Part II

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ENVIRONMENTAL VARIABILITY AND ITS IMPACT ON INVERTEBRATE FISHERIES

The importance of oceanic conditions for the productivity of marine fisheries is increasingly being acknowledged. Environmental fluctuations on interannual and interdecadal time scales (Hare and Mantua 2000) complicate fishery science and management. Intense fishing pressure, more suited for highly productive conditions, can interact with poor environmental conditions and result in stock depletion. In the eastern Pacific it has long been recognized that populations of fish and the organisms they interact with respond to short-term El Niño Southern Oscillation (ENSO) events as well as to Pacific Decadal Oscillations (PDO), that is, interdecadal ocean "regimes" of warm or cool ocean conditions (Ebbesmeyer et al. 1991; Mantua et al. 1997). Sardine populations appear to have increased dramatically during the last interdecadal warm period (Jacobson and MacCall 1995), which suggests they are a "warm-water species," while rockfish (Love et al. 1998) and salmonid populations appear to have declined under these conditions (Mantua et al. 1997).

Less is known about the impacts of ocean conditions, both short- and long-term, on invertebrate populations and fisheries. Clearly, ocean conditions affect invertebrate fisheries, as is dramatically demonstrated by California's market squid (*Loligo opalescens*) fishery, which nearly collapses during El Niño events. One of the mysteries associated with this phenomenon is how squid populations rebound after warming events given their short life span (< 1 year). Long-lived invertebrates, such as red abalone (*Haliotis rufescens*) off southern California, are also affected by El Niño, exhibiting lower growth rates in warmer water (Haaker et al. 1998) and indirect effects from reductions in the quantity and quality of kelp food resources (Vilchis et al. 2004).

The increasing demand for marine invertebrate resources worldwide magnifies the importance of understanding the relationship between ocean conditions and invertebrate productivity. In California, invertebrate fisheries have surpassed finfish fisheries in both volume and ex-vessel price, making them among the most important fisheries in the state (Rogers-Bennett 2002), as is the case elsewhere (Caddy 1989). Fished marine invertebrates are a diverse group that exhibit a wide range of life-history strategies, from short-lived species that have mating behaviors (e.g., market squid) to long-lived, free-spawning species (e.g., sea urchins, *Strongylocentrotus franciscanus*) that have a variety of larval planktonic periods. However, little work has been done with invertebrate fisheries to weigh the potential benefits of fixed versus variable management and recovery strategies in response to variable environmental conditions (MacCall 2002). If we are to better manage this diverse group, we need to have a more mechanistic understanding of the relationship between environmental variability and marine invertebrate productivity so that these factors can be explicitly incorporated into population and fishery models.

The articles in this section are based on presentations given at CalCOFI's 2003 symposium "Environmental Variability and Its Impact on Invertebrate Fisheries."[1] Christian Reiss and his coauthors describe the dramatic effects of warm-water El Niño events on squid paralarvae during winter in the Southern California Bight and on adults during summer in the California Current. They show that temperature at hatching plays a significant role in the variability of mean growth rates of squid, and they present an age-based, temperature dependent population model for squid.

J. M. (Lobo) Orensanz and his coauthors describe a basinwide contraction in the geographic distribution of female snow crab (*Chionoecetes opilio*) in the eastern Bering Sea that started with the positive PDO warming phase three decades ago. Subsequent cooling in the 1990s,

[1]Several presentations made at the symposium were not submitted for publication in *CalCOFI Reports*.

however, did not result in southern crab reoccupying its historical grounds, possibly as a consequence of the expansion of predatory cod or of impediments to larval dispersal. The authors propose an "environmental ratchet hypothesis" in which grounds lost during warm periods may not be reoccupied during cool periods, a feature that may be generally applicable to benthic invertebrate populations.

Juan Valero and his coauthors describe a steady decline in recruitment of geoduck clams (*Panopea abrupta*) from 1940 to 1970 followed by a post-1975 recovery that correlates with two environmental variables: sea surface temperature (positively) and river discharge (negatively). This recruitment pattern appears to be geographically coherent between British Columbia and Washington State and consistent with the hypothesis that large-scale climactic forcing drives these patterns.

Chris Harley and Laura Rogers-Bennett examine the potential combined effects of climate change and fishing on exploited intertidal invertebrate populations. Intertidal populations are particularly vulnerable to climate change since many species live at their physiological extremes and are exposed to both atmospheric and oceanic conditions. The authors use three case studies to demonstrate how species-specific life-history traits and fishing intensity influence the effects of climate on populations, as well as how there may be synergistic interactions between fishing and climate.

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LITERATURE CITED

Caddy, J. F. 1989. Marine invertebrate fisheries: their assessment and management. New York: Wiley.

Ebbesmeyer, C. C., D. R. Cayan, D. R. Milan, F. H. Nichols, D. H. Peterson, and K. T. Redmond. 1991. 1976 step in the Pacific climate: forty environmental changes between 1968–1975 and 1977–1984, pp. 115-126. *In* Proceedings of the Seventh Annual Climate (PACLIM) Workshop, eds. J. L. Betancourt and V. L. Tharp, eds. Calif. Dep. Water Res., Interagency Ecological Studies Program Tech. Rep. 26.

Haaker, P. L., D. O. Parker, K. C. Barsky, and C. S. Y. Chun. 1998. Growth of red abalone, *Haliotis rufescens* (Swainson), at Johnson's Lee, Santa Rosa Island, California. J. Shellfish Res. 17:747–753.

Hare, S. R., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in Pacific North America. Prog. Oceanogr. 47:103–145.

Jacobson, L. D., and A. D. MacCall. 1995. Stock-recruitment models for Pacific sardine (*Sardinops sagax*). Can. J. Fish. Aquat. Sci. 52:566–577.

Love, M. S., J. E. Caselle, and W. Van Buskirk. 1998. A severe decline in the commercial passenger fishing vessel rockfish (*Sebastes* spp.) catch in the Southern California Bight, 1980-96. Calif. Coop. Oceanic Fish. Invest. Rep. 39:180–195.

MacCall, A. D. 2002. Fishery-management and stock-rebuilding prospects under conditions of low-frequency environmental variability and species interactions. Bull. Mar. Sci. 70:613–628.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bull. Am. Meteorol. Soc. 78:1069–1079.

Rogers-Bennett, L., ed. 2002. Review of some California fisheries for 2001: Market squid, sea urchin, Dungeness crab, lobster, prawn, abalone, groundfish, swordfish and shark, Coastal Pelagic finfish, ocean salmon, nearshore live-fish, Pacific herring, white seabass, and kelp. Calif. Coop. Oceanic Fish. Invest. Rep. 43:13–30.

Vilchis, L. I., M. J. Tegner, J. D. Moore, C. S. Friedman, K. L. Riser, T. T. Robbins, and P. K. Dayton. 2004. Effects of ocean warming on the growth, reproduction, and survivorship of red and green abalones in southern California: implications for restoration and recovery of depleted stocks. Ecol. Apps. 15(2):469–80.