton to describe the stratification of the water masses, specifically to measure acoustically the depth of the oxycline. Considering that the acoustic data are collected during egg surveys, it is likely that micronekton/zooplankton distribution could be critical information for evaluating the survival of larvae, etc.

In any case, I would strongly recommend developing research on this part of the biomass, as it is easily available through acoustic sampling once extracted from the fish echoes.

4.2.6. Timing (day/night, school makeup)

As stated above, the sampling strategy separating acoustics (day) and trawls (night) is not current and whenever it is applied it is due to particular constraints. In any case, this is not optimal, although probably impossible to improve with no major changes in the survey strategy (e.g. use of purse seine or different types of trawls for fishing schools; use of specific acoustic surveys not linked with egg surveys, etc.). Day-time trawling requires particular trawls as the trawling speed must be fast (Clupeids in general are fast swimmers when avoiding a net).When species are not present in the same area, this is not a major problem, as usually the catch is monospecific and the only concern should be on how representative of the demographic structure the catch is. When multiple species are present ,this can become an issue if the species have different avoidance behaviour. In this case, the easily caught fish are overrepresented in the catches. The use of pelagic trawls by night on scattered fish has another drawback, i.e. when species (or age classes) do not share the same bathymetric layer. In this case too, there is a risk of overestimation of one part of the community present.

On the contrary, night catches on scattered fish present some advantages, of which the most important one is that the catch is more likely to represent the community of fish present. Indeed, the daily catch using a trawl (but also a purse seine) is directed on schools that are strongly uniform in fish characteristics (same species, same dimension), and usually once a first school is caught, the net has to be lifted. Therefore, the fish present in the first school are overrepresented in the sampling, and another source of bias appears.

Finally, having no information on the actual fish present in given schools hampers any research on school typology or relationships between fish (species, age) and school behaviour. This point is not directly linked to abundance estimates, but could help understanding the discrepancies that often appear between fisheries research models and real life scenarios.

Overall, the particular case of the CPS presents some favorable situations: species are separated during a long part of the year; sardine which is the most important species seem to scatter in a single surface layer (primary document, part 1, figure 5); and they appear to be catchable by the existing trawl. In conclusion, although there is room for many improvements, the results are correct for the existing surveys (2006-2010).

4.2.7. Trawl design-net, tow speed, etc

Considering the contradictory sources of biases that have been listed above, it appears that the choice of a trawl is likely to be the only simple solution. Sardine and most of CPS (excluding anchovies) are rather fast swimmers and able to avoid the net. This means that trawling, for scattered as well as schooling fish, should be performed at more than 4 or 5 knots, which requires a particular kind of net. The modern research vessels are able to trawl at these speeds, and plans of this kind of net are currently available in the literature. Trawling is probably easier to do than purse seining and yields a less biased set of information for the particular case of general abundance estimates, and I recommend the use of fast speed trawls for improving the trawl sampling during these surveys.

4.2.8. Acoustic Equipment Specifications

The acoustic-trawl surveys have been conducted with four to five frequencies (typically 18, 38, 70, 120, and 200 kHz). The use of a vertical echo sounder is appropriate for assessing fish distribution and estimating abundance. Multiple-frequency data are likely to permit automatic group recognition (e.g., plankton versus fish versus invertebrates) and potentially species identification. Multiple-frequency methods were applied for apportioning the acoustic backscatter to CPS (e.g., Demer *et al.*, 2009) as detailed in Demer *et al.* (background document).

The transducer is mounted on a blister or keel extending from the vessel hull, precluding observation of animals present nominally 10 m below the surface. The vertical echosounder is unable to provide information about organisms residing near the surface, particularly at night. However, this is not a concern for abundance estimation because the acoustic observations contributing to the biomass estimates are made during the day. The pulse-repetition interval is, in general, 0.5 seconds, or one ping each 2.5 m at 10 knots. This may be low for observing small, near-surface schools close to the vessel, but is adequate for estimating biomass.

The acoustic data collected depends on the type of equipment installed and the settings decided at the start of the survey. For vertical echosounders, several issues should be considered in relation to these settings:

- Choice of frequencies. Each group of species is better observed by a given set of frequencies (e.g., plankton, small and big fish, fish with and without swimbladders, and squids). Multiple frequencies allow for group differentiation.
- 'VRM extraction process and overall threshold'. This may lead to exclusion of some of the total biomass (mostly plankton, but also small non-schooling fish), and must consequently be set given the survey objectives. This is especially important for visual analysis of the echograms.
- Ping rate. The ping rate will affect the description of small spatial structures (e.g., schools). A very low ping rate results in a loss of information about these structures, while a very high rate will lead to redundant data. The use of multiple acoustic devices may impose a certain ping rate, but this may affect the precision of the results or their use for some particular research topics, principally studies on school structure and behavior
- Transducer location. The choice between a fixed and a towed transducer depends on the location of the target species (e.g., shallow versus deep).
- Complementary sensors. Use of additional acoustic devices (e.g., multibeam and short-range and long-range scanning sonar may be used for behavior and avoidance observations; an ADCP may be used for measuring vertical stratification of the seawater and for describing habitat features) can add information, but this may affect fish behavior (e.g., the sonar signal may affect schools) or the transmission rates of other devices.

A particularly interesting effort undertaken during these surveys is the use of high frequency multibeam sonar, especially for measuring fish avoidance (see below) and fish stratification close to the surface. Using this instrument is helpful to define the avoidance magnitude during the survey, knowing that such behaviour can change from one moment to the other.

The use of multiple vessels in standard assessment surveys may add complexity to the interaction between the observer and the observed. The present surveys were conducted using four vessels ranging from 41 to 65 m in length, with displacements ranging at least two fold. Some of these vessels have been studied in details as far as noise effect to fish is concerned (De Robertis et al, Wilson et al., etc). Concerning the point of acoustic equipment specification, all the ships were equipped with similar tools (although not with all the frequencies), and the acoustic settings and use of equipment were similar.

Overall, I consider that the acoustic specification is appropriate for abundance estimation, noting that a layer near the surface is not sampled. However, the acoustic sampling may not be adequate for research on school characteristics and a description of the global pelagic ecosystem. For this part of the research, I recommend that the team continues to: (a) consider other existing methods (e.g. Lawson *et al.*, 2001; Haralabous and Georgakarakos, 1996; Kloser *et al.* 2002; Lebourges-Dhaussy and Fernandes, 2010) for species identification; (b) evaluate the potential use of non-vertical echosounders; (c) develop methods that categorize the acoustic record and thus support automatic species identification, and (d) work on definition and precision of the VMR process.

4.2.9. Vessel avoidance

Fish response to vessel passage has been documented for small pelagic species in other areas (e.g. Freon and Misund, 1999). There is a potential for bias in abundance estimates from acoustic surveys if vessel passage causes fish to change their orientation in the water column, or exhibit some kind of consistent movement, either avoidance or attraction. Sardine, in particular, are often found near the surface at least at some times of the year, and fishermen have noted strong avoidance responses to vessel passage. As echosounders used in the CPS acoustic-trawl survey are mounted approximately 3.75 to 7.5 m deep to which must be added a "blind zone", it is clear that for those fish between the surface and 10 m deep, no abundance estimate can be done using vertical echosounder. This is a critical issue to address when deciding how or whether to use the abundance estimates based on acoustic-trawl data for stock assessment.

The influence of fish avoidance has been investigated using two approaches: (a) the distribution under and to the side of the vessel was examined using multibeam sonar, and (b) volume backscattering (S_v; dB re 1 m^{-1}) of fish schools observed in successive pings was examined to test the hypothesis that a vessel impact would lead to a reduction in S_v and an increasing average depth during passage. Studies with similar equipment on European pilchard in the Mediterranean Sea show increased schools off track (Soria *et al.*, 1996), while Chilean sardine in contrast showed no increase in schools off track (Gerlotto *et al.*, 2004). Results from the first study indicated that CPS school counts peaked sharply under the vessel, and declined steadily with distance away from the vessel track and depth, suggesting no increase in schools off track, as might be expected if there is lateral movement in response to the vessel. Results from the second study indicated that in most cases for CPS in the CCE there was little evidence for differences in depth or backscatter from the front to the end of schools, suggesting that any diving behavior takes place before the school passes through the acoustic beam, although minor diving apparently was noted when schools were shallow.

Further complexity in potential fish behavior is caused by interactions among the stimuli. In the present case, the vessels vary substantially in size and horsepower and have different propulsion and noise-reducing arrangements. The potential exists for vessel-specific impacts on the survey results if the target species are sensitive to any of the stimuli described above (Hjellvik *et al.*, 2008). An important work on fish avoidance to research vessels has been done by the ICES Study group on this question (SGFARV) and a Cooperative Research Report is in press. Most of the major questions and recommendations on the field of fish avoidance will be listed in this document.

Vessel noise may potentially affect fish behavior during surveys. Fish may avoid the sound source, either by diving or moving to the side, or both. Such behavior may lead to reduced fish density under the transducer during the moment of recording. Furthermore, TS might change as a result of changing fish tilt angle during the avoidance response, thus impacting, in most cases reducing, estimates of density. The International Council for the Exploration of the Seas (ICES) has therefore recommended using noise-reduced vessels to reduce these potential impacts.

Nevertheless, the results from the recently built "silent vessels" are contradictory, and further work is needed in order to define the actual sources of stimuli that induce fish avoidance. For instance, particular parts of the sound spectrum, e.g. infrasound, appear to be responsible for changes in fish behavior in response to survey vessels (Ona *et al*., 2007; Sand *et al*., 2008). This implies that noise as measured by the ICES standard (Mitson, 1995) does not necessarily reflect the strength of the vessel's avoidance stimulus. Rather, the stimulus may be more associated with the size of the vessel and its displacement than the noise emission.

Some studies (e.g. Dagorn *et al*., 2001; Røstad *et al*., 2006) suggest that vessels may attract fish, thus increasing densities measured by acoustics. The authors argue that visual stimuli may attract fish and affect observations in shallow water and at short distances from the vessel. Nevertheless, this particular behaviour is unlikely to have any effect on an abundance estimate of CPS, as the attraction dynamics are too slow compared to the vessel speed.

During the surveys performed, there was clear evidence that schools seen on the surface dived to at least 10m (Cutter and Demer 2007). If this behaviour is general, then this diving behaviour is "good news" for the abundance estimate, as surface schools are observed below the blind zone under the ship. The question remaining is that of a possible horizontal avoidance before the ship has passed over the schools: if this is the case, this gives rise to concern that the abundance may not be correctly recorded.

As a general conclusion, I am convinced that avoidance of school is probably not a critical issue. Nevertheless, behaviour is never a stable pattern and is influenced by a number of parameters (climatic, meteorological, presence of preys or predators, physiological stage, background noise, etc.). In order to take these points into account, I recommend that a continuous monitoring and analysis be organized for the duration of each survey to provide an evaluation of the bias due to school avoidance, using multibeam sonars. Some information from the fishery seems to indicate that inside the fishing area there is a significant horizontal avoidance. This point should be studied, through a particular experiment, e.g. aboard fishing vessels.

4.2.10. Target strength

The TS calculation follows the conventional methods, and three formulas coming from peer reviewed papers are used to give TS – length relationships. The values used are standardized to 20 log slope, and use weight at length conversion to biomass.

I have no major comment to make on this particular point. The ASTP uses specific TS equations when available (sardine) and equations from related and similar species when unavailable; this is the common method. I recommend of course to investigate TS values locally and particularly for pacific mackerel (as the ASTP uses the Chilean Jack Mackerel equations) if this is to be used as an absolute estimate.

4.2.11. Hydrography

There are two points of importance here:

- Measurements of hydrographic variables are theoretically needed to correct the acoustic properties of the water in the sonar equation; this is not a major issue in this work as the surface temperature does not vary substantially. In any case, the bias induced by a permanent factor is marginal compared to the other sources of bias in an acoustic survey system.
- In order to improve the definition of the potential habitat, it is important to collect as many parameters as possible during the survey. Moreover, it is also necessary to obtain vertical information (CTD stations) with the idea to correlate acoustic characteristics of the biological distribution (e.g. plankton) with the stratification of water masses.

Hydrographic stations are therefore as necessary as the trawl samples, although they are usually performed systematically (as is the case in this survey design) and do not require any major recommendations.

4.3. ToR 3

Evaluate and provide recommendations for the application of these methods for their utility in stock assessment models and for their ability to monitor trends at the population level for Pacific sardine and other CPS. Survey methods or results that have a flawed technical basis, or are questionable on other grounds, should be identified so they may be excluded from the set upon which stock assessments and other management advice is to be developed.

I am not an expert in stock assessment modeling and my comments and recommendations in this area are limited. I supported the discussions and recommendations of the Panel in this topic and particularly the following conclusions and recommendations:

> *"Treating any survey estimate as an absolute estimate of abundance is a strong constraint in stock assessment models, and the appropriateness of that assumption can only be evaluated in the context of the other information available for the assessment.*

Pacific Sardine

Pacific sardine are an actively-managed CPS species with an SS3-based stock assessment. (…) Given current information, the Panel ***agrees*** *that the acoustic-trawl surveys can be considered to provide estimates of absolute abundance for the survey area with the associated length-composition, and the assessment author should consider the use of these data in the September 2011 sardine assessment. It* ***recommends*** *that prior to the September 2011 assessment, 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 range of possible biomass levels. In addition, the CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.*

Jack mackerel

Jack mackerel are a monitored CPS species. There are few recent data on which to base estimates of abundance and distribution for this species. The acoustic-trawl survey data are the only scientific information on abundance for the area surveyed. The Panel ***agrees*** *that even though less information is available for this species than for Pacific sardine on the key uncertainties, the estimates of absolute abundance for the survey area can be used as estimates of the biomass of jack mackerel in US.*

Pacific mackerel

While there is no reason why the acoustic-trawl surveys cannot be used to provide estimates of abundance for Pacific mackerel, the estimates of abundance for Pacific mackerel are more uncertain as measures of absolute abundance than for jack mackerel or Pacific sardine.

Northern anchovy

There is also no reason why acoustic-trawl surveys cannot be used to estimate abundance for northern anchovy. However, the perceived current size of the population, along with its more inshore distribution, means that the present survey data cannot be used to provide estimates of relative or absolute abundance for northern anchovy. "

Apart these recommendations that I fully support, I have a concern that I presented to the Panel, on the meaning and use of "absolute abundance estimate". If I am correct, "absolute estimate" means that the results of abundance measurement are given in actual biomass (e.g. number of individuals or densities in kilos). If this is the case, the only points to consider are those that play a role in the process from echoes (backscattering) to weights. This relates to TS, avoidance, trawl samples, extraction of fish from the global biological noise. We have seen that neither of these points was considered a major issue, and if there is need to carefully study each one of them and improve the results, they were unlikely to affect significantly the results. Therefore, most of the values that are given by these surveys are "absolute biomass estimates". Relative estimates exist when we know that there is some permanent and stable bias or unknown parameter (for instance, no information on TS), and, in this case, the results give a correct curve, correlated with the actual one but weighted by an unknown factor. These two estimates can be called “true” estimates, as they vary similarly to the actual abundance and show similar curves.

We can face a situation where the results are neither absolute nor relative but wrong. This case may happen if the fishing capacities are bad, for instance, or when we begin to work with acoustic information from fishing vessel: some of these sets of data can be wrong (e.g. uncalibrated, including false echoes, no information on settings, non-scientific echo-sounder and no information on TVG, etc.). Such data are useless. The last case is when we have correct (not wrong) data but we are in a situation where we lack of essential information. For instance, we know that the stock is occupying a wider albeit unknown distribution area than the “window” observed by the survey. In this case, the results, even if they can be given in absolute values, are not representative of the truth. Let us call them “false” estimates. They can be given either in absolute or relative values, but they will remain “false”.

In our cases, we face different situations:

- Sardine abundance is absolute (correct TS, no avoidance, correct sampling) and true (observation of the whole stock);
- Mackerel is absolute (correct TS, no avoidance) and false (present outside of the observation window);
- Jack mackerel is relative (no ad hoc TS equation) and probably false (present outside of the observation window);
- Anchovy is absolute (correct TS, no avoidance, good sampling) and false (inadequate survey design)

From these observations, it seems clear that we can expect to get an “absolute-true” value of abundance from anchovy with an appropriate survey design. We can expect an absolute value for jack mackerel with an appropriate TS equation but neither it nor the mackerel could be measured in “true” estimates, except if a clear correlation can be calculated between one parameter (e.g. mean density, school characteristics…) and the total biomass. In this case the abundance would become relative (no value of the actual overall biomass) and true (correlated with the actual biomass).

4.4. ToR 4

Evaluate the effectiveness of the survey methods for detecting the appropriate spatial scale and seasonal timing for annually estimating stock abundances.

Here too, my general conclusion does not diverge significantly from those of the panel and I support the following statements with some particular comments:

> ***Pacific Sardine***
>
> *Given current information, it is considered that the acoustic-trawl surveys can be considered estimates of distribution of abundance for the survey area. It is expected that the area survey covers the vast majority of Pacific sardine at the time when the surveys were conducted. There is a need for a number of analyses to be conducted using auxiliary information to provide best estimates for the*

biomass outside of the survey area as well as range of possible biomass levels. In addition, the CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.
(**note**: for sardine, the major points to take into consideration are the horizontal avoidance if it exists, the dimension of the stock existing outside the survey area in early spring, the accuracy of trawl samples)

Jack mackerel
Jack mackerel are a monitored CPS species. The acoustic-trawl survey data are the only scientific information on abundance for the area surveyed. Even though less information is available for this species than for Pacific sardine on the key uncertainties, the estimates distribution by the survey area can be used for jack mackerel in US waters. The estimate for summer may be more reliable as the various CPS are more separated at that time.

Pacific mackerel
A major concern for this species is that a sizable (currently unknown) fraction of the stock is outside of the survey area. While the estimates for survey area are valid, and some information on distribution is available, if the acoustic-trawl data are to be used to provide estimates of stock biomass, auxiliary information will be needed to estimate the annually-varying proportion of the whole stock in the survey area.
(note: this would require to select some indicator relating the abundance inside the surveyed area with the overall abundance. Some works have been done (e.g. Petitgas, 1994. Spatial strategies of fish populations. In: ICES CM 1994/D:14.) that could be applied and adapted for such a research.

Northern anchovy
The current size of the population, along with its more inshore distribution means that the present survey data cannot be used to provide estimate of relative or absolute abundance or distribution for northern anchovy. A few northern anchovy were sampled nearshore, mostly off Oregon and Washington (2006, 2008, and 2010), north of Monterey Bay (2006) and in the Southern California Bight (2006 and 2008). Apart from the occasional large catches (~ 300kg) off the mouth of the Columbia River and other likely locations such as off Santa Barbara and Monterey Bay, anchovy were scarce in these surveys, even off southern California where they once were the most abundant species. The sampling scheme would need to be modified (more transects and trawls in the areas where northern anchovy are found) if estimates of distribution of northern anchovy required.

As a last comment in this field, I consider that in an ideal situation:

- The acoustic surveys should be autonomous and not dependent on egg surveys, which impose some constraints in the acoustic survey design, such as the location of fishing samples.

- Surveys should be more frequent, e.g. in spring, summer and autumn, in order to evaluate better the parts of the different populations that are outside the surveyed area. In any case, if such an increase is impossible, summer surveys must be repeated as frequently as spring surveys.
- The research on the potential habitat for sardine (but also for other species) has to be continued and considered a priority; for such research the use of non-fish scatterers is indispensable.

4.5. ToR 5

Decide through Panel discussions if the ToRs and goals of the peer review have been achieved. If agreement cannot be reached, or if any ToR cannot be accomplished for any reason, then the nature of the disagreement or the reason for not meeting all the ToR must be described in the Summary and Reviewer's report. Describe the strengths and weaknesses of the review process and Panel recommendations.

There were no major disagreements between the Panel and the Team or among Panel members. Some of the points that I considered before the meeting as critical and questionable, deserving correction or discussions were exposed and consistent answers were given. I have been convinced, for instance, by the discussions on the potential habitat that did not convince me in reading prior to the meeting. The Panel received an important but essential set of documents that helped to get a correct idea and perform an efficient analysis of the works done by the team. I have been impressed by the wide range of expertise present in the Panel, which allowed considering all the points of the ToR. This would probably not have been possible in the case of individual reports with no common meeting. The exchange of ideas and expertise enriched considerably the results.

I agree with John Simmonds when he says that "*While generally the meeting facilities were good (...) there were considerable technical difficulties with the network access provided by SWFSC, this was barely functional, requiring additional printing and making exchange of documents more difficult*".

The Acoustic-Trawl Survey Technical Team was of a particularly high standard, and provided the Panel with all the information needed for analyzing its work. Some works were performed during inter-sessions under requirement of the Chair and delivered to the Panel in time. My general conclusion is that this team is of an outstanding level and that the survey methodology developed will become a case study to show how each part of the process was taken into consideration, analyzed, and the best possible answer was given. I have learnt a lot on multibeam sonar data analysis, for instance, and on innovative methods for avoidance estimates.

It is clear that the whole Panel was of high quality and the discussions always were of high level. The role of the rapporteur was essential, as we were fed with the results of the discussions almost in real time. I want to highlight the role of three key participants in this meeting : André Punt, who leaded the group with an extreme efficiency and made it possible to maintain the discussions and work at a high level; John Simmonds appeared to be essential for most of the conclusions and recommendations expressed, and especially in all the matters related to precision measurements and variance estimates of the results; and David Demer, who prepared the works of the panel and answered in a very clear and convincing way to all the question, showing that most of them have been anticipated by the team. These three persons allowed me (and probably the other members of the team) to follow the whole work, even in areas where my expertise was not strong.

5. Recommendations

I fully support the general conclusions that the Panel listed, as below:
Pacific Sardine It is Recommended that the acoustic-trawl surveys be considered estimates of distribution of abundance for the survey area.

It is recommended that there is a need for a number of analyses to be conducted using auxiliary information to provide best estimates for the biomass outside of the survey area as well as range of possible biomass levels. In addition, the CVs for the estimates need to be modified to fully account for the uncertainty of the trawl data.

Jack mackerel Even though less information is available for this species than for Pacific sardine on the key uncertainties, it recommended that estimates distribution by the survey area can be used for jack mackerel in US waters.

Northern anchovy: It is recommended that if estimates are required the sampling scheme would need to be modified

There are a series of specific aspects detailed below:

1. Immediate (prior to the next stock assessments)

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

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

2. Short-term

a. Investigate 'gross' species selectivity effects by comparing the ratio of catch rates and acoustic density in areas where single species dominate.

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

c. Consult experts in trawl design to evaluate the current trawl design in relation to the survey objectives

d. 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 and check the performance of the selection process on each survey.
e. Develop further studies on effect of avoidance: study trends in frequency response over depth strata in schools, compare results from the 18 kHz and other transducers to examine possible avoidance reactions.
f. Continue to consider the advantages and disadvantages of conducting acoustic-trawls surveys at different times of the year and extending the survey into Canadian and Mexican waters.
g. 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.

3. Long-term
a. Evaluate if differ fishing trawling practices / gears would be beneficial.
b. Use a trawl/vessel configuration that can support directed trawl sampling.
c. Conduct repeated trawl sampling experiments to obtain better understanding of small-scale variability.
d. Test the efficiency and selectivity of the trawl by comparing samples from the same area taken with the survey trawl and purse seine.
e. Apply state of the art acoustic and optic technology to investigate fish behavior and escapement at various critical positions of the trawl.
f. Conduct validation tows on various kinds of backscatter to assure that the filtering algorithm is performing as intended to separate out CPS.
g. Make efforts to obtain in situ target strength measurements for CPS species in California Current Ecosystem.

6. Conclusion

The work of the Panel was facilitated by the great professionalism of the team and its help for any problem and question. The reports and presentations provided an excellent basis to evaluate the performance of the acoustic-trawl survey. Thanks to the excellent preparation of the meeting; I found the work easy and I expect that the results of the meeting will be of high quality.

The work submitted to our expertise appeared to be of a high standard and no correction or important change was required. The recommendation is to aim to improve the methodology with no fundamental change.

The framework of the expertise process is also remarkable, among the expertise processes in which I have participated around the world, this one is certainly the best, in every point: preparation, documentation, organization, members, etc.

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Appendix 1: Bibliography of materials provided for review

Primary Documents

David A. Demer, Juan P. Zwolinski, Kyle A. Byers, George R. Cutter, Josiah S. Renfree, Thomas S. Sessions, and Beverly J. Macewicz 2011 Acoustic-trawl surveys of Pacific sardine (Sardinops sagax) and other pelagic fishes in the California Current ecosystem: Part 1, Methods and an example application.

Juan P. Zwolinski, Kyle, A. Byers, George R. Cutter, Josiah S. Renfree, Thomas, S. Sessions, Beverly J. Macewicz, and David A. Demer 2011 Acoustic-trawl surveys of Pacific sardine (Sardinops sagax) and other pelagic fishes in the California Current ecosystem: Part 2, Estimates of distributions and abundances in spring 2006, 2008, and 2010

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Appendix 2: Statement of Work for John Simmonds

External Independent Peer Review by the Center for Independent Experts

Panel Review of an Acoustic-Trawl Method for Surveying CPS

3-5 February 2011

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by the CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The Pacific Fishery Management Council (PFMC) uses information from surveys to make decisions related to harvest guidelines for managed coastal pelagic species (CPS) (i.e., Pacific sardine and Pacific mackerel) and Overfishing Levels (OFLs) / Acceptable Biological Catches (ABCs) for monitored CPS (i.e., northern anchovy, jack mackerel and market squid). The current assessments for Pacific sardine and Pacific mackerel are based on the 'Stock Synthesis' framework. The assessment for Pacific sardine uses age- and length-composition data from four fisheries, the results from an aerial survey, and measures of female spawning biomass and total egg production (DEPM) from combined trawl and egg surveys, to estimate the parameters of a population-dynamics model. The survey outcomes and hence model-derived estimates of Pacific sardine spawning-stock biomass (SSB) have recently decreased, resulting in dramatically lower harvest guidelines for 2008 and 2009. The Southwest Fisheries Science Center's (SWFSC's) current standard survey covers the 'core' spring-spawning area between San Diego and San Francisco. The exploited stock ('northern subpopulation') is believed to migrate seasonally, potentially from northern Baja California, Mexico in the spring to British Columbia, Canada in the summer. The DEPM is an indirect measure of fish distribution and abundance. As the sardine population recovered from historic lows and recently reoccupied its former historic range, migrating as far north as Canada in the summer, multiple types and more direct estimates of CPS biomass, particularly sardine biomass, may be needed to improve stock assessments.

Three CIE reviewers will serve on a Panel to evaluate an acoustic-trawl method for surveying CPS. The SWFSC's Fisheries Resources Division (FRD) has explored the use of acoustic-trawl methods, which are commonly used by other regions and countries to estimate the abundances and distributions of CPS. Acoustic-trawl methods may provide a more robust (i.e., accurate and precise) and efficient means to routinely survey the Pacific sardine populations as well as the populations of jack mackerel, Pacific mackerel, and northern anchovy. In spring 2006, 2008, and 2010, and summer 2008, FRD conducted acoustic-trawl surveys off the U.S. west coast, from the Mexican to Canadian borders, and developed methods for estimating the abundances and distributions of CPS from these data. The Panel will review the acoustic-trawl survey design and analysis methods, documents, and any other pertinent information for acoustic-trawl surveys of Pacific sardine, Pacific mackerel, jack mackerel, and northern anchovy.

The Panel report will be used to guide improvements to the acoustic-trawl survey and analysis methods, the resulting time series of estimates of abundance and distribution for CPS species, and estimates of their uncertainty. The report will also be used to evaluate the appropriateness of using the results from the survey as inputs to the assessment model for Pacific sardine and Pacific mackerel. The assessment models for Pacific sardine and Pacific mackerel will be reviewed by separate Stock Assessment Review (STAR) Panels. However, the report of this Methods Review Panel will be considered by the assessment analysts and STAR Panels.

An overview of the ToRs for the Panel is attached in **Annex 2**. The tentative agenda of the Panel review meeting is attached in **Annex 3**. Finally, an outline of the summary report of the Panel is attached as **Annex 4**.

Requirements for CIE Reviewer: Three CIE reviewers shall participate in the Panel and conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. Three CIE reviewers shall have expertise and work experience in the design and execution of fisheries-independent acoustic-trawl surveys for estimating the abundance of coastal pelagic fish species, and expertise with sardines is desirable. The CIE reviewers shall have knowledge of the life history strategies and population dynamics of coastal pelagic fish species.

Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location/Date of Peer Review: The CIE reviewers shall participate as independent peer reviewers during the panel review meeting at NOAA Fisheries, Southwest Fisheries Science Center, 3333 North Torrey Pines Court, La Jolla, California, 92037-1023, during 3-5 February 2011 in accordance with the agenda (Annex 3).

Statement of Tasks: The CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Following the CIE reviewer selections by the CIE Steering committee, the CIE shall provide the CIE reviewers' information (name, affiliation, and contact details) to the Contracting Officer's Technical Representative (COTR), who will forward this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers (reviewer hereafter). The Project Contact is responsible for providing the reviewer with the background documents, reports, foreign national security clearance, and information concerning other pertinent meeting arrangements. The Project Contact is also responsible for providing the Panel Chair (Chair hereafter) a copy of the SoW in advance of the Panel. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When a reviewer who is a non-US citizen participates in a panel review meeting at a government facility, the Project Contact is responsible for obtaining a Foreign National Security Clearance for the CIE reviewers. For the purpose of their security clearance, each reviewer shall provide requested information (e.g., name, contact information, birthdate, passport number, travel dates, and country of origin) to the Project Contact at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations (available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/sponsor.html).

Pre-review Background Documents: Two weeks before the review, the Project Contact will electronically send to each reviewer, by email or FTP, all necessary background information and reports for the review. If the documents must be mailed, the Project Contact will consult with the CIE on where to send the documents. The CIE reviewers shall read all documents in preparation for the review, for example:

- documents on current survey methods, in particular, related to DEPM and aerial surveys of sardine and other CPS;
- document on SWFSC acoustic-trawl surveys conducted between 2006 and 2010;
- documents from past Panels; and
- miscellaneous documents, such as the ToR, SoW, agenda, schedule of milestones, deliverables, logistical considerations, and PFMC's ToR for CPS Stock Assessment Methodology Reviews.

The CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. Any delays in submission of pre-review documents for the CIE review will result in delays with the CIE review process, including a SoW modification to the schedule of milestones and deliverables.

Panel Review Meeting: Each CIE reviewer shall participate in the Panel and conduct an independent review in accordance with the SoW and ToRs. **Modifications to the SoW and ToR cannot be made during the review, and any SoW or ToR modification prior to the review shall be approved by the COTR and CIE Lead Coordinator.** Each reviewer shall actively participate in a professional and respectful manner as a member of the Panel, and their review tasks shall be focused on the ToRs as specified in the contract SoW.

Respective roles of the CIE reviewers and Chair are the PFMC's ToR for CPS Stock Assessment Methodology Review (see p. 6-8). The CIE reviewers will serve a role that is equivalent to the other panelists, differing only in the fact that they are considered 'external' members (i.e., outside the PFMC's membership and not involved in management or assessment of west coast CPS, particularly sardine). The reviewers will serve at the behest of the Chair, adhering to all aspects of the PFMC's ToR as described in Annex 2. The Chair is responsible for: 1) developing an agenda; 2) ensuring that Panel members (including the Reviewers) and those being reviewed (the "proponents") follow the ToR; 3) participating in the review of the methods (along with the Reviewers); and 4) guiding the Panel (including the Reviewers), FRD, and NWSS to mutually agreeable solutions.

The Project Contact is responsible for any facility arrangements (e.g., conference room for Panel meetings or teleconference arrangements). The CIE Lead Coordinator can contact the Project Contact to confirm any meeting facility arrangements.

<u>Contract Deliverables - Independent CIE Peer Review Reports</u>: In addition to participating in the Panel, each CIE reviewer shall also complete an independent-review report in accordance with the SoW, i.e., in the required format as described in Annex 1; and addressing each ToR as described in Annex 2.

<u>Other Tasks – Contribution to Summary Report</u>: Reviewers will assist the Chair with contributions to the Summary Report. The Panel is not required to reach a consensus and, therefore, the reviewers should provide a brief summary of their views on the findings and conclusion reached by the Panel in accordance with the ToRs (format defined in Annex 1).

Specific Tasks for CIE Reviewer: The following chronological list of tasks shall be completed by the CIE reviewers in a timely manner, as specified in the **Schedule of Milestones and Deliverables**:

1) prepare for the review by thoroughly reading the documents provided by the Project Contact;
2) participate in the panel review meeting in La Jolla, CA during 3-5 February 2011 as indicated in the SoW, and conduct an independent review in accordance with the ToRs (Annex 2); and
3) write an independent-review report, addressed to the "Center for Independent Experts," and submit it to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and CIE Regional Coordinator, via email to David Die ddie@rsmas.miami.edu, no later than 17 March 2011 indicated in the SoW. The report shall be written using the format and content requirements specified in Annex 1, and address each ToR in Annex 2.

Schedule of Milestones and Deliverables: The CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

28 December 2011	The CIE sends the CIE reviewers' contact information to the COTR, who forwards it to the Project Contact.
10 January 2011	The Project Contact sends the pre-review documents to the CIE reviewers.
3-5 February 2011	The CIE reviewers participate in the Panel review meeting and conducts an independent review.
3 March 2011	The CIE reviewers submit their reports to the CIE Lead Coordinator and CIE Regional Coordinator for final review and revisions.
17 March 2011	The CIE submits independent peer review reports to the COTR for contractual compliance.
24March 2011	The COTR distributes the final reports to the Project Contact and the regional Center Director.

Modifications to the Statement of Work: Requests to modify this SoW must be made through the COTR who submits the modification for approval to the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the CIE within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToR of the SoW as long as the role and ability of the Reviewer to complete the SoW deliverable in accordance with the ToRs and the deliverable schedule is not adversely impacted. The SoW and ToRs cannot be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, the reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via email the contract deliverables (the CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards: (1) the CIE report shall have the format and content in accordance with Annex 1; (2) the CIE report shall address each ToR as specified in Annex 2; and (3) the CIE report shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon notification of acceptance by the COTR, the CIE Lead Coordinator shall send via email the final CIE reports in pdf format to the COTR. The COTR will distribute the approved CIE reports to the Project Coordinator, the regional Center Director, and the PFMC.

Key Personnel:

William Michaels, Program Manager, COTR
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations.

2. The main body of the Reviewer's report shall consist of the following sections, in accordance with the ToRs: Background, Description of the Reviewer's Role in the Review Activities, Summary of Findings for each ToR, and Recommendations and Conclusion.

   a. The Reviewer should describe in their own words the review activities completed during the panel meeting, including providing a detailed summary of findings, recommendations, and conclusion.

   b. The Reviewer should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where they were divergent.

   c. The Reviewer should elaborate on any points raised in the Summary Report that might require clarification.

   d. The Reviewer shall provide a critique of the review process, including suggestions for improving both the process and products.

   e. The CIE report shall be a stand-alone document for others to understand the proceedings and findings of the meeting without having to read the Panel report. The report shall be an independent review of each ToR, and shall not simply repeat the contents of the Panel report.

3. The Reviewer's report shall include the following separate appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: The CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the review meeting.

Annex 2: Terms of reference (ToRs) for the peer review of the acoustic-trawl method for surveying Pacific sardine and other CPS

The CIE reviewers will participate in the panel-review meeting to conduct independent peer reviews of the acoustic-trawl method as it pertains to surveys of coastal pelagic fish species (CPS) in the California Current Ecosystem (CCE), principally Pacific sardine, but potentially also including jack mackerel, Pacific mackerel, and northern anchovy, depending on their biomasses and distributions, and the sampling effort afforded. The survey area is the CCE off the west coast of the United States of America (US), generally between the Mexico-US and the US-Canadian borders. The latitudinal and offshore extents of the surveys are seasonal, extending further north in the summer and further offshore in the spring. Survey estimates are to include absolute biomasses, and their total random sampling errors, and spatial distributions. The review solely concerns technical aspects of the survey design, method, analysis, and results, and addresses the following ToR:

ToR 1 – Review documents detailing acoustic-trawl survey and data analysis methods and results according to the PFMC's ToR for CPS Stock Assessment Methodology Reviews. Document the meeting discussions. Evaluate if the documented and presented information is sufficiently complete and represents the best scientific information available.

ToR 2 – Evaluate and provide recommendations on the survey method used to estimate the abundances and distributions of Pacific sardine and other CPS, and associated sources of uncertainty. Recommend alternative methods or modifications to the proposed methods, or both, during the Panel meeting. Recommendations and requests to FRD for additional or revised analyses during the Panel meeting must be clear, explicit, and in writing. Comment on the degree to which the survey results describe and quantify the distributions and abundances of CPS, in particular Pacific sardine, and the uncertainty in those estimates. Confidence intervals of survey estimates could affect management decisions, and should be considered in the report.

ToR 3 – Evaluate and provide recommendations for the application of these methods for their utility in stock assessment models and for their ability to monitor trends at the population level for Pacific sardine and other CPS. Survey methods or results that have a flawed technical basis, or are questionable on other grounds, should be identified so they may be excluded from the set upon which stock assessments and other management advice is to be developed.

ToR 4 – Evaluate the effectiveness of the survey methods for detecting the appropriate spatial scale and seasonal timing for annually estimating stock abundances.

ToR 5 – Decide through Panel discussions if the ToRs and goals of the peer review have been achieved. If agreement cannot be reached, or if any ToR cannot be accomplished for any reason, then the nature of the disagreement or the reason for not meeting all the ToR must be described in the Summary and Reviewer's report. Describe the strengths and weaknesses of the review process and Panel recommendations.

The Reviewer’s report should be completed, at least in draft form, prior to the end of the meeting.

Annex 3: Participants and Agenda

Participants

Methodology Review Panel Members:
Martin Dorn, SSC, NMFS, Alaska Fisheries Science Center
François Gerlotto, Center for Independent Experts (CIE)
Olav Rune Godø, Center for Independent Experts (CIE)
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
John Simmonds, Center for Independent Experts (CIE)

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

Acoustic-Trawl Survey Technical Team:
Kyle, A. Byers, NMFS, Southwest Fisheries Science Center
George R. Cutter, NMFS, Southwest Fisheries Science Center
David Demer, NMFS, Southwest Fisheries Science Center
Josiah Renfree, NMFS, Southwest Fisheries Science Center
Beverly J. Macewicz, NMFS, Southwest Fisheries Science Center
Juan P. Zwolinski, NMFS, Southwest Fisheries Science Center

THURSDAY, FEBRUARY 3, 2011 – 8:00 A.M.

A. Call to Order, Introductions, Approval of Agenda, and Appointment of Rapporteurs
B. Terms of Reference for the CPS Methodology Reviews
(8:30 a.m., 0.5 hour)
C. Presentation on the acoustic-trawl survey — David Demer
(9:00 a.m., 1.5 hours)

BREAK

C. Presentation on the acoustic-trawl survey (Continued) — David Demer
(11 a.m., 1 hour)

LUNCH

C. Presentation on the acoustic-trawl survey (Continued) — David Demer
(1 p.m., 1.5 hours)

D. Panel discussion — Panel
(2.30 p.m., 1 hour)

BREAK

E. Requests to FRD — Panel
(4.00 p.m., 1 hour)

FRIDAY, FEBRUARY 4, 2010 – 8:30 A.M.

F. Responses to Panel Requests (FRD) David Demer
(8.30 a.m., 2 hours)

BREAK

G. Panel discussion Panel
(11 p.m., 1 hour)

LUNCH

H. Requests to the FRD Panel
(1 p.m., 1 hour)

I. Report drafting Panel
(2.30pm, 1 hours)

BREAK

J. Responses to Panel Requests (FRD) David Demer
(4 p.m., 0.5 hours)

K. Requests to FRD Panel
(4.30 p.m., 0.5 hours)

SATURDAY, FEBRUARY 5, 2010 – 8:30 A.M.

K. Responses to Panel Requests (FRD) David Demer
(8.30 a.m., 1.5 hours)

BREAK

L. Report Drafting Panel
(11am , 1 hours)

LUNCH

M. Report review Panel
(1 p.m+)

Annex 4: Panel Summary Report (Template)

- Names and affiliations of Panel members

- List of analyses requested by the Panel, the rationale for each request, and a brief summary of the proponent's responses to each request.

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

- Explanation of areas of disagreement regarding Panel recommendations:
  - among Panel members; and
  - between the Panel and the proponents

- Unresolved problems and major uncertainties, e.g., any special issues that complicate survey estimates, estimates of their uncertainty, and their use in stock assessment models.

- Management, data, or fishery issues raised the public (i.e., non-Panel and proponent participants) at the Panel meetings.

- Prioritized recommendations for future research, and data collections and analyses.

Appendix 3: Panel Membership or other pertinent information from the review meeting.

Andre Punt (PFMC, Chair),	aepunt@u.washington.edu
Martin Dorn (AFSC),	Martin.Dorn@noaa.gov
François Gerlotto (CIE),	francois.gerlotto@ird.fr
Olav Rune Godø (CIE),	olav.rune.godoe@imr.no
John Simmonds (CIE),	ejsimmonds@googlemail.com
M. Okoniewski (CPSAS),	mokoniewski@pacseafood.com
G. Krutzikowsky (CPSMT),	Greg.Krutzikowsky@state.or.us
Kerry Griffin (PFMC),	Kerry.Griffin@noaa.gov
Mike Burner (PFMC),	Mike.Burner@noaa.gov
observers, and SWFC/FRD.	

Bill Michaels <William.Michaels@noaa.gov>,
Vetter Russ Russ.Vetter@noaa.gov

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON COASTAL PELAGIC SPECIES (CPS) SURVEY METHODOLOGY REVIEW

A Coastal Pelagic Species Advisory Subpanel (CPSAS) representative attended the Acoustic-Trawl Method Review held in La Jolla February 3-5, 2011. The CPSAS report is a brief summary of the CPSAS representative's stated concerns as listed in the final report, Agenda Item C.3.a, Attachment 1, and found in Appendix 6. CPS fishermen harvest sardines in far greater quantity than all other CPS species in the Acoustic-Trawl survey: For that reason the concerns expressed are limited to only sardines.

The CPSAS believes that the Acoustic-Trawl survey methodology is an important developmental step forward to provide better data for the sardine stock assessment. The CPSAS commends the Southwest Fisheries Science Center team for the fundamental work they have done in constructing this survey. Likewise the review panel deserves recognition for their thorough investigation. Nevertheless, CPSAS members have several reservations about the Acoustic-Trawl survey and the outlined application for surveying West Coast sardine stocks.

A brief outline of the CPSAS' reservations: As the CPSAS understands, the key tool for acoustic measurement is a downward looking EK 60 scientific echo-sounder from Simrad. Per the Methods Review Panel (Panel) final report on page 10: "The transducer is mounted on a blister or keel extending from the vessel hull, precluding observation of animals present nominally 10 m below the surface."

1. **Vessel Avoidance**: The Panel queried the survey author extensively on whether sardines avoid the survey vessel in a lateral or vertical manner as the vessel passes through schools. The author suggested that the sardines dive and the vast majority of the schools are seen by the echo-sounder as the vessel passes. Fishermen in the Northwest and Canada believe that in most cases sardine schools will split or move sideways as vessels penetrate into a school. This splitting reaction has been recorded onto a computer in Canada by a fisherman using "side-scan" style sonar. It poses the question whether vessel avoidance results in surface schooling fish moving to an adjacent location where the transducer's signal is not fully reflected by fish that were in the vessel's path. The CPSAS believes significant amounts of schooling fish may be missed as a result.

2. **Timing and range of Survey**:
   (A) Timing: Fishery data indicates that a large proportion of the sardine population can be found simultaneously in both the Pacific Northwest and Canadian coastal waters in August and September. The Acoustic-Trawl survey relies heavily on habitat modeling and migration theory to support a June-July survey in the Northwest. Migration theory is based on tagging studies from 70 years ago. The studies suggest that some portion of the population do migrate in some years, but does not conclusively prove that the entire population migrates every year. Sardines have been harvested in the Northwest in every month except January. Canadian harvests go into mid-December at times when the habitat model indicates they should be elsewhere.

(B) The survey does not extend into Canadian waters. Many fishermen believe the biomass of sardines in Canadian waters may be equal to that in the Northwest. As stated, the highest historical harvests and catches per unit of effort for the Northwest and Canada occur in August and September. This indicates a heavy and simultaneous concentration of fish in Canada and the Northwest during this season.

(C) The mean Acoustic-Trawl survey transect starting point is approximately six miles off the coast, with a large variation. California fishermen concentrate their harvest efforts within three miles of shore. Northwest fishermen often see the densest concentrations within six miles of shore.

The CPSAS is concerned that the survey does not take place at times when fishery data indicates the heaviest concentrations of fish in both Canada in the NW occur. There are significant geographical areas where intense harvest occurs, but are not surveyed. The CPSAS believes that habitat and migration models cannot provide inference equal to actual surveys in venues and at times when sardines are in peak abundance.

Conclusions: While the CPSAS endorses the use of the Acoustic-Trawl survey method we believe there is more that needs to be done. Use of sonar to precisely establish avoidance behavior is warranted. Fishermen and other local knowledge sources should be utilized to establish the best survey timing and survey range rather than reliance on theoretical inference.

The CPSAS thanks the Scientific Review Panel and the Acoustic-Trawl Team for their hard work. This technology shows a lot of promise. Overlay of aerial survey methodology and work with the Canadians may be able to provide further improvements for the Acoustic-Trawl survey. The CPSAS would like this to be a collaborative work that allows for the best possible advancement of the science.

PFMC
04/08/11

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON THE COASTAL PELAGIC SPECIES (CPS) SURVEY METHODOLOGY REVIEW

The Coastal Pelagic Species Management Team (CPSMT) reviewed the Acoustic-trawl Methodology Review Panel Report (Agenda Item C.3.a Attachment 1) and offers these comments. The acoustic-trawl method for surveying coastal pelagic species (CPS) finfish off the west coast of the U.S. was developed by the Advanced Survey Technologies Program (ASTP) at the National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center (SWFSC) and reviewed by a Methodology Review Panel (Panel) in February 2011. The Panel's review focused on six issues: 1) design of the acoustic and trawl sampling, including how representative the data for the four managed finfish CPS species were; 2) analysis of the survey data for estimating CPS abundances; 3) evaluating the potential biases in sampling design and analysis; 4) characterizing the uncertainty in CPS biomass estimates; 5) deciding if acoustic-trawl estimates of CPS biomass can be used in stock assessments and management advice for Pacific sardine, jack mackerel, Pacific mackerel, and northern anchovy; and 6) providing guidance for future acoustic-trawl research.

The CPSMT commends the ASTP for their outstanding work and the Panel for a thorough review of the acoustic-trawl methods utilized by the SWFSC. While reviewing the acoustic-trawl method, the acoustic-trawl data collected to date, and its use for estimating the biomass of the four CPS finfish under Federal management, the Panel found the following:

Pacific sardine

- Population biomass estimated for the survey area, along with associated length-composition data, can be used as relative or absolute abundance for stock assessment after completion of two tasks.
- The 2011 sardine assessment author should consider using these data in the 2011 assessment.
- Not all sardine are likely to be within the survey area.
- The estimate of population biomass is sensitive to assumptions made about density inshore of the transect lines. In response to a Panel request, the ASTP found their population biomass estimate increased by 15 percent if the inshore – offshore gradient of density was utilized rather than the mean transect density.
- The Panel recommended a suite of sensitivity tests for the Stock Assessment Team (STAT) to explore when utilizing the acoustic-trawl biomass estimates in an assessment.

Pacific mackerel:

- The uncertainty of the acoustic-trawl biomass estimates for this species is greater than any other CPS. This is reflected by the very high coefficients of variation for the spring surveys.
- Biomass estimates are valid for the survey area. However, additional information will be needed to provide estimates of total stock biomass, because in any given year, an

unknown, but sizeable portion of this stock resides outside the survey area (i.e., off Baja California).
- Ultimately, the portion of the stock outside the current survey area varies seasonally and annually.

Jack mackerel:

- Uncertainties related to biomass estimates are much greater for this species than for Pacific sardine, and include catchability, avoidance, etc.
- This acoustic-trawl biomass estimate is the only recent scientific information available for this stock.
- Biomass estimate in the survey area can be used as an absolute abundance in U.S. waters (even though the survey does not cover all U.S. waters).
- The summer biomass estimate is probably more reliable than the other estimates made during other seasons because of patterns in distribution.

Northern anchovy:
- Acoustic-trawl data collected to date cannot be used to estimate biomass because the survey design does not adequately sample the distribution of this species.
- Acoustic-trawl survey methods can provide estimates of biomass if surveys were designed to sample the habitat where this species is most abundant (i.e., nearshore).

The CPSMT endorses the findings of the Panel and looks forward to having a third method to estimate abundance for Pacific sardine for use in the 2011 assessment. The biomass estimates of Pacific mackerel may prove useful to the STAT in the context of sensitivity analysis. However, the highly variable but low estimates of Pacific mackerel density, coupled with survey coverage limitations, will likely preclude inclusion of an abundance time series in any formal assessments at this time for this species. The biomass estimate for jack mackerel will be useful because of the paucity of recent information on this stock, but the range of this stock will probably fall well outside the survey area in any given year.

Biomass estimates for northern anchovy cannot be derived from the acoustic-trawl surveys conducted to date. However, the Panel concluded that acoustic-trawl methods could provide biomass estimates for northern anchovy if surveys were designed for that purpose. The CPSMT believes that acoustic-trawl surveys that provide biomass estimates for the northern and central subpopulation stocks would be valuable because the most recent biomass estimates for these stocks date from the mid 1970s and mid 1990s, respectively.

The Panel identified key issues to be investigated by the ASTP to improve acoustic-trawl methods in the future. The CPSMT anticipates that the results from these investigations and future acoustic-trawl surveys will be useful for managing CPS in the future.

PFMC
04/08/11

Agenda Item C.3.b
Supplemental SSC Report
April 2011

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON COASTAL PELAGIC SPECIES (CPS) SURVEY METHODOLOGY REVIEW

An acoustic-trawl survey methodology review took place in February, 2011, at the Southwest Fisheries Science Center (SWFSC) in La Jolla, California. The review Panel, made up of two Scientific and Statistical Committee (SSC) members and three reviewers from the Center for Independent Experts (CIE), provided a report (Agenda Item C.3.a, Attachment 1) with several recommendations to be implemented prior to use of the methodology in a stock assessment. Overall, the Panel concluded that the design of the acoustic-trawl survey is satisfactory and could be used to estimate abundance for CPS species.

For Pacific sardine, the Panel concluded that estimates from the acoustic-trawl survey can be included in the 2011 stock assessment as 'absolute estimates' if the following two tasks are completed:

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

2) The coefficient of variation for the estimates needs to be modified to fully account for the uncertainty of the trawl data.

The Panel also recommended that the results of the acoustic-trawl survey could be used to estimate the biomass of jack mackerel in U.S. waters (even though the survey does not cover the entire distribution of the stock). The estimates of abundance for Pacific mackerel are more uncertain as measures of absolute abundance than for jack mackerel or Pacific sardine. The present survey cannot provide estimates of abundance for the northern anchovy stocks without an increase in the density of survey transects in certain areas.

The SSC endorses the conclusion of the Panel's report that the survey estimates can be used in the 2011 sardine stock assessment, but has concerns whether the survey should be used as an estimate of absolute abundance. Instead, the SSC recommends that logic used in the whiting assessment be applied, where the acoustic survey is used as a relative abundance index absent strong evidence that the survey provides an estimate of absolute abundance. The SSC encourages further research to evaluate vessel avoidance and the spatial distribution of sardine relative to survey transects Some of this research may be possible in the near term, but it is unlikely to be completed by the Pacific sardine Stock Assessment Review Panel in October.

The SSC agrees with and recommends the following when considering the use of the acoustic-trawl survey data: (a) examine the sensitivity of the results to alternative acoustic-trawl abundance estimates; (b) determine if use of the acoustic-trawl results as absolute estimates of abundance leads to patterns in the residuals; (c) examine the implications of ignoring some or all of the acoustic trawl estimates [e.g., the estimates from the summer 2008 and spring 2006 surveys.

Lastly, the SSC would like to note that having the CIE reports available for this discussion was valuable. We also compliment the technical team and the review panel for their hard work and thorough review.

PFMC
04/09/11