

UC San Diego

Research Final Reports

Title

Assessing the Impact of Climate Change on the California Squid Fishery: An Integrated Approach

Permalink

<https://escholarship.org/uc/item/3d67w27z>

Authors

Marinovic, Baldo B.
Croll, Donald A.
Mangel, Marc S.

Publication Date

2003-07-30

ASSESSING THE IMPACTS OF CLIMATE CHANGE ON THE CALIFORNIA SQUID FISHERY: AN INTEGRATED ECOSYSTEM APPROACH

Baldo B. Marinovic
Institute of Marine Sciences
UCSC

Donald A. Croll,
Department of Biology,
UCSC

Marc S. Mangel,
Department of Applied
Mathematics and Statistics
UCSC

The overall objectives of this project were to:

- Establish the nature and magnitude of the link among the physical dynamics of coastal upwelling, primary production, krill production, and productivity of the most important commercial fish species in California (market squid, *Loligo opalescens*)
- Using the information from the first objective, construct models to explore various scenarios of the impacts of global climate change on nearshore krill and squid productivity.

The specific yearly goals of the project were:

2001-2002

1. Conduct field based surveys on physical oceanographic dynamics; phytoplankton abundance & distribution; and zooplankton (and in particular krill) composition, abundance & distribution within the Channel Islands National Marine Sanctuary (CINMS) and Monterey Bay National Marine Sanctuary (MBNMS).
2. Conduct diet analyses of larval, juvenile and adult squid collected from the CINMS and MBNMS.
3. Conduct laboratory based investigations on krill growth and development at different temperature and feeding treatments.
4. Develop models on krill population dynamics and prey availability to squid

2002-2003

1. Continue to conduct field based surveys of physical oceanographic dynamics; phytoplankton abundance & distribution; and zooplankton (particularly krill) composition, abundance & distribution.
2. Continue to conduct diet analyses of larval, juvenile and adult squid collected from the CINMS and MBNMS.
3. Continue to conduct laboratory based investigations on krill growth and development and different temperature and feeding treatments.
4. Implement models on krill population dynamics and prey availability to squid and empirically test model output using data collected during field surveys

ACCOMPLISHMENTS TO DATE:

Field Surveys & Diet Studies

A total of 15 surveys were conducted between March 2001 and February 2003 along a existing grid of 7 transects within the Monterey Bay Upwelling Center (MBUC). In addition 5 ancillary cruises were conducted to sample krill populations during the winter months. During these surveys approximately 150 CTD & Chlorophyll samples and 165 zooplankton samples were collected. In addition continuous sea surface temperature and hydroacoustic backscatter were collected along the survey grid. All hydrographic and acoustic data have been analyzed and all zooplankton samples have been processed for biovolume, broad taxonomic composition, and euphausiid (krill) abundance, species composition, and demographics.

In addition to the proposed survey work listed above, we participated in the annual spring rockfish cruises conducted by the Southwest Fisheries Center (NMFS) Santa Cruz Laboratory in the Spring (May/June) of 2002 and 2003. A total of 186 midwater trawls (84 in 2002; 102 in 2003) were conducted between Point Pinos and Point Reyes and processed for squid and krill abundance. A total of 10,414 squid were collected during these trawls (8721 in 2002 & 1693 in 2003) and processed, and a subset from each year were examined for diet contents. In addition a total of 28 squid samples consisting of a total of 1508 squid were collected from commercial sources in both Monterey Bay (18 samples; 882 squid) and the Channel Islands (10 samples, 626 squid). These samples consisted of individuals caught from spawning aggregations and they were similarly processed for size structure and demographics.

Modeling

During this work we expanded upon previous models investigating the relationship between squid population dynamics and environmental variability (Mangel et al, 2002). We analyzed the California squid fishery on within-season and between-season time scales. Within season analyses (empirical and modeling) suggest that cohorts of squid persist offshore and move inshore for reproduction throughout the season. In order to predict the timing of inshore movement of squid, we developed a life history model using stochastic dynamic programming. This model allows us to link squid growth and reproduction with environmental factors, particularly upwelling, temperature, and food abundance, in a consistent Darwinian framework. Using the model, we predict the timing of squid movement inshore in cold and warm environments, and the amount of biomass inshore. We have compared the model predictions with fishery independent data collected on the fishing grounds and considered the implications of our work for management of the squid fishery.

RESULTS OF PRELIMINARY ANALYSES:

Data collected on hydrographic and biological (phytoplankton & zooplankton) parameters within the MBUC during the survey work described above have 1) provided valuable additional data to our ongoing baseline for the region and 2) indicated some

interesting seasonal and interannual patterns for both zooplankton biovolume (abundance) and krill abundance.

Peak krill recruitment typically occurred in the spring and early summer for all years between 1997 and 2002, yet there was a high degree of variability between years in both the magnitude of recruitment and the persistence of krill abundance into the later summer and fall months (Fig 1b, 2a). For example krill recruitment was extremely high in the spring/early summer of 2000 and correspondingly low in the spring/early summer of 2002. Similarly, krill abundance in the late/summer and fall of 2000 & 2001 was on average twice that observed in the late/summer fall of 2002. Persistence of krill stocks appears to be a function of 1) the magnitude of recruitment and 2) The persistence of sufficient levels of sporadic coastal upwelling in the later summer and fall months (Fig 1a). This difference in patterns of recruitment and persistence was similarly reflected in patterns of growth between years. For example individuals recruiting to *Euphausia pacifica* stocks in the spring of 2001 demonstrated earlier recruitment and better growth & survival into the late summer that those observed in the following year (Fig 3).

Contrary to interannual patterns of krill abundance in the MBUC, a sharp and significant increase in zooplankton biovolume occurred between 1999 and 2000 (Figs 1c, 2b) which appears to be associated with the theorized shift in the Pacific Decadal Oscillation (PDO) from a warm to a cool phase following the 1997/98 El Nino event. Zooplankton biovolumes have continued to remain high through the end of 2002. In contrast, krill abundance, while demonstrating both high seasonal and interannual variability between 1997 and 2002, has demonstrated no net trend associated with this transition. Preliminary examination of the taxonomic composition of the zooplankton samples collected suggests that the large increase in biovolume is due to gelatinous forms, in particular salps in 2000 and 2001 and ctenophores and medusae in 2002. This pattern reflects similar results to those reported for zooplankton within the Southern California.

Analysis of squid diet revealed distinct differences between spawning individuals collected by commercial activity in the nearshore environment and those collected from the outer shelf and slope regions by midwater trawls. In general, squid stomachs collected from spawning individuals were largely empty while those collected from offshore stocks had a variety of diet items including krill (most abundant), copepods, fish, zoea/megalopa, and cephalopods. Currently we are in the process of analyzing the spatial relationships between krill and squid from data collected during the 2002 and 2003 rockfish surveys described above in an effort to better characterize squid foraging habitat within the central California region.

Preliminary examination of seasonal krill abundance and commercial squid landings in the Monterey Bay region indicate a positive correlation between the two, though it appears this is not a simple linear relationship (Fig 4). The impacts of the 1997/98 El Nino event show up clearly in both metrics. In addition squid catches are typically high in the late spring/early summer during the period corresponding to peak krill recruitment and high catches persisting into the summer months during years of higher krill abundance (eg 2001).

FUTURE WORK:

We intend to complete our analyses of krill/squid distributions collected during the 2002 & 2003 rockfish surveys and incorporate the data into our modeling efforts in order to further refine our understanding of the effects of seasonal/interannual environmental variability on squid population dynamics and life history strategy. We hope to present these results in the fall at the annual CalCOFI symposium as part of the invertebrate fisheries symposium. Furthermore we will continue to collect data on oceanographic parameters with the MBUC in coordination with our role in the newly formed, NOAA funded Center for Integrated Marine Technology (CIMT) and use this data to refine our understanding environmental variability and krill/squid population dynamics generated from the current investigation. More information on the CIMT may be found at its website: <http://cimt.ucsc.edu/siteNew/index.html>.

PUBLICATIONS AND TALKS RESULTING FROM THIS PROJECT:

Publications:

Submitted

Croll, D. A, B. B. Marinovic, S. Benson, F. P. Chavez, N Black, R. Ternullo, and B. R. Tershy. From wind to whales: Trophic links in a coastal upwelling system. Marine Ecology Progress Series.

Reum, J. C. and B. B. Marinovic. Thaliacean abundance in Monterey Bay, CA from 1998-2001 in relationship to oceanographic and productivity regimes. Marine Ecology Progress Series.

Ish T., E. J. Dick, P. V. Switzer, and M. S. Mangel,. Environment, Krill and Squid: From Fisheries to Life Histories and Back Again. Deep Sea Research, Topical Studies in Oceanography.

Talks:

Marc Mangel. Environment, Krill and Squid: From Fisheries to Life Histories and Back Again. Plenary talk, Third Colloquium on the Oceanography of the Eastern Pacific Ocean, CICESE, Ensenada, Mexico, September 2002

Teresa Ish. Environment, Krill and Squid: From Fisheries to Life Histories and Back Again: Poster presentation at the 4th Mote Symposium, Sarasota, FL in November 2002 (award: best poster by a young investigator).

Baldo Marinovic. Krill: constant currency in a fluctuating pelagic economy. Invited talk, Monterey Bay National Marine Sanctuary Currents Symposium, March 2003.

Baldo Marinovic. Zooplankton and Squid: Important forage species. Invited talk, Pelagic Predators, Prey and Processes: Exploring the scientific basis for offshore marine reserves, January 2002.

STUDENTS SUPPORTED BY THIS PROJECT:

Sibel Bargu, PhD in Marine Sciences at UCSC (completed 12/01). Thesis: Krill: Victim or vector? Examining the place and role of krill in domoic acid poisoning events in Monterey Bay, CA.

Teresa Ish, MSc in Marine Sciences at UCSC (completed 6/03), Thesis: Conceptual Tool for Managing Two Monterey Bay Fisheries. (Runner-up for the 'Most Outstanding Student in the Ocean Sciences Graduate Program).

Rosalyn Antrobus, BS in Biology at UCSC (completed 6/02). Senior Thesis: Examination of seasonal diet of krill using scanning electron microscopy. (awarded honors)

Johnathan Reum, BS in Biology at UCSC (completed 6/03) Senior Thesis: Thaliacean assemblages in Monterey Bay, CA: Possible environmental regulators of abundance. (awarded honors)

COOPERATING ORGANIZATIONS:

National Marine Fisheries Service – Southwest Fisheries Science Center, Santa Cruz Lab. Provided sampling support as part of a cooperative study on krill and squid distribution during their annual juvenile rockfish surveys.

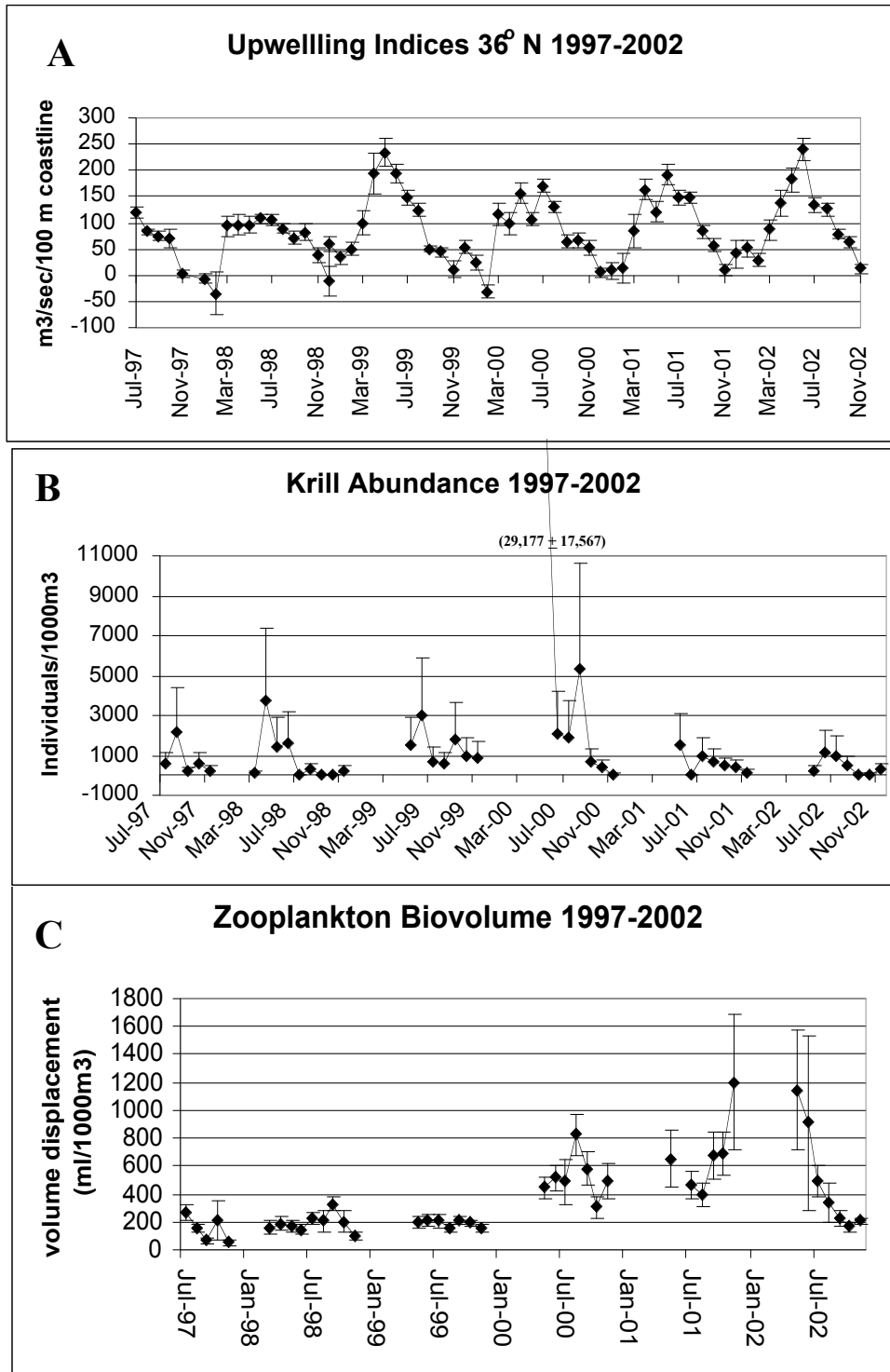


Figure 1. Oceanographic and Biological Parameters for Monterey Bay, CA for 1997-2002. A: Mean monthly upwelling indices (\pm se) for 36°N latitude. B: Mean monthly krill abundance (\pm se) collected in seasonal net tows within Monterey Bay. C: Mean monthly displacement volume (\pm se) collected in seasonal net tows within Monterey Bay.

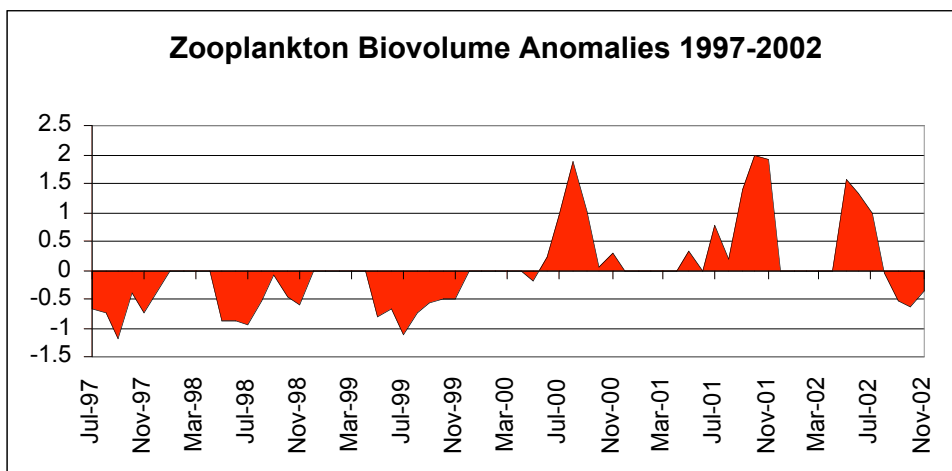
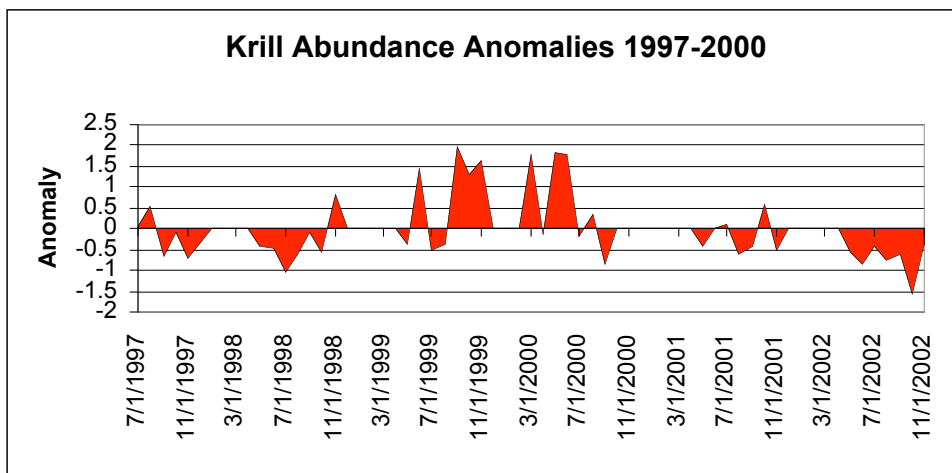


Figure 2. A: Monthly anomalies for krill abundance collected within Monterey Bay based on the long term mean between 1997-2002.. C: Monthly anomalies for zooplankton displacement volumes collected within Monterey Bay based on the long term mean between 1997-2002.

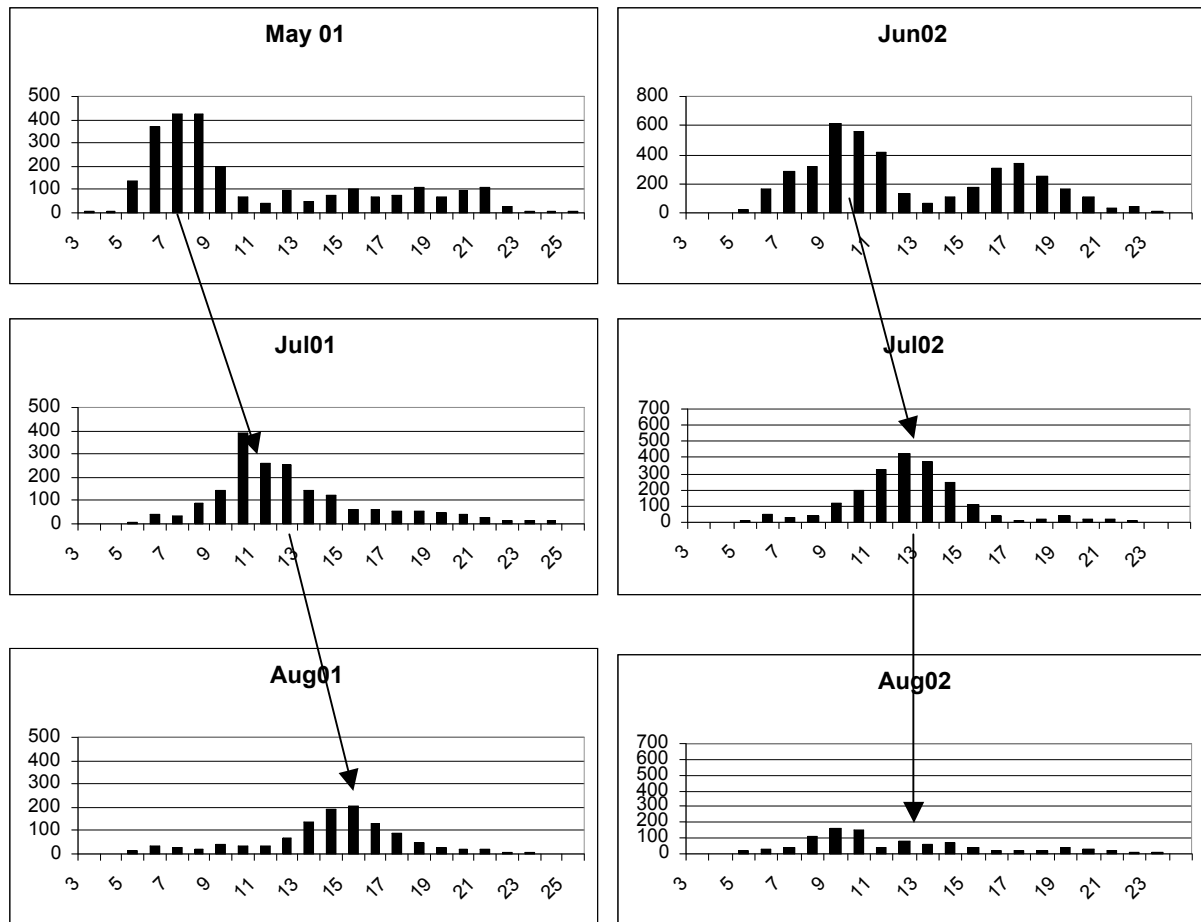


Figure 3. Length frequency distributions (# per 1000 m³) for *Euphausia pacifica* individuals collected in net samples within Monterey Bay, Ca in the spring and summer of 2001 (A) and 2002 (B). Note, y axis scale is not the same for different years.

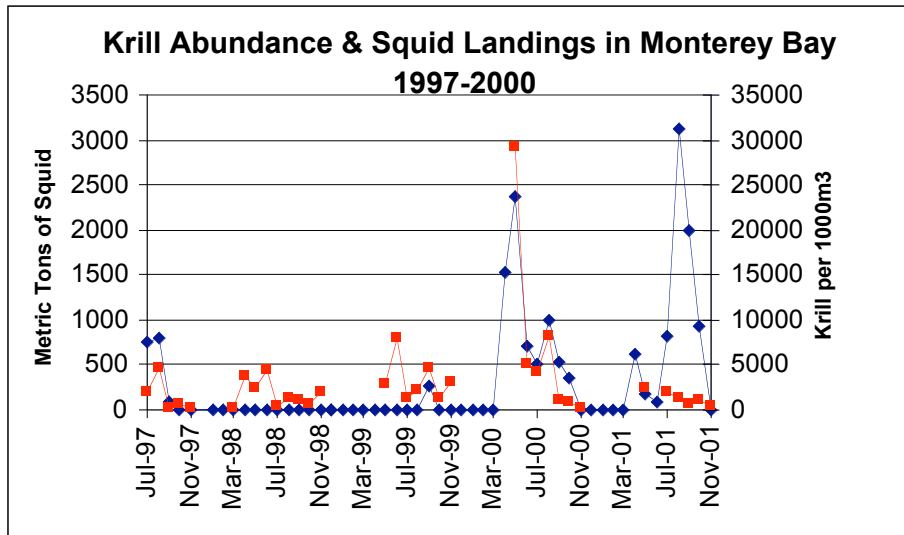


Figure 4. Relationship between krill abundance (red) and squid landings (blue) in Monterey Bay between 1997 and 2001. Squid landing data from the PFEG live access server:
<http://www.pfeg.noaa.gov/>