Simulated influence of the 1976-77 regime shift on anchovy and sardine in the California Current System

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The well-known 1976-77 regime shift in the Pacific Ocean affected many species in the California Current System (McGowan et al., 2003). Chavez et al. (2003) labeled the periods before and after the 1976-77 regime shift as a cool “anchovy regime” followed by a warm “sardine regime.” However, the responses and mechanisms for what happened in that period for the Northern anchovy (*Engraulis mordax*) and the Pacific sardine (*Sardinops caeruleus*) in the California Current remains elusive.
In this study, we used a fully-coupled end-to-end model (Fiechter et al., 2015; Rose et al., 2015) to simulate the variation in population dynamics of anchovy and sardine for past 50 years. This model is a multi-species, spatially explicit (3D), time-evolving, and consists of four coupled submodels (hydrodynamics, Eulerian nutrient-phytoplankton-zooplankton-detritus (NPZD), an individual-based full life cycle anchovy and sardine model; agent-based fishery). The end-to-end and spatial detail features of the model allows us to not only simulate population dynamics but also to analyze the bottom up effects of environmental variation on the temporal and spatial dynamics of the populations.
Analysis of a 50-year historical simulation (1959-2008) showed that anchovy recruitment (survival to age-1) was lower just after 1977, while sardine recruitment was relatively unaffected by the regime shift. These different responses to the 1976-77 regime shift have been hypothesized to be a contributor to the species replacement from anchovy to sardine observed in the 1980s. The recruitment success of both species was influenced by the growth and survival of individuals in the larval stage. The modeled zooplankton density shift from high to low in 1976-77 was most drastic in winter in the coastal area. Anchovy larvae feed extensively in the winter in the coastal area, while sardine larvae were mainly distributed in the offshore area in the spring. The differential seasonal and spatial responses of zooplankton in the simulation caused anchovy recruitment to be more sensitive than sardine to the 1976-77 regime shift. The zooplankton shift itself was a result of the nutrient concentration changes in surface layer. Nutrient concentrations decreased from 1977 due to the weakening of both the coastal upwelling and mixed layer shoaling, which reduced the vertical nutrient flux from the bottom layer to the surface layer.
Our end-to-end modeling approach provided a consistent analysis that linked the climate regime shift to anchovy and sardine population responses. In addition, our results suggest a possible mechanism for the responses related to seasonal and spatial aspects of the nutrient dynamics affecting the food for larvae that lead to a negative effect on anchovy recruitment and relatively little response of sardine. These results support the idea that anchovy and sardine populations are controlled by the different environmental factors related to their differences in habitat niches (Rykaczewsk and Checkley, 2008).

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