Environmental models for marine mammal stock assessments

Karin A. Forney
Southwest Fisheries Science Center
Santa Cruz, CA

A well-recognized challenge in marine mammal stock assessments is the impact of environmental variability on estimates of stock abundance and population trends. This is a particular problem in dynamic ecosystems marked by pronounced seasonal and interannual variability in oceanographic conditions, such as the California Current System. Marine mammals are long-lived and generally respond to environmental variability in two ways: 1) true changes in abundance, attributable to changes in survival and reproduction of individuals, or 2) changes in the distribution or arrangement of animals. In the latter case, uncertainty is introduced into stock assessments and trend analyses, because the proportion of the population that is sampled may differ from year to year and sampling variances may not be constant. Environmentally explicit models can aid in distinguishing true changes in population size from apparent fluctuations caused by such sampling variability. Static environmental variables, such as bathymetry, distance to coast, and bottom characteristics, are generally taken into account during the design of sampling programs. Dynamic features, such as water temperature, salinity, frontal structures, prey availability, and weather factors, must be sampled during marine mammal surveys and subsequently included as covariates in the analysis of abundance time series. Most of these measures are proxies for more complex and poorly understood processes that influence the distribution of marine mammals.

A recent example in which environmental models helped to resolve uncertainties in population trends involves the central California stock of harbor porpoise, *Phocoena phocoena*. An initial trend analysis of survey data collected from 1986-1995 suggested a population decline, despite low statistical power and an absence of apparent explanatory causes. When a measure of oceanographic condition, the monthly average sea surface temperature anomaly, was included as a covariate in the framework of generalized additive models, the apparent decline disappeared and a stable population was indicated. This suggests that environmental factors affected the availability of animals during each survey, either because individuals moved out of the study area or because their distribution within the study area had changed. Large-scale movements of harbor porpoise off the U.S. West Coast are considered unlikely based on pollutant studies and molecular analyses that indicate limited movement. A redistribution of animals within the study area is supported by interannual difference in the clustering behavior of animals off central California during the 1986-1999 surveys. Changes in clustering can affect sampling variances, causing standard regression analyses to perform poorly when investigating trends in abundance. Efforts are currently underway to measure porpoise clustering behavior and identify potential relationships with environmental variables during fine-scale surveys in central California. The inclusion of environmental variables that may affect clustering behavior is expected to improve trend analyses and stock assessments for this species in the future. Such methods of environmentally explicit stock assessments also have broad application to other marine mammal species.

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George M. Watters

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