

**Program:** Habitat Information Use in Stock Assessments

**Project Title:** Identifying essential spawning habitats for improving assessment and management of the market squid fishery off California.

**Progress Report:** April 14, 2015.

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## **Introduction**

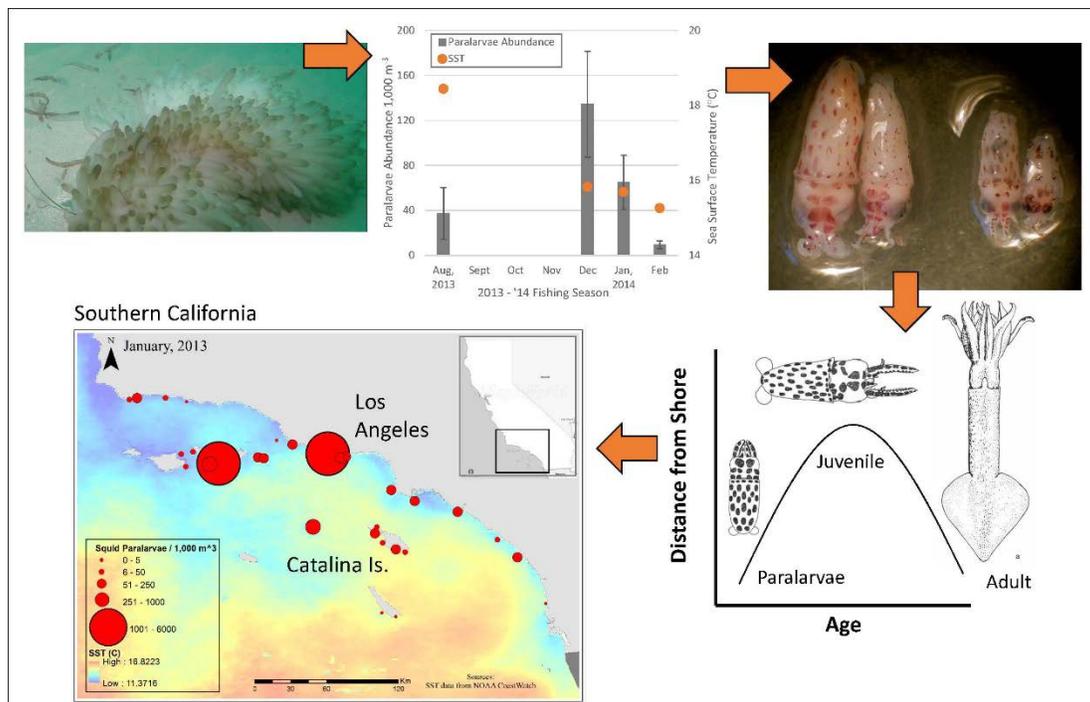
The market squid habitat assessment project aims to better understand the physical and ecological factors that control recruitment into the major spawning grounds of this species, and to improve the assessment and management of market squid stocks off California. Funded in the FY 2014, this project has conducted field surveys, laboratory analysis of water chemistry, paralarvae, juvenile and adult squid, laboratory experiments, training of undergraduates and educational activities for high school students. Based on this project, the SWFSC Coastal Pelagic Species Life history Team (CPS-LHT) has strengthened research collaboration with the California Department of Fish and Game (CDFW) and the California Wetfish Producers Association (CWPA) to better model and manage market squid stocks. In this progress report we provide summaries of various research activities and results that were conducted in 2014 and 2015 with funding support from the Habitat Information Use in Stock Assessment Program.

### **1) Summary of 2014-15 Market squid surveys and research results:**

Market squid samples were collected from various surveys during the 2014-15 period. The primary objective of this research was to identify the spawning dynamics of market squid off California as related to environmental conditions. Squid paralarvae and water samples were collected from three fishing vessels chartered out of Oxnard, Santa Barbara, and Moss Landing. These vessels conducted surveys in southern California and Monterey Bay in summer and fall 2014 and in winter 2015. Juvenile squid were collected during the April 2014 DEPM survey and the spring 2014 juvenile rockfish survey conducted by the SWFSC. Adult squid were sampled by CDFW from port landings and during the summer 2014 SaKe survey conducted by the SWFSC from northern California to the USA/Canada border. Finally, underwater cameras were used during each survey cruise conducted in Monterey Bay to monitor seasonal changes in egg beds density.

- a) **Research results:** Data collected during the surveys allowed us to track market squid movement from their spawning ground into their juvenile habitats, and then to their place of recruitment after 6 to 8 months of life (Figure 1). While paralarvae abundance were high in southern California during the spring of 2014, our data showed that this species did not recruit in this area during the following summer season. Rather, most adult squid recruited in Monterey Bay, where spawning took place and paralarvae abundance was high in summer 2014. Water was unusually warm in southern California during the summer of 2014, which might have caused adult squid to move northward to recruit and spawn in cooler water within Monterey Bay. Further, adult market squid were

particularly abundant off Oregon and Washington from July to August, which corroborates the overall northward shift of the stock to cooler water conditions. Note that in contrast to January 2013 (Figure 1) little spawning took place in the southern and northern California in January 2015, indicating that these habitats were still not suitable for spawning due to warmer water, and that most of the adult population were still located in Oregon/Washington habitats.



**Figure 1.** Market squid life cycle: egg beds, seasonal paralarvae abundance, water temperature conditions, and life stage distribution at age in the southern California Bight during the 2013-2014 fishing season. Note that mean age of adult squid were approximately 6 months.

- b) Research presentation: Abundance and environmental parameters were related using survey data collected in summer 2014 and previous data collected by CWPA. These models and data were presented as a poster in the 2014 CalCOFI Meeting at the Scripps Institution of Oceanography. The poster title, authors and abstract are provided below:

**Following market squid (*Doryteuthis opalescens*) paralarvae abundance through an ENSO transition, observations from a cooperative program.**

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**Abstract:** We conducted seasonal nearshore surveys at squid aggregation sites to investigate trends in abundance and understand the drivers of variability in market squid paralarvae abundance. Collections began in 2011 for southern California (SC), and 2014 for Monterey (17 surveys, 427 net tows). High variability in abundance among stations was evident throughout the time series, although certain regions were consistently more productive than others. Generally, high SC paralarvae abundance was associated with cool and productive La Niña conditions. Highest paralarvae abundances were observed in January of 2012 (377 paralarvae 1,000 m<sup>-3</sup> ± 184 SE) and 2013 (308 ± 178), before declining significantly (*p*-value = 0.008) in January 2014 (65.0 ± 24.1). Adult market squid landings showed similar trends, with high landings throughout this La Niña period (the harvest limit was reached each year from 2010/11 - 2014/15). The greatest landings per month occurred in November, 2011 (45,980 MT) and a significant relationship was found between landings during a given month and paralarvae abundance two months later (*p*-value < 0.001, *r*<sup>2</sup> = 0.75). As 2014 has transitioned to neutral ocean conditions, squid have spawned earlier in the year in SC and landings have shifted north toward Monterey, potentially because of warming (El Niño-like ocean conditions) and reduced ocean productivity. Future work will further investigate fluctuations in squid abundance, statolith ageing for growth and natural mortality assessments, as well as stable isotope and microchemistry work to address natal habitats of market squid landed in the fishery.

- c) Research publication: We are preparing a draft manuscript entitled “*Temperature drives variability in the abundance and distribution of market squid (Doryteuthis opalescens) paralarvae along the California coast, 2011 – 2015.*” This paper will be co-authored by Joel van Noord and Emmanis Dorval and will be submitted to be the SWFSC internal review process in June. We expect to submit the manuscript to the journal of Marine Ecology before the end of summer 2015.

## 2) Summary of the Optimization of the Egg Escapement Model:

Various research activities have been conducted to optimize the market squid egg escapement model. This model is used to compute fishing mortality, proportional egg escapement and biomass. CDFW is currently using this model for long term monitoring of the fishery, by evaluating seasonal responses of the market squid population to fishing pressure. This research project seeks to optimize this model by developing new seasonal age and growth data for all life stages and by improving the computation of biological parameters such as potential fecundity, daily mortality, and daily rate of egg deposition.

The computation of these biological parameters relies on female reproductive tissue (ovary plus oviduct) and mantle tissue punches collected from fishery samples. For example, the residual

fecundity of individual squid (i.e. the standing stock of oocytes and ova in harvested females) is estimated using an equation combining gonad weight and a mantle condition index, which is the dry weight per surface area of each mantle punch. The original protocol for processing mantle samples was to dry the mantle tissue punches in a natural convection oven for 14 days at 56°C. The reproductive tissues were collected, placed in formalin, and weighed at a later date. This process, although successful, proved time and labor intensive given the number of samples that needed to be processed for the accurate and precise estimation of fishing mortality and egg escapement rates from the model. This amount of processing time was also identified to be one of the primary factors that have impaired the application of the model to the management of the fishery.

Using adult squid sampled collected by CDFW in 2014, we conducted an experiment at the Southwest Fisheries Science Center (SWFSC) to determine the optimal number of days that can be used to dry the mantle punches more efficiently. Further, a preservation experiment was conducted to estimate a conversion factor, for estimating formalin preserved gonad weight from fresh gonads. Likewise, egg escapement time series previously developed from preserved gonad weights (i.e., 1999-2009) can be used with fresh gonad weight data to build a new time series from 1999 to 2014. Finally, since 2014 age readings of statoliths have been conducted to develop growth parameters by region and season. Previous egg escapement models have used growth data collected in 1998 and 1999. These data are now outdated and thus a new time series needs to be developed to ensure the accuracy of model prediction in current years.

a) Mantle experiment results: We found no evidence that drying these tissues at a low temperature (56°C) for a prolonged period of time (i.e. 14 days) could be beneficial for deriving the mantle index condition. Rather, drying the mantles at 60°C for 3 days was as effective as drying them at 56°C for 14 days.

b) Gonad experiment results: A new equation has been derived to convert fresh gonad weight to formalin preserved gonad weight. Thus, a new time series of gonad weights from port sampling data has been recalculated from 1999 to 2014.

c) Ageing method results: Paralarvae, juvenile and squid statoliths have been aged and the new data are being used to develop a new time series for the egg escapement model from 1999 to 2014.

d) Application to stock assessment: We submitted a report to CDFW in the Fall of 2014 defining new procedures to process mantle punches and gonads for the derivation of residual fecundity based on the mantle condition index and gonad weights. Based on these new data, the development of the egg escapement can be done in a timely basis at the end of each season. These new data will be combined with the age and growth information to assess annually the market squid fishery.

Finally, results from this research will be used to provide the Pacific Fisheries Management Council (PFMC) information for developing management strategies for the market squid fishery. The results will be summarized in the Stock Assessment and

Fisheries Evaluation (SAFE) document, which will be publicly available on the PFMC website.

e) Publication: We are working on a draft manuscript entitled “*Optimizing biological parameterization in the egg escapement model of the market squid, Doryteuthis opalescens, population off California.*” This paper will be co-authored by Jenny McDaniel, Emmanis Dorval, and Julianne Taylor, and will be submitted to be the SWFSC internal review process in July 2015. We expect to submit the manuscript to the journal of North American Journal of Fisheries Management by the end of summer 2015.

### **3) Summary of Outreach: Education and Training Activities**

We have developed an outreach program for educating high school and undergraduate students interested in fisheries biology and for sharing the data with the public and management agencies. Specifically, we have:

- Continued our involvement with the Upward Bound (UB), the San Diego Metropolitan High School Learning through Internships/Interests (LTI) programs, and local high school programs:
  - March 10<sup>th</sup>, 2015: 30 high school students from the Del Lago Academy, Campus of Applied Science.
  - March 12<sup>th</sup>, 2015: 30 high school students from the Del Lago Academy, Campus of Applied Science.
- We have partnered with the San Diego Science Alliance Better Education for Women in Science and Engineering Program (SDSA- BEWiSE) to foster interest in scientific careers.
  - April 12, 2015: 30 students in the 8<sup>th</sup> and 9<sup>th</sup> grade;
- Recruited and hosted undergraduate students for summer internship, volunteer from different universities such as;

University California San Diego: Mohammad Sedarat;  
University of San Diego: Rachael Taylor;  
University of Southern Mississippi: Kaela Gartman.