

Part II

SYMPOSIUM OF THE CALCOFI CONFERENCE, 2009

FORECASTING FISHERY PRODUCTIVITY IN THE CALIFORNIA CURRENT

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The ability to forecast the productivity of fisheries has been a goal of fisheries managers for 100 years (Hjort 1914). Fisheries are challenging to predict for many reasons, including wide fluctuations in recruitment success between year classes, poorly known stock-recruit relationships and dramatic differences in ocean conditions between years (Cushing 1982, Fogarty et al. 1991, Mullin 1994). For many commercially important species, recruitment is irregular and strong year classes often sustain the fishery between recruitment droughts that may last a decade or more. Researchers are starting to find relationships between recruitment and physical oceanographic parameters as our understanding of the role of physical forcing on marine populations expands. In some cases, specific mechanisms linked to physical oceanographic conditions (forcing) appear to drive recruitment success (e.g., Gaines and Bertness 1993, Botsford et al. 1994, Peterson and Schwing 2003). This important first step, describing relationships between recruitment and ocean conditions, is in and of itself useful in forecasting fishery productivity. We know for example, that years with warm ocean temperatures are “good” for sardines and this can information has been incorporated into fishery harvest control rules (Conser et al. 2001). The 55-year CalCOFI time series encompasses a wide range of ocean conditions and is uniquely suited to examine relationships between larval abundances and ocean condition. The papers presented in this symposium explore a wide array of approaches examining the potential for and utility of forecasting productivity of various species of commercially important stocks.

Field et al. explore the use of four sources of data of juvenile bocaccio (*Sebastes paucispinus*) abundance to see if their inclusion improves stock assessment results. The current stock assessment model uses the age-structured Stock Assess III model which incorporates fishery-dependent and -independent data such as larval data (CalCOFI), trawl surveys and juvenile abundance data. Here they evaluate the performance of the 4 additional recruitment indices by re-running the model with and without the juvenile indices. Field et al. find that the

re-run model results for biomass trends and recruitment estimates are nearly identical to those from the original stock assessment model. They also find that recruitment indices can overestimate recruitment before the year class shows up in the fishery-dependent size-frequency data. Bocaccio populations appear to be dominated by highly variable recruitment events which significantly impacts rebuilding targets.

Caselle et al. describe the development of an index of rockfish (*Sebastes* spp.) recruitment in southern and central California and relate this to indices of ocean condition. They focus on two groups of nearshore rockfishes recruiting to artificial collectors at 5 sites starting in 2000. They find that south of Point Conception annual recruitment of the two groups occurs together and is strongly correlated with upwelling in the summer months. In central California, annual recruitment in the two rockfish groups are not concordant, with one group correlating well to upwelling in the summer months while the other group had highly variable recruitment uncorrelated with physical oceanographic indices.

Hannah shows how a pre-recruitment index was used to improve forecasts of productivity in the Oregon ocean shrimp (*Pandalus jordani*) fishery. An index of pre-recruits (age-0) was developed in northern and southern Oregon from 1980 to the present. For northern Oregon, incorporation of the pre-recruit index into the best environmental model improved the model fit, while fit was not improved for the southern Oregon fishery model. The southern Oregon model while unable to predict recruitment failures during the 1983 and 1998 ENSO events was able to predict the strong year class in 2009.

Shanks et al. developed an index of Dungeness crab (*Cancer magister*) megalopae abundance in spring in southern Oregon. They examined the use of this index as a predictor of the strength of the commercial fishery four years later when the cohort recruited to the fishery. During the first 6 years there was a strong correlation between the larval index and the commercial catch four years later; strong commercial catches were associated with early onset of the spring transition and upwelling.

However, this correlation broke down in the last three years when annual larval numbers in the traps jumped from 1,000–80,000 (1997–2001) to 1.2–2.4 million (2007–2009). There was a strong negative correlation with day of the spring transition and megalopae index in 1997–2001 but this relationship also breaks down during the high catches in 2007–2009. These new megalopae catches equate to a commercial catch greater than 10 times the record catch, however density-dependent mortality of juvenile crabs may affect recruitment more strongly during large recruitment years.

Lastly, White and Rogers-Bennett explore the use of physical oceanographic variables as proxies for recruitment success in both traditional and spatially explicit models of fishery productivity. Using Caselle et al.'s results for kelp rockfish as an example, they find that when the proxy is a good predictor ($r > 0.8$) of actual larval survival there was a strong correlation between the proxy and recruitment especially when recruitment was variable. In the spatially explicit model, the same held true for incorporating the proxy into the model and larval dispersal distances did not influence the utility of the proxy. The use of the proxy improved the model predictions over years in which there was recruitment information but was less effective beyond the time to grow into the fishery. This paper provides an example of how oceanographic indices reflecting ocean condition can be incorporated into fishery models.

The papers in this symposium are examples of advances being made in our understanding of how fisheries productivity and major recruitment events are influenced or driven by ocean conditions. These papers also illustrate some of the challenges that remain, primar-

ily understanding the scale over which productivity indices operate. It is also clear that strongly predictive indices may break down in the face of long-term oceanographic regime changes, and/or may not extend to oceanographically distinct regions. Working with these caveats will be crucial to moving forward in our understanding of the links between oceanographic conditions and fisheries. We encourage future research to build on the work presented here to develop indices as predictive tools for improving fisheries ecology and management.

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