# West Coast Sardine Survey

## Justification for Exempted Fishing Permit in 2009

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The purpose of this Exempted Fishing Permit (EFP) request is to obtain approval to utilize the portion of sardine quota (1200 mt), which the Pacific Fishery Management Council has set-aside for sardine research in 2009, to improve upon and continue the aerial sardine survey work started on a pilot scale in 2008.

In 2008, the Northwest Sardine Survey LLC (NWSS), a consortium of the Northwest Sardine Industry, conducted a "proof of concept" project to determine if high quality, quantitative digital aerial imagery could be collected and processed on a scale large enough and rapidly enough for a practical fisheries stock assessment application – namely the in-season enumeration and measurement of sardine schools (Wespestad et al. 2008). The project was successful in this endeavor. In approximately one month's time (from late August through late September 2008), over 2000 images were processed by one scientific technician, who discerned and individually measured the surface area of over 3000 sardine schools. Furthermore, every school selected and measured on the digital images was documented and archived to allow for subsequent examination and review by other observers.

While aerial counts of school number and measurements of school cover ($m^2$) as collected in 2008 are recognized as useful metrics to begin to develop an index of abundance extending over a period of years for the sardine stock, a direct point estimate of biomass is also desired to more quickly characterize the stock status. Our initial work has shown that point sets, coupled with quantitative digital imagery, are a promising method to establish the relationship between sardine cover ($m^2$) and biomass (mt) for this purpose.

Sampling limitations in 2008, however, resulted in too few samples to quantify this relationship with good accuracy or precision. A research set-aside of sardine quota was not available in 2008 and it was necessary to conduct research sampling opportunistically during the fishery. As a result, short and intense fishing periods and poor weather conditions limited our ability to fully test the methodology in our pilot project year.

The objective of this EFP request is to provide an opportunity to collect the data needed to improve our quantification of sardine school density under more controlled conditions and in a directed manor -- separate from the open period of the fishery. The survey design to be employed in 2009 largely follows the plan developed and executed successfully in 2008. The primary differences in 2009 will be 1) the opportunity to make use of the portion of the sardine quota explicitly set-aside for research (1200 mt), to obtain better estimates of sardine school density than could otherwise be obtained during the directed fishery, 2) to extend the coverage of the survey to both the north and the south along the Pacific Coast.

## Materials and Methods

### *Biological Sampling*

As in 2008, samples will be routinely collected from vessels delivering at fish processing plants. Fishermen will keep observed research hauls (point sets) separate from the bulk of landings so total tonnage of observed hauls may be determined. Port sampling will be conducted opportunistically throughout the open fishing periods, and additionally during the EFP set-aside opening for research. Samples will be collected from unsorted catch while being pumped from the vessel. Fish will be 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 processed.

Length, weight, and maturity over the course of the season are of primary interest. 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. Random otolith samples will also be taken for aging analysis. Sardine maturity will be established by referencing maturity codes (female- 4 point scale, male- 3 point scale) supplied by Beverly Macewicz NMFS, SWFSC (Wespestad et al 2008, Table 1a).

### *Aerial Survey*

Survey design

As in 2008, our survey will employ the belt transect method using a systematic sampling design, with each transect a single sampling unit (Elzinga et al 2001). From a random starting point, parallel transects will be conducted in an east-west orientation, generally parallel to the gradient of sardine schools distributed along the coast. To fully encompass the expected width of the sardine school distribution transects will originate at the shoreline and will extended westward for 35 miles but possibly further offshore to the south. Transects will be spaced 10 miles apart. In 2008, 10 parallel transects were sampled off the coast of Washington-Oregon with three replicate surveys. The intention of NWSS for 2009 is to expand the spatial coverage of the survey northward (to the Canadian border), and southward (to the Northern California border) from the area covered in 2008.

Considerable effort was expended in 2008 by NWSS to establish and validate the quantitative aerial survey methodology by conducting a proof of concept study in the Northwest (Wespestad et al. 2008); however, the technique has not been validated for the waters off California. If it can be demonstrated that the same methods used by NWSS in the Northwest in 2008 can be implemented in California, the NWSS welcomes a collaboration to extend the spatial coverage of the survey southward from the Northern California border to the Monterey Bay area. Such a southward extension of the survey would benefit the project considerably by allowing for a single coordinated synoptic survey effort that would extend from Cape Flattery to Monterey Bay.

Data collection

The photogrammetric-aerial digital camera mounting system and data acquisition system used in 2008 will be used to acquire digital images and to log data along the transects (Aerial Imaging Solutions; see Wespestad et al. 2008, Appendix A). The system records altitude, position, and spotter observations, which are directly linked to the time stamped quantitative digital imagery. Surveys will be flown with Piper Super Cub PA18 aircraft(s) at a speed of 80-90 mph. Surveys will be conducted on days when weather conditions permit clear visibility of the ocean surface from an altitude of 8000 ft (2438 m). Using standard photogrammetric relationships (see below), the approximate width-swept by the camera with a 24 mm lens is 12,000 ft (3657 m) at that altitude. Digital images will be collected with 60% overlap to ensure seamless coverage along the length of the transects.

In 2008, quantitative aerial photogrammetry was validated by collecting digital imagery of an object of known size (an airplane hangar) at a series of altitudes ranging from 500 ft. to 8000 ft. Additional validation will be conducted in 2009 to determine if a calibration constant can (or should) be used to improve accuracy based on this ground-truth information.

Digital images will be analyzed to determine the number, size, and shape of sardine schools on each transect. Adobe *Photoshop Lightroom 2.0* software will be used to bring the sardine schools into clear resolution and measurements of sardine school size ($m^2$) and shape (perimeter, circularity) will be made using Adobe *Photoshop CS3-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 is then obtained by taking the average of *GCS* for all images collected along the transect. Transect length is obtained from the distance between start and stop endpoints using the GPS data logged by the data acquisition system. Transect area is then the product of mean transect *GCS* and transect length.

As in 2008, purse seine vessels operating during periods of open fishing will again be used opportunistically to capture fish (i.e. "point sets") in conjunction with aerial over-flights to determine the relationship between school surface area (as documented with quantitative aerial photographs) and the biomass of fish schools (as measured from the

landed weight of fully captured schools). For fully captured schools, the total weight of the school will be recorded and numbers per unit weight will also be determined.

Point set data collected in 2008 were limited in scope. Few valid point sets were obtained, and those that were collected generally fell on the upper tail of the school size distribution as recorded during the aerial survey. For 11 point sets in 2008, school cover from aerial photographs ranged from 657.4 $m^2$ to 9308.4 $m^2$ with a mean of 3055.7 $m^2$ ; however, the majority of school size measurements taken from photographs along aerial survey transects fell between 200 – 2000 $m^2$ (cf. Wespestad et al 2008, Table 6 and Figure 8). To obtain better precision and representativeness in 2009, we will attempt to conduct a larger number of point sets, and will stratify point set sampling by school size. This effort will be facilitated by focused point set sampling which will be conducted during the EFP portion of the fishery, which will allow us to obtain additional point sets beyond those which could be obtained opportunistically during the fishery alone.

The project Principal Investigator(s) will specify how to spatially distribute the research set-aside portion of the sardine quota. It is critical that the limited research set-aside (1200 mt) is used sparingly and wisely to achieve the best scientific result. If the necessary proof of concept work can be completed in California (comparable quantitative aerial photography coupled with point sets, and associated echo sounding to measure school depth), a portion of the research set-aside may also be utilized in California to conduct point sets to compare spatial variation in the relationship between school surface area and biomass with observations from the Northwest.

Data analysis

*School density*. Belt or strip transects represent a special case of quadrat sampling; with the additional consideration that all transects may not be of equal length or area. In our survey, unequal transect areas can result from either 1) variation of transect width (e.g. from a lower visibility causing reduced flight altitude) or 2) variation in transect length (e.g. due to premature transect termination due to fog or other weather conditions). To account for this contingency, we will employ an unequal-area transect density estimator computed by dividing the mean number of sardine schools per transect by the mean transect area (Stehman and Salzer 2000). In this formulation

$$\hat{D} = \frac{\bar{y}}{\bar{a}}$$

Where $\hat{D}$ = the sample-based estimator of density, $\bar{y}$ = sample mean number of schools per transect, and $\bar{a}$ = sample mean transect area. The estimated variance of $\hat{D}$ is derived from standard ratio estimation theory as

$$\hat{V}(\hat{D}) = \frac{1}{\bar{a}^2}\left(\frac{N-n}{N}\right)\frac{s_e^2}{n} \quad \text{(Thompson 1992)}$$

where N = the total number of transects in the region, $n$ = the number of transects sampled in the region, and $s_e^2 = \sum_u (y_u - \hat{D}a_u)^2 / (n-1)$ where $y_u$ = the number of schools in transect $u$, and $a_u$ = the area of transect $u$. Stehman and Salzer (2000) note that, while $\hat{V}(\hat{D})$ is an approximation generally valid for a sample size of 30 (Cochran 1977), simulations suggest it may also be valid for smaller sample sizes if the distribution of transect areas is nearly symmetric, or if the correlation between $a$ and $y$ is close to 1.

*Total number of schools*. Given the estimate of density $(\hat{D})$ and the total study area ($A$), an estimate of the total number of schools $(\hat{T})$ is

$$\hat{T} = \hat{D}A$$

and its standard error $\widehat{SE}(\hat{Z})$

$$\widehat{SE}(\hat{T}) = \widehat{SE}(\hat{D})A \quad .$$

*School cover and biomass*. Our measurements of the surface area of individual sardine schools from the digital imagery affords us the opportunity to estimate total sardine school cover. Cover is defined as the vertical projection of an object from the ground as viewed from above (Elzinga et al 2001). Let $z_u$ denote the value for sardine school cover ($m^2$) on transect $u$. Cover for the entire study area $(\hat{Z})$ can then be estimated using the unbiased estimator for a population total, $\hat{Z} = N\bar{z}$, with estimated variance

$$\hat{V}(\hat{Z}) = \frac{N^2\left(1-\frac{n}{N}\right)s_z^2}{n}$$

where $s_z^2$ is the sample variance of z.

To estimate sardine biomass for the study area using school cover data, the relationship between individual school cover and school biomass is required,. An initial examination of this relationship in 2008 was explored by examining a scatter plot of school cover ($m^2$) vs. school biomass (mt) using the fishery point set data. As noted above, in 2009 we will attempt to increase the sample size and representativeness to improve quantification of this relationship.

***Hydroacoustic Measurement of the Vertical Dimension***

In 2009, NWSS will again use vessels equipped with echo sounders to attempt to measure the depth and height of schools in the Northwest. Each vessel will be equipped with a Simrad ES 60 recording echo sounders and connected to the ships 50/200 mHz

single beam transducers. This configuration will allow for recording of the water column under the ship. Our objectives in 2009 are: 1) to record school vertical dimensions prior to taking a purse seine set, and 2) to run portions of transects with the aerial survey to estimate the portion of sardine schools unobserved from the air.

As in 2008, echo sign will again be recorded continually throughout the season; however, in 2009, a directed effort will also be made during the EFP portion of the fishery to collect paired echo sign and aerial survey observations.

***EFP Purse Seine Vessel Selection and On-Board Observation***

Our priorities for selecting vessels to participate under this EFP will include: 1) vessels having demonstrated a previous successful involvement in the survey, 2) vessels which have installed the necessary electronic equipment or have the capacity to install this equipment, and 3) vessels having the ability to separate the point sets into different hatches. It must also be understood that we have limited funds for this project so it will be necessary that any vessel selected will have to work basically at cost.

At sea observation of point sets may be accomplished by volunteer observers from state or federal agencies, or from paid observers if funding permits. Alternatively, it may be preferable to obtain independent verification of the point set data via videotaping or other electronic methods. This will be further discussed at the STAR Panel meeting in May.

***Disposition of fish harvested under the EFP***

Fish harvested under this EFP will be sold to fund the sardine research described above. Participating processors will be identified prior to any fish deliveries made under this EFP, and they will process the fish at cost. 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, and that the amounts harvested correspond to the total of the amounts harvested while conducting the point set research.

**Budget**

Funds derived from the capture and sale of the 1200 mt 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 paid for by the sale of the fish captured during the point sets. Fishing vessels will be chartered to catch the sardines and conduct echo soundings of fish schools. Participating processors will not profit on the sale of the EFP sardine quota; rather, they will process the fish at cost. Airplanes conducting the surveys and assisting in point set captures will work under hourly rates. Equipment needs, operational costs and scientific support will also be subtracted from the sale of the 1200 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.

## 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 pilot survey work conducted in the Northwest in 2008, the EFP in 2009 will enable us to obtain critical information needed to convert aerial survey measurements of sardine school surface area into estimates of sardine biomass. Our efforts to accomplish this in 2008 were hampered without a set-aside of sardine OY for research. 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 manor, separate from the race for fish which ensues during the open access 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. If the methods applied in the Northwest in 2008 by NWSS can also be implemented in California we also welcome the opportunity to extend the survey southward to include Monterey Bay and nearby areas.

## Literature Cited

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