

# Forecasting Northeastern Pacific Ecosystem Responses to La Niña

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A decade of coastal ecosystem studies in the northeastern Pacific Ocean (NEP) have been carried out by the U.S. Global Ocean Ecosystems Dynamics (GLOBEC) program. Our understanding of how these ecosystems respond to climate forcing was assessed by way of a forecasting exercise conducted during the annual GLOBEC-NEP scientific investigator meeting held 24–25 September 2007 in Seattle, Wash. The forecasting exercise used a real-life situation as a means of identifying the strengths and gaps in the understanding of climate/ocean physics/ecosystems interactions. The nature of the exercise was not divulged ahead of time, in part to encourage interactions among participants, and also to simulate conditions under which such requests are made by the media or by local regulatory agencies and policy makers.

The exercise began with a presentation of climate predictions for the ensuing 12 months, as provided by the U.S. National Oceanic and Atmospheric Administration's (NOAA) Climate Prediction Center and other groups. La Niña conditions developed in the tropical Pacific during the summer of 2007, leading to an expectation that La Niña conditions would persist into 2008. The charge to the workshop participants (oceanographers, marine ecologists, and fisheries scientists) was to consider the 12-month La Niña forecast in developing projections of potential conditions and consequences for the marine ecosystems of the California Current System (CCS) and the coastal Gulf of Alaska (CGOA).

Three independent groups of experts—each of which included approximately 12 scientists, with some effort to include diverse expertise (balance of CCS/CGOA and climate/physics/biology)—provided forecasts of the ecosystem consequences of an extended La Niña, including estimates of each group's certainty (or confidence) of their predictions (Table 1). In addition, each group developed advice for fisheries management and monitoring strategies appropriate for the situation.

There was strong consensus within and among the groups on most projections, especially for atmospheric forcing and physical ocean conditions, and for many biological parameters as well. For other projections, such as the impact of winds on vertical mixing and nutrient concentrations in the CGOA, there was disagreement among groups (Table 1, italic entries) or low confidence, due in some cases to disagreement among experts within a group.

The process of gathering and consolidating expert opinions revealed limits of predictability due to the lack of mechanistic understanding, scarcity of observations of current conditions, and high intrinsic variability in certain parameters.

## *Expert Opinions and Confidence Levels*

Table 1 summarizes the opinions of the three expert groups. Forecasts that a group felt could be stated with high confidence (>90–99% certainty) are indicated with two asterisks, while those that could be anticipated with moderate confidence (>66–90% certainty) are indicated with one. The lack of an asterisk indicates a prediction that is more likely than not to occur, but with lesser confidence attached.

In general, there was more unanimity in predictions of CCS impacts among the groups than in the forecasts for the CGOA. This was true for both physical oceanography and the biological responses to the La Niña conditions. Several groups considered preconditioning (e.g., the observed recent conditions and changes of the systems, especially in the CCS) of the marine ecosystems in developing their forecasts. Confidence in forecasts was possible because of reasonably good time series observations of recent physical and biological conditions in the CCS. The reason for greater uncertainty and some group-to-group differences in the CGOA may have been that there were fewer recent observations of the CGOA than of the CCS.

Another tool used in this assessment by the groups was historical precedent—e.g., comparing the evolution of the current La Niña-like conditions to prior events—in a comparative approach. One group (group 3) considered the CGOA region as two separate subregions (northern Gulf and southeastern Gulf) because of anticipated differences in La Niña storm tracks and rainfall patterns and the impact on the productivity of the systems in these two subregions.

All three groups noted the importance of monitoring, in that knowledge of recent conditions and trends is necessary to make predictions with high confidence. Increased monitoring was recommended for the northern portions of each region, since they represent the habitat for the majority of the juvenile chinook and coho salmon of the CCS, and the habitat during an important life stage of pink salmon in the CGOA. The inner channels of southeastern Alaska, where there are few direct observations, were also mentioned as a region of special interest.

Effective monitoring of physical conditions could be attained by a combination of real-time reports from a few moorings and regular surveys by gliders. These semi-automated observation platforms would need to be complemented by dedicated research vessels to provide biological and physical data from intermittent, adaptive sampling and by satellite remote sensing. The consensus of the workshop participants was that these measurement programs would be valuable every year and that an impending La Niña should not necessarily dictate a change in coastal ecosystem monitoring.

## *Insights From the Exercise Process*

The process of forecasting by expert groups was illuminating. Consensus on some projections was readily achieved (especially for atmospheric and physical processes, and more commonly for the CCS than for the CGOA). There was more debate about other impacts that La Niña might have on these systems—particularly on higher trophic level responses that might have complex multidisciplinary processes determining specific responses. The exercise was effective in identifying what we know, and where, and our confidence regarding future (short-term, 6- to 12-month) forecasts. Perhaps more important, the process identified crucial aspects of the system that we do not understand or monitor sufficiently to make reliable forecasts.

The participants also discussed the extent that GLOBEC-funded research in the northeastern Pacific has contributed new essential knowledge on these systems that enables predictions of this sort. There was a general feeling that GLOBEC-NEP research over the past decade has significantly advanced our knowledge of how climate change and variability affect lower trophic production, community structure, and higher trophic levels in the CCS. GLOBEC research in the CGOA has shown that lower trophic level communities also vary in abundance, species composition, and dynamics from year to year, with implications for predators such as pink salmon.

For the CGOA, however, there appears to be less mechanistic understanding of the factors involving the bottom-up forcing, and this contributed to a reluctance of the experts to make predictions with high confidence for the CGOA. An additional factor may be that based on past events, La Niña appears to have more systematic impacts on coastal ocean ecosystems in the south (CCS) than in the north (CGOA).

With regard to the predictions itemized in Table 1, we can now say that the forecasts of the physical conditions for the NEP are verifying well as a whole. It will be interesting to see how well our biological predictions turn out.

**Table 1.** Forecasts and Confidences in Northeastern Pacific Responses to La Niña<sup>a</sup>

Element	Expert Group 1	Expert Group 2	Expert Group 3
<b>CCS Atmosphere</b> SLP anomaly Upwelling winds Precipitation	offshore ridge** strong** wet N*; dry S* (winter*; *spring*)	offshore ridge** strong** wet N*; dry S* (winter–spring)**	offshore ridge** strong** wet N*; dry S* (winter–spring)**
<b>CCS Ocean</b> SST Southward transport Stratification Salinity Spring transition Hypoxia Eddy activity	cool* high* weak* ... early* high* ...	cool* high* weak* fresh N; salty S early* high* ...	cool** ... weak* fresh N*; salty S* ... high* high*
<b>CCS Biology</b> Primary productivity Zooplankton community composition Juvenile salmon survival Adult salmon return Other species	high* high boreal*; low subtropical* high* ... ...	high* high boreal*; low subtropical* high* high N*; low S high squid*	high* high boreal**; low subtropical** high* high (2009–2010)* high HAB potential high tuna offshore* high hake (U.S.)*
<b>CGOA Atmosphere</b> Downwelling winds Wind mixing <i>Air temperature</i> Precipitation	weak* weak cool* dry*	weak* weak warm* dry*	weak* weak cool* dry N*; wet S
<b>CGOA Ocean</b> SST Stratification ACC transport <i>Nutrient concentrations</i> Eddy activity	cool* weak weak* low ...	cool* weak weak* high* ...	cool* ... weak* high* high at shelf break*
<b>CGOA Biology</b> Spring bloom timing Primary production Secondary production Juvenile salmon survival Adult salmon return Other species	late ... high ... ... ...	... high* ... high* ... high Shelikof Strait pollock*	late high high* high* high jack and adult* ...

<sup>a</sup>Two asterisks means high (>90%) certainty; one asterisk means moderate (>66–90%) certainty; no asterisk means average (>50–66%) certainty for the California Current System (CCS) and coastal Gulf of Alaska (CGOA) regions. N and S refer to northern and southern subregions, respectively. Ellipses mean no prediction was made. ACC, Alaska Coastal Current; HAB, harmful algal blooms; SLP, sea level pressure; SST, sea surface temperature. *Italic* indicates where different expert group opinions differed.

The participants found the exercise worthwhile. Several participants commented that the exercise made them think about what they knew and how confident they were in that knowledge.

On the basis of our experience, we would recommend that other groups—

particularly those involved in multidisciplinary endeavors—consider carrying out similar expert opinion prediction exercises. The exercises may be particularly useful for identifying gaps in knowledge that might be addressed by future research programs.

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