

MARKET SQUID PARALARVAL RESEARCH UPDATE, 2020-21

Promising indications of increased market squid abundance and ocean productivity as La Niña transition continues in the California Current:

Highlights:

- ENSO (El Niño Southern Oscillation) transition began in the Monterey Bay area (MBA) during the summer of 2020 and La Niña conditions have been ongoing since August, 2020; projections anticipate continued cool-water conditions through 2021.
- These cool-water, La Niña conditions are starting to influence higher trophic levels, especially in central California.
- Paralarval density in central California was higher than it has been since 2015.
- Surface chlorophyll and zooplankton displacement volume were also much greater than previous years.

Summary

An historic El Niño occurred in 2015 and brought devastating and long-lasting effects to the California Current Ecosystem and organisms within, including the California market squid (*Doryteuthis opalescens*) (Di Lorenzo and Mantua, 2016; Jacox et al., 2016; Van Noord and Dorval, 2017). Combined with this El Niño, a marine heat-wave developed in the North Pacific, bringing anomalously warm temperatures, along with an increase in the prevalence of warm water species. These conditions resulted in a substantial reduction in oceanic productivity (Brodeur et al., 2019; Gentemann et al., 2017). As a result, low paralarval densities were observed from 2015-2019 within our sampling area of southern and central California (Van Noord, 2020). However, ocean conditions in the north and equatorial Pacific began to transition during the summer of 2020, and the effects of this period of low productivity seem to be waning. This transition began in the Monterey Bay area (MBA) during the summer of 2020. During this period, market squid paralarval abundance was higher than it has been since 2015, when warm water conditions shifted the spawning population north (Van Noord and Dorval, 2017). Additionally, sea surface temperature cooled, surface chlorophyll increased (SCHL), and zooplankton displacement volume (ZPDV) was the highest it has been since our sampling effort in the MBA began in July, 2014. After a slow start to the commercial fishing season in southern California (SC), landings began to increase in March and April, indicating this change in ENSO state is being felt in higher trophic levels across the food web.

Study overview

The California Wetfish Producers Association (CWPA) is committed to studying the long-term population dynamics of coastal pelagic species (CPS), including the California market squid, which, at times, constitutes one of the largest and most valuable fisheries in the State of California. As part of this effort, the CWPA, along with state and federal partners at the California Department of Fish and Wildlife (CDFW) and NOAA's Southwest Fisheries Science Center (SWFSC), have established a long-term time series of paralarval abundance in Southern California (SC, Point Conception to La Jolla) and the Monterey Bay Area (MBA, Half Moon Bay to Big Sur, Fig. 1). This time-series and data (Fig. 2) are used to understand

trends in the population dynamics of the animal, and the influence of environmental conditions on market squid recruitment, density, and trends in abundance.

Background

Market squid are short-lived (<12 months) and semelparous (animals spawn once and die) (Fields, 1965; McGowan, 1954; Zeidberg et al., 2012). Spawning can occur opportunistically throughout the year, and duration to maturity varies depending on ocean temperature and food availability (Jackson and Domeier, 2003; Navarro, 2014). Market squid are widely distributed along the Pacific coast from Baja California to Southeast Alaska, far beyond the historical fishery in California (Navarro et al., 2018; Okutani and McGowan, 1969). Yet, based on coastwide distribution and abundance of market squid from midwater and bottom trawl surveys, these squid are commercially harvested over a fraction of their range (~71% of the resource is estimated to occur in CA according to **Appendix D – Squid MSY Analyses** from Review Draft CPS FMP Amendment 9). Typically, however, in California spawning of commercially viable populations begins in the MBA during spring, followed by SC during autumn (Zeidberg et al., 2006). However, during remarkably warm years (such as this recent El Niño), market squid shift their range north along the California Current where they may be landed in northern California and Oregon (<https://www.dfw.state.or.us/fish/commercial/statistics.asp>).

During spawning, adults aggregate in shallow waters and attach egg capsules to the seafloor. Paralarvae hatch after approximately two months of incubation, although hatching time can depend on water temperature (Zeidberg et al., 2011). Therefore, paralarval sampling effort is focused on the summer hatching season in the MBA and winter in the SCB, the time when paralarvae are expected to be most prominent within the water column. Additional sampling is conducted opportunistically as funding allows. The market squid fishing season runs from April first through March 31st of the subsequent calendar year.

Paralarvae are captured aboard chartered fishing vessels (both commercial passenger fishing vessels (CPFV), and dedicated commercial vessels). Zooplankton nets, with 505µm mesh and 0.6m mouth diameter, are towed obliquely through the water column to depths of ~30-40m, at fixed stations over traditional spawning grounds in the two main fishing areas of SC and the MBA. These spawning grounds are neritic (~ <1km from shore) and over shallow, sandy substrate (70-200m). Market squid paralarvae are sorted from samples under a dissecting microscope and density estimates are calculated using the amount of filtered sea-water, standardized to individuals per 1,000 m³, zooplankton biomass is quantified by displacement volume, and paralarval condition is assessed using mass, length, and age measurements.

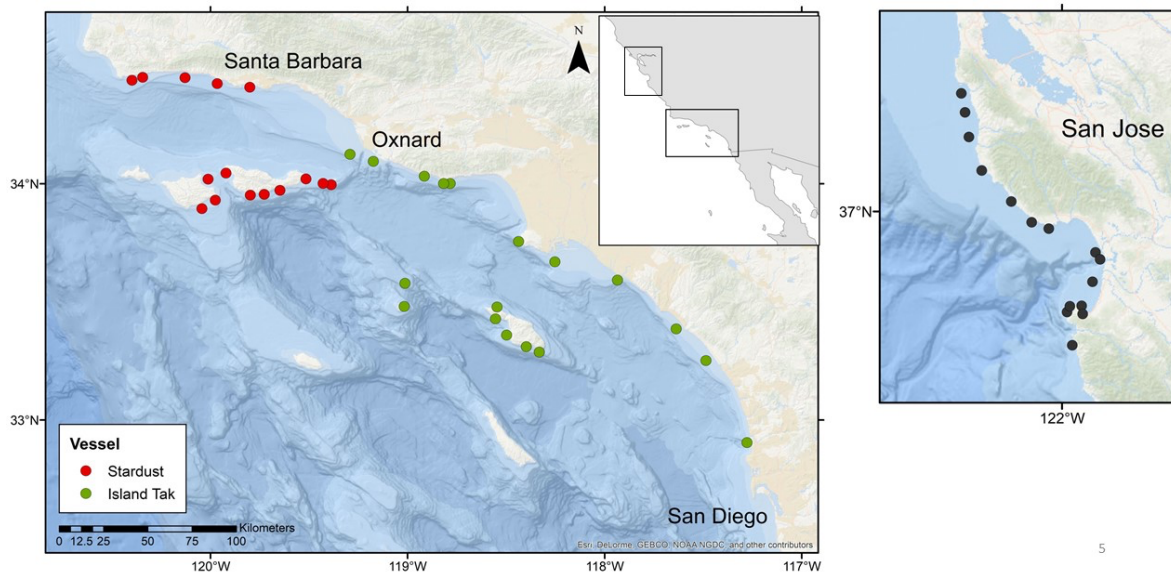
2020-2021 Collection Effort

Four surveys, utilizing three fishing vessels, were chartered to conduct 96 bongo net tows during the 2020-2021 fishing season. The CWPA Market Squid Paralarval Research Program (MSPRP) now includes 11 years of observation, totaling 75 survey trips and 1,370 net tows.

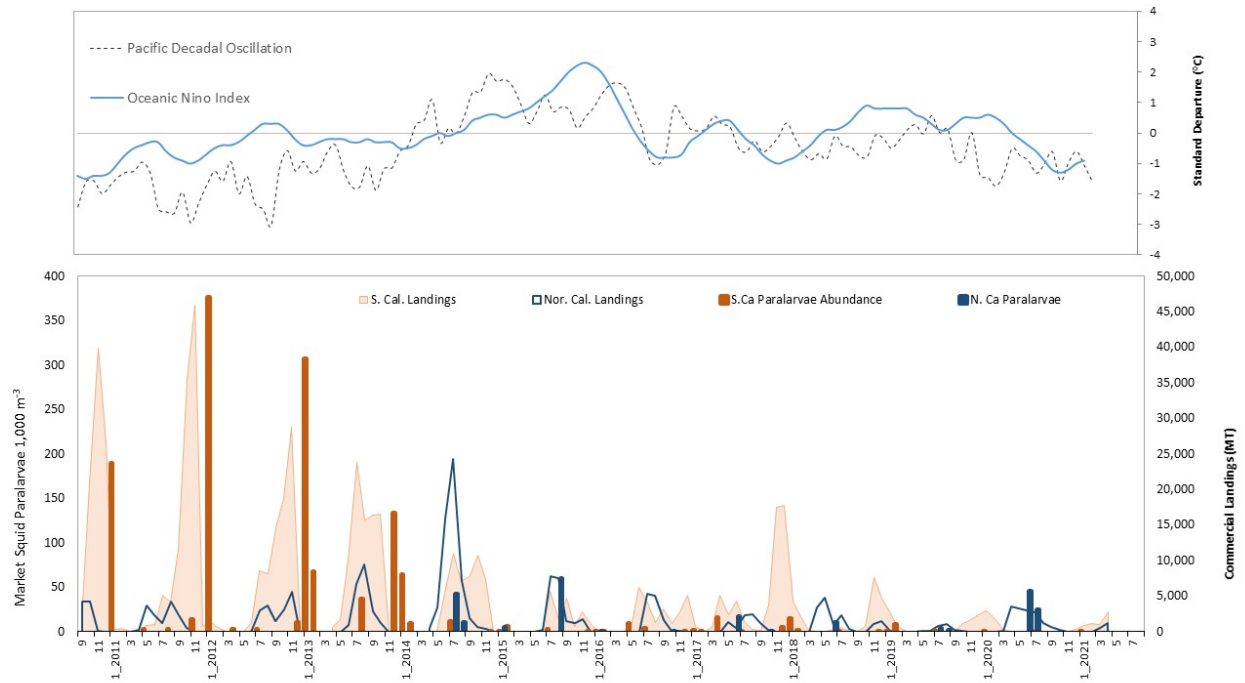
Three surveys were conducted during the summer of 2020 (Fig 3): two in the MBA and one in SC. Funding support for the MBA effort was provided by NOAA's SWFSC. Fourteen stations were sampled in the MBA during June, 2020. Congruent sampling occurred in July, covering 33 stations in SC and 16 in the MBA. The effects of the ENSO transition appear to have started in central California during the summer of

2020. During this time, paralarval abundance was high in the MBA and low in SC. Mean paralarval abundance in the MBA during both June (45.6 ± 105.8 SD) and July (25.8 ± 87.1 SD) was as high as it has been since August, 2015, the beginning of the warm water transition. Paralarvae were encountered at 78% of stations in June and 38% in July, 2020 in the MBA. Paralarvae were found at only 9% of stations in SC during July, 2020. At-station, sea-surface temperature (SST) was cooler than long-term averages during the summer sampling period (Fig. 4). Zooplankton Displacement Volume (ZPDV) was substantially greater in the MBA during this summer sampling compared to all previous effort.

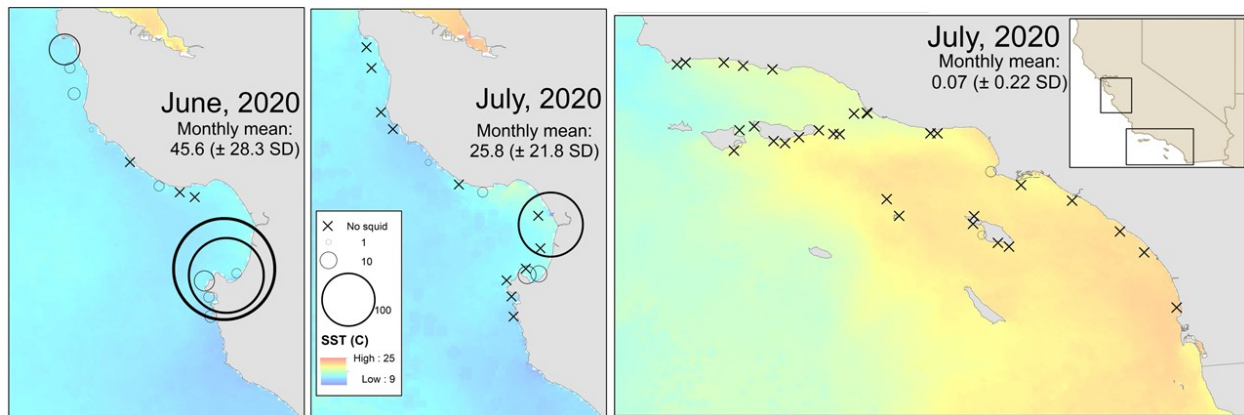
Sea surface temperatures in SC remained elevated throughout the autumn of 2020, perhaps delaying the recruitment of adult market squid to the traditional spawning grounds (Fig. 5). Paralarval abundance remained low in SC during the January, 2021 sampling effort. Mean paralarval abundance was 0.99 individual per 1,000m³ filtered sea water (± 0.74 SD), with paralarvae found at 12% of stations. SST declined throughout late autumn and winter, and is now comparable to temperatures seen during the previous La Niña, which was when market squid landings were at historic highs (Fig. 2). Commercial landings have begun to increase in both SC and the MBA as of late March and April, 2021, suggesting a response to the decline in temperature. Market squid paralarval surveys will be conducted throughout the summer to assess the recruitment strength of market squid and to monitor the effects of this La Niña transition.



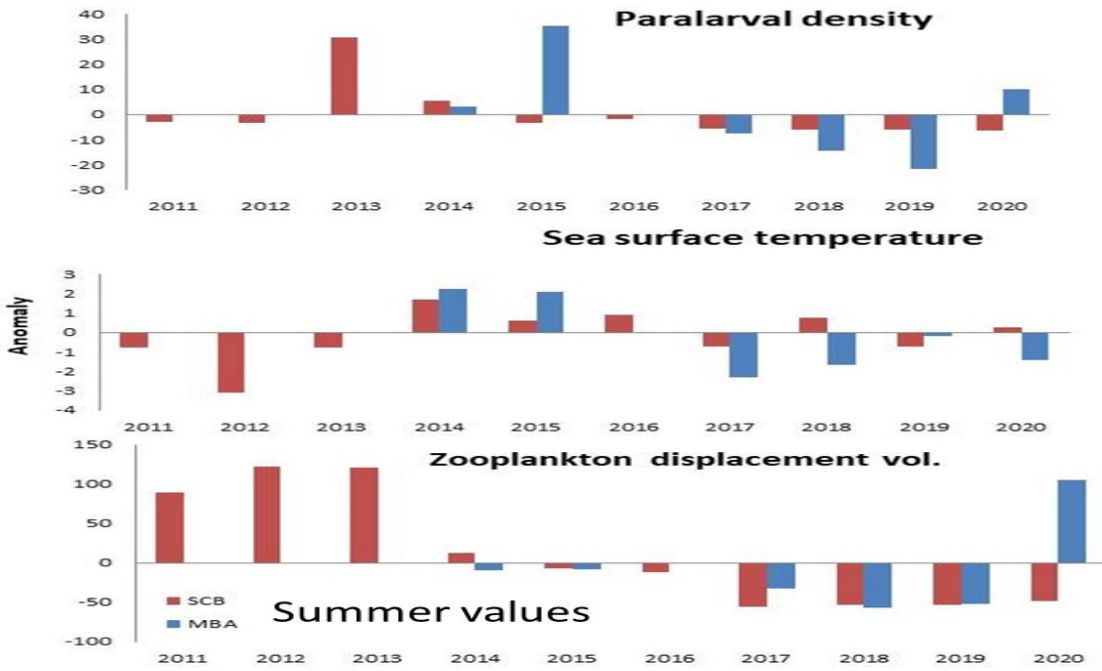
(Fig. 1. Station map for market squid paralarval sampling in Southern California (left) and the Monterey Bay Area (right). Three fishing vessels are chartered for sampling.)



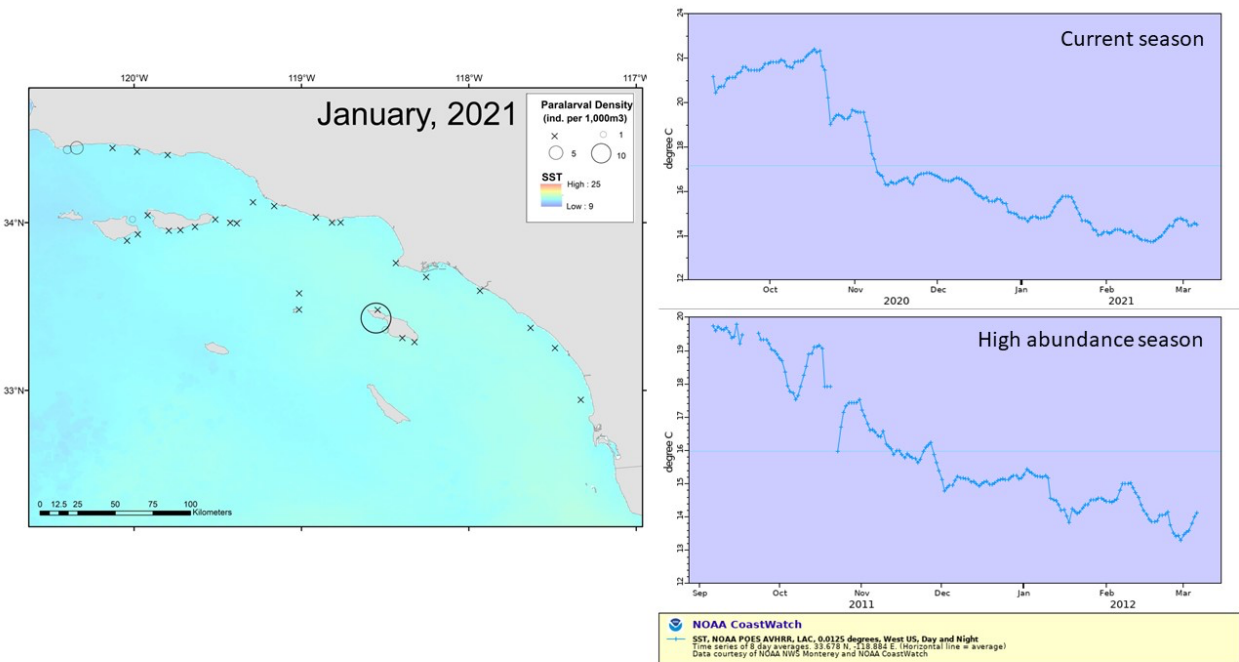
(Fig. 2. Long time series from September, 2011 through the present showing (top panel) the Pacific Decadal Oscillation (PDO, dashed line) and the Oceanic Niño Index (ONI, solid blue line). These indices indicate whether these regions are colder (negative values) or warmer (positive values) than that of the long-term average (value of 0). Bottom panel shows market squid landings (shaded areas and lines) and paralarval abundance (columns) for SC (orange) and the MBA (blue). PDO values obtained from NOAA’s National Centers for Environmental Information, <https://www.ncdc.noaa.gov/teleconnections/pdo/>. ONI values obtained from NOAA’s Climate Prediction Center, <https://origin.cpc.ncep.noaa.gov>)



(Fig. 3. Choropleth map showing sea surface temperatures during summer effort in the Monterey Bay Area (left) and Southern California. Sampling locations are indicated by symbols, an “x” indicates locations where net tows occurred, but no paralarvae were encountered, circles indicate positive net tows, with circle size corresponding to density at that location. Temperature data is obtained from NOAA’s Coastwatch, <https://coastwatch.pfeg.noaa.gov/coastwatch/>).



(Fig. 4. Anomaly values for summer effort in Southern California (red) and the Monterey Bay Area (blue) for paralarval density, sea surface temperature, and zooplankton displacement volume, from 2011 – 2020.)



(Fig. 5. Choropleth map (left) for Southern California showing sea surface temperature and paralarval density for January, 2021. An “x” indicates a sampling location where no paralarvae were encountered, while circles indicate the presence of market squid. Larger circles indicate greater paralarval densities. Right panels show the trend in sea surface temperature during the typical recruitment and hatching

seasons for the current season (top right) and the 2011-12 fishing season, which corresponded to very high commercial landings. Since the autumn of 2020 was warm, recruitment (and therefore paralarval abundance) may have been delayed. This delay is correlated with an increase in March and April landings (as seen in Fig. 2). Temperature data are available from NOAA Coastwatch.)

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