California Aerial and Acoustic Sardine Survey

Justification for Exempted Fishing Permit in 2009

To be conducted in coordination with the PNW Survey to
extend the survey area synoptically along the Pacific Coast into California

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Background

This proposal is submitted to the Pacific Fishery Management Council to justify and request the use of up to 600 mt* of Pacific sardine through the Exempted Fishing Permit (EFP) process specified in the CPS Fishery Management Plan for use in California. The proposed survey is to expand and improve upon survey methods developed by the Northwest Sardine Survey LLC, a consortium of the Northwest Sardine Industry (PNW) during 2008 and 2009. The CWPA proposal closely follows the PNW EFP proposal in basic survey methods, and to ensure close approximation of techniques, employs the PNW proposal narrative extensively in this proposal.

(*Note: CA use of the set aside will be taken under the guidance of CA scientists, in coordination with PNW scientists, with the goal to achieve representative samples for school size, density and volume in both regions.)

The PNW survey conducted in 2008, was essentially 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 developing the methodology and we intend to follow those survey methods as closely as possible to conduct a similar aerial survey of northern California coinciding with the PNW survey, and with intensive utilization and further enhancement of hydroacoustic methods in Monterey Bay, California.

The PNW survey recognizes that aerial counts of school number and measurements of school coverage (m2) as collected in 2008 are useful metrics to develop an index of abundance extending over a period of years for the sardine stock. PNW initial work has shown that point sets (setting a purse seine on a school of sardine to land and document actual school tonnage), coupled with quantitative aerial digital imagery, are a promising method to establish the relationship between sardine cover (m2) and biomass (mt) for this purpose. CWPA intends to further quantify this metric by using digital split beam scientific echosounders (one now owned by CWPA and a second transducer to be obtained). In addition, improving on the core survey protocol, we will also be working in partnership with acousticians from NMFS, SWFSC, who will deploy advanced acoustic equipment to further improve quantification of sardine schools (see Appendix A attached).

Because PNW incurred sampling limitations in 2008 that resulted in too few samples to quantify point sets with good accuracy or precision during the open derby fishing period, they are seeking a parallel research set-aside of sardine quota which was not available in 2008. CWPA also intends to conduct research sampling opportunistically during the directed fishery and, for similar reasons, we believe it necessary to have access to a portion of the research set aside, not to exceed 600 mt (*see note above), to focus undivided attention on conducting the survey with scientific rigor following the open access period.

During 2008, California Wetfish Producers Association (CWPA) tested the availability of sardine schools for aerial photographic surveys in Monterey Bay California. During four flights over Monterey Bay during daylight in summer and fall months, sardine schools of various sizes and depths in the water column were photographed, with pilot estimates of tonnage and actual landings recorded. These photographs were reviewed and enhanced to reveal that sardines were available during daylight hours and could be photographed as was done in PNW. Recent discussions with scientists of NMFS, SWFSC

resulted in the opportunity to improve the acoustic confirmation of sardine school size, volume, and density using advanced acoustic techniques and gear developed at SWFSC (see attached Appendix A). CWPA has reached agreement with SWFSC to cooperate in this survey in Monterey Bay in summer 2009, in conjunction with the aerial survey work planned by CWPA, and in coordination with the PNW survey.

The objective of this EFP request and that of PNW is to provide an opportunity to collect the scientific data needed to improve our quantification of sardine school density and improve understanding of the coast-wide sardine resource. The survey design to be employed by CWPA in California follows the plan developed by PNW, and will be timed to occur synoptically with the survey planned in the PNW, with close coordination and communication among contracted PNW and CA scientists.

Materials and Methods

Biological Sampling

As in 2008 and as proposed by PNW, 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

Following PNW protocol, the CWPA 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 offshore along the coast. To fully encompass the expected width of the sardine school distribution transects will originate at the shoreline and will extended offshore to include the extent of sardine schools. Transects will be spaced approximately 10 miles apart. An estimated 24 transects is planned, based on survey design by PNW scientists, intended to survey the coast from the OR/CA border to at least Monterey Bay. The full scope of the CWPA survey spatial coverage will be determined by the actual level of funding derived from the sale of the EFP sardine set-aside for research and CWPA contributions to the research project.

Data collection

CWPA will use photogrammetric-aerial digital camera mounting equipment and data acquisition systems similar to the PNW system. CWPA will use the same techniques described by PNW below:

'The system will record 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 transects.

In 2008, PNW validated quantitative aerial photogrammetry 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 (m2) 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 by PNW 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 m2 to 9308.4 m2 with a mean of 3055.7 m2 ; however, the majority of school size measurements taken from

photographs along aerial survey transects fell between 200 – 2000 m2 (cf. Wespestad et al 2008, Table 6 and Figure 8). Thus, to obtain better precision and representation in 2009, the PNW 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 the survey to obtain additional point sets beyond those which could be obtained opportunistically during the fishery alone. The CA survey also will conduct a number of point sets to provide a scientifically acceptable sample size, and will target schools of varying sizes.

Data analysis (from PNW request)

Note: To ensure consistency of survey analysis the CA survey will follow the procedure proposed by PNW for data analysis:

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

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

where N = the total number of transects in the region, n = the number of transects sampled in the region, and $s_e^2 = \sum_s \left(y_u - \hat{D}a_u\right)^2 /(n-1)$ 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 $\widehat{SE}(\hat{Z})$

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

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 zu denote the value for sardine school cover (m2) on transect u. Cover for the entire study area $(Z^{\wedge})$ 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 (m2) vs. school biomass (mt) using the fishery point set data.'

Hydroacoustics

CWPA will use vessels equipped with echo sounders to attempt to measure the depth and height of schools from the fishing vessels. CWPA will simultaneously deploy BioSonics DT~X digital scientific split beam transducers to quantify school size and density. In Monterey Bay this protocol will be enhanced by deployment of SWFSC acoustic equipment operated by SWFSC acousticians as described in Appendix A. This additional acoustic measurement will be conducted in cooperation with CWPA and in conjunction/communication with the PNW survey.

Our objectives are: 1) ground truth aerial observations by recording school size and density prior to making a purse seine "point set", and 2) to compare/quantify acoustic transects with the aerial survey to estimate the portion of sardine schools observed and unobserved from the air.

EFP Purse Seine Vessels and On-Board Observation

Three purse seine vessels (CWPA members) have agreed to participate in this survey, fishing at cost. They will cooperate with NMFS and CDFG to ensure full compliance with the EFP.

As with PNW, 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 have been identified for 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 up to 600 mt of the sardine research set-aside taken during point sets outside the directed fishing period will be used to pay for the research to be conducted under this proposed EFP. Participating processors will not profit from the sale of the EFP sardine quota; rather, they will process the fish at cost and remit the proceeds to CWPA. As a 501(c) nonprofit, CWPA will serve as repository for the proceeds of fish sold in the California portion of the research survey. Fishing vessels will be chartered to catch the sardines and conduct echo soundings of fish schools. 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 600 mt research quota. As with PNW, CWPA anticipates the revenue from the fish sales will be sufficient to cover the costs to capture, process, and conduct the survey.

Conclusions

As we testified in November 2008, we believe developing a second index of sardine abundance is essential to achieve effective sardine management, and we support the aerial survey methodology developed by the Pacific Northwest sardine industry. CWPA and CA members of the CPS Advisory Subpanel also supported increasing the research set aside from 600 mt to 1,200 mt to enable the CA wetfish industry to participate in a synoptic [or near synoptic] aerial survey in the summer of 2009, when

CA sardines are present and visible at the surface during daylight hours. Extending the survey into California this year is important to improve understanding of the extent of the resource and coast-wide migration patterns. As noted above, we request a portion of the research set aside to conduct this survey in California. CA use of the set aside will be taken under the guidance of CA scientists, in coordination with PNW scientists, with the goal to achieve representative samples for school size, density and volume in both regions.

We have invested substantial time and money into sardine research, and like PNW industry, we require both the undivided time outside the derby fishery and proceeds from the sale of research fish to effectively accomplish this research in a scientifically approved manner. We have offered, and continue to offer, to work cooperatively in conjunction with PNW scientists to conduct a successful survey that will both improve survey methodology through the use of advanced acoustic technology, and expand knowledge of the sardine resource. Developing a repeatable annual summer survey to measure the [near] coast-wide extent of the sardine resource, augmenting spring egg production surveys, will achieve our ultimate goal to inform and improve the coast-wide stock assessment.

Literature Cited

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Appendix A. Proposed Quantitative Acoustic Ground Truth of Sardine School Aerial Surveys in Monterey Bay.

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Methods

Aerial surveys are to be conducted for schools of sardine. The remote observations of near-surface fish schools will be used to estimate fish abundance. These estimates are to be validated by purse-seine capture of a number of schools. Here we propose to augment these measurements with active-acoustic measurements made with a multi-frequency split-beam echosounder system (Simrad EK60), and a single-frequency multi-beam sonar (Kongsberg-Mesotech SM20/2000). After a fish school is spotted, and before it is netted, a vessel equipped with the acoustic instrumentation will drive around the school to acoustically estimate the size and shape of the school; and then drive over the school multiple times to acoustically estimate the fish density.

EK60 multi-frequency echosounder

Throughout the survey, volume backscattering strengths (Sv; dB re 1 m) and in-situ target strengths (TS; dB 1 m2) will be measured continuously by four calibrated Simrad EK60 split-beam echosounders operating at frequencies of 38, 70, 120, and 200 kHz. The echosounders will be configured with Simrad ES38-12, ES70-7C, ES120-7C, and ES200-7C transducers. The four split-beam transducers will be pole mounted on the side of the ship's hull, and positioned approximately 2m beneath the water surface. Synchronized pulses of 1024 μs will be transmitted downward every 0.5 seconds, received with bandwidths of 0.8745, 1.6375, 2.3435, 2.7785, and 2.986 kHz, respectively, digitized to a range of 150 m, and stored in .raw-data format. Except for the EK60 sounders being used for these surveys, all other echo sounders and sonars operating at or near the survey frequencies will be secured.

SM20/SM2000 Multi-beam sonar

A Kongsberg-Mesotech SM2000 200 kHz multi-beam sonar (180 degree-head with a nominal 155 degree usable swath) and an SM20 processor will be used. The system forms 128 beams that insonify a 180 degree swath. The SM2000 has two transducers: a cylindrical array that can be used to both transmit and receive when operating in imaging mode; and a long stave that can be used as the transmitter, when operated in echosounding mode, with receiving on the cylindrical array. This survey will be conducted in echosounding mode only. The SM2000 sonar head will also be mounted on a pole, attached at an angle of 30 degrees off vertical at a depth of apx. 2 m below the mean water surface.

Triggering

One of the EK60s and the SM2000 both operate at 200 kHz. Therefore, the EK60s and the SM20 processor surface telemetry board (STB) will be triggered using a multiplexer unit. Triggering will be synchronous for all EK60s, and asynchronous (alternating) between the EK60s and the SM20 to prevent interference. That is, a trigger pulse will be sent to the EK60s every second; one-half second after the pulse is sent to the EK60s, a pulse will be sent to the SM20.