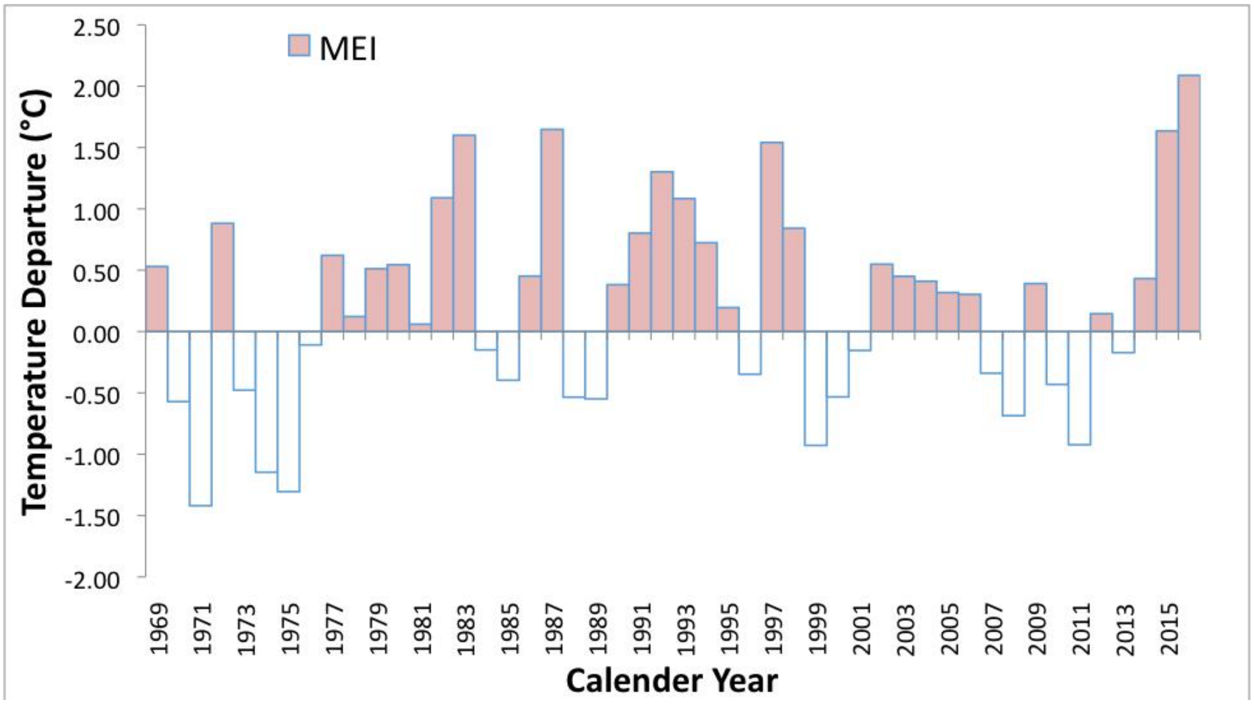
SQUID RESEARCH UPDATE: 2015 — Year in review

Continued warm waters

The 2015-16 fishing year was characterized by continued ocean warming and the peak of an historically strong El Niño (Fig. 1), which ranked among the top three El Niño events since records began in the 1950's. Local sea surface temperatures during the 2015-16 fishing year were consistently and anomalously warm throughout nearly all California state waters.

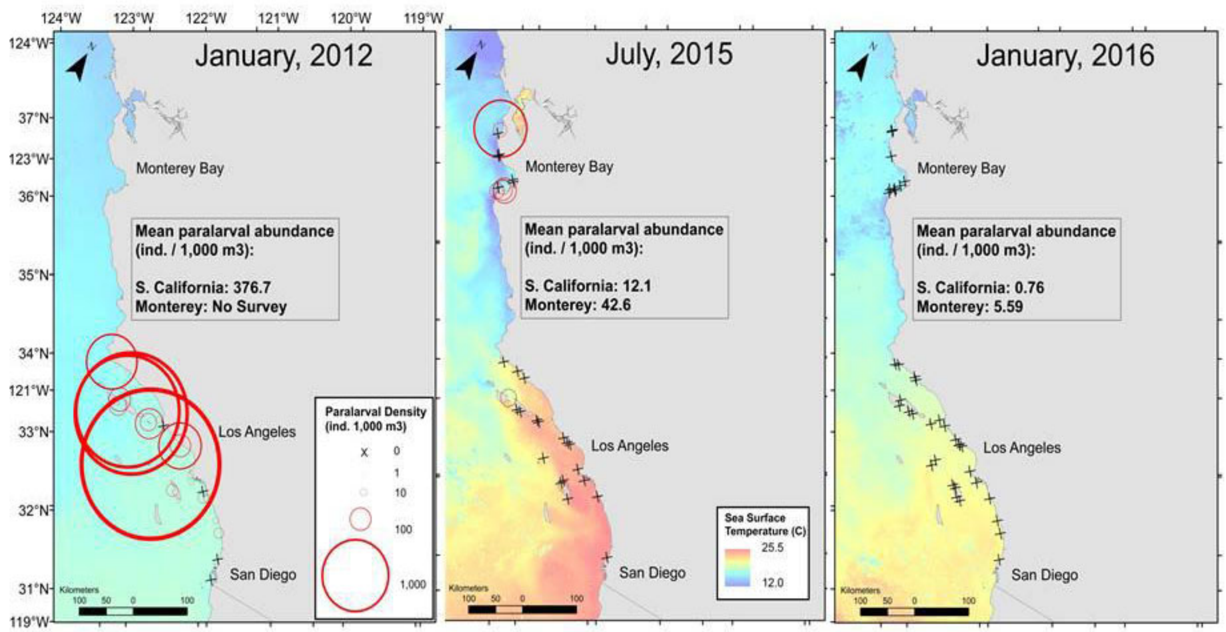


(Fig. 1 Multivariate ENSO (El Niño Southern Oscillation) Index (MEI) averaged by calendar year from 1969 through April of 2016, red indicates El-Niño ocean conditions and temperatures that are warmer than the 30 year long-term average, and blue indicates La Niña conditions and cooler than normal conditions. MEI data available from NOAA, http://www.esrl.noaa.gov/)

The effect of El Niño on market squid

El Niño ocean conditions, and the warm waters associated with them, adversely affect squid in a major way. The drastic population decline due to warm ocean conditions has been well-documented in the literature (e.g. Koslow and Allen, 2011; Reiss et al., 2004; Zeidberg and Hamner, 2002), landings data from the fishery, and from CWPA's on-going research efforts. As ocean conditions transitioned towards an El Niño during the 2014-15 fishing season, market squid matured faster, spawned earlier during the season, and shifted their distribution toward the north, presumably seeking cooler ocean conditions. As the El Niño peaked during 2015-16, paralarval abundance, as measured by the CWPA research program, continued a steady decline. This trend and the effect of the El Niño-Southern Oscillation (ENSO) state on squid abundance is clear, and especially stark, compared to previous highs seen during favorable conditions in 2012 (Fig. 2).

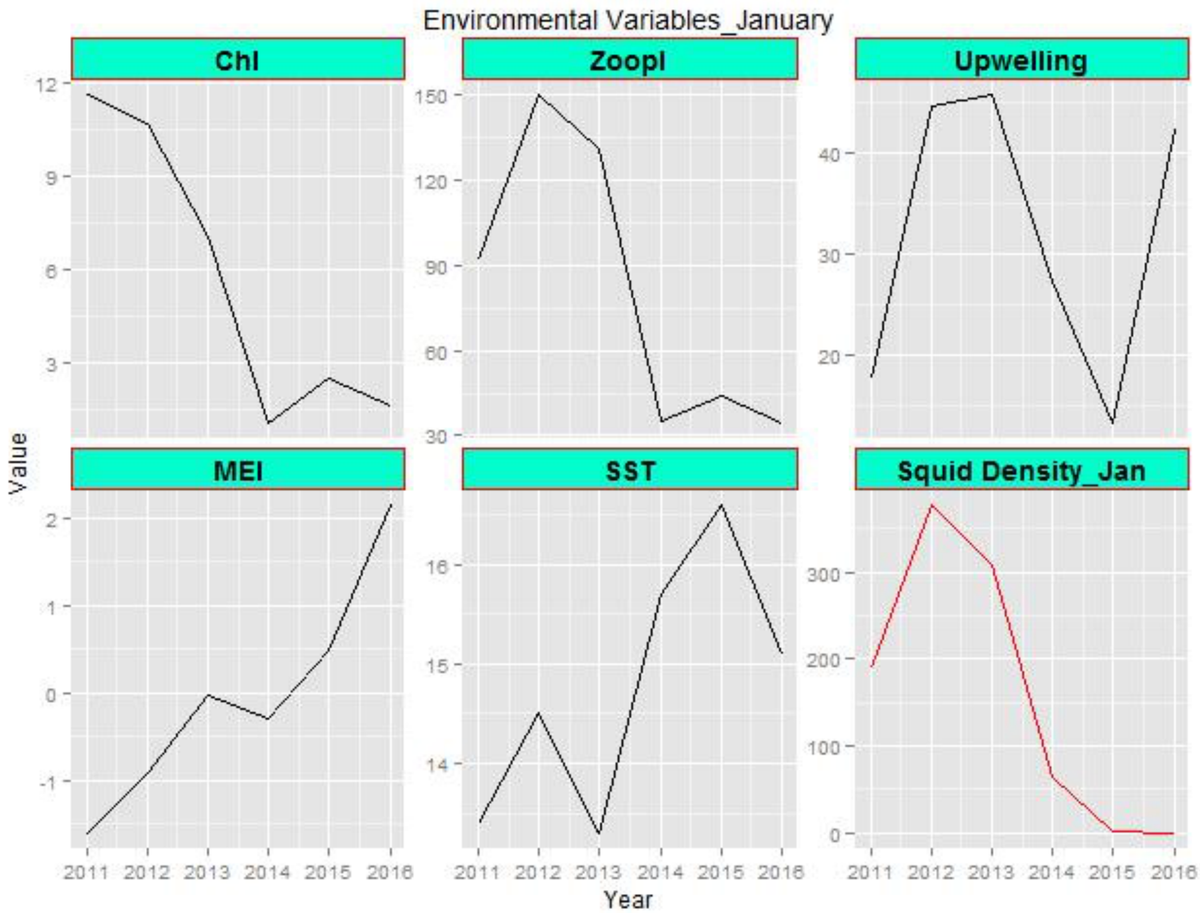
While it is evident that El Niño events cause detrimental effects on the fishery for market squid, the rapid recovery of the resource is equally remarkable. This is illustrated by landings data and the increase in occurrence of market squid in the diets of predators, such as sea lions (Lowry & Carretta 1999), and also documented by increased abundance of paralarvae in CWPA surveys. Within a four-year period surrounding the 1997-98 El Niño, landings dropped from 80,000 to 3,000 mt, before rebounding to 118,000 mt (Fig. 2).



(Fig. 2 Chloropleth maps showing sea surface temperature (°C) by color and paralarval abundance by red circles. Red colors indicate warmer temperatures, and larger circles indicate greater paralarval density observed at a given sampling location. "X" indicates survey locations where no paralarvae were found. This figure shows the drastic effect that local sea surface temperatures and ENSO cycles have on controlling squid abundance. In 2012 the nearshore ocean experienced moderate La Niña conditions, while 2015-16 was characterized by a strong El Niño, according to NOAA statistics: http://www.cpc.ncep.noaa.gov/)

ENSO patterns drive local conditions

As El Niño peaked during the 2015-16 season, many local variables co-varied either positively or negatively with this global event (Fig. 3). From 2011 through 2016, as the ENSO state transitioned from a cool and productive La Niña environment, to a warm and more eutrophic El Niño environment, local chlorophyll-a, zooplankton displacement volume, upwelling, and paralarval abundance declined sharply.



(Fig. 3 Many local variables showed a negative relationship with the ENSO patterns. January data is shown yearly from 2011-2016. Variables were either locally captured on CWPA research vessels, including small zooplankton displacement volume (Zoopl, measured in ml / 1,000m3) and Squid Density (paralarvae / 1,000m3) or derived from NOAA satellites, including: Chlorophyll-a (CHL, mg / m3), upwelling (m3 / second / 100m of coastline), Multivariate ENSO index (MEI, standard departure in °C), and sea surface temperature (SST °C). CHL, Zoopl, SST, and Squid Density values were gathered at each unique station and average for a monthly January value. Upwelling is a regional index with one value for southern California and one for Monterey, Ca. MEI is a global value.)

Conclusion

This research provides clear evidence that the densities and distribution of market squid paralarvae show a strong relationship to local variables, especially sea surface temperatures, where colder temperatures and corresponding oceanographic conditions promote greater paralarvae densities, while warmer temperatures cause the population to spawn earlier, shift north, and then contract from nearshore spawning habitat. Warm temperatures pose ecological and physiological limitations on squid through feeding constraints and metabolic stress that alter the timing and location of spawning (to be discussed in a future update). These findings indicate that squid abundance, distribution, and timing of spawning are largely driven by environmental forcing, while the effect from the fishery is likely to be negligible. Current fishery management measures appear to be effective. Harvest limits as well as weekend closures and a statewide network of marine protected areas provide spatial and temporal refugee for uninterupted spawning. This strategy allows the population to thrive and expand in positive environmental conditions.