Agenda Item G.4.a
Supplemental SWFSC Report
November 2016

Southwest Fisheries Science Center Summary of Current Information Available on Coastal Pelagic Species with Emphasis on the Central Subpopulation of Northern Anchovy

At the request of the Pacific Fishery Management Council (Council), the Southwest Fisheries Science Center (SWFSC) is providing an additional summary of the most up to date survey information regarding the status of northern anchovy populations and other Coastal Pelagic Species (CPS) along the west coast, and where possible, we relate the survey results to the unusual environmental conditions observed in the California Current the last four years. The SWFSC has also updated the Council on the changing environmental conditions and the presence of the “Warm Blob” or the “North Pacific Marine Heat Wave” and the receding 2015-2016 El Niño, and its potential for continued effects on the biota of the California Current at its June 2014, November 2014, March 2015 and November 2015 meetings. In fact, one of the conclusions from last year’s update was that “northern anchovy distribution as well as other species may have shifted both spatially and temporally out of the normal CalCOFI sampling area in recent years due to severe environmental changes (i.e., the “Warm Blob”, the Pacific Decadal Oscillation, early El Niño effects) suggesting that the historical CalCOFI sampling grid in the Southern California Bight may not be adequately tracking the northward shift in anchovy abundance and distribution.”

At the November 2015 Council meeting, the SWFSC reported that it would do a stock assessment on the Central Subpopulation of Northern Anchovy (CSNA) based on the guidance provided by the Council sponsored CPS data-limited workshop that was held, May 2-5, 2016 and reported to the Council at its September meeting (http://www.pcouncil.org/wp-content/uploads/2016/08/E2a_Workshop_Rpt_SEPT2016BB.pdf). At the workshop, the Panel reviewed both information from CPS fisheries around the world and the specifics of the data available for the CSNA. The workshop panel (Panel) agreed that the best approach for providing management advice for the CSNA was to develop an integrated stock assessment model that would use fishery-dependent monitoring data on age and length, and abundance indices based on ichthyoplankton and ATM surveys. This assessment should also consider the use of data from the SWFSC juvenile rockfish survey. However, the Panel also concluded that an integrated assessment could not be feasibly completed for “several years” due to the lack of basic biological information (see http://www.pcouncil.org/wp-content/uploads/2015/10/H4a_SWFSC_Rpt2_DataLimited_Nov2015BB.pdf).

As part of the integrated assessment, the workshop highlighted the importance of ageing anchovy otoliths collected for recent years and assessing maturity for these years. Both the SWFSC and the states of Washington, Oregon and California have been collecting pertinent biological samples on northern anchovy from the fisheries and from independent surveys since 2014, and the State of California and SWFSC has reassigned aging staff to work on processing anchovy samples. The

Panel went on to recommend that the SWFSC provide the following information at the November 2016 Council meeting:

- Construct an index of abundance for CSNA based on the CalCOFI egg and larval data and provide estimates of absolute spawning biomass. These estimates will be negatively biased to an unknown extent due to the egg and larval surveys not covering the full range of the stock, and could be further biased due to the "DEPM light" approach. The document entitled "Egg and Larval Production of the Central Subpopulation of Northern Anchovy in the Southern California Bight" (Agenda Item G.4.a) was review by the CPS Subcommittee of the SSC on October 11, 2016 and responses to comments are presented in Appendix 1. Estimates of absolute spawning biomass were not provided as was discussed with the Council in September 2016. Moving forward with such an estimate was considered premature.
- Provide the Acoustic Trawl Method (ATM) survey results for 2015 and 2016. The Panel stated that the ATM survey results for 2015 could be analyzed to provide a (negatively biased) estimate of absolute abundance of the CSNA for the surveyed area if catchability is assumed to be 1 and the estimates of absolute spawning biomass from the ichthyoplankton-based model could be compared to the estimate of biomass from the ATM survey, while realizing that both are expected to be underestimates. The 2015 ATM survey results from the 2015 "SaKe" summer survey are provided in Appendix 1 of this document. Unfortunately, the ATM results of the 2016 California Current Ecosystem Survey (CCES) have not been full analyzed and cannot be presented at this time. The Panel cautioned that "use of these data for management purposes should be restricted to providing an estimate of abundance only for the area and the portion of the water column surveyed, until a Methodology Review (and possibly additional research) can be undertaken to address concerns about the proportion of the population inshore of the survey area and that in the surface waters." Currently, a methodology review for the ATM survey is scheduled for January 30 – February 2, 2018 in order to address the nearshore and surface water questions. Transboundary questions as to what proportion of the CSNA resides in Mexican waters or what portion of the Northern Substock of Northern Anchovy (NSNA) are in Canadian waters remains unanswered.

Winter 2016 CalCOFI, Spring 2016 CalCOFI-CPS Survey

Coastal pelagic fish egg abundance has declined off central and southern California in the last 15 years (2000–2015) (Figure 1). Sardine, anchovy, and jack mackerel eggs were found at very low concentrations in the spring of 2015 as well as the Winter (Figure 2) and Spring of 2016 (Figure 3) in the Southern California Bight. Although historical peak anchovy spawning is thought to occur in December-February which is earlier than the March-April spring survey, the anchovy spawning that extends into spring shows the same trend to lower egg densities as do sardine and jack mackerel. Jack mackerel are lightly fished, and although commercial catches of anchovy sardine are higher, the observed decline in egg densities of all three species suggests that environmental factors are likely to be the major cause of the decline in spawning of these forage fishes (Koslow, et al. 2015).

Conditions off central and southern California continued to be unusually warm in winter and spring 2016. Few anchovy eggs were collected in the CUFES during the 2016 Winter CalCOFI survey in the southern California Bight (SCB) and from Monterey to San Francisco in water temperatures from 12-15^{o}C similar to optimal anchovy spawning temperature ranges reported by Ahlstrom and Elbert (1959) (Figure 2). In the Spring CalCOFI/CPS survey, anchovy eggs were collected at levels above 10 eggs/m^3 in in the SCB (Figure 3). Mackerel eggs were found in water with surface temperatures of 14–18^{o}C. Sardine eggs are rarely found north of San Francisco in the spring, but in 2015 and 2016 sardine spawned at least 445–556 km further north than usual (Figure 3). In 2015, sardine spawning was centered near the California–Oregon border (41–43^{o}N) in a band about 90–110 km from shore in surface water temperatures of 12–13^{o}C. In 2016, sardine spawned from the California Oregon border to Central Oregon (43-45^{o}N) from 5-110 km from shore.

2016 Summer "California Current Ecosystem Survey" and 2015 Summer "SaKe" Survey

The summer 2016 California Current Ecosystem Survey (CCES) using FSV Lasker commenced on June 28th at the northern end of Vancouver Island and ended on September 17th at the U.S. Mexico border. A total of 4,500 nautical miles of east-west transects were completed. A total of 6.8 million gallons of seawater was filtered through the underway Continuous Fish Egg Sampler (CUFES) and 260 CTD casts were made (Figure 4). One hundred and nineteen trawls caught 11 tons of target CPS and thousands of fish were measure and counted. During the survey the FSV Lasker was selected to test and evaluate the new Simrad EK80 continuous beam echo sounder which is replacing the industry standard EK60 split beam echo sounder. Use of side-scanning and forward-looking sonars such as the ME70, MS70, and SX90 echosounders/sonars, which will facilitate improved characterizations of fish behaviors and abundances in the upper water column and in nearshore areas, will be available in the spring and summer of 2017 once the systems are fully evaluated.

Of the 119 trawls, 46 were positive for Northern anchovy (*Engraulis mordax*) 519 kg (39%), 22 were positive for Pacific sardine (*Sagax sardinops*) 1,534 kg (18%), 34 were positive for Pacific Mackerel (*Scomber japonicus*) 2,711 kg (29%), 42 were positive for Jack Mackerel (*Trachurus symmetricus*) 4,360 kg (35%), and 57 were positive for market squid (*Dorytheuthis opalescens*) 229 kg (48%) (Figure 5). A total of 2500 otoliths and 700 ovaries were collected for age and maturity information. The length frequency distributions of the 1,491 northern anchovy caught in the trawls (Figure 6) suggest that at least three different year classes were present (YOY, age 1, age 2 and possibly age 3).

In comparison, the summer 2015 "SaKe" survey using the FSV Shimada commenced on June 20th at the US/Mexico border and ended on September 6th near the Alaska/Canada border above the Queen Charlotte Islands. The total survey distance was approximately 5,393 nautical miles. Processing of acoustic data was completed for ATM biomass estimates and is presented in Appendix 1. A total of 160 Nordic 264 trawls for adult fishes were accomplished with the following catch of target species: Northern anchovy 91 kg, Pacific sardine 442 kg, Pacific mackerel 63 kg, Jack mackerel 1,958 kg, Market squid 2,694 kg, and Pacific hake (*Merluccius productus*) 170 kg. Northern anchovy juveniles and adults (91 kg total) ranging in size from 30mm SL to 150mm SL were collected in 47 out of 160 trawls (29% frequency of occurrence) and collected from San Diego to Vancouver Island (Figure 5). Pacific sardine juveniles and adults (442 kg total) ranging in size from 30mm SL to 270mm SL were collected in 21 out of 160 trawls (13% frequency of occurrence) and ranged from southern California to the Pacific Northwest.

A total of 941 CUFES samples were taken resulting in the following eggs being collected for target species: Northern anchovy: 943, Pacific sardine: 2,255, Jack mackerel: 16,626, Pacific hake: 73, and all other pelagic fish eggs: 73,728. Other biological and oceanographic samples taken include 123 CTDs associated with the trawls, 59 bongo tows and 51 neuston tows.

Densities and timing of anchovy eggs observed in both surveys suggest that anchovy were spawning at multiple locations along the west coast as well as at different times during the summer of 2016 and 2015. Anchovy eggs collected in three concentrations suggest that anchovy spawning was occurring during June in Washington waters north of the Columbia River, in July off San Francisco, and to a limited extent in the southern California bight in August and September. In addition, Pacific sardine eggs were collected from Canada to southern California suggesting that sardine were spawning during June in the southern California Bight, in July off San Francisco, off central Oregon in July and off the Columbia River in August. Although anchovy can spawn year-round, it appears that spawning peaks that normally occur in the winter may have shifted due to the unusual environmental conditions.

Juvenile Rockfish Midwater Trawl survey for pelagic juvenile (young-of-the-year, YOY) rockfish - Central California Coast, May-June 2016

Since 1983, the SWFSC has conducted an annual midwater trawl survey for pelagic juvenile (young-of-the-year, YOY) rockfish (Sebastes spp.) and other groundfish off of Central California (approximately 36 to 38°N) since 1983, and has enumerated most other pelagic micronekton encountered in this survey since 1990 (Ralston et al. 2013, Ralston et al. 2015) (Figure 7). Beginning in 2004, the survey, which is conducted in late spring (May-June), expanded the spatial coverage to include waters from the U.S./Mexico border north to Cape Mendocino. The primary objectives are to estimate the abundance of YOY rockfish and other groundfish for stock assessments and fisheries oceanography studies, but the survey also quantifies trends in the abundance and composition of other components of the micronekton forage assemblage (including other juvenile fishes, krill, coastal pelagic species, and mesopelagic species), as well as collection of oceanographic information (CTD casts, continuous data on surface conditions and productivity, and acoustic data) and seabird and marine mammal abundance data.

The 2016 data represent a continuation of the very high catches of YOY rockfish in the central California areas (core and south central regions), but catches in the north central region were lower than previous years and catches in the south region were very low, and catches of juvenile Pacific sanddabs also declined to lower levels relative to previous years. The abundance of both krill and market squid also declined in most areas relative to 2015, with abundance close to or below average levels, while the abundance of adult Pacific sardine and northern anchovy remained very low for most regions as well. Both of these species have been very rarely encountered in most of the times and regions monitored since 2009, with the exception of adult anchovy in the Southern California Bight in 2016 (Figure 8b). Catches of YOY anchovy, which are enumerated separately from age 1+ anchovy, were the highest ever observed in the Southern California Bight while in other regions of the California Current their numbers were reduced compared to 2015 (Figure 8d).

In 2015, the abundance of adult Pacific sardine and northern anchovy remained low, although larval catches for both species were at high or record levels in most areas (see http://www.pcouncil.org/wp-content/uploads/2015/11/H3a_Sup_SWFSC_Rpt_Nov2015BB.pdf). Average adult northern anchovy catch-per-tow between 1983 and 2004 was 0.9, increasing to 2.12 in 2006, before declining to 0.19 in 2008. Between 1998 and 2014, average catch per tow of northern anchovy young-of-year (YOY) was low (0.0015). In 2015, the catch-per-tow of northern anchovy YOY increased to 2.6 and was at record levels over the 2015 sampling period, with the frequency of occurrence near 80% for the entire survey (Figure 8). This would suggest that 2015 summer anchovy spawning was widespread and not centered only in Monterey Bay.

Conclusions

The SWFSC agrees with McClatchie, et al (2016), MacCall, et al. (2016) and Koslow, et al. (2015), that there has been a non-fishery related decline in forage species in the southern California Bight for since 2011. However, it also appears that northern anchovy distribution, as well as other species may have shifted both spatially and temporally out of the normal CalCOFI sampling area in recent years due to noticeable environmental changes (i.e., the “Warm Blob”, the Pacific Decadal Oscillation, early El Niño effects) suggesting that the historical CalCOFI sampling grid in the Southern California Bight may not have adequately tracked recent shifts in anchovy abundance and distribution.

Evidence of multiple spawning locations and high numbers of potential recruits of both northern anchovy subpopulations observed along the west coast in 2015 appears to have resulted in at least some recruitment as observed by the multiple year classes collected in both the 2016 “CCES” survey and Juvenile Rockfish survey for southern California. However, while the increased recruitment signals are positive, it is premature to assess their overall contribution to the stock without conducting a formal stock assessment.

The SWFSC is committed to completing an integrated stock assessment of the CSNA as soon as the appropriate biological information can be collected, verified, and processed. Results from the 2016 Spring CalCOFI and CPS surveys as well as the ATM biomass estimate from the 2016 summer “CCES” should be available prior to the April 2016 Council meeting. A methodology review of the ATM survey methods for both Pacific sardine and northern anchovy is scheduled for January 30-February 2, 2018 allowing for additional information to be collected on behavior of CPS in the upper water column as well as distribution and abundance in nearshore areas where large survey vessels are unable to collect information.

Questions remain as to the transboundary nature of the CSNA (as well as the NSNA). Appendix Figures 1 and 2 in the document "Egg and Larval Production of the Central Subpopulation of Northern Anchovy in the Southern California Bight" (Agenda Item G.4.a) indicate widespread distribution of anchovy eggs and larvae both north and south of the traditional CalCOFI grid in the southern California at both high and low abundance levels; suggesting that relying on CalCOFI data alone is not sufficient to estimate anchovy biomass. Also, preliminary results from the surveys from summer of 2016, along with observations of Bluefin tuna stomachs full of anchovies, and early observations of a trend indicating a return of normal sea lion pup weights, suggest that the southern California Bight may be returning to a more productive state. However, additional analyses will be required to quantify these results.

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Figures

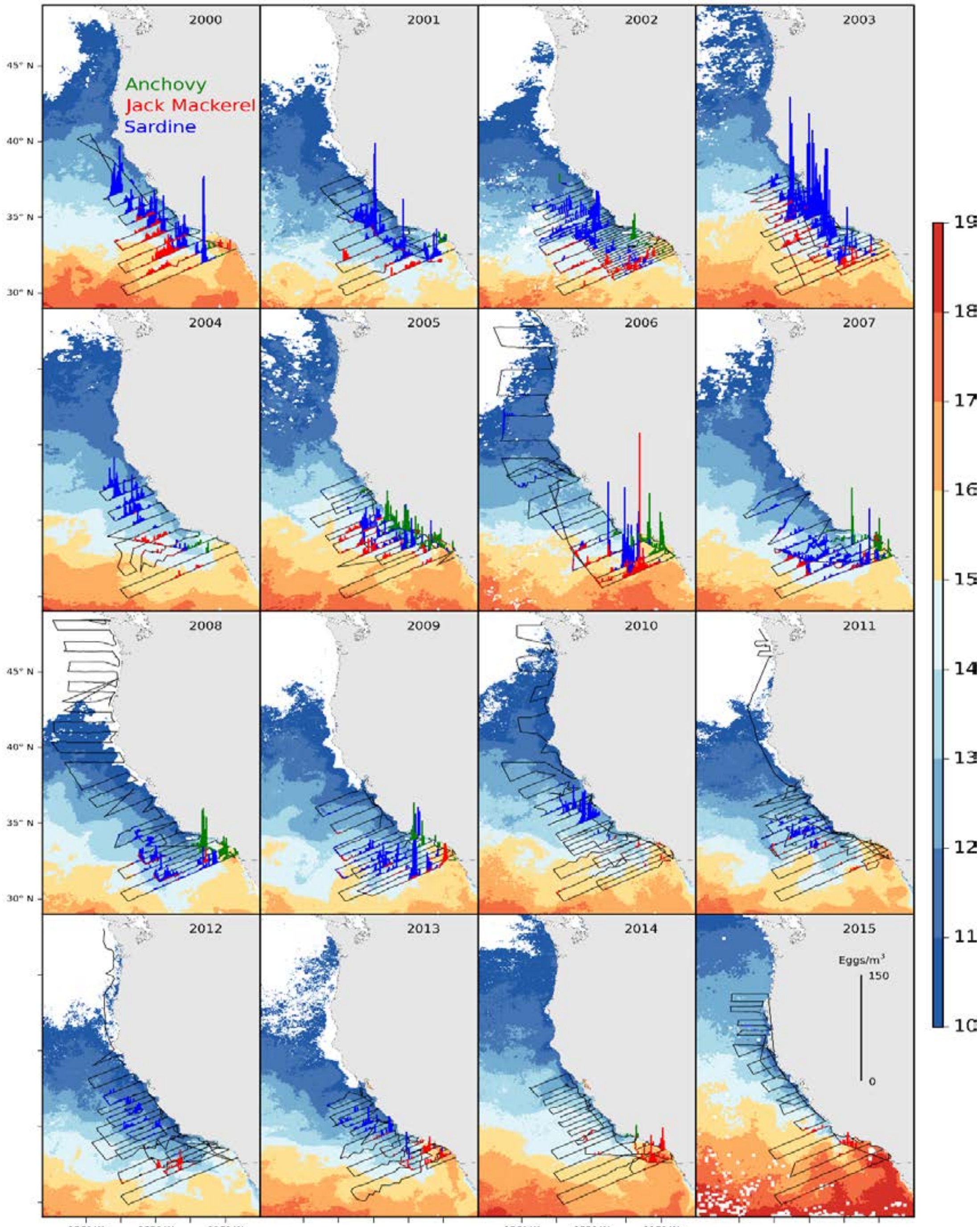

Figure 1. Density of eggs of sardine (blue), anchovy (green), and jack mackerel (red) collected with the Continuous Underway Fish Egg Sampler overlaid on satellite sea surface temperatures (^{o}C) derived from a monthly composite of April Pathfinder 5.5-km resolution (2000-2008) or AVHRR 1.4-km resolution (2009-2015) imagery. Ship track is shown by the black line (https://swfsc.noaa.gov/textblock.aspx?Division=FRD&ParentMenuId=218&id=1340).

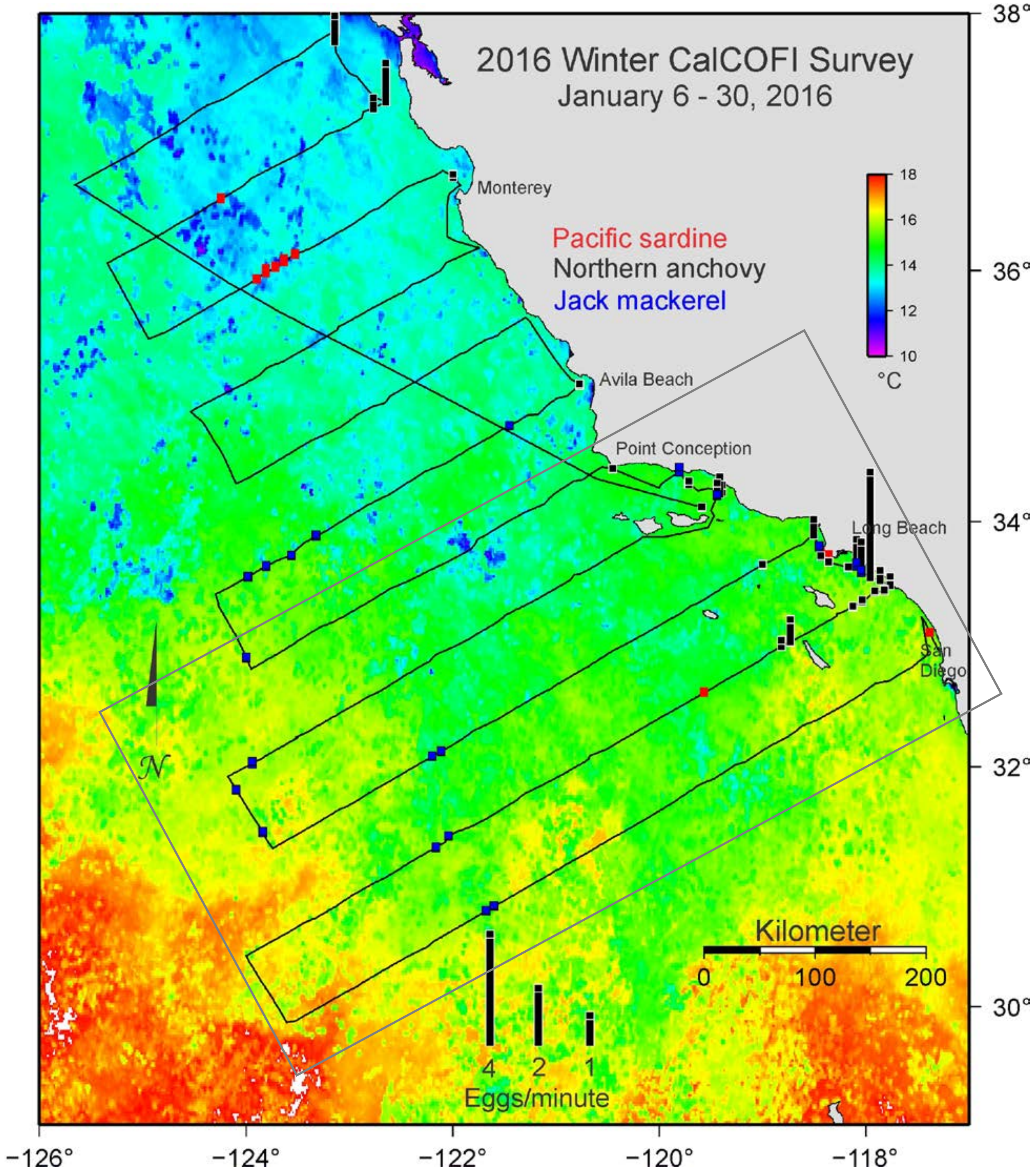

Figure 2. 2016 Winter CalCOFI CUFES sampling of northern anchovy eggs/minute plotted over Sea Surface Temperature (SST). Anchovy spawning temperatures normally are between 12-15 ºC. The grey box represents the standard CalCOFI sampling grid (https://swfsc.noaa.gov/textblock.aspx?Division=FRD&ParentMenuId=218&id=1340).

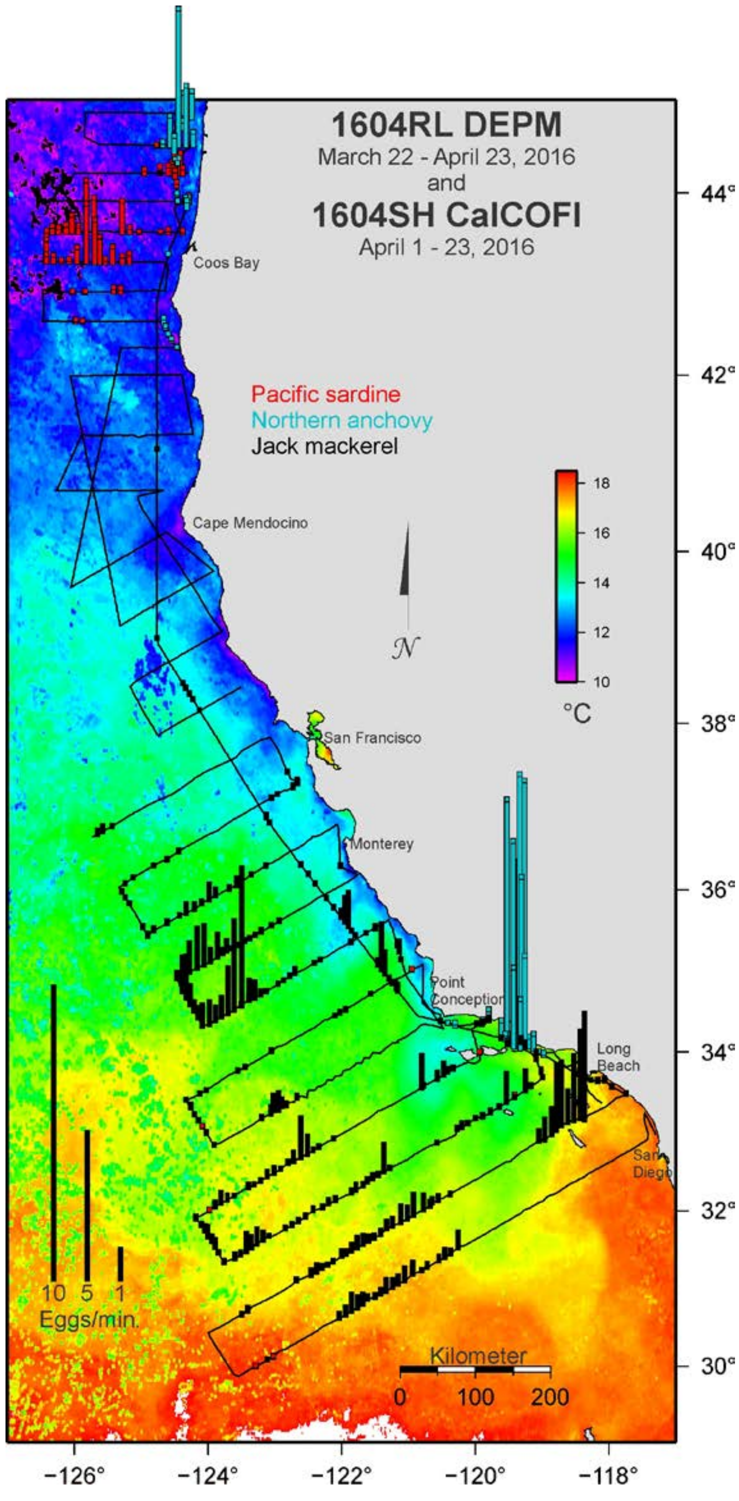

Figure 3. 2016 Spring CPS Survey. CUFES sampling of northern anchovy eggs/minute plotted over Sea Surface Temperature (SST). Anchovy spawning temperatures normally are between 12-15 °C. (https://swfsc.noaa.gov/textblock.aspx?Division=FRD&ParentMenuId=218&id=1340).

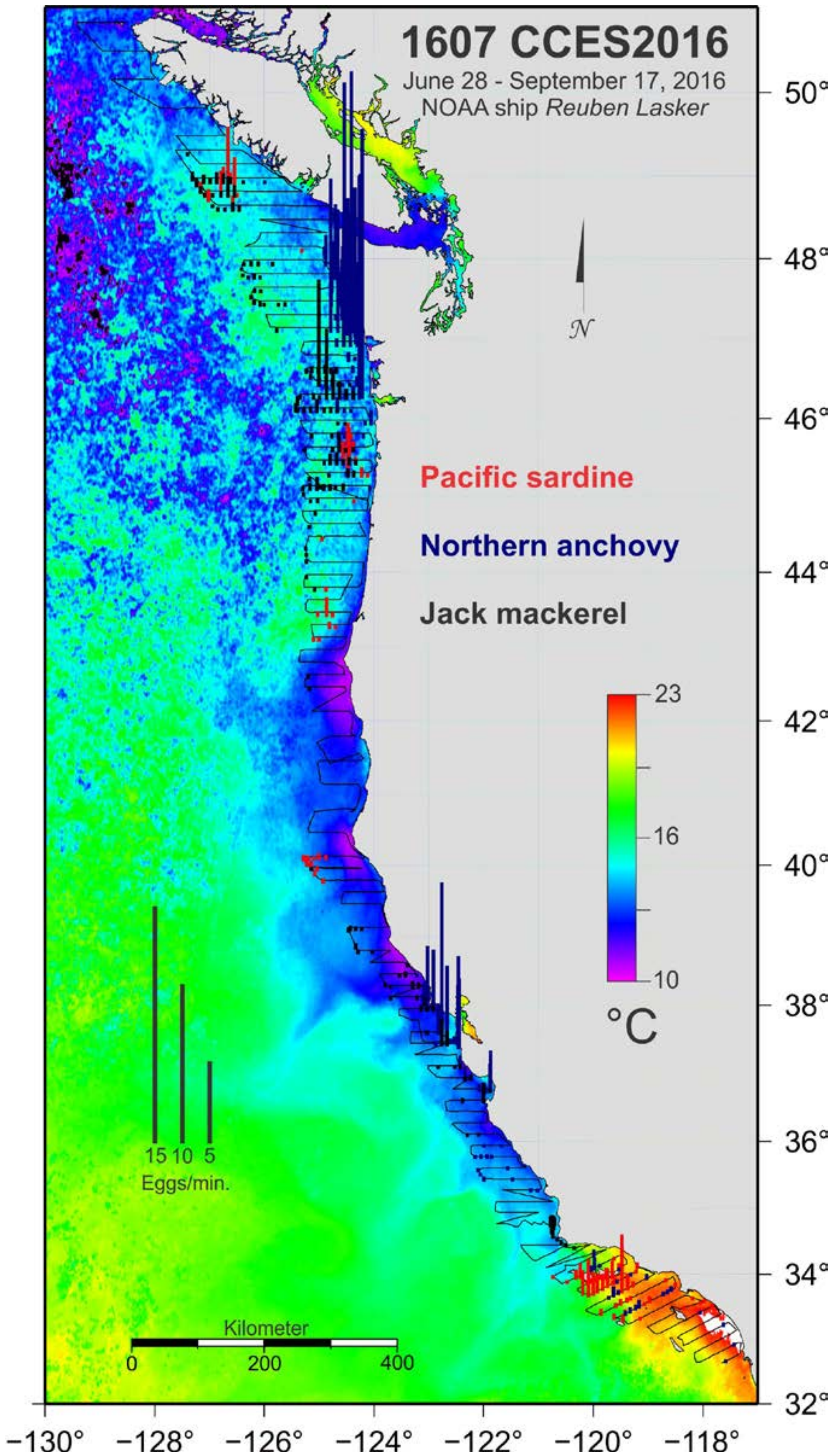

Figure 4. Density of eggs of sardine, anchovy, and jack mackerel collected with the Continuous Underway Fish Egg Sampler (CUFES) during the summer CCES survey overlaid on satellite sea surface temperatures (°C) (https://swfsc.noaa.gov/textblock.aspx?Division=FRD&ParentMenuId=218&id=1340).

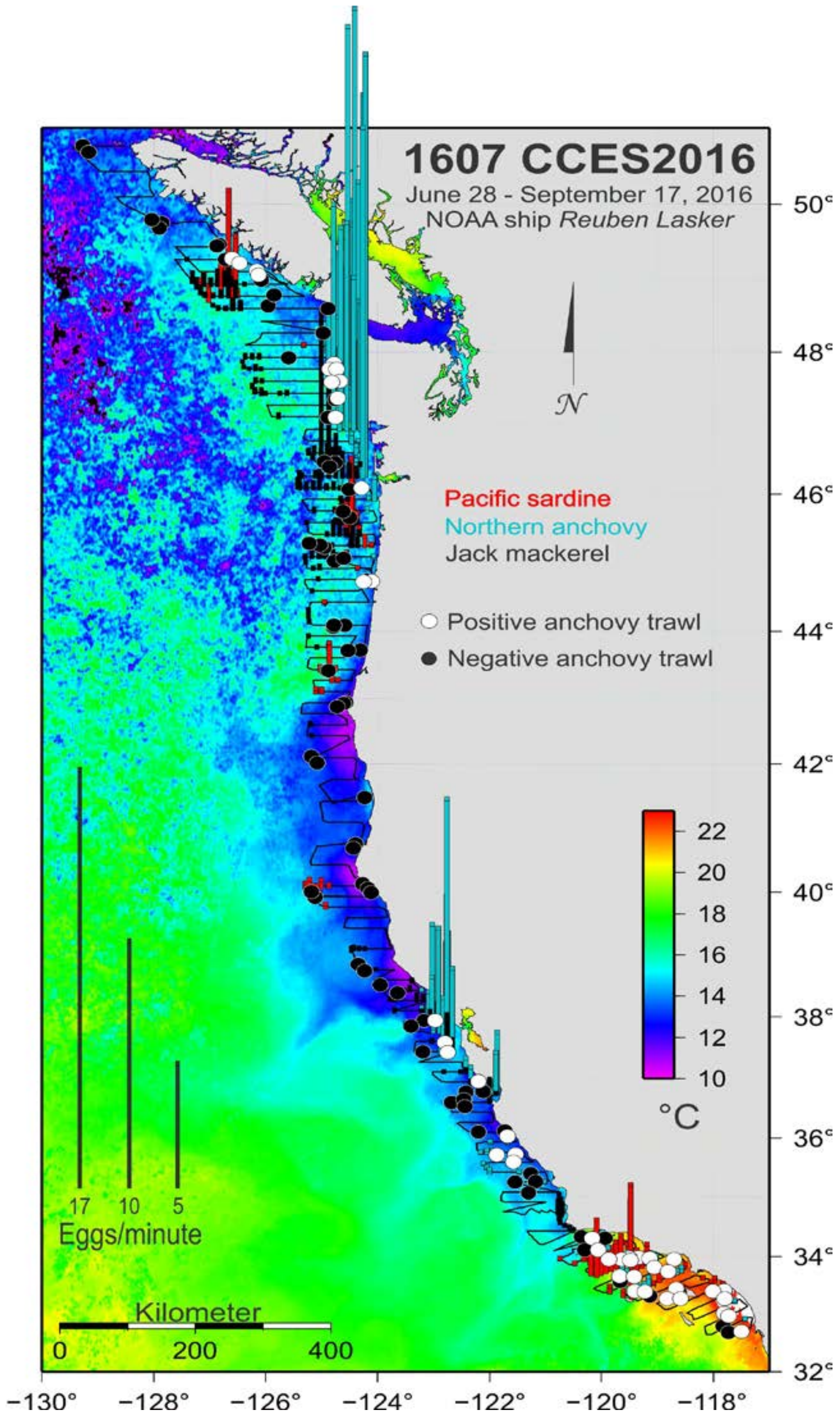

Figure 5. Juvenile and Adult anchovy collected in the 2016 summer "California Current Ecosystem Survey" from June 20-September 6, 2015. Trawling occurred from north to south. Positive trawls for northern anchovy are indicated with white circles, black circles represent no anchovy in the trawl. Circle size does not represent abundance. Bars represent densities of eggs of sardine, anchovy, and jack mackerel collected with the Continuous Underway Fish Egg Sampler (CUFES) (https://swfsc.noaa.gov/textblock.aspx?Division=FRD&ParentMenuId=218&id=1340).

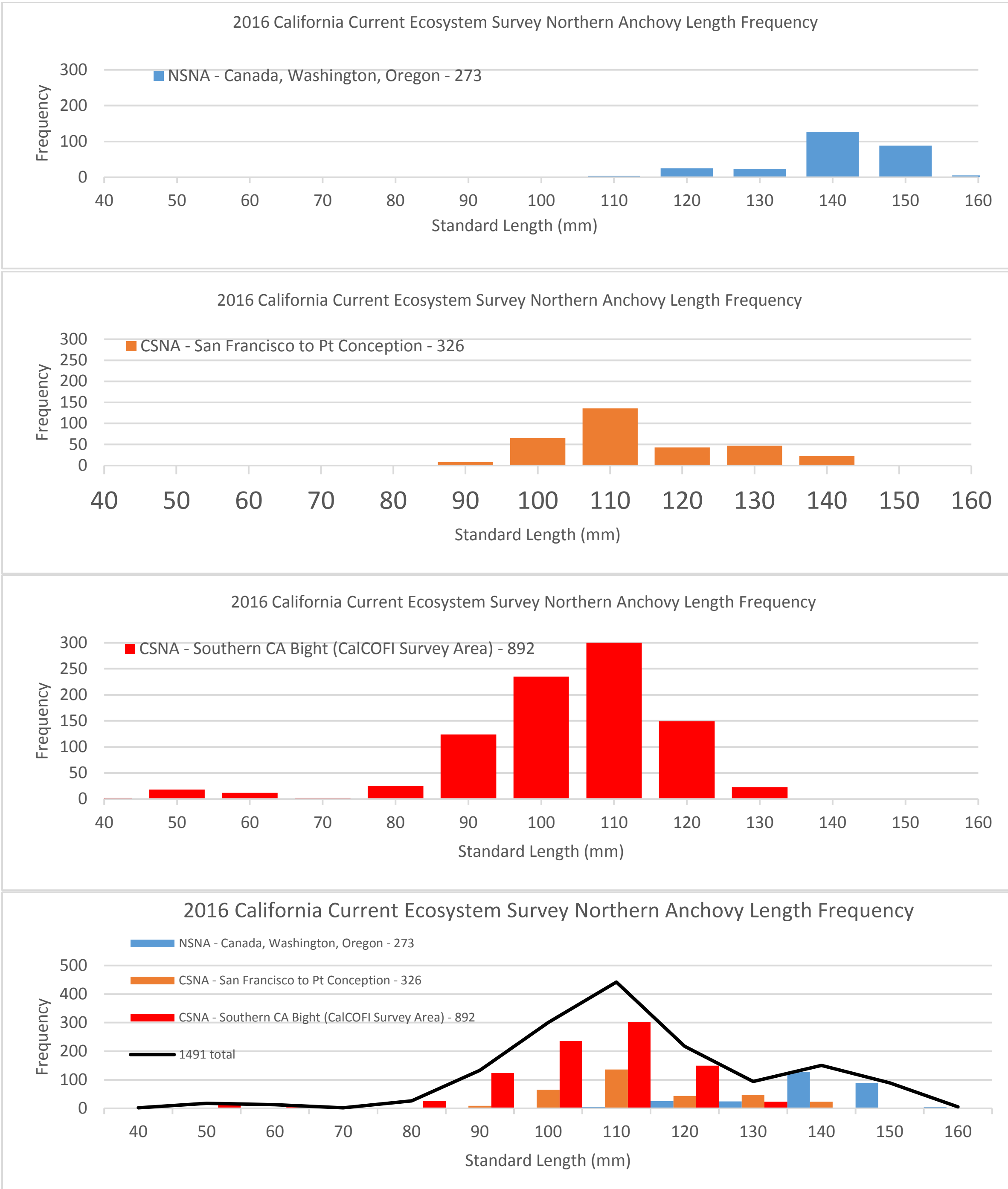

Figure 6. Length frequency of northern anchovy collected in the 2016 summer "California Current Ecosystem Survey" from June 28-September 17, 2016 by area: a) Canada, Washington and Oregon (i.e., Northern Substock of Northern Anchovy - NSNA, b) San Francisco to Point Conception (CSNA), c) Southern California Bight (CSNA) and d) All and the Total . Trawling occurred from south to north. Positive trawls are only indicated to represent positive trawls for northern anchovy and does not represent abundance (https://swfsc.noaa.gov/textblock.aspx?Division=FRD&ParentMenuId=218&id=1340).

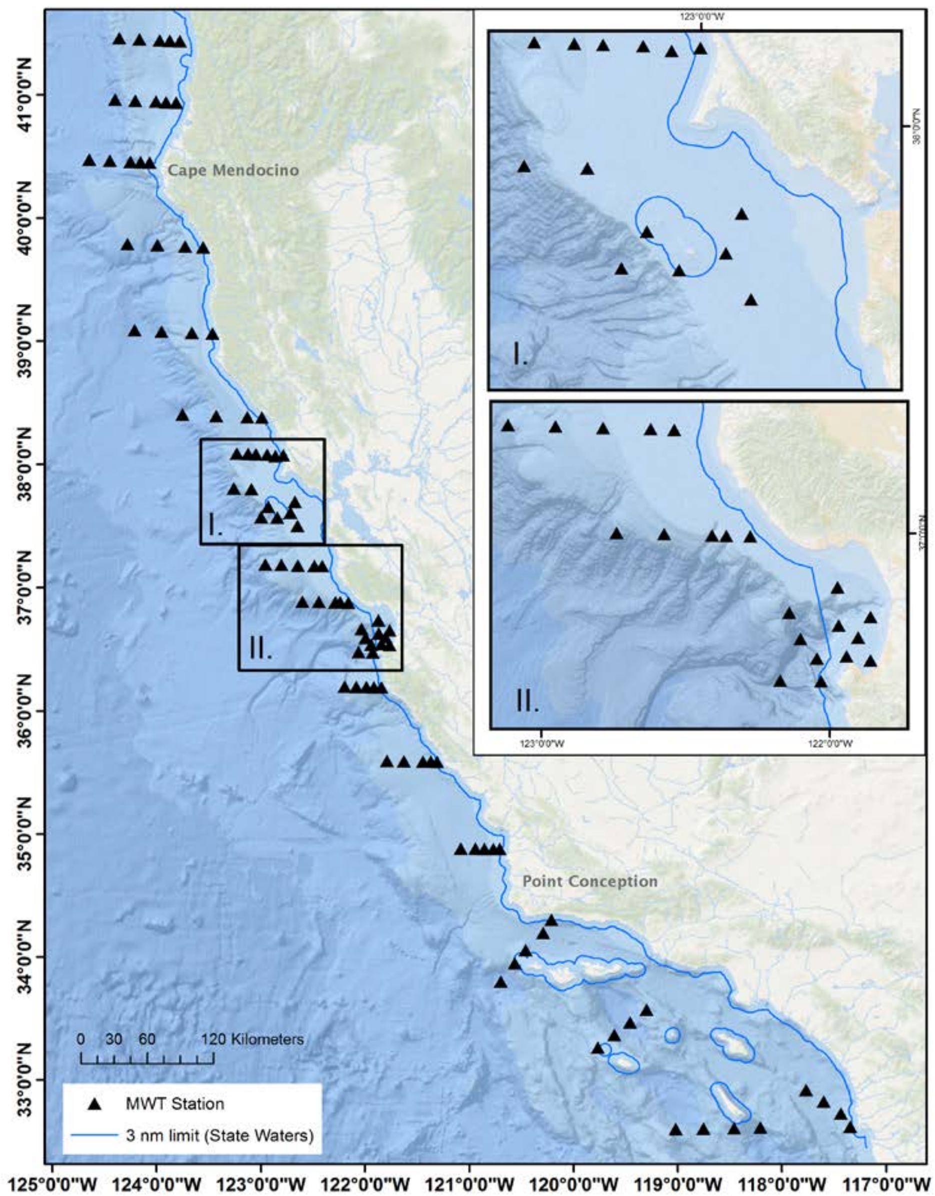

Figure 7. Rockfish Recruitment and Ecosystem Assessment Survey sampling map. Four to seven midwater trawls of 15-minute duration were conducted each night along each transect. A modified-Cobb midwater trawl was used at night. Core stations are from Point Reyes to Monterey (Boxes I and II), Stations north of Point Reyes are in the northern area, while stations south of Monterey are in the southern area (https://swfsc.noaa.gov/textblock.aspx?Division=FED&ParentMenuId=54&id=20615).

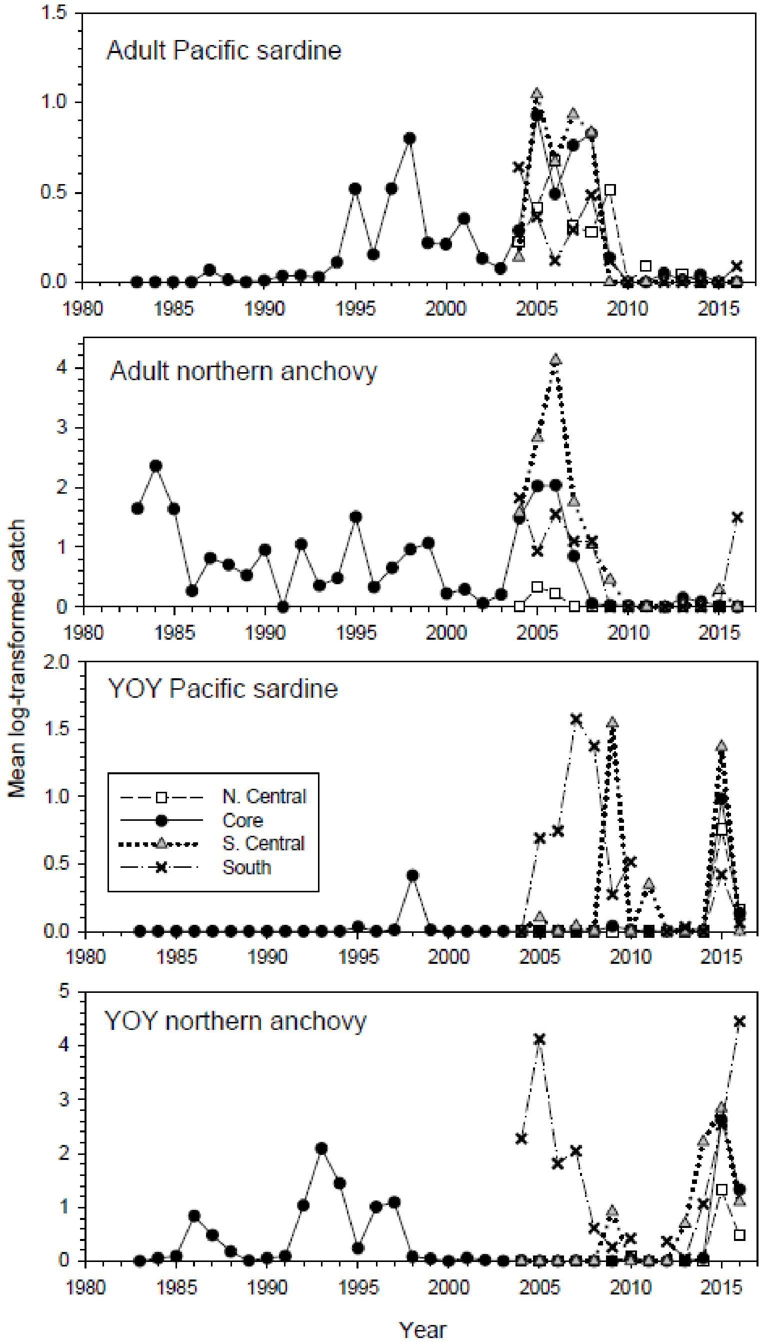

Figure 8. Abundance (mean log-transformed catch) of a.) Adult Pacific sardine, b.) Adult northern anchovy, c.) YOY Pacific sardine and d.) YOY northern anchovy in the young-of-the year in the rockfish recruitment survey in the core (Central California) region (1990-2016) and the southern and northern California survey areas (2004-2016, excluding 2012 for the northern area) (https://swfsc.noaa.gov/textblock.aspx?Division=FED&ParentMenuId=54&id=20615).

APPENDIX 1: DRAFT NOAA TECHNICAL MEMORANDUM

November 2016

THE DISTRIBUTION AND BIOMASS
OF THE CENTRAL-STOCK NORTHERN ANCHOVY
DURING SUMMER 2015, ESTIMATED FROM ACOUSTIC-TRAWL
SAMPLING

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U.S. DEPARTMENT OF COMMERCE
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Summary

In summer 2015, the biomass of the central subpopulation of northern anchovy was estimated using the acoustic-trawl method (ATM) to be 31427 metric tons (t), CV = 24.6%. The anchovy, observed mostly off the coast north of Point Conception, had standard lengths ranging from less than 4 to 13 cm, with a 6-cm mode, indicating that the majority of them were spawned in 2015.

Introduction

Acoustic-trawl surveys, which combines information collected with echosounders and nets, have been used to survey coastal pelagic fish species (CPS; e.g., sardines, anchovies, and mackerels) off the west coast of the United States (U.S.) for more than 40 years (Mais, 1977; Mais, 1974; Smith, 1978). Currently acoustic-trawl surveys are used more widely to estimate the abundances, demographics, and distributions of epipelagic and semi-demersal fishes (e.g., Swartzman, 1997; Williams et al., 2013; Zwolinski et al., 2014) and plankton (Hewitt and Demer, 2000).

In the acoustic-trawl method (ATM) survey currently used in the California Current (Zwolinski et al., 2014), multi-frequency split-beam echosounders transmit sound pulses downward beneath the ship and receive echoes from animals and the seabed in the path of the sound waves. The backscattered signal, i.e., the sound that is scattered back to the transducer, is then compensated for absorption and spreading of the sound waves, providing an indication of the numbers and physical properties of the targets in the water column. Fish, particularly those with strong schooling behavior and highly reflective swimbladders (Foote, 1980), create conspicuous, high intensity echoes. Under certain conditions, the summed intensities of the echoes from a group of targets is linearly related to their numerical density, and provided that the average backscatter of those targets is known, the acoustic backscatter can be converted to numerical density (Simmonds and MacLennan, 2005) .

Ideally, acoustic and trawl data are collected across the entire distribution area of stocks, providing estimates of population abundance or biomass that can be used to inform stock assessments or aid management decisions. Decades after a successful ATM campaign to survey abundant anchovy and mackerel populations off the coast of California (Mais, 1974; Jacobson et al., 1994), the ATM was reintroduced in the California Current Ecosystem (CCE) in spring 2006 to sample the then abundant sardine population (Cutter Jr. and Demer, 2008). Since 2006, this survey effort has continued and expanded through annual or semi-annual surveys (Zwolinski et al., 2014). Beginning in 2011, the ATM estimates of sardine abundance, age structure, and distribution have been incorporated in the annual sardine assessments (Hill et al., 2016).

An ATM survey was performed in summer 2015, sampling the entire west coast of the U.S. to estimate the abundances and distributions of CPS, together with their biotic and abiotic habitat (Zwolinski et al., *in preparation*). Presented here are estimates of the abundance, demographics, and distribution of the central stocks of Northern anchovy (*Engraulis mordax*) during summer 2015.

Methods

The 2015 summer survey was conducted using the NOAA Fisheries Survey Vessel (FSV) *Bell M. Shimada*. Acoustic data were collected during the day to allow sampling of fish schools aggregated throughout the surface mixed layer. Trawling was conducted during the night to sample fish dispersed near the surface (Mais, 1974).

The summer survey occurred over 80 days (20 June to 9 September, 2015), and transects spanned the west coast of the U.S. and Canada from San Diego to the northern end of Vancouver Island (Fig. 2). Further details on echosounder calibrations, survey design, and sampling protocols are detailed in Zwolinski et al. (*in preparation*).

Acoustic data from each transect were processed using estimates of sound speed and absorption coefficients calculated with contemporaneous data from Conductivity-Temperature-Depth (CTD) probes. Echoes from schooling CPS were identified with a semi-automated data processing algorithm as described in Demer et al. (2012). The CPS backscatter was integrated within an observational range of 10 m below the sea surface to the bottom of the surface mixed layer or, if the seabed was shallower, to 3 m above the estimated acoustic dead zone (Demer et al., 2009). The vertically integrated backscatter was further averaged along 100-m intervals, and the resulting nautical area backscattering coefficients (s_A; m^2 n.mi.$^{-2}$) were apportioned based on the proportion of the various CPS found in the nearest trawl cluster. The s_A were converted to biomass and numerical densities using species- and length-specific estimates of weight and individual backscattering properties (see details in Demer et al., 2012; Zwolinski et al., 2014).

Survey data were post-stratified to account for spatial heterogeneity in sampling effort and anchovy density. Total biomass in the survey area was estimated as the sum of the biomasses in each individual stratum. Sampling variance in each stratum was estimated from the inter-transect variance, and total sampling variance was calculated as the sum across strata (Demer et al., 2012; Zwolinski et al., 2012). The 95% confidence intervals were estimated as the 0.025 and 0.975 percentiles of the distribution of 1000 bootstrap survey-mean biomass densities. The bootstrap estimates were constructed by resampling the transects within the strata with replacement (Efron, 1981). Coefficient of variation (CV) for each of the mean values was obtained by dividing the bootstrapped standard errors by the point estimates (Efron, 1981).

Results

The summer survey totaled 2614 n.mi. of daytime east-west tracklines and 160 night-time surface trawls combined into 58 trawl clusters. A single post-survey stratum was defined considering transect spacing, and echoes or catches of CPS (Figures 1 and 2; Tables 1 and 2).

Northern anchovy were widely spread off the coast of central California, and to a lesser extent in the Southern California Bight (Figures 1 and 2). The biomass of northern anchovy was estimated at 31427 t, $CI_{95\%}$ = [17 780, 48 302] t, CV = 24.6% (Table 2). The distribution of density-weighted standard length (SL) had a mode at 6 cm (Table 2; Figure 4), indicating that the majority of the anchovy were spawned in 2015.

Discussion

Before 2015, the ATM surveys have either not sampled adequately the distribution of the stocks of northern anchovy, or the populations have been too small for precise ATM estimates of their respective biomasses (Zwolinski et al., 2014). In the case of the central subpopulation of northern anchovy, recent fishery-independent estimates using egg and larval (MacCall et al., 2016; Koslow et al., 2015) and aerial surveys (PFMC, 2015) suggest that only a limited numbers of anchovy occupy the inshore habitat, but these analyses are preliminary since there was a mis-match between the observed distribution of anchovy in 2015 and spatial extent of the survey data used in these analyses. Similar concerns about the adequacy of the ATM survey to provide estimates of anchovy biomass were reported during a recent review of the ATM methodology (2011), and reiterated at the 2016 Data-limited Workshop as reported to the Council at its September 2016 meeting (http://www.pcouncil.org/wp-content/uploads/2016/08/E2a_Workshop_Rpt_SEPT2016BB.pdf). It was noted that until a Methodology Review of the current ATM survey can be undertaken to address concerns about the proportion of the anchovy population inshore of the survey area and in the surface waters, present survey data cannot be used to provide estimates of relative abundance or absolute abundance of northern anchovy. The estimate contained is this report does at least provide a negatively-biased minimum estimate anchovy abundance. If in future surveys there is indication that a small, yet non-negligible portion of the stock is contained in the shallow coastal habitats, a correction factor can be applied.

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Table 1. Northern anchovy biomass by stratum for the summer 2015 survey (see Figs. 5 and 6).

Stratum	**Transect**		**Trawls**		**Anchovy**		
Area (n.mi.^{2})	**Number**	**Distance (n.mi.)**	**CPS clusters**	**Number of Anchovy**	**Biomass (10^3 tons)**	**95% confidence interval (10^3 tons)**	**CV (%)**
19445	**27**	**1016**	**18**	**11246**	**31.427**	**[17780, 48302]**	**24.6**

Table 2. Northern anchovy abundance estimates versus standard length for the summer 2015 surveys.

Standard length (cm)	Abundance (millions)
4	3.28
5	1246.38
6	3606.17
7	1362.99
8	1175.84
9	1058.74
10	523.19
11	203.63
12	39.25
13	0.43
14	0
15	0
16	0
17	0
18	0
19	0
20	0

Figure 1. Summer 2015 results: Acoustic backscatter (s_A, m^2 $n.mi.^2$) from coastal pelagic fish species (CPS; left); acoustic proportions of CPS in trawl clusters (right), including northern anchovy (*Engraulis mordax*), Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), and Pacific herring (*Clupea pallasii*).

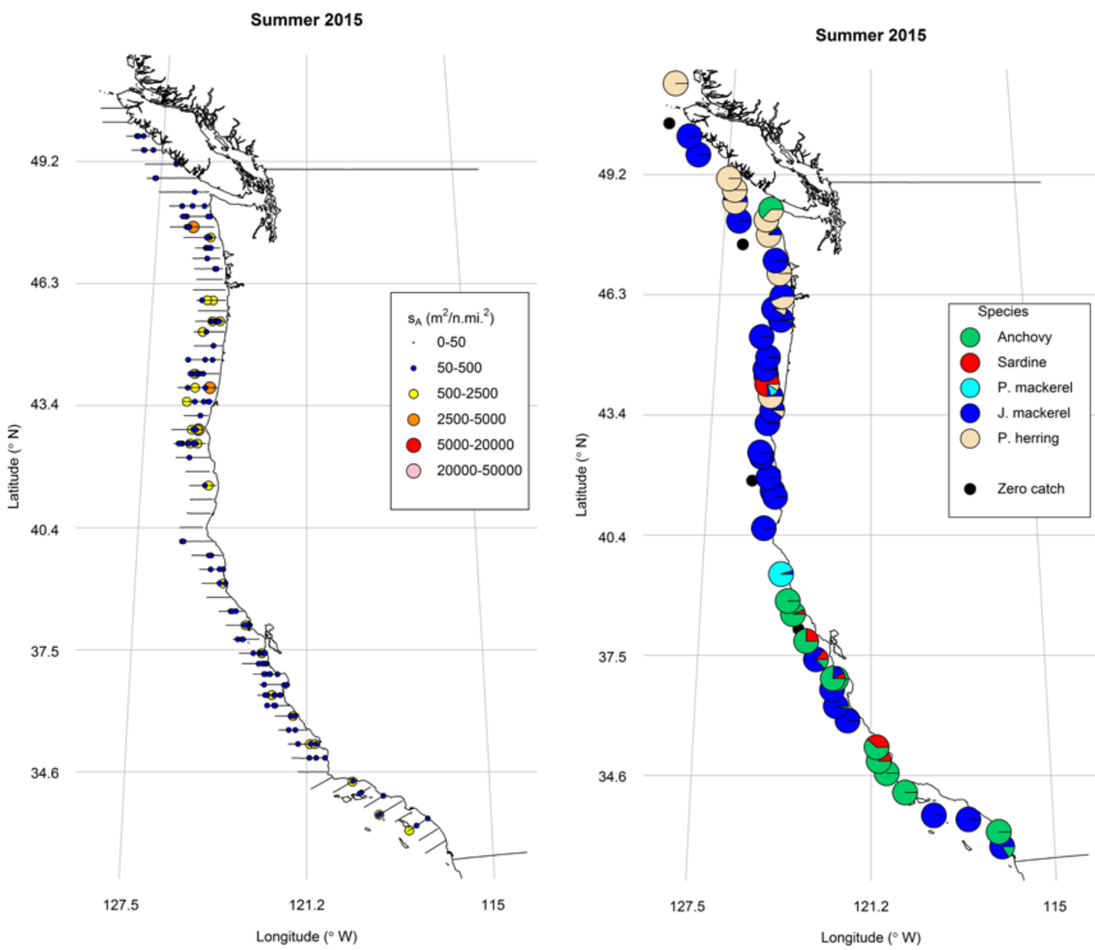

Figure 2. Anchovy biomass densities in the single stratum off central and southern California (Table 1) estimated using the acoustic-trawl method in summer 2015. The blue numbers represent the locations of trawl clusters with at least one anchovy.

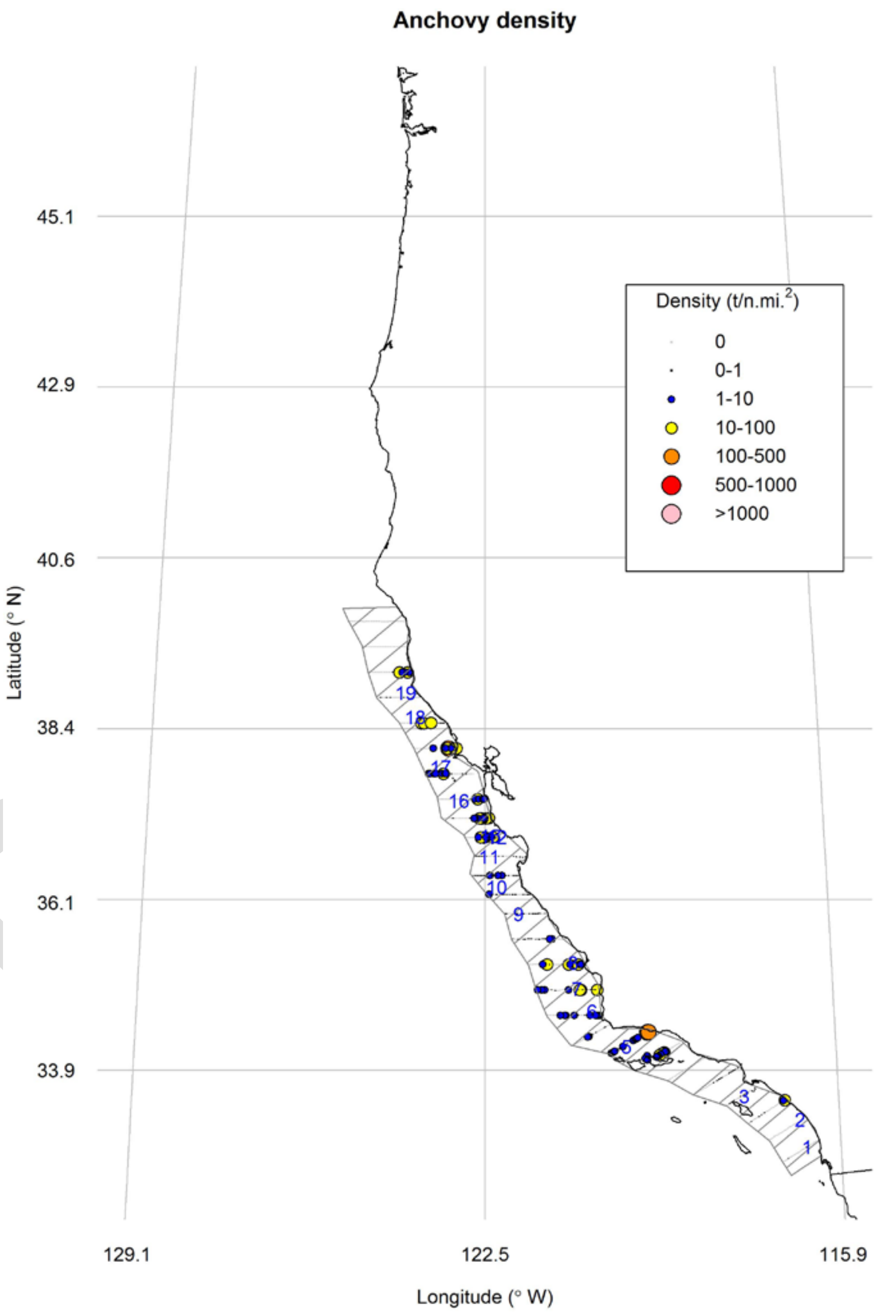

Figure 3. Length-class distribution of anchovy per night-time cluster (Fig. 2), the number of individuals caught, and their contribution in percentage to the density-weighted length distribution (Fig. 3, Table 2).

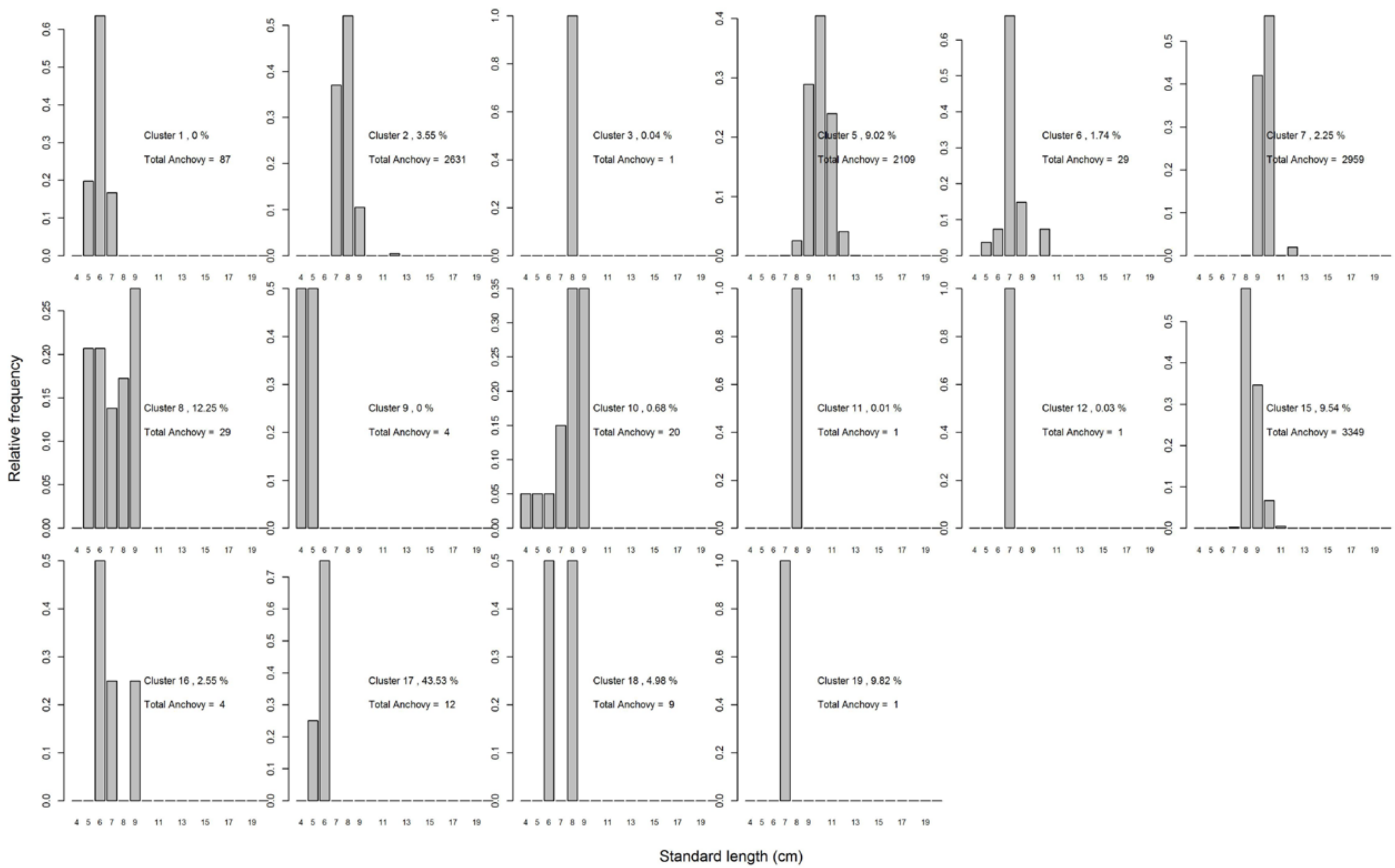

Figure 4. Estimated length-disaggregated abundance (upper panel) and biomass (lower panel) of central stock northern anchovy in the survey area (Fig. 2) for the 2015 summer survey.