Mapping Human Impacts to Marine Ecosystems in the California Current: Summary of NCEAS Research

Coastal development, marine pollution, and commercial fishing are among a wide range of human activities that impact ocean ecosystems off the coasts of California, Oregon, and Washington. Yet little is known about how those activities are distributed, where they overlap, and what their cumulative impact is on specific ecosystems. Recently, scientists from several academic and non-governmental institutions, working through the National Center for Ecological Analysis and Synthesis (NCEAS), created a model to analyze and map human impacts to ocean ecosystems using the most comprehensive data and approach to date. Since applying this model on a global scale (results published in *Science*, February 15, 2008), they have refined it and are applying it at a regional scale to the California Current, an area that extends from the US-Canada border to central Baja, Mexico. The overall goal of this research is to estimate and visualize the overall human impact on California Current ecosystems.

What makes this model unique?

Past studies of human impacts on the ocean have largely focused on single activities or single ecosystems in isolation. In addition, previous maps of impacts have not accounted for the fact that different ecosystems respond differently to different activities, and that many different human activities often affect the same place. The NCEAS model analyzes the cumulative impact of human activities, explicitly accounts for differences in how each marine ecosystem responds to the stresses from these human activities, and displays the results in a high-resolution map.

How did they create the maps?

Researchers gathered maps of the 19 major ecosystem types in the California Current (e.g., beach, salt marsh, rocky reef, seagrass, canyons, seamounts). They then created or gathered maps showing 9 land-based and 16 ocean-based human activities that directly or indirectly impact these ecosystems (e.g., nutrient runoff, global warming, shipping, fishing).

To understand how each human activity impacts each ecosystem uniquely, the researchers interviewed approximately 120 experts, including academic, agency, and non-governmental scientists. Through these expert surveys, they obtained data on five ecological criteria: spatial scale, frequency, functional impact, resistance, and recovery time. In using this common currency of ecological response to different human activities, the researchers could directly compare the impacts of very different activities on ecosystems. For example, the results allowed them to compare (i.e. rank) the impact of agricultural runoff on kelp forests relative to ocean acidification on rocky intertidal areas. The results produced a “vulnerability weight” for each “activity-by-ecosystem” combination that was then used to translate the presence and magnitude of a human activity at a location into its actual impact on the ecosystems present there.

The researchers then calculated the cumulative impact of all human activities on marine ecosystems by multiplying the sum of each human stressor by the ecosystem-specific “vulnerability weight” for all stressors in each square kilometer of ocean in the California

Current. They were able to partially ground-truth their results by comparing the impact scores to previous field research.

In addition to examining how an activity impacts an ecosystem, the researchers examined how two or more activities interact to impact an ecosystem. For example, they could estimate how agricultural runoff, recreational fishing, and ocean acidification interact to multiply (or in some cases diminish) the impact to a kelp forest. The researchers came up with some very interesting findings. Some activity interactions were additive (overall impact equals the sum of individual parts), some were synergistic (overall impact is greater than the sum of individual parts), and some were even antagonistic (overall impact is less than the sum of individual parts). The results, though meaningful, were inconclusive, and so the researchers did not incorporate these data into the map.

This is the most comprehensive research to date showing the cumulative impacts of human activities on ocean ecosystems. However, the results are only as strong as the data available. Missing and incomplete data on threats and ecosystems has mostly resulted in conservative estimates of human impacts. For example, the model includes data on the 25 activities with the greatest ecological impact to California Current ecosystems, but there are an additional 28 activities that are not included, such as tourism, ocean dumping, some aquaculture, and science research. Fortunately, the researchers designed this to be a flexible tool, allowing the maps to be easily and quickly updated as new data become available.

How can we use the results?

On a broad level, the resulting maps help identify hotspots of human impacts and areas that are relatively pristine. Conservation groups, policymakers, and resource managers can use this information to help focus their efforts and resources. Management strategies can be designed to allow sustainable activities to continue and prohibit or move activities with greater impact. For example, navigation lanes can be rerouted, marine protected areas could be created, or ocean zoning could be implemented to protect sensitive areas of the ocean while allowing economic activities to continue. The results can also be used to guide and support other kinds of management interventions.