Pooling Data
Between the open oceans and the land masses lie the coastal zones, where rivers meet salt water. More than half the world’s population lives in coastal zones, and the majority of marine fishing occurs there. All totaled, coastal zones cover a strip of land equivalent to 1 million kilometers long and 50 kilometers wide. They support fisheries, wetlands, harbors, sea life, coral reefs, tidal basins, deltas, aquaculture, tourism, and recreational water activities.

However, “coastal zones are not adequately studied in relation to their importance,” says Dennis Swaney, an environmental biologist at Cornell University’s Boyce Thompson Institute for Plant Research in Ithaca, New York. Furthermore, estuaries, like many other ecosystems, have traditionally been studied as individual systems, with no context for comparison with other individual systems.

To remedy this situation, Swaney and other concerned scientists joined forces to better understand the dynamics of coastal zones. These scientists have been collecting data that allow them to measure and compare the health of estuaries worldwide. The effort was begun in 1993 with a 10-year grant from the United Nations Environment Programme and the Global Environment Facility. It is part of the Land–Ocean Interactions in the Coastal Zone (LOICZ) project of the International Geosphere–Biosphere Programme, a Stockholm-based international research venture addressing the interactive physical, chemical, and biological processes that regulate the Earth.

The project uses a straightforward “budget” model to calculate the reactions of carbon, nitrogen, and phosphorus within coastal zones. Budget models are used in many fields, such as geology, ecology, and agriculture, to track some material or population. Budget models themselves are nothing new, but this project is innovative in applying a standard budget model to disparate systems worldwide to study them. “We developed an approach to treat coastal areas around the world equally in order to compare them,” says Donald Gordon, an oceanographer at the Bedford Institute of Oceanography in Halifax, Nova Scotia. Gordon first conceived the idea of modeling estuaries for LOICZ and developed the methodology with Fredrik Wikler, a professor of marine systems ecology at Stockholm University. The LOICZ budget model is extremely simple, says Swaney, yet describes the flow of material into a system, the flow of material out of a system, and any change in the flow of material. Some materials undergo transformation, such as nitrate from farm fertilizer being transformed into nitric oxide by bacteria. The fluxes into and out of the system are simply added up, much as one balances a checkbook, using a simple spreadsheet (software to calculate LOICZ budgets is currently undergoing beta testing).

The LOICZ budget model relies on conservation of mass, a fundamental concept in the physical sciences. As water flows through estuaries and mixes with seawater, carbon, nitrogen, and phosphorus are taken up or released by biological processes. This produces positive or negative consequences, or consequences that change with time. For instance, nitrate runoff from agricultural fertilizer may increase both plant growth and fish populations—a positive consequence. However, in the long term, harmful algal blooms may predominate and kill the fish—a negative consequence. Nutrient budgets therefore help scientists infer biological activity.

In general, data are more readily available for nitrogen and phosphorus than for carbon. Nitrogen and phosphorus are far less abundant in seawater than dissolved carbon, which makes it easier to detect small changes in the concentration of nitrogen and phosphorus, compared to carbon. In these cases, the LOICZ model uses the “Redfield ratio” to estimate carbon from known changes in nitrogen and phosphorus. In the 1930s, Alfred Redfield of the Woods Hole Oceanographic Institute at Cape Cod, Massachusetts, observed that the amount of carbon, nitrogen, and phosphorus within the ocean environment remains relatively constant in the proportion 106:16:1. This rule of thumb reflects the steady demand for nutrients by marine organisms. The Redfield ratio remains a valid way to estimate the amount of a nutrient taken up or released, based on the known consumption of others, in calculating budgets.

To obtain baseline information about the status of estuaries worldwide, the LOICZ model uses secondary data obtained locally, gathered, for example, by health officials, environmental biologists, or even a school laboratory activity. “It’s not always the most reliable data,” admits Swaney. Nonetheless, working with secondary data is the only way that global models can be obtained in the fairly short time frame of LOICZ’s current funding, says Gordon, and funding was not available to collect new data within the limitations of LOICZ. Although the model greatly simplifies the details of the processes involved in coastal zone ecosystems—for example, by focusing on the exchange of just three nutrients—it provides uniform baseline information for a large number of sites worldwide.

Pooled Data

The budget sites vary dramatically in their characteristics, ranging in area from less than 1 square kilometer to up to 1 million square kilometers. Some sites are less than a meter deep, while others reach depths of hundreds of meters. Some receive little impact from the land around them, whereas others receive heavy loads of inorganic nutrients derived from human wastes, agriculture, and industries.

Plenty of data have been collected by environmental scientists to describe the state of estuaries in North America, South America, Australia, and Europe, but information about estuaries in Africa and Asia is lacking. “We
new information concerns European environmentalists. However, it offers hope as well, because quantitative assessments are the first step toward evaluating situations and taking action.

**Future Challenges**

The next challenge for those interpreting the LOICZ information lies in extrapolating baseline data for specific sites into more detailed environmental information. Scientists need to find patterns of how the health of estuaries varies with human activities and environmental factors in relation to their site and location. One goal is to construct a global inventory of data for well-characterized environments that can be extrapolated to understudied sites with similar climates, demographics, and coastal conditions. Then, if a remediation process helps to clean up the well-studied site, for instance, the same process should benefit the corresponding understudied site.

Although the LOICZ project is retrospective and relies on existing data to establish a baseline view of estuaries, the same general computations can be made for other contaminants or nutrients in coastal zones. LOICZ has no organized effort under way to expand the number of nutrients covered, but “there’s nothing to stop other people from looking at other materials the same way,” says Smith. “Any chemical in the water can be plugged into the model.”

If LOICZ were to add a new parameter in the future, it likely would be measurements of sediments that affect light-dependent life forms. “The effect of particles is relatively easy to measure with simple turbidity indicators,” says Swaney, and some data sets already exist.

Ideally, once established, budgets should be updated yearly with new data not only for carbon, nitrogen, and phosphorus, but also for new compounds that show increasing environmental importance. One example is silica. When dams are built on rivers, silica-consuming organisms are trapped behind them. This upstream concentration depletes silica down-stream, sometimes shifting algal populations toward destructive forms. LOICZ hopes to get renewed funding to do more projects like this.

LOICZ has no control over how local officials use findings about estuaries. “Collecting data is no guarantee that if we find problems, they will be fixed,” says Swaney, “but a budget may be the first step in improving things.” Monitoring contaminants could guide cleanup efforts and direct corrective actions. Coastal zone assessments could dictate changes in agricultural practices, erosion control efforts, damming projects, sewage treatment facilities, and tourism demands.

Improving coastal zones involves a complex interplay of social sciences, biology, chemistry, geology, and politics. The ultimate goal is to make or keep coastal zones sustainable to ensure biological diversity, generation of renewable resources, and maintenance of natural processes. This requires integrated, long-term planning efforts based on innovative scientific research in a number of disciplines to guide coastal zone development. Experts hope the LOICZ findings will motivate local policymakers to take steps to clean up polluted estuaries and correct adverse conditions before they worsen. Right now, pollution hits coastal zones hard, warns Smith. Once they die, the open seas are the next target.

Carol Potera

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**Suggested Reading**

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