CWPA REVISED EFP APPLICATION SUBMITTED AND APPROVED FOR 2018 RESEARCH

4a. Date: February 16, 2018

4b. Applicant: California Wetfish Producers Association (CWPA)
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On behalf of CWPA and California's wetfish industry, we would appreciate the Council's consideration of and support for the following EFP request:

Background: At its June 2017 meeting, the Pacific Fishery Management Council conditionally approved the California Department of Fish and Wildlife (CDFW) / CWPA aerial survey methodology for use in future CPS stock assessments, consistent with recommendations contained in the **Southern California Coastal Pelagic Species Aerial Survey Methodology Review** report (PFMC 2017).

This research project intends to sample CPS schools using aerial spotter pilots with plane and aerial camera system to fly aerial surveys near shore and photo-document schools, coupled with qualified purse seine vessels chartered to capture a subset of the schools identified while the pilot photographs the "point sets." The purpose is to address issues identified in the aerial survey methodology review. The survey period is scheduled for late August 2018.

4c. The proposed survey plan provides the following explanation of purpose and goals (excerpted from the draft survey plan):

Overview and Justification
The goal of the Coastal Pelagic Species Near-shore Cooperative Survey (CPS-NCS) research in 2018 is to continue a pilot study to develop sampling methodology for estimating CPS biomass in shallow waters that are not accessible to NOAA ships. Current biomass estimated for anchovy and sardine stocks is believed to be negatively biased, because substantial fractions of these stocks reside in shallow nearshore waters (< 40m) that cannot be surveyed by NOAA vessels. Although the California Department of Fish and Wildlife (CDFW) and the California Wetfish Producers Association (CWPA) have conducted aerial surveys in nearshore waters of the Southern California Bight (SCB) since 2012, and in the Monterey-San Francisco area in summer 2017, it has been difficult to quantify the uncertainty of estimated biomass, due to lack of replication among other issues. Further, there are not adequate data to validate biomass and school composition by species estimated by spotter pilots during the CDFW-CWPA aerial surveys, making it difficult to quantify their bias. We aim to develop methodology for quantifying the level of bias and uncertainty of aerial surveys… [K]nowledge gained from the pilot CPS-NCS survey could be applied to conduct broader sampling surveys, to reduce bias and improve variance estimation when assessing CPS stocks in the future.

This research plan seeks to address recommendations identified by the aerial survey methods review Panel. For example (excerpted from the methodology review report):

- Point set data are limited and hard to collect in Southern California waters, but are a core source of information to validate the survey estimate of biomass. Noting the difficulty for collecting point sets, the Panel nevertheless recommends that additional point set data be collected (or alternative approaches for ground-truthing survey estimates be applied, such as using the volume of schools combined with estimates of packing density).
- Conduct replicate transects and surveys to allow estimation of variance for density.
- Further work is needed to develop a variance estimator to more fully account for the various sources of uncertainty.

For aerial flights, two spotter pilots flying in the same plane will make independent estimates of school size and species composition, and will photograph vessels approaching and wrapping the schools. For each CPS school observed, the two observers will record their individual tonnage estimates and species identifications on separate log sheets. Survey vessels will also have Go-Pro cameras mounted on their consoles to record school depth, shape and density depicted on their sonar and fathometer during the capture process. Fishermen will also record their observations on log sheets, and participating processors will record species composition and weight for each set. Examples of photo series and logs are appended to this EFP request (Appendices 1-3).

Attempts will be made to capture entire schools of CPS, to the degree possible, thus adding to the 90+% capture point set archive currently used in the CDFW / CWPA nearshore aerial surveys. All schools captured will be stored in separate hatches onboard, and will be weighed individually at the dock and fully sorted for species composition by the participating processors. In addition, biologists onboard the purse seine vessels will pull samples from the beginning, middle and end of each set and preserve fish on ice for later processing to obtain biological characteristics of the sampled fish.

All fish captured, including sardines requested in this EFP application, will be processed and sold by participating processors, and fishermen will be paid for their catches at the usual rates. Aside from the sale of fish captured in this project, processors are not compensated for the extra labor they will incur in weighing and fully sorting each school individually, and documenting species composition by school, versus the normal procedure of offloading the entire catch and documenting by load. If the point sets are not weighed and not fully sorted by individual set, the point set validation data will be meaningless. The revenue derived from the sale of the fish captured, including EFP fish, will help offset the extra labor, time and other costs that both fishermen and markets will accrue when participating in this research project. Further, sale of the EFP fish provides a beneficial use of the resource and avoids waste.

Replicate aerial transects will also be flown as part of this project. These replicate transects will allow for an estimation of variance for the number and size of fish schools, and relative density over time. This project also hopes to coordinate with NOAA's offshore acoustic survey for CPS, and possibly evaluate acoustic questions in the nearshore area if sufficient funding is available and the survey periods coincide.

4d. Rationale for issuing the EFP: In light of the probability of continued closure of the directed sardine fishery in 2018, despite the abundance of sardine that fishermen have been observing in nearshore waters for the past few years, this EFP will allow fishermen to retain the entirety of any school they are directed to catch without question, including pure sardines or mixed schools exceeding the allowed 40% incidental catch rate. This EFP will facilitate fulfilling the goals and objectives of this research and will avoid wasting a valuable resource. Absent an EFP, fishermen would be limited in targeting observed schools, or risk a violation if the captured schools contained sardine above the allowed incidental catch limit.

In November, 2017 the Science and Statistical Subcommittee (SSC) reviewed this EFP application and recommended: (1) to conduct power analysis to determine the effective sample size needed for validating school biomass estimated by spotters; (2) to perform an analysis on school distribution along the coast line in order to more clearly determine the percent of schools and areas that cannot be surveyed by purse seine vessels, and hence to propose alternative methodology for sampling these areas.

The most recent years of consistent field methods of the aerial survey were 2015-2017. The survey observed both sardine and anchovy in 2016 and 2017 (Table 1). Accordingly, we have conducted statistical analyses using point set data from 2010 (Table A1, see Appendix 4) and 2016-2017 data to select the number of point sets needed to be conducted in the 2018 project, and present various scenarios in Table 2 below based on the level of precision that can be achieved during a projected 7 day study period, using prior information on variance estimated from a study conducted in the SCB in 2010 (PFMC 2017, see Appendix 4).

Table 1. Summary data from 2016-17 aerial surveys for Pacific sardine and northern anchovy observations.

	2016-17 Aerial Survey
Survey days	15
Observed Schools	1,920
Observed Tons	107,040
Mean School Size (mt)	56
Mean Schools per Day	128
Total Schools for 7 Days	896
Sardine tons > 7m depth	18,690 (55%)
Sardine tons < 7m depth	15,589 (45%)
Anchovy tons > 7m depth	69,642 (96%)
Anchovy tons < 7m depth	3,119 (4%)
Proportion of sardine	47%

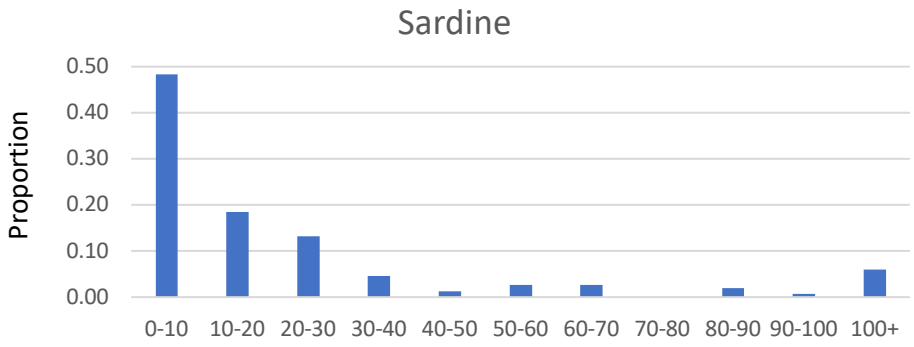
Table 2. Selection of sample size (n) and related target catch (mt) for conducting point set surveys based on various levels of bound ($b = 2\sqrt{V_r}$) on percent of error when estimating the ratio (r=1.07) between purse seine catch and school biomass estimated by spotter. Approximate estimation of the CV of the ratio is also provided.

b	CV_r (%)	Target n (EFP)	Target Catch (mt)
0.11	5.1	9	510
0.10	4.7	11	623
0.09	4.2	14	770
0.08	3.7	17	974
0.07	3.3	23	1272
0.06	2.8	31	1732
0.05	2.3	45	2494
0.04	1.9	70	3896
0.03	1.4	124	6927

Our target n sample size is 23 schools, which we believe is a reasonable goal for this project. This number corresponds to an expected target catch of 1,272 mt (Table 2). This tonnage estimate includes all CPS. After CPS schools are identified (and their tonnage estimated) by the spotter pilot, fishermen will be directed to catch CPS schools that represent the proportion of school sizes seen during the past 2 years of the survey (Figure 1, Table 3). For those school sizes where the point set target is < 1 school, the selection for those will be pooled with adjacent size schools (see "Expected Point Sets" column on Table 3).

It is expected that nearly all CPS observed in these nearshore areas will be sardine and anchovy, as in previous surveys. The proportion of sardine to total tons for 2016-2017 sardine and anchovy observations was 47% (Table 1). This is then applied to the expected catch of 1272 tons from 23 schools, resulting in nearly 600 tons of sardine.

Based on this analysis, we are requesting 600 mt of sardine to cover large pure sardine schools and mixed fish schools with sardine proportions exceeding the 40% incidental harvest limit. Sardine biomass as a portion of sets will be recorded and will not exceed 600 mt. This equates to an average of approximately 86 tons of sardine per day if the project is completed in 7 days. The additional data will result in an improvement by reducing the variance of the ratio to achieve an approximate CV_r of 3.3%.



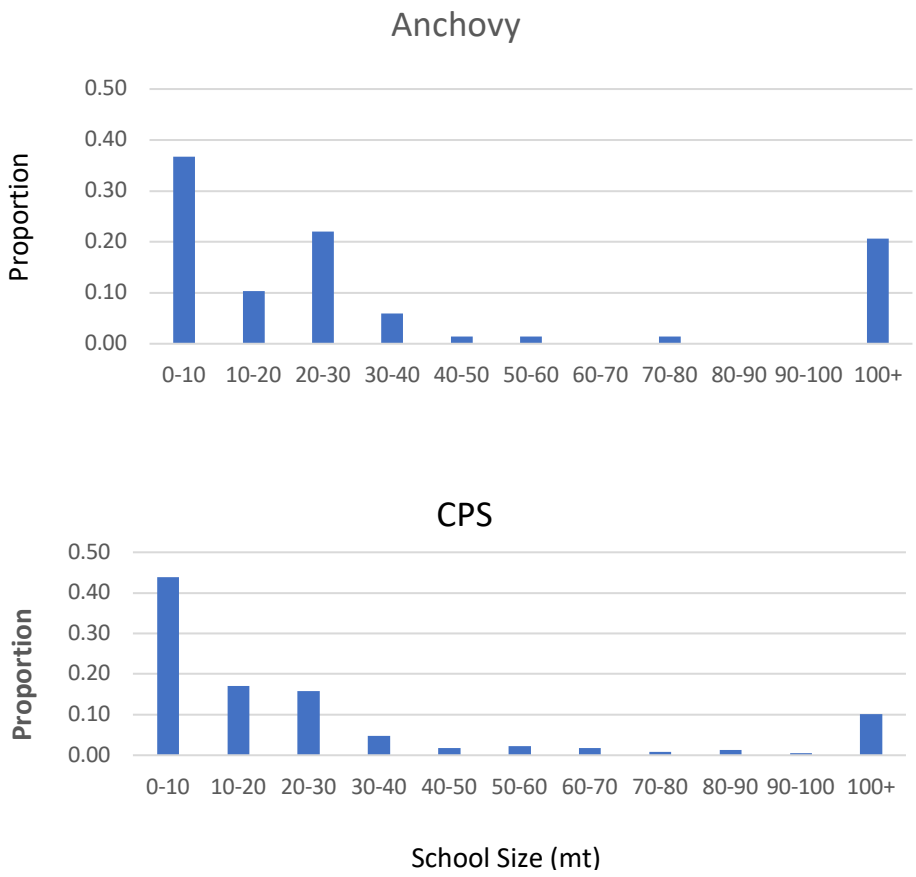


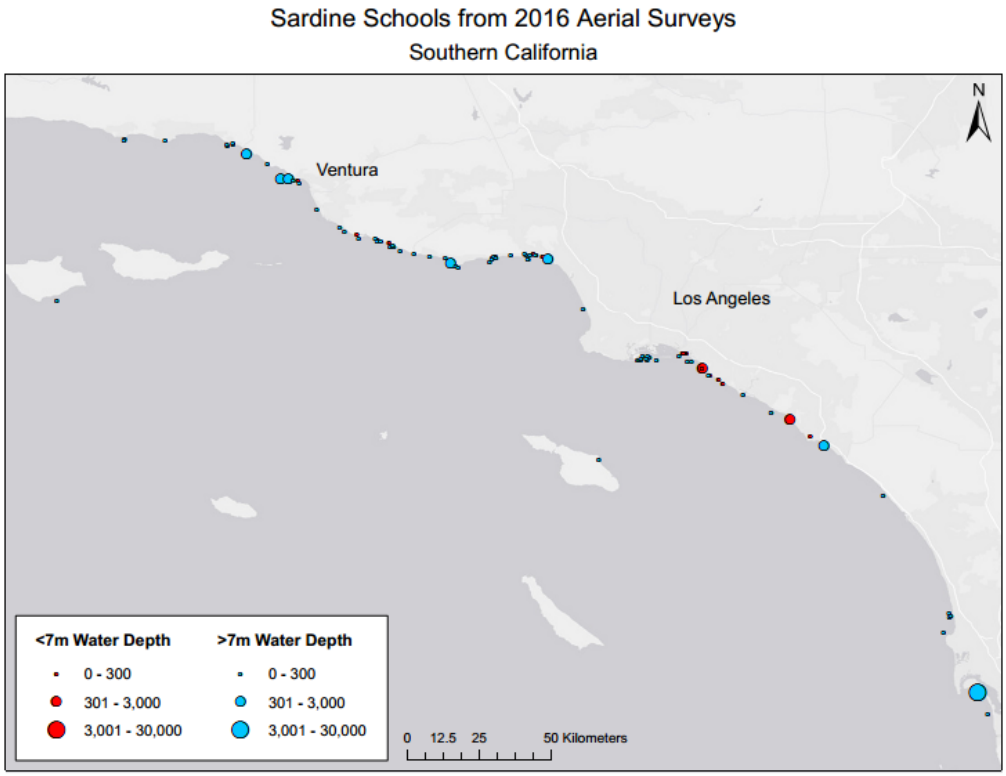
Figure 1. Sardine (top), anchovy (middle) and CPS (bottom) school size distribution from 2016-2017 aerial surveys.

Table 3. Targets of CPS schools by size from observed proportions from Figure 1. Number of point sets is based on goal of 23 total point sets over study period.

School Size (mt)	n	Proportion	Point Set Target	Expected Point Sets
0-10	100	0.44	10.1	10
10-20	39	0.17	3.9	4
20-30	36	0.16	3.6	4
30-40	11	0.05	1.1	1
40-50	4	0.02	0.4	1
50-60	5	0.02	0.5	
60-70	4	0.02	0.4	1
70-80	2	0.01	0.2	
80-90	3	0.01	0.3	
90-100	1	0.00	0.1	
100+	23	0.10	2.3	2
Total	228	1	23	23

We suggest that, to facilitate and simplify accounting, the Council follow the protocol established for other EFPs and designate the 600 mt sardine requested in this EFP as a research set aside off the top of the ACL, separate from the incidental catch allowance. Any amount unused would simply roll back into the ACL at the conclusion of the research period.

Not all research areas and issues recommended by the 2017 Review Panel can be fully addressed in the 2018 research. The 2018 survey will be conducted primarily in shallow water between 7m and 40m, where 96% of anchovy and 55% of sardine biomass observations occurred in 2016-2017 surveys (Table 1, and Figures 2-3 below). CPS schools also occur inside 7m depth, ranging into the surf zone. Based on observations corroborated by fishermen, school properties in extreme shallow water are similar to schools sampled at the inshore extent of this survey. Additional point set data can be collected to obtain the optimal sample size for the survey. Therefore, we are proposing to replicate the nearshore survey in summer 2019 to cover additional area of school occurrence, obtain increased sample size for the survey, and meet the recommendations of review panels.



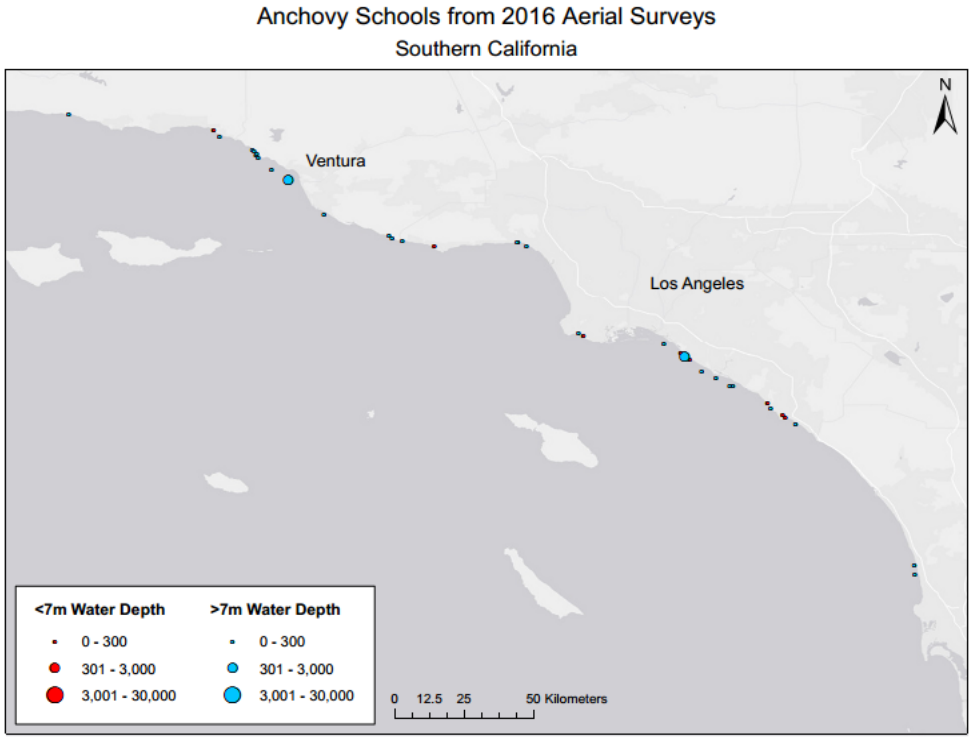


Figure 2. Nearshore distribution of Pacific sardine (top) and northern anchovy (bottom) by school size (mt) and depth strata (< 7m and > 7m) during the 2016 Southern California CDFW-CWPA aerial surveys.

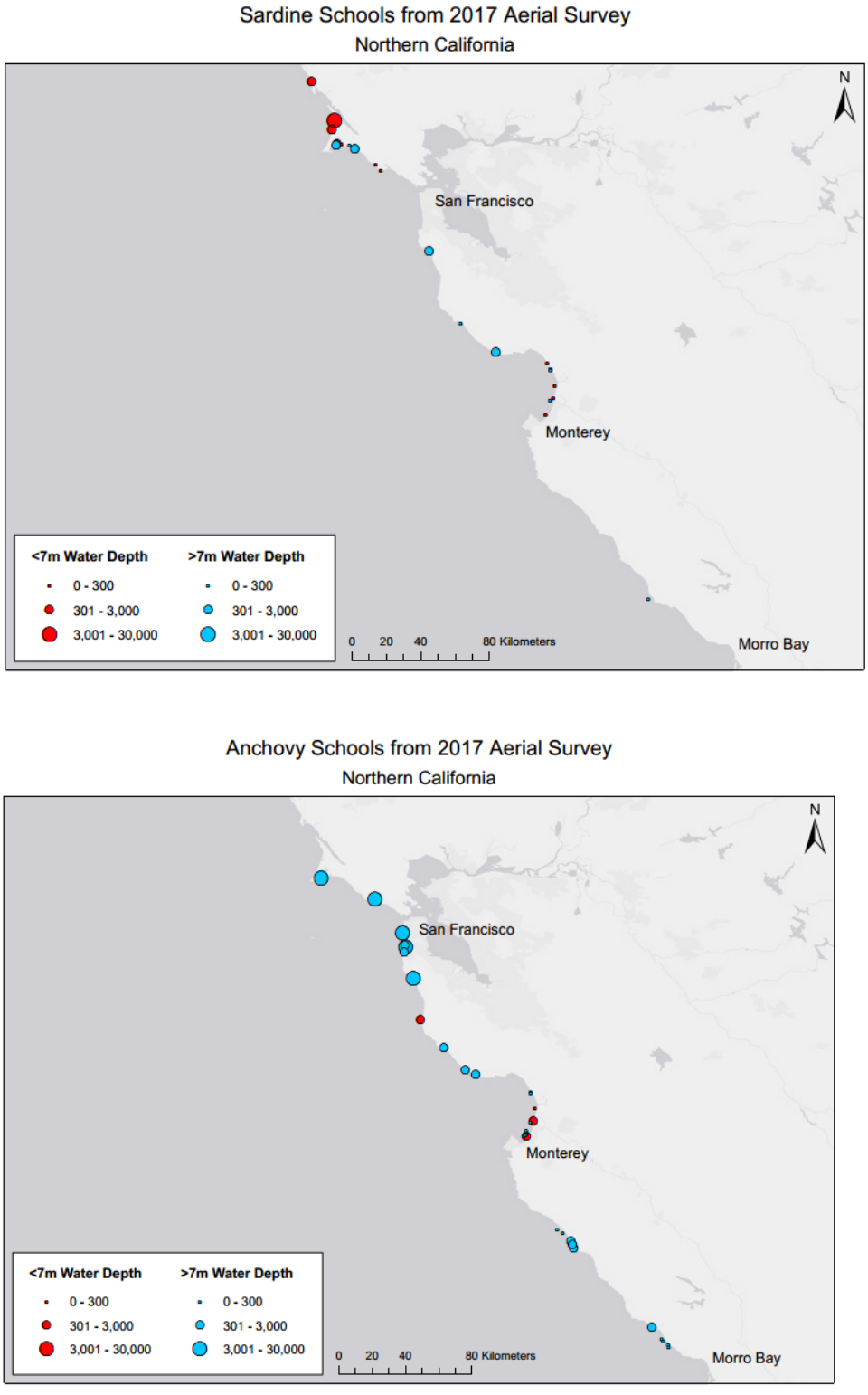


Figure 3. Nearshore distribution of Pacific sardine (top) and northern anchovy (bottom) by school size (mt) and depth strata (< 7m and > 7m) during the 2017 Northern California CDFW-CWPA aerial survey.

4e. Significance of this EFP: This research is essential to develop useful and cost-effective survey methods to quantify the biomass of CPS in the nearshore area where large NOAA ships cannot transect. The survey methods developed in this project can be expanded to other nearshore areas coast-wide, which would improve the accuracy of future stock assessments. In addition, the collaboration between industry, the scientific community, and federal and state agencies mandated to assess and manage fisheries is a win–win for all, facilitating increased understanding of the uncertainties in quantifying highly variable CPS resources, utilizing fishermen's knowledge of the ocean and providing a practical, efficient method for measuring fishery resources.

4f. Continuation of this EFP: The longevity of this EFP is contingent on a number of factors, chief among them sufficient funding to continue and possibly expand the survey, and the status of the sardine fishery in the future. We plan to replicate the nearshore survey research for at least one more year in summer 2019 to obtain optimal sample size for the survey, improve survey coverage of school occurrence, and meet the recommendations of review panels.

4g. Participating vessels: CWPA has identified 4 vessels that meet the criteria for this research project:

Vessel Name	Skipper	Owner	USCG #	CPS Permit #
Eileen	Nick Jurlin	South Sound Fisheries Inc.	D252749	38
Provider	Jamie Ashley Richie Ashley	Provider LLC	D572344	1
Cape Blanco	Corbin Hanson	Tri-Marine Fish Co.	648720	53
Triton	Pete Ciaramitaro	Triton Fishing Inc.	CF7218UH	14

Participating processors: Two wetfish processors have been identified – each processor normally offloads two of the participating vessels:

Tri-Marine Fish Company, 220 Cannery Street, San Pedro, CA 90731
(offloads FV Eileen, FV Cape Blanco Contact: Vince Torre)
South Coast Trading Company, 2148 West 16th Street, Long Beach CA 90813
(offloads FV Provider, FV Triton Contact: Lillo Augello)

4h. Description of species harvested: Under this project, purse seine vessels will be directed to capture schools of CPS observed by aerial spotter pilot (or potentially, backscatter observed by acoustic trawl). The schools could contain sardine, anchovy, Pacific or jack mackerel, or other coastal pelagic species. An EFP is necessary because the directed sardine fishery is closed, and will likely remain closed in 2018. There are no constraints on capturing the other CPS species other than Annual Catch Limits, which this project will not exceed. No measurable impacts to non-target species are anticipated.

4i. Justification for EFP request: This EFP application requests 600 mt be allocated as a research set-aside for a projected seven-day research project, which amounts to about 86 mt per day. Vessels will be directed to capture as many schools as possible in a given day, and will strive for 100 percent capture of individual schools, if possible. In light of recent-year observations of abundant sardine in nearshore waters, the likelihood is that sets will capture sardine, either in pure schools or in mixed schools exceeding 40% incidental catch of sardine by weight. Without an EFP, such captures would be in violation. The issuance of an EFP also allows the sale of the fish to help offset additional costs incurred by participating fishermen and processors. Please also see the distribution matrix and information provided under Item 4d.

***4j. Accounting for EFP fish*:** Biologists will accompany the vessels during purse seine captures to sample individual sets, and will take a subset of each set for later processing to obtain biological characteristics of individual fish. As noted above, all schools captured will be stowed in individual hatches in the hold, and when delivered to market each set will be weighed and fully sorted for species composition. Processors will maintain records of the weight of individual species groups, including sardine, to validate species composition.

CWPA will notify Enforcement approximately 24 hours before vessel(s) go out to inform them of vessel name(s) and location(s) to be surveyed, and processors(s) who will be receiving research fish that day. The survey plan anticipates sending only one or two vessels per day. Participating vessels will fly CWPA research flags for identification purposes. CWPA will also maintain a record of the volume / total weight of each species captured and will monitor progress toward attaining the EFP limit. These weights and species composition per set will also be included in the final report.

***4k. Data Collection Methods*:** According to the survey plan:

Biological sampling
The catch taken from each school will be subsampled on the boat throughout the pumping of each haul. … biologists will subsample the fish at the beginning, middle, and end of pumping each set aboard the vessel, using Monorail nets (16" x 16" frame and 12" bag depth) or any similar sampling nets. The three collected fish subsamples will be mixed in a basket, stored in plastic bags and preserved on ice or frozen until landing. Up to 50 fish per species per point set will be delivered to a CDFW biologist upon landing of the daily catches. At the CDFW laboratories these samples will be sorted by species and measured for biological characteristics (length, weight, sex, maturity etc.). For each species and each school, the catch will be additionally subsampled to obtain up to 25 otoliths for ageing.

Statistical analyses
Based on the objectives of this pilot research, CPS biomass and associated variances will be estimated from data collected during the aerial and purse seine survey. The sampling unit of the survey will be one transect flown for a number of hours during the day…. Further, purse seine data will be used to validate aerial tonnage estimates, school species composition, and [to obtain] length, and age composition …, providing additional information to quantify uncertainty surrounding biomass estimated by the pilot and observer. More details regarding the process of biomass estimation from the CPS-NCS will be provided in a separate document.

Scientific data collection and analysis will be supervised by CDFW and CWPA scientists, who will collaborate on procedures to ensure and evaluate data quality during the survey, and data analysis methodology through completion of the project. Weather permitting, we will strive to have multiple replications of each transect, as well as purse seine sets on schools of various sizes (in proportions as depicted in Figure 1), to derive unbiased estimates of biomass and associated variances.

4l. Vessel selection: Criteria were established to qualify vessels for participation in this research project. From those requirements CWPA identified four vessels meeting the criteria for vessel size, equipment and skippers' experience, whose skippers, importantly, committed to participate in this research, notwithstanding any other fishing opportunities during the project period.

***4m. Time and Place of Research Fishing*:** This project will take place in nearshore waters of the Southern California Bight. The tentative time frame for the survey is late August 2018. If timing and sufficient funding permit, this project will also coordinate with the 2018 NOAA summer survey, if the RV Reuben Lasker is surveying outer waters on schedule. Fishing gear used is purse seine net of suitable mesh size and length for capturing CPS schools observed by aerial spotter pilots (or potentially by acoustic backscatter).

Thank you for your consideration.

Best regards,

Diane Pleschner-Steele
Executive Director

Attachments:

Appendix 1 - 2010 Point Set Photographs
Appendix 2 - Fishermen's Log Form
Appendix 3 - Flight Log Form
Appendix 4 – Selecting sample sizes for 2018 purse seine and aerial survey point sets

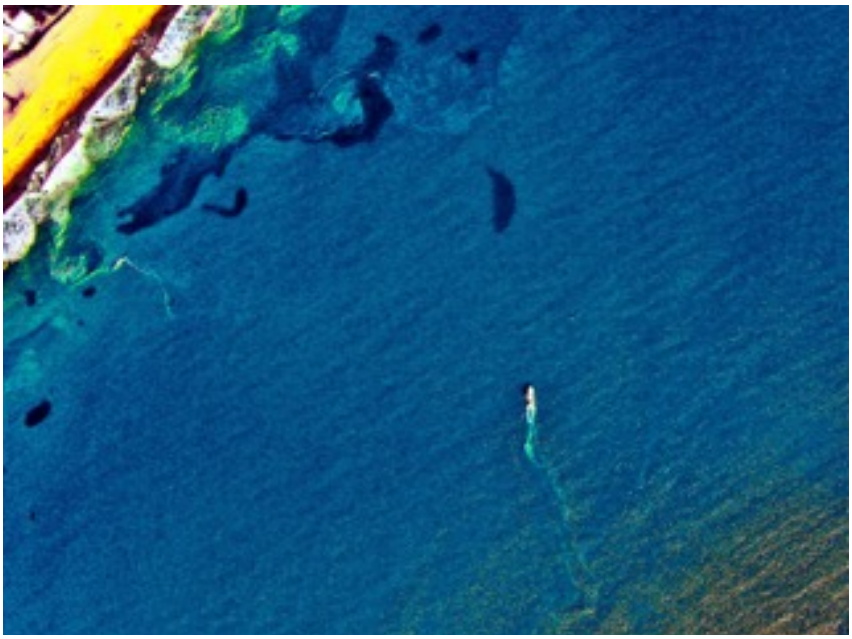
References

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. Pacific Fishery Management Council, Portland, OR, October 15, 2010. 51p.

Lynn, K, D. Porzio, T. Nguyen, and L. Ryley. 2017. Southern California aerial survey for Pacific sardine (*Sardinops sagax*) and Northern anchovy (*Engraulis mordax*). PFMC June 2017 meeting, Agenda Item D.2.a, CDFW Report.

PFMC. 2017. Southern California coastal pelagic species aerial survey methodology review. PFMC June 2017 meeting, Agenda Item D.2, Attachment 1, Methodology Review Panel Report.

Appendix 1. 2010 point set photographs. Note the typical schooling pattern of CPS in nearshore waters in CA. Individual schools break away from the shoaling fish for a short period, and often outrun the vessel in the capture attempt.



FV Eileen approaches 20-ton sardine school in 2010 summer aerial survey.

FV Eileen in process of wrapping school. This was a 100% capture point set.

Appendix 2. Fisherman's log form.

2018 CPS Nearshore Cooperative Survey

Fisherman's Log Form

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	Total Est. School Tonnage (mt)	Fish Hold (FP, FS, MP, MS, AP, AS)	Sampled By Biologist on Board (Y/N)	Other Vessel utilized: Name, est. weight, fish hold	*Delivered Weight (mt)	*Fish Ticket Number

Comments:_____
_____
_____
_____
_____
_____

Weather Codes: 1= calm, clear; 2= light wind, good visibility; 3= moderate wind, fair visibility; 4= poor fishing conditions.

Appendix 3. Flight log form.

2018 CPS Nearshore Cooperative Survey

Flight Log Form

Date: _______________ **Pilot:** _______________________ **Plane:** ________________________

Processor: ____________________ **Observer:** ____________________

Set #	Time	Photo #	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)	% Species Composition

Comments:____

Set #	Time	Photo #	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)	% Species Composition

Comments:____

Set #	Time	Photo #	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)	% Species Composition

Comments:____

Set #	Time	Photo #	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)	% Species Composition

Comments:____

Set #	Time	Photo #	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)	% Species Composition

Comments:____

Set #	Time	Photo #	Position (Lat/Long)	Altitude (ft)	Vessel	Species Observed	% of School Captured	Est. school Tonnage (mt)	% Species Composition

Comments:____

Appendix 4. *Selecting sample sizes for 2018 purse seine and aerial survey point sets (Extract from 2018 Nearshore Cooperative Survey draft design, In Preparation by E. Dorval, K. Lynn, B. Macewicz and D. Griffith*

In the fall of 2010, a study was conducted by the fishing industry to validate aerial survey biomass estimates by using purse vessels to wrap and catch CPS schools that were spotted by an airborne observer (Jagielo et al. 2010). A subset of these purse seine samples (namely "point sets") has been used to estimate the ratio between aerial survey observations and catch landed per school, providing a mean to correct for potential bias in biomass estimated from aerial surveys conducted by CDFW-CWPA from 2012 to 2016 (Lynn et al. 2017). However, a 2017 Review Panel found purse seine data used by Lynn et al. (2017) were insufficient to provide adequate precision and accuracy for biomass estimation for the 2012-2016 surveys (PFMC 2017). Thus, the panel recommended that additional point sets be collected to increase the accuracy and precision of the correction factor for use in future aerial survey data analyses. Here we conducted an analysis to determine the effective number of purse seine samples that will need to be collected during the 2018 CPS Nearshore Survey (NCS), using point set data collected in 2010 and aerial school and biomass data collected during the last 2 years of aerial surveys conducted by CDFW-CWPA, i.e. 2016-17.

Although the CDFW and CWPA began aerial surveys in the Southern California Bight in 2012, the last two years of surveys (2016 and 2017) contained data that were collected using similar standardized methods. Further, because anchovy abundance was reportedly low in 2015, no schools of this species were observed in daylight hours from this survey in 2015 (although fishermen reported an abundance of anchovy when fishing at night). With the observed increase of the anchovy stock off California (starting in 2016), the dynamics and composition of nearshore CPS schools that may be observed during the 2018 CPS-NCS are more likely to be similar to the 2016-17 period than to previous years. These data are summarized in Table 1, showing that on average 128 schools have been observed per day of aerial survey, with a mean school size of 56mt. Purse seine ground-truthing did not occur during these three years and thus no point set data exist to directly account for bias in these aerial survey biomass estimates. However, we can reasonably assume (as in Lynn et al. 2017) that the 2010 school size estimates likely represent a random sample of any one of the surveys conducted in 2016-2017. Likewise, parameters estimated from the 2016-17 and 2010 survey data (Table 2) could be used to compute the approximate number of purse seine point sets that should be conducted during the 2018 CPS-NCS.

Assuming that the adjusted landed tons (y_i') and the estimated school size (x_i') is linearly related through the origin (Table A1), an estimate of the ratio of these observations (i.e. the slope of the regression line) could be provided by:

$$r = \frac{\sum_i^n y_i'}{\sum_i^n x_i'} \quad (1)$$

Hence, based on Table A1 data, r is estimated to be 1.07; and the variance of the observed sample could be estimated as:

$$s_r^2 = \frac{\sum_i^n (y_i' - r \times x_i')^2}{n-1}, \quad (2)$$

Likewise s_r^2 = 87.28 (i.e. using data in Table A1).

Based on equation *Eq. 1* and 2 and assumptions made above, an approximate estimate of the variance of the ratio (V_r) for the population we expect to survey in 2018 is given by the formula:

$$V_r = \frac{(N-n)}{nN} \times \left(\frac{1}{\mu_{x'}^2}\right) \times s_r^2 \quad (3)$$

Where, *N* is the finite population size (i.e. 896 schools for a 7-day survey) for the 2018 survey, *n* is the number of point set collected in 2010 (i.e. 26) and $\mu_{x'}$ is the mean size of CPS schools observed during the 2016-17 aerial surveys off California. We assume the composition of schools by species and size in 2018 will be similar to 2016-17. Note that V_r is an approximation because we don't know the variance of the population we expect to sample in 2018, but it is reasonable to replace it by s_r^2 computed from the 2010 aerial survey data (Table A1).

Assuming the data are normally distributed, a 95% confidence interval of V_r can be provided by $2 \times \sqrt{V_r}$; and an approximate number of samples (*n*) that would be required to estimate the ratio with a bound (*b*) on the error of estimation (i.e. $2 \times \sqrt{V_r}$) can be calculated as:

$$n = \frac{N s_r^2}{N \times \frac{b^2 \times \mu_{x'}^2}{4} + s_r^2} \qquad (4)$$

Again, *n* is an approximation because we do not know the variance of *r* for the targeted population and thus we used the s_r^2 as an estimate of it. In Table 2 different estimates of *n* are presented, based on various levels of *b.*

Table A1. Point Set data collected from 2010 study (Jagielo et al. 2010).

Aerial observation	**Purse seine sampling**	**Aerial observation**	**Purse seine sampling**		
Est. Size_Pilot (mt)	Est. % school wrapped	Adj. Est_Size_Pilot (mt)	Landed biomass (mt)	Adj. landed biomass	Residual squared
x'		**x**	**y**	**y'**	$(y_i' - rx_i')^2$
5	100	5	4.8	4.8	23.5
30	90	27	40.2	44.6	1993.3
30	100	30	38.5	38.5	1485.2
15	100	15	10.9	10.9	118.6
15	100	15	15.4	15.4	236.0
10	95	9.5	15.0	15.7	248.1
5	100	5	6.7	6.7	45.3
12	90	10.8	17.9	19.9	396.4
10	100	10	2.8	2.8	8.1
10	100	10	9.6	9.6	92.5
10	95	9.5	14.9	15.6	244.5
25	100	25	20.0	20.0	401.3
12	95	11.4	10.7	11.3	127.8
50	95	47.5	58.7	61.8	3819.1
25	100	25	31.3	31.3	981.3
35	100	35	44.0	44.0	1931.9
65	95	61.75	67.4	71.0	5035.0
45	100	45	45.0	45.0	2028.1
55	90	49.5	38.8	43.1	1861.0
55	95	52.25	23.9	25.2	635.5
45	95	42.75	46.8	49.3	2429.1
80	100	80	84.9	84.9	7208.0
25	95	23.75	20.2	21.2	451.5
50	100	50	64.2	64.2	4120.2
35	90	31.5	40.5	45.0	2022.8
75	100	75	84.6	84.6	7157.2