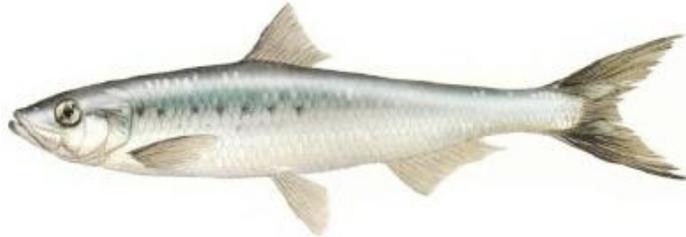


**Workshop on Enhancing Stock Assessments of Pacific Sardine  
in the California Current through Coordinated Comparative Surveys**

May 23-24, 2011  
La Jolla, California



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## Introduction

The Pacific sardine (*Sardinops sagax*) fishery on the US west coast provides important contributions to the nation's economy, both historically and currently (PFMC 2010). This species is managed by the Pacific Fishery Management Council under its Coastal Pelagic Species (CPS) fishery management plan (FMP). Annual sardine landings recently peaked in 2007 at over 120,000 mt, with an ex-vessel value close to \$14,000,000 (PFMC 2010). Regionally the sardine fishery is important to local fishing communities and generates employment opportunities to residents, both in fishing and processing sectors.

Up until 2008, the stock assessment of sardine was largely driven by fishery independent spawning biomass estimates based on the daily egg production method (DEPM). This data input to the assessment is derived from NOAA Fisheries Service data collected by the SWFSC Fisheries Resource Division (FRD), primarily during surveys conducted during the spring. In the Pacific Northwest, however, large concentrations of sardine occur and are harvested over continental shelf waters off of Oregon and Washington during the late summer and early fall. As a consequence, the sardine industry in the Pacific Northwest initiated the development of a pilot aerial survey in 2008, which was reviewed by the PFMC's Scientific and Statistical Committee (SSC)<sup>1</sup> and was endorsed for further development and potential incorporation into the 2009 stock assessment. A more fully developed aerial Sardine Survey was conducted during the summer of 2009, which was funded by the industry in both the Northwest and California, largely based on proceeds from sardine landings under an EFP that was granted by the PFMC and NMFS. The absolute biomass estimate that was derived from the Sardine Survey in 2009 (incorporating only data gathered in Northwest due to weather limitations in the south) was then incorporated into a full stock assessment that was conducted later that year<sup>2</sup>. There were, however, large differences in the precision and estimated size of the sardine stock, depending on the data source, i.e., the DEPM or the aerial survey. The aerial survey was conducted again in 2010 and was expanded into southern California. However, although point sets were successfully obtained in southern California, persistent marine layer precluded point sets off Monterey for the second year, the survey was again restricted to the Pacific Northwest (Washington and Oregon) and was included as an absolute biomass estimate of the stock ( $q = 1.00$ ) (Hill *et al.* 2010).

Due to differences between the DEPM and aerial survey data, concerns were raised about the accuracy of these approaches and a workshop was held to compare and contrast methods appropriate to surveying the sardine stock<sup>3</sup>. A variety of survey methods were considered at the workshop, including: (1) DEPM, (2) acoustic-trawl, (3) aerial/purse-seine, (4) aerial LIDAR, and (5) trawl swept-area. The strengths and weaknesses of each of these approaches to surveying sardine were discussed and summarized.

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<sup>1</sup> Aerial Survey Methods for Pacific Sardine – Report of STAR Panel Meeting. Agenda Item H.2.a, Attachment 3, June 2009.

<sup>2</sup> Pacific Sardine STAR Panel Meeting Report. Agenda Item I.1.c, STAR Panel Report, November 2009.

<sup>3</sup> Workshop on Enhancing Stock Assessments of Pacific Sardine in the California Current Through Cooperative Surveys. Agenda Item I.1.b., Attachment 1, November 2010.

To develop a research plan to experimentally compare survey methods for estimating the biomass of Pacific sardine (*Sardinops sagax*) off the US West Coast, NOAA National Marine Fisheries Service (NMFS) and the Pacific Fishery Management Council (PFMC) conducted a workshop, May 23-24, 2011 in La Jolla, California. The workshop was a follow-up to the 2010 sardine workshop. The objectives of the 2011 workshop, as identified in the terms of reference, were to: (1) develop a plan for a coordinated synoptic sardine survey designed to compare the estimates of abundance estimates from different survey methods, (2) enhance collaborative research opportunities and coordination between the sardine industry and NMFS, and (3) develop a plan for a coordinated survey including budget, timeframe, PIs, and operational requirements.

Technical experts in five survey methods for estimating Pacific sardine biomass (acoustic-trawl, aerial, DEPM, LIDAR, and trawl swept-area) participated in the workshop and in developing a coordinated survey proposal for 2012. Experts in the fields of oceanography, sardine fishing, stock assessment, and sardine management also participated. Participants were drawn from the sardine fishing industry, the NMFS, the States of Oregon, Washington, and California, the PFMC, Canada and Mexico. In addition to differences between methods, it was acknowledged that sardine are migratory and seasonal shifts in biomass and length composition are routinely observed in fishery landings between the three countries and among the three US states participating in the fishery. As a result it was deemed important that methods be compared synoptically.

The group reviewed proposed plans to implement five survey methods and together developed a coordinated 2012 survey plan for comparing sardine biomass estimates derived from data collected with each of the methods. Two budget scenarios were evaluated, i.e., a base expected 2012 budget, 'base budget', and a 'full budget' that would fulfill the needs of implementing a comprehensive west coast sardine survey. The full-budget scenario would enable a comparison of aerial-LIDAR, aerial-imaging, acoustic-trawl, DEPM, and trawl swept-area methods.

What follows is the coordinated survey plan that the group developed. This plan represents increased collaboration opportunities within NMFS (between the Southwest Fisheries Science Center (SWFSC) and the Northwest Fisheries Science Center (NWFSC)) as well as between NMFS and the fishing industry. Conducting the proposed surveys will also enhance the Pacific sardine stock assessments as well as support those who depend on the fishery. The resulting comparisons will provide a better understanding of how the methods and the resources required can be best leveraged for maximum gain.

## 2012 Pacific Sardine Biomass Survey Plans

The following section outlines two different budget scenarios. The first option is based on the assumption that full funding will be available for all survey approaches to accomplish an optimal sampling effort during the late summer of 2012. The second scenario assumes level budgets (no increase in survey funds will be available).

### Budget Scenario I – Full Funding Assumption

Key aspects of this scenario are: (1) a two-ship survey conducted by the SWFSC Fisheries Resources Division (FRD) encompassing Canadian to Mexican waters collecting acoustic-trawl and DEPM data, (2) three replicate aerial-imaging surveys conducted by the Northwest Sardine Survey (NWSS), extending from Queen Charlotte Sound in Canada to the California-Oregon border, a portion of which (at least one replicate) will be scheduled to coincide with the FRD survey in Canada/WA/OR, (3) a west coast aerial-LIDAR survey led by the NOAA Earth System Research Laboratory (ESRL) tracking the FRD acoustic-trawl survey, (4) a cooperative industry-agency California aerial-LIDAR survey following the FRD survey track lines in southern California coordinated with the west coast LIDAR survey, potentially with additional point sets, (5) a ship survey conducted by the Canadian Department of Fisheries and Oceans (DFO) off the west coast of Vancouver Island collecting trawl data for calculating swept-area biomass, and (6) a two ship survey conducted by Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) in Mexican waters collecting ichthyoplankton and acoustic-trawl data.

#### FRD Acoustic-trawl & DEPM

*Principal Investigators:* Vetter and McClatchie

*Operating Equipment:* R/V *Bell M. Shimada* = 40 days (5 in Mexico), F/V *Frosti* = 45 days (5 in Canada), total = 85 vessel days at sea, echosounder, trawl, and ichthyoplankton sampling

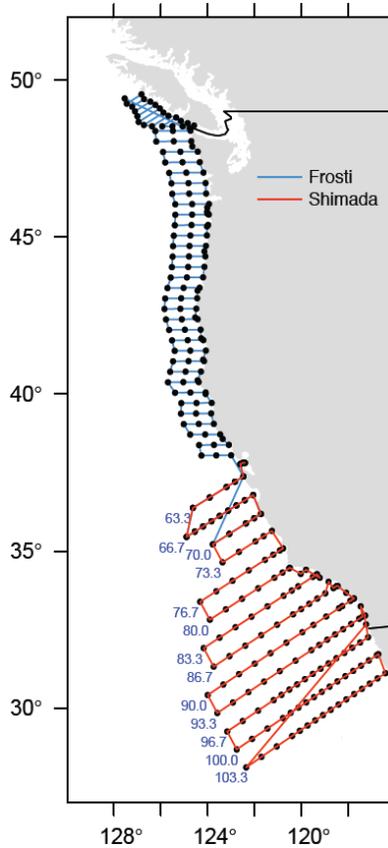
*Timeframe:* July 20 – August 31, 2012

*Field Operations:* echosounder, trawl, and ichthyoplankton sampling

*Data Collected:* species, length, reproductive state, age, genetics, abundance, and distribution

*Number and Position of Stations and Tracklines:* see map for the 308 stations occupied by *Shimada* (153) and *Frosti* (155)

*Analytical Methods to be Used:* DEPM procedure, trawl biomass, acoustic-trawl biomass, spatial, and regional analysis



*Budget:*

Category	Item	Cost - Full funding
Ship time	Frosti charter	\$360,000
	Shimada	\$680,000
Equipment	Trawl net	\$100,000
	Marine-mammal excluder	\$20,000
	Sonar for Frosti	\$325,000
Shipping	Equipment to Frosti	\$8,000
	Equipment to Shimada	\$8,000
Travel	San Diego to Vancouver - Frosti	\$750
	San Diego to San Francisco - Shimada	\$600
Personnel	Pre-cruise preparation Frosti	\$4,185
	Pre-cruise preparation Shimada	\$4,185
	Days at sea Frosti	\$165,042
	Days at sea Shimada	\$176,045
	Sample processing, data processing and statistical analysis to include larval sorting, histology, otolith analysis, acoustic analysis, IMECOAL data processing, and DEPM analysis	\$252,603
TOTAL		\$2,104,409

*Permits Required: Yes (Mexico portion)*

### Canadian Swept-Area Trawl Survey

*Principal Investigator(s):* Schweigert

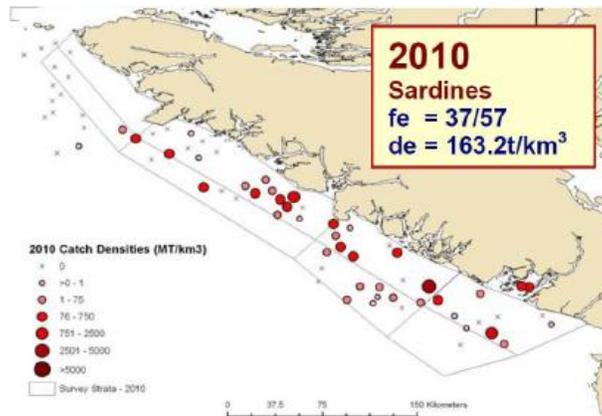
*Operating Equipment:* R/V Ricker

*Timeframe:* July 15 – August 31

*Field Operations:* Stratified-random station selection off west coast of Vancouver Island

*Data Collected:* sardine lengths, biomass, and distribution; trawl performance

*Number and Position of Stations and Tracklines:* see figure below for 2010 stations



*Analytical Methods to be Used:* swept-area of trawls and sardine biomass yield density estimates in spatial strata; sample frame includes depths to 100 m; stratified abundance estimates applied to stratum size and aggregated over strata

*Budget:* does not apply

*Permits Required:* none

### Coastwide Aerial-LIDAR and Imaging Survey

*Principal Investigator(s):* Churnside (ESRL)

*Operating Equipment:* NOAA Twin Otter (40 days and 100 hrs), LIDAR, video and FMC cameras, ocean color radiometry suite, and SST radiometer

*Timeframe:* July 20 – August 31, 2012

*Field Operations:* Follow ship (either *Shimada* or *Frosti*) tracks within 2 days, day and night

*Data Collected:* LIDAR and images

*Number and Position of Stations and Tracklines:* survey follows FRD acoustic-trawl tracklines with double (day and night) coverage

*Analytical Methods to be Used:* manual ID of schools, echo-integration, compare biomasses from other methods, e.g., laboratory target strength, historical point sets

*Budget:* ~\$140 K (for Twin Otter), \$250 K (labor – data collection and analysis), \$10 K (travel, etc.)

*Permits Required:* clearance to fly US plane in non-US airspace

## Northwest Sardine Survey

*Principal Investigator(s):* Jagielo

*Operating Equipment:* three airplanes (two Piper Super Cubs, one Cessna 337), Aerial Imaging Solutions FMC mount system (3), four commercial purse-seine vessels

*Timeframe:* July 10 – September 15 (will depend on EFP)

*Field Operations:* Two-stage sampling design: stage one is aerial-transect sampling, stage two is at-sea point-set sampling

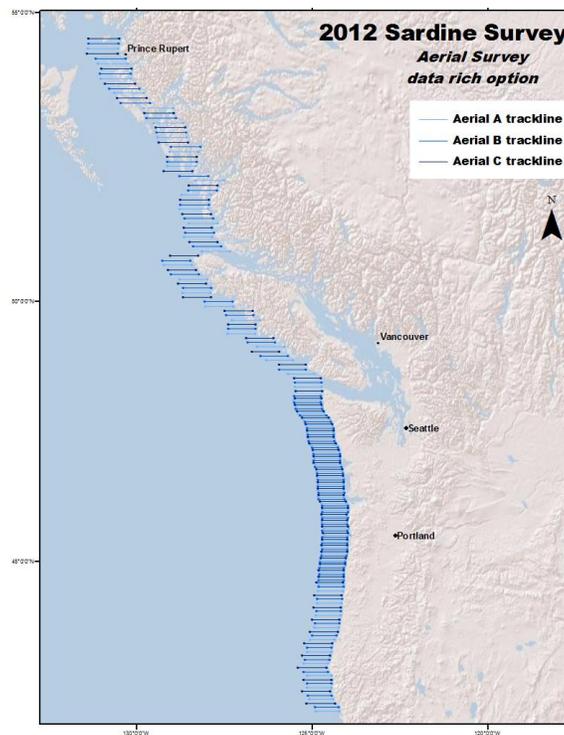
*Data Collected:* measurements of school surface area from digital images, landed weight and biological characteristics of fully-captured schools

*Number and Position of Stations and Tracklines:* three replicate sets of strip transects with the starting latitude of each randomized (see figure below); aerial survey conducted in Canadian waters in Queen Charlotte Sound and off the west coast of Vancouver Island.

*Analytical Methods to be Used:* measurements of school, size, and shape using image analysis software

*Budget:* US portion assumes EFP is awarded at a static level; Canadian portion requires additional funding

*Permits Required:* possibly for Canada; EFP required for US portion



### SoCal Cooperative Aerial-LIDAR

*Principal Investigator(s):* Churnside and LeRoi

*Operating Equipment:* NOAA Twin Otter (50 additional hours within the same 40 days and 100 hrs as FRD survey), LIDAR, video and FMC cameras, ocean color radiometry suite, SST radiometer, image intensifier lens for camera, and four charter vessels

*Timeframe:* the early part of July 20 – August 31, 2012 (with *Shimada* survey), depending on sardine location and timing of EFP (for point sets)

*Field Operations:* Follow *Shimada* tracks within two days, day and night.

*Data Collected:* LIDAR return, bioluminescence, and images, point sets (number to be determined)

*Number and Position of Stations and Tracklines:* offshore boundary defined by CalCOFI lines for the LIDAR but may include additional adaptive flights to survey specific sites with point sets, line extensions when appropriate, and/or high-density areas; point sets likely to be more spatially restricted.

*Analytical Methods to be Used:* Aerial imaging similar to NWSS, combine images and LIDAR with point sets.

*Budget:* ~\$225 K for charter vessels (\$7500/day/vessel), \$50 K (aircraft), \$125 K (labor); sale of EFP catch will cover costs for scientists, data processing, and spotter pilot.

*Permits Required:* EFP for point sets.

### IMECOCAL

*Principal Investigator(s):* Baumgartner (CICESE), Salinas, and possibly Quinones

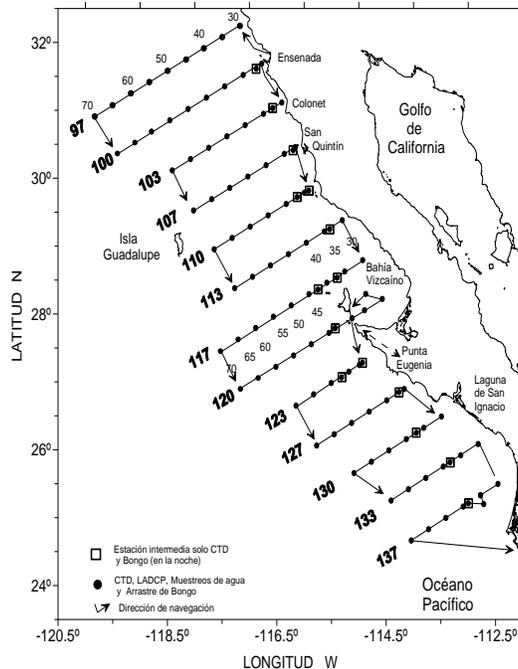
*Operating Equipment:* RV *Ulloa*, FV *Leifo Pol*, EK60

*Timeframe:* 20 July – 11 August 2012

*Field Operations:* ichthyoplankton sampling with CUFES, bongo and Calvet (*Ulloa*); acoustic (EK60) and trawling (*Leifo Pol*)

*Data Collected:* egg concentrations and distributions, species length compositions, reproductive states, ages, abundance, integrated echo-return.

*Number and Position of Stations and Tracklines:* 94 stations following the trackline shown below; all sample sites are CalCOFI stations; *Leifo Pol* to follow *Ulloa* over the same trackline gathering acoustic-trawl samples.



*Analytical Methods to be Used:* SWFSC FRD protocols for both DEPM and acoustic-trawl methods for estimating biomass.

*Budget:* 20 days *Ulloa* shiptime and 15-20 days for *Leifo Pol*

*Permits Required:* experimental fishing permit pending for *Leifo Pol*.

### **Budget Scenario II – Level Funding Assumption**

This budget scenario represents a contraction of the full funding scenario by: (1) dropping one of the two FRD survey vessels (*Shimada*), (2) reducing (or dropping) the Canadian aerial strip-transect lines from the NWSS while retaining a comparison opportunity (at least one replicate) with the FRD survey in WA/OR, and possibly Canada, (3) limiting the west coast LIDAR survey to the region sampled by the FRD research vessel, (4) limiting the Southern California cooperative survey to the CalCOFI survey area, and (5) dropping the acoustic-trawl sampling in Mexican waters. The DFO survey would not be altered under this scenario.

#### FRD Acoustic-trawl & DEPM

*Principal Investigators:* Vetter and McClatchie

*Operating Equipment:* *Frosti* for 40 days working south from Canada; California waters sample by July CalCOFI; echosounder, trawl, and ichthyoplankton sampling

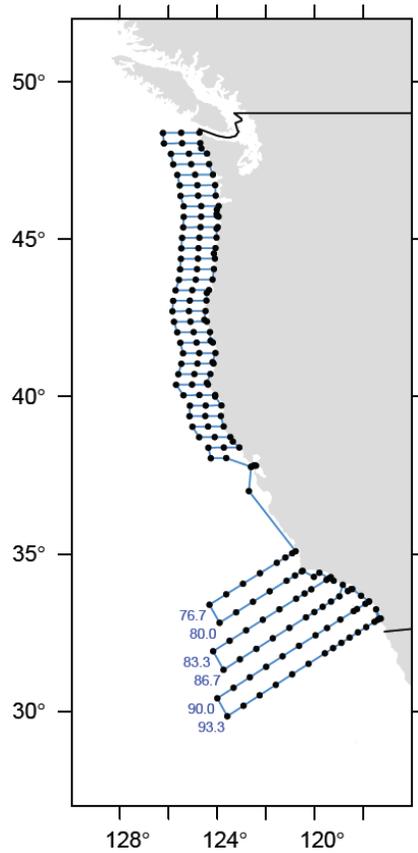
*Timeframe:* July 20 – August 31, 2012

*Field Operations:* echosounder, trawl, and ichthyoplankton sampling.

*Data Collected:* species, lengths, reproductive state, age, genetics, abundance and distribution.

*Number and Position of Stations and Tracklines:* see map below for 190 stations occupied by *Frosti* and July CalCOFI cruise

*Analytical Methods to be Used: DEPM, trawl, and acoustic-trawl*



*Budget:*

Category	Item	Cost - Level funding
Ship time	Frosti charter	\$320,000
	Shimada	\$0
Equipment	Trawl net	\$50,000
	Marine-mammal excluder	\$10,000
	Sonar for Frosti	\$325,000
Shipping	Equipment to Frosti	\$8,000
	Equipment to Shimada	\$0
Travel	San Diego to Vancouver - Frosti	\$750
	San Diego to San Francisco - Shimada	\$0
Personnel	Pre-cruise preparation Frosti	\$4,185
	Pre-cruise preparation Shimada	\$0
	Days at sea Frosti	\$146,704
	Days at sea Shimada	\$0
	Sample processing, data processing and statistical analysis to include larval sorting, histology, otolith analysis, acoustic analysis, IMECOCAL data processing, and DEPM analysis	\$157,000
<b>TOTAL</b>		<b>\$1,021,639</b>

*Permits Required:* None

Canadian Trawl Survey

*Principal Investigator(s):* Schweigert

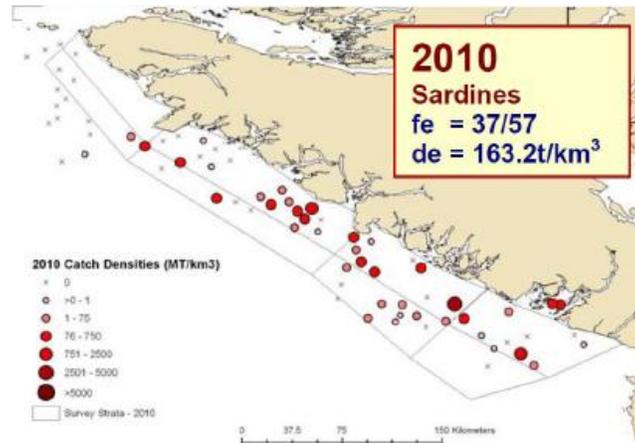
*Operating Equipment:* Ricker

*Timeframe:* July 15 – August 31

*Field Operations:* Stratified random station selection off west coast of Vancouver Island

*Data Collected:* sardine biomass and lengths; trawl performance

*Number and Position of Stations and Tracklines:* see figure below for 2010 stations.



*Analytical Methods to be Used:* swept-area of trawls and sardine biomass yield density estimates in spatial strata; sample frame includes depths to 100 m; stratified abundance estimates applied to stratum size and aggregated over strata

*Budget:* does not apply

*Permits Required:* None

Coastwide Aerial-LIDAR and Imaging Survey<sup>4</sup>

*Principal Investigator(s):* Churnside (ESRL)

*Operating Equipment:* LIDAR, video and FMC cameras, ocean color radiometry suite, and SST radiometer

*Timeframe:* July 20 – Aug 31, 2012

*Field Operations:* aerial strip transects in Pacific Northwest

*Data Collected:* LIDAR return and imagery

*Number and Position of Stations and Tracklines:* follow *Frosti* tracklines within 2 day (both night and day)

*Analytical Methods to be Used:* manual ID of schools, echo-integration, compare biomasses from other methods, e.g., laboratory target strength, historical point sets

*Budget:* \$125K LIDAR labor + \$10K shipping and travel

*Permits Required:* None

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<sup>4</sup> Funds currently do not exist for this survey but it was included for completeness

Northwest Sardine Survey

*Principal Investigator(s):* Jagielo

*Operating Equipment:* three airplanes (two Piper Super Cubs, one Cessna 337), Aerial Imaging Solutions FMC-mount system (3), four commercial purse-seine vessels

*Timeframe:* July 10 – September 15 (will depend to some extent on EFP)

*Field Operations:* two-stage sampling design: stage one is aerial-transect sampling, stage two is at-sea point-set sampling.

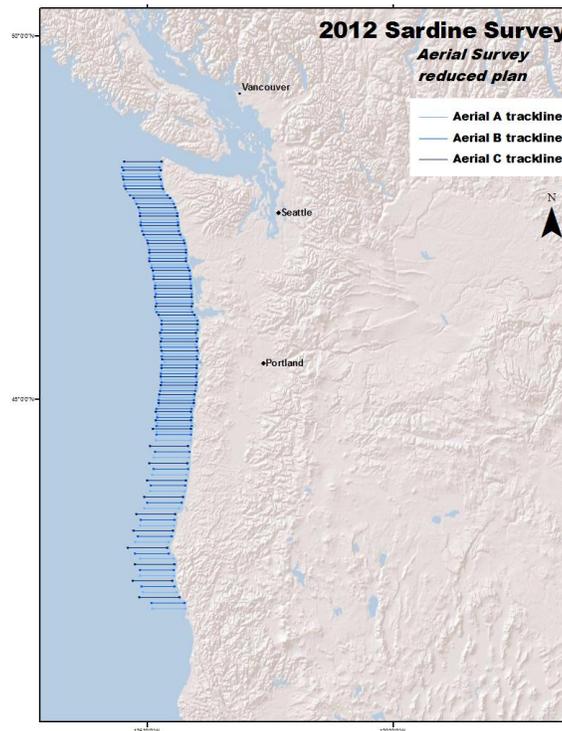
*Data Collected:* measurements of school surface area from digital images, landed weight and biological characteristics of fully-captured schools

*Number and Position of Stations and Tracklines:* three replicate sets of strip transects off the coast of Washington and Oregon only, with the starting latitude of each randomized (see figure below).

*Analytical Methods to be Used:* measurements of school size and shape using image-analysis software

*Budget:* US portion assumes EFP awarded at static level.

*Permits Required:* EFP required for US portion.



### SoCal Cooperative Aerial-LIDAR

*Principal Investigator(s):* Churnside, LeRoi, and Sweetnam

*Operating Equipment:* CDFG Partanavia, LIDAR, video or FMC cameras, image intensifier lens for camera, three charter vessels (30 point sets)

*Timeframe:* the early part of July 20 – August 31, 2012 (with *New Horizon*/CalCOFI survey) depending on sardine location and timing of EFP (for point sets)

*Field Operations:* Follow CalCOFI tracklines within two days, day and night

*Data Collected:* measurements of school surface area from digital images, landed weight and biological characteristics of fully-captured schools; LIDAR return for school density and depth, approximately 30 point sets, bioluminescence images

*Number and Position of Stations and Tracklines:* for LIDAR, offshore boundary defined by CalCOFI lines completed by the FRD, but may include additional adaptive flights to estimate abundance at specific sites where point sets have occurred, line extensions when appropriate, and/or high-density areas; point sets likely to be more spatially restricted

*Analytical Methods to be Used:* Aerial imaging similar to NWSS, combine images with LIDAR and point set data

*Budget:* \$113K for charter vessels (\$7500/day/vessel); \$125K LIDAR labor + \$10K shipping and travel; sale of EFP catch to cover the costs for scientists, data processing, and spotter pilot

*Permits Required:* EFP for point sets

### IMECOCAL

*Principal Investigator(s):* Baumgartner (CICESE)

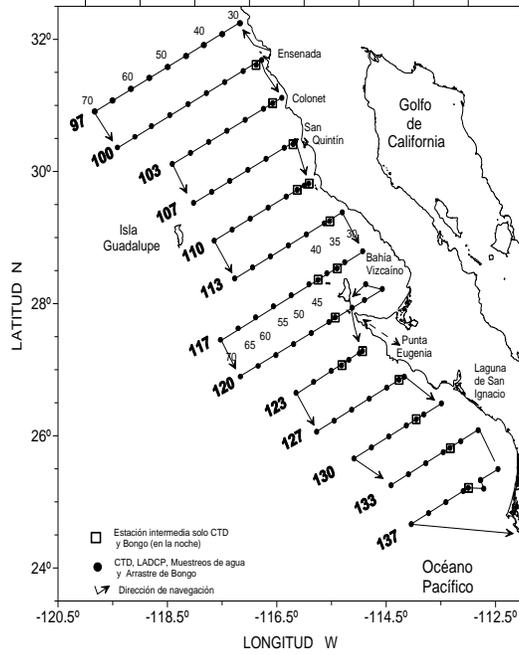
*Operating Equipment:* *Ulloa*

*Timeframe:* July 20 – August 11, 2012

*Field Operations:* ichthyoplankton sampling with CUFES, bongo and Calvet

*Data Collected:* egg and larval concentrations and distributions

*Number and Position of Stations and Tracklines:* 94 ichthyoplankton stations following the trackline shown below; cruise will progress from the north to the south; all sample sites are CalCOFI stations

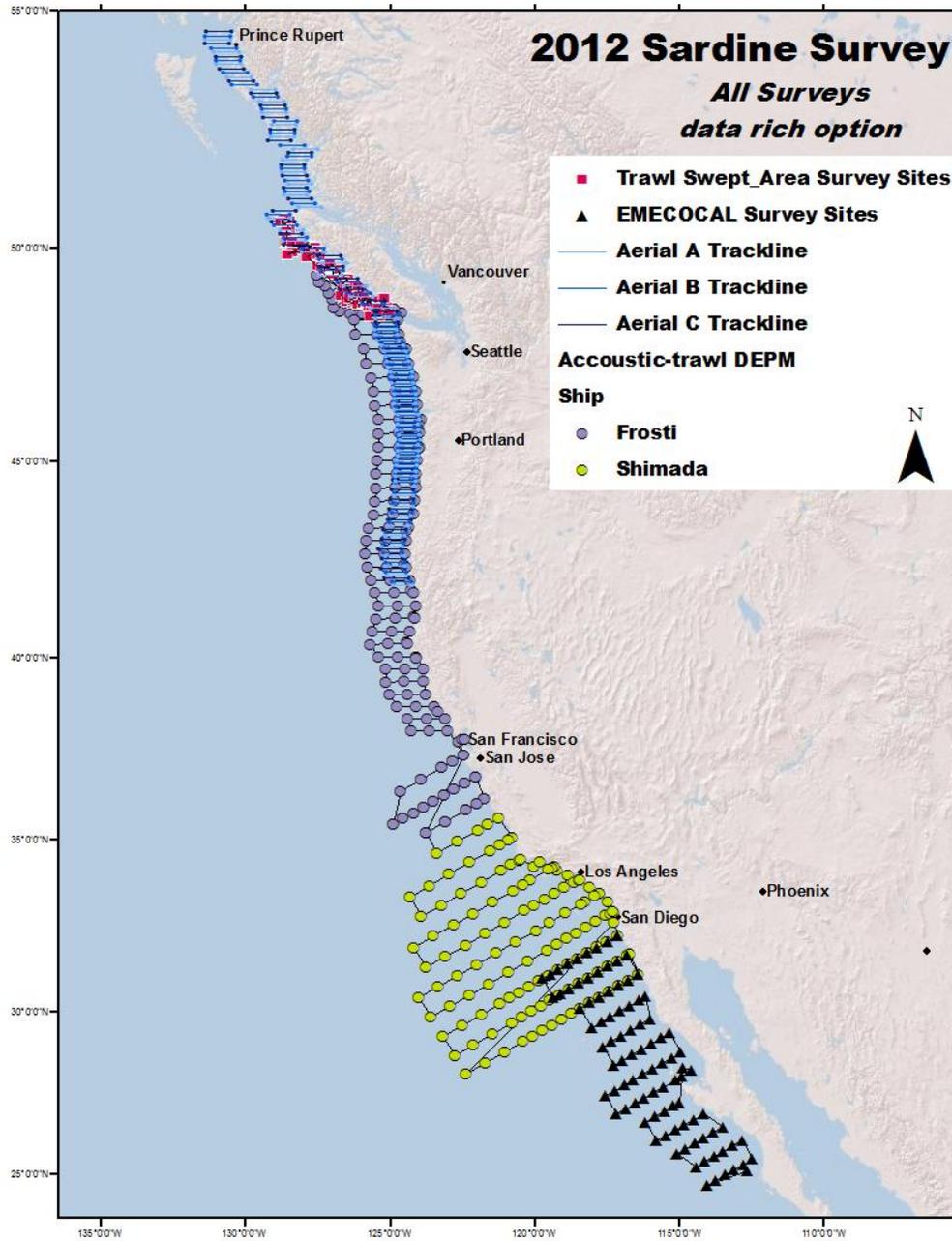


*Analytical Methods to be Used:* SWFSC FRD protocols for both DEPM and acoustic-trawl methods

*Budget:* 20 days *Ulloa* shiptime, \$5 K technician time

*Permits Required:* none

The following figure shows the fully funded survey plan, with station locations for all sampling methods superimposed.



## Discussion

Completion of these surveys in the manner described above will allow for a number of comparisons of the different methods. In particular, we can compare absolute sardine biomass estimates obtained from six different survey approaches, including: (1) FRD acoustic-trawl (A-T (FRD)), (2) FRD DEPM (DEPM (FRD)), (3) NWSS (aerial imaging), (4) DFO trawl (DFO Trawl), (5) Mexican acoustic-trawl and ichthyoplankton (IMECOCAL), and (6) aerial-LIDAR (LIDAR) surveys. Possible comparisons of abundance estimates derived from these six survey approaches are summarized in the table below.

Survey Method	A-T (FRD)	DEPM (FRD)	Aerial Imaging	DFO Trawl	IMECOCAL(+)
<b>DEPM (FRD)</b>	yes**				
<b>Aerial Imaging</b>	<b>yes</b>				
DFO Trawl	yes	no	yes		
IMECOCAL(+)	yes*	yes	yes*		
LIDAR	yes	yes (south)	yes	yes	yes*

\*Where there is overlap with three transects in SoCal/Mexico

\*\*Only if spawning females are present in summer survey

(+) IMECCAL may add multiple methods, dependent on availability, funding, etc (see #4 below)

In some instances it should be possible to make a robust comparison of methods. For example, if the acoustic-trawl survey and the NWSS are fully funded, there will be an extensive region of spatial overlap in the surveys, which will largely be conducted contemporaneously. This particular comparison (bolded in blue) is perhaps the single most important one to conduct, given the differences in survey biomass estimates that was described in the Introduction and the resulting reservations by industry concerning the accuracy of the stock assessment. On the other hand, comparisons of alternative survey methods with results of the DEPM are unlikely to be very powerful because late summer ichthyoplankton surveys for sardine will not likely encounter high abundances of eggs. However, a comparison of the DEPM and the acoustic-trawl method can probably be achieved by summarizing the FRD's previously conducted spring surveys that were conducted in the Southern California Bight and along the central California coast. These three survey approaches (FRD acoustic-trawl, NWSS aerial-imaging, and DEPM) are currently the only three survey methods that have been approved by the PFMC's SSC for inclusion in the Pacific sardine stock assessment. In that sense the two other methods (LIDAR and trawl swept-area biomass) are in an earlier stage of development. Finally, it is also important to reiterate that the objective is not to compare the various methods and then select the "best." Rather, the objective is to evaluate the relative advantages and disadvantages of each, so that they can be combined to provide the best balance between cost and precision.

Although not specifically addressed in the workshop Terms of Reference (Appendix 1), an additional important source of uncertainty in the sardine stock assessment is the extent to which fish migrate into Canadian waters. Although a comparison of the FRD acoustic-

trawl and the NWSS aerial survey methods will be possible, even under the level funding scenario, a full evaluation of the proportion of the stock north of the US-Canada border may only be accomplished under the full funding scenario. Even then, interannual variation in the extent of northward migration of the sardine stock is likely to occur and a single year of sampling would not be able to determine that variation.

## **References**

- Hill, K.T., N.C.H. Lo, B.J. Macewicz, P.R. Crone, and R. Felix-Uraga. 2010. Assessment of the Pacific sardine resource in 2010 for U.S. management in 2011. NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-469, 142 p.
- PFMC. 2010. Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches – Stock Assessment and Fishery Evaluation 2010. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland OR 97220, 71 p.

## List of Briefing Materials

### Documents

- Document 1 Proposed coast-wide lidar survey of sardines  
*J. Churnside, NOAA Earth System Research Laboratory*
- Document 2 Summary of the Coast-wide Sardine Trawl Survey Plan for 2011  
*J. Schweigert, DFO Canada*
- Document 3 Summary of the Northwest Sardine Survey (NWSS) Aerial Sardine Survey Plan  
*T. Jagielo, NWSS*
- Document 4 Spawning biomass of Pacific sardine using the DEPM method for 2010 spring CCE survey and 2008 spring and summer CCE surveys  
*N. Lo, B. Macewicz, D. Griffith, NOAA Fisheries SWFSC*
- Document 5 Acoustic-trawl survey conducted during the Spring 2011 California Current Ecosystem Survey from FV *Frosti* and FSV *Bell*  
*M. Shimada*  
*Juan P. Zwolinski, Kyle A. Byers, George R. Cutter Jr., Thomas S. Sessions, Beverly J. Macewicz, and David A. Demer*

### Informational Papers

- Paper 1 Summary of advantages and limitations & challenges of survey methods (extracted from the 2010 Pacific Sardine Workshop report <http://swfsc.noaa.gov/SardineWorkshop2010/>)
- Paper 2 West Coast Aerial Sardine Survey 2011 Application for Exempted Fishing Permit
- Paper 3 Acoustic-Trawl Survey Method for Coastal Pelagic Species Report of Methodology Review Panel Meeting
- Paper 4 Aerial surveys of fish in estuaries: a case study in Chesapeake Bay  
*J.H. Churnside, A.F. Sharov, R.A. Richter*
- Paper 5 Proceedings of the Sardine Symposium 2000
- Paper 6 Predicting habitat to optimize sampling of Pacific sardine (*Sardinops sagax*)  
*J.P. Zwolinski, R.L. Emmett, D.A. Demer*

## Appendix 1 – Terms of Reference

### Goals and Objectives:

1. Develop a coordinated synoptic sardine survey plan that will allow a comparison of abundance estimates developed from different survey methods. The comparisons are expected to assist interpretation of the data elements that are incorporated into the sardine stock assessment.
2. Improve collaborative research opportunities and coordination between the sardine industry and NMFS;
3. Develop a proposed survey budget, timeframe, PIs, and operational requirements.

### Responsibilities/Roles:

*Core participants* include the Executive Committee and the survey experts of each method. Their responsibilities include:

1. review all documents pertinent to the workshop;
2. provide proposed survey plans as working papers for their respective methods;
3. develop and draft an executable sardine survey plan for 2012;
4. provide constructive recommendations for developing a coordinated survey plan;
5. maintain flexibility and openness to survey designs that accomplish the primary goal of the workshop;
6. collaborate to develop a final executable sardine survey plan for 2012;
7. survey experts will consider both the scientific credibility of the survey designs, i.e. the ability of a proposed plan to provide the intended abundance estimate, as well as the budgetary and logistical requirements;
8. the Executive Committee will consider and comment on the budgetary and logistical needs of the plan (funding and availability of platforms and personnel).

*Subject matter experts* include experts in oceanography, stock assessments, sardine fishing, and general sardine knowledge pertinent to the workshop objectives. Their responsibilities include:

1. provide relevant subject material and commentary as requested by the Core Participants, Facilitator or Chair of the Workshop to help the Core Participants develop an acceptable survey plan during the Workshop itself.

*The facilitator* responsibilities include:

1. guide the Working Group (Core participants and Subject matter experts) in developing the plan, adhering to this Terms of Reference, and finding mutually agreeable solutions;
2. coordinate writing of survey plan;
3. manage discussions and public comment so that work can be completed.

*The workshop chairman's* responsibilities include:

1. guide the Executive Committee in developing a workshop and assisting the Facilitator in ensuring the Working Group meets its objectives;
2. develop a workshop agenda;
3. review the Working Group workshop report before it is forwarded to the SWFSC and presented to the Pacific Fishery Management Council.

*The public* will have at least one period for commenting on the activities of the workshop; comments should be germane to the topic at hand.

Expectations:

The primary purpose of the workshop will be to develop a coordinated synoptic sardine survey plan that will allow a comparison of sardine abundance estimated using different survey methods. The Working Group will not revisit, but will build on discussion and topics resulting from the Sardine-I workshop. The Working Group will begin its work with the SWFSC 2012 summer cruise as a proposed survey design, to be spatially and temporally coordinated with other approaches to estimating sardine abundance, as appropriate and reasonable.

Survey Methods to be Considered

Acoustic-trawls  
Aerial surveys  
DEPM  
LIDAR  
Swept Area Trawl

Draft Product – to be completed within one week of workshop.

Final Product – to be delivered to SWFSC within two weeks of workshop.

An executable sardine survey plan for 2012 including the following for each survey method:

1. Principal Investigators
2. operating equipment
3. timeframe
4. field operations to be conducted
5. data to be collected
6. number and position of stations and track lines
7. analytical methods to be used to summarize the data collected
8. budget

Participants:

Chairman – Mark Helvey

Executive Committee

Kerry Griffin  
Kristen Koch  
Mike Okoniewski  
Diane Pleschner-Steele  
Sarah Shoffler  
Cisco Werner

Facilitator – Steve Ralston

Survey Experts

Acoustics: David Demer  
Aerial Survey: Tom Jagielo, Don LeRoi  
DEPM: Nancy Lo  
LIDAR: James Churnside  
Trawl survey (swept area): Bob Emmett, Jake Schweigert

SWFSC survey: Russ Vetter  
Subject Matter Experts  
Fishing: David Haworth, John Lenic  
Oceanographic: Ed Weber  
Sardine: Dale Sweetnam, Lorna Wargo, Greg Krutzikowsky, Sandy McFarlane  
Stock Assessment: Kevin Hill  
IMECOCAL Survey: Baumgartner

## Appendix 2 – Agenda

### Workshop on Enhancing Stock Assessments of Pacific Sardine in the California Current Through Coordinated Comparative Surveys

May 23-24, 2011  
La Jolla, California

- I. Opening and introduction
- II. Arrangements and process
- III. Review of plans for ship-based sardine survey methods
  1. DEPM survey
  2. Acoustic-trawls survey
  3. Swept area trawl survey
- IV. Review of plans for plane-based sardine survey methods
  1. Aerial survey
  2. LIDAR survey
- IV. Draft plan(s) for different budget scenarios.
- V. Clearing of plan and commitments for follow through and clean up
  1. Discussion on follow through
  2. Clearing of plan
- VI. Close of workshop

### **Appendix 3 – Alphabetical List of Attendees**

Tim Baumgartner  
Jim Churnside  
Paul Crone  
Bob Emmett  
Kerry Griffin  
David Haworth  
Mark Helvey  
Roger Hewitt  
Kevin Hill  
Tom Jagielo  
Kristen Koch  
Greg Krutzikowsky  
John Lenic  
Don LeRoi  
Nancy Lo  
Bev Macewicz  
Sandy McFarlane  
Diane Pleshner-Steele  
Steve Ralston  
Rosa Runcie  
Jake Schweigert  
Sarah Shoffler  
Dale Sweetnam  
Lorna Wargo  
Cisco Werner  
Russ Vetter  
Ed Weber