

Workshop Considers Biotic Impacts of Extratropical Climate Variability in the Pacific

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Fisheries collapse in the Pacific Northwest. Fisheries resurge in Alaska. Such headlines reflect changes in the Pacific biosphere, occurring at all trophic levels from plankton through sea birds and at all scales from a few kilometers of patchiness to nearly synchronous changes across distances of 10,000 kilometers. Are the large-scale, Pacific-wide changes in the biosphere a response to changes in the physical ocean environment, itself linked to large-scale ocean-atmosphere changes? Plankton biologists, fisheries researchers, marine mammal and bird specialists, physical oceanographers, statisticians, and climate dynamicists tackled this question at the tenth 'Aha Huliko'a Hawaiian Winter Workshop.

Diagnostic studies of the Pacific-wide climate system have identified recurring spatial patterns on interannual through decadal time scales. Similar patterns are seen in related atmospheric and oceanic fields such as sea level pressure and sea surface temperature. These patterns are usually characterized by, e.g., the El Niño-Southern Oscillation and the Cold Tongue Index. North Pacific climate variability is also in the Pacific North America and North Atlantic oscillation patterns among others. A surprisingly strong teleconnection, called the Arctic oscillation has been found between the Aleutian and an Arctic-Asia pressure pattern.

Time series of many of these indices show a "regime shift" around 1976-1977. The reality of this regime shift drew a good deal of discussion, if not resolution, at the workshop. Because time series are short, it is difficult to distinguish regime shifts and periodicities from continuous low-frequency variability with a red spectrum, as exhibited by climate simulations with present-day coupled ocean-atmosphere general circulation models.

El Niño has long been recognized as a powerful influence on Pacific marine ecosystems in both low and high latitudes. Participants considered how El Niño interacts with the extratropics and how it might affect lower frequency variability. With the 1997-98 El Niño in progress at the time of the workshop it was natural to compare the evolution of that event with the strong El Niño of 1982-1983. The 1982-1983 event originated in the tropics, followed by coastal signals that propagated to higher latitude, but the elevated temperatures around the Gulf of Alaska were concurrent with, or preceded, the 1997-1998 event. Ocean currents advected thermal anomalies from mid-latitude central Pacific surface waters to low-latitude western Pacific intermediate depths in approximately eight years.

Mechanisms of physical variability were explored in basinwide ocean models. A 30-year hindcast showed both thermal and wind-forced anomalies propagating westward from the North American coast, inducing circulation changes in the subpolar gyre and, phase-lagged, in the subtropical gyre. An intense cooling during the 1982-1983 winter induced a particularly strong response. Anomalous sea surface temperatures after 1976 may have been caused by a shift in wind patterns without anomalous thermal forcing.

Possible relationship to these patterns and mechanisms of physical variability were discussed in a review of variations in marine populations of plankton, mammals, and birds, through fish through birds. Phytoplankton data have been collected from many stations in the subpolar North Pacific. In particular, one observes a sharp decline in phytoplankton production over the central and western subpolar gyre, and increased production in the Oyashio region following the apparent regime shift in 1977. Impacts at phytoplankton levels are reflected also in higher trophic levels, as seen in shifting patterns of greater success and failures among competing species of copepods. Even when plankton biomass populations may not clearly reveal changing patterns, such changes are often seen under other photosynthetic parameters.

Economic concern for biotic impacts arises in cases of commercial fisheries. Large spatial scales and temporal scales of fluctuations in recruitment point to an environmental role in fisheries population. Dramatic changes to many Pacific salmon populations, as well as steelhead trout, took place following the 1977 climatic regime shift. In the past two decades, Alaska salmon production has been exceptionally high while in Oregon, Washington, and southern British Columbia salmon production has been quite low. Further alarming decreases in Oregon coho and British Columbia coho and steelhead populations suggest another oceanic climate regime shift around 1990. However, recruitment success is influenced by other effects as well and this may distort any clear correlation with physical indices. In groundfish stocks one has to consider the "storage effect" since groundfish of different year classes live together. In longer lived iteroparous stocks, the reproductive potential resulting from recruitment success is stored for several years.

Impacts of the physical environment are seen also at higher trophic levels, in mammals and birds. Declining populations of monk seals on Hawaii might be attributed to lower trophic level food limitation, in turn affected by apparent shifts in ocean temperature and mixed layer depths. Declines also are

seen in Steller sea lions, harbor seals, and fur seals throughout much of their range in the North Pacific. At the same time, shifts are apparent in patterns of seabirds such as kittiwakes and murre. This might be correlated with ocean temperatures or larger regime shifts. In so many of these situations it is difficult (and dangerous) to infer causal relations on the basis of observed correlations. However, such widespread synchronous physical and biological changes point toward mechanistic relations between a dynamic environment and living systems.

There will be ongoing need for more complete spatial and temporal observational databases in which to inquire about possible physical-biotic relations. An example of such a program is seen in the Hawaiian Ocean Time-series (HOT), which records changes in the physical upper ocean along with nutrients, oxygen and dissolved, suspended and sinking organic matter. Such surveys also have been reported also in marginal seas of the western Pacific and are an ongoing concern of the North Pacific Marine Science Organization.

Alongside expanding databases, there are developing ideas and numerical models. Competing limitations on primary productivity because of available illumination and adequate nutrient supply suggest an "optimal stability window," such that large-scale influences on ocean stability may impact shifting populations not only for plankton but all along the food chain. Quantitative aspects of these relations demand

numerical modeling, transporting multiple trophic levels through the vertical structure of a model with details of oceanic turbulence. Processes under investigation in one-dimensional (vertical) models can be strongly modified by three-dimensional eddies and fronts, phenomena that also are investigated with numerical modeling. Even simple biology-only models yield aperiodic interannual and interdecadal fluctuations; understanding the complexity of physical-biological interactions in increasingly ambitious models is a daunting challenge.

The scope of widespread biotic changes, ranging from photosynthetic parameters in phytoplankton up through fish, mammals, and birds, and the possibility that these impacts are linked to large-scale climatic shifts, pose a wealth of tantalizing research questions. Addressing these questions invites broad perspective, both across disciplines from life sciences to physical sciences and within disciplines ranging from field observation, theoretical construction, and numerical modeling.

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