SQUID RESEARCH UPDATE: 2016

CWPA's cooperative market squid research program is now in its 10th year. We're pleased to announce that findings from our quarterly surveys for the years 2011-2016 have been published in the scientific journal Marine Ecology. The lead author is our supervising squid scientist, Joel Van Noord,

HIGHLIGHTS FROM VAN NOORD, ET AL Published 20 Jun 2017 (download the full paper)

Van Noord JE, Dorval E. *Oceanographic influences on the distribution and relative abundance of market squid paralarvae (Doryteuthis opalescens) off the Southern and Central California coast*.
Mar Ecol. 2017;38:e12433. https://doi.org/10.1111/maec.12433

Abstract: *Market squid (Doryteuthis opalescens) are ecologically and economically important to the California Current Ecosystem, but populations undergo dramatic fluctuations that greatly affect food web dynamics and fishing communities. These population fluctuations are broadly attributed to 5–7-years trends that can affect the oceanography across 1,000 km areas; however, monthly patterns over kilometer scales remain elusive. To investigate the population dynamics of market squid, we analysed the density and distribution of paralarvae in coastal waters from San Diego to Half Moon Bay, California, from 2011 to 2016. Warming local ocean conditions and a strong El Niño event drove a dramatic decline in relative paralarval abundance during the study period. Paralarval abundance was high during cool and productive La Niña conditions from 2011 to 2013, and extraordinarily low during warm and eutrophic El Niño conditions from 2015 to 2016 over the traditional spawning grounds in Southern and Central California. Market squid spawned earlier in the season and shifted northward during the transition from cool to warm ocean conditions. We used a general additive model to assess the variability in paralarval density and found that sea surface temperature (SST), zooplankton displacement volume, the log of surface chlorophyll-a, and spatial and temporal predictor variables explained >40% of the deviance (adjusted r2 of .29).* ***Greatest paralarval densities were associated with cool SST, moderate zooplankton concentrations and low chlorophyll-a concentrations****. In this paper we explore yearly and monthly trends in nearshore spawning for an economically important squid species and identify the major environmental influences that control their population variability.*

Summary: This study represents the most comprehensive, on-going effort to directly assess the relative abundance of market squid paralarvae in nearshore waters and the conditions that influence the variability in the stock, density and distribution. Warm temperatures pose ecological and physiological limitations on squid through feeding constraints and metabolic stress that alter the timing and location of spawning. We found that the densities and distribution of market squid paralarvae show a strong relationship to local sea surface temperatures and ocean productivity, where colder temperatures and moderate zooplankton displacement volumes promote greater paralarval densities, while warmer temperatures cause the population to spawn earlier, shift north, and contract. These findings indicate that squid abundance, distribution, and timing of spawning are largely driven by environmental forcing, while the effect from the fishing pressure is likely much less.

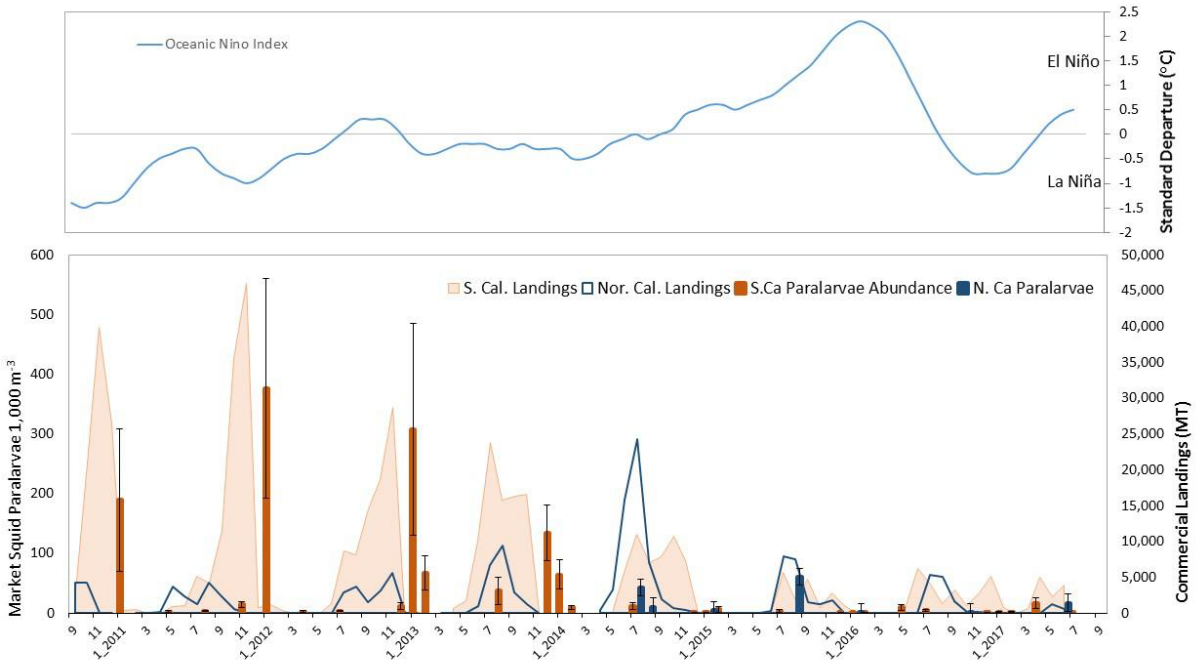
Major findings: ENSO cycles control the abundance, distribution and maturity rate of market squid

The abundance, distribution, and maturity rate (which controls the timing of spawning and recruitment to fishing grounds) of market squid are strongly influenced by warm and cool cycles of the El Niño Southern Oscillation (ENSO). During La Niña events the ocean temperature is cooler and the ecosystem is more productive than normal.

During El Niño events the opposite is true, the ocean temperature is warmer and the ecosystem is unproductive compared to the long-term average.

Warm oceanic conditions pose ecological and physiological challenges to market squid at multiple life-history stages.

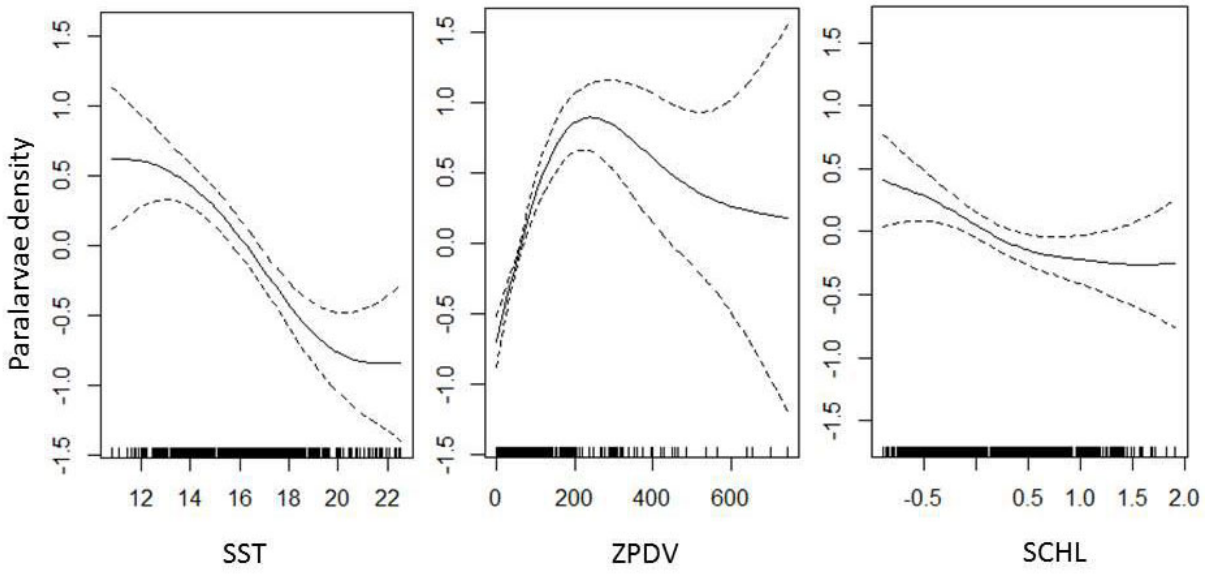
- Warm waters yield fewer zooplankton, resulting in reduced prey for squid
- Warmer waters result in greater egg failure and less paralarvae hatching
- Paralarvae are born with reduced egg-yolk (an initial and critical food source)
- Metabolic rate is increased with greater ocean temperatures, requiring more food for sustaining growth
- Maturation rate increases, which alters timing of spawning and can effect synchronicity with seasonal upwelling events.



The above time series shows the effect of an ENSO cycle (top panel showing the Oceanic Niño Index) on squid abundance, distribution, and timing of spawning (bottom panel):

- Ocean conditions are cool and productive (La Niña) from late 2010 – 2013, commercial landings (shaded areas) and paralarval abundance (bars) are high, particularly in southern California (orange colors).
- Ocean temperatures gradually rise in late 2013 (neutral conditions) and cause a temporal shift in spawning, squid mature early and recruit to the Southern California spawning beds during late spring and summer, instead of autumn and winter.
- Continued warming causes a distributional shift, squid can be found recruiting further north (blue lines and bars) to Monterey Bay spawning beds.
- As a near-record El Niño peaks in 2016, both commercial landings and paralarval abundance decrease to very low levels in the traditional spawning locations.

Oceanographic variables explain variability in paralarval density



- Sea surface temperature (SST) and zooplankton displacement volume (ZPDV – a measure of zooplankton abundance and availability as prey) are strongly correlated with paralarval density.
- The above figure shows the effect of SST and ZPDV on paralarval density. The solid lines indicate the estimated paralarval density at a measured SST or ZPDV measurement. A value of 0 on the vertical axis indicates no effect on paralarval density. A positive value indicates greater paralarvae, and a negative value indicates fewer. The dotted line is the 95% confidence interval.
- The left panel shows greater paralarval densities associated with colder temperatures, and an adverse effect of warm temperatures (>17 C°) on paralarval density.
- The right panel indicates zooplankton abundance and paralarval densities are positively correlated, when zooplankton abundance is low, paralarvae abundance is also low. As zooplankton abundance increases, paralarval densities increase as well. This trend continues until the ocean environment is saturated with enough zooplankton and there is no effect after ~200 ml displacement.
- Sea surface temperature, zooplankton abundance, chlorophyll concentration, and geographic and temporal variables combined to explain 41% of the variability associated with paralarval densities (Van Noord & Dorval 2017).