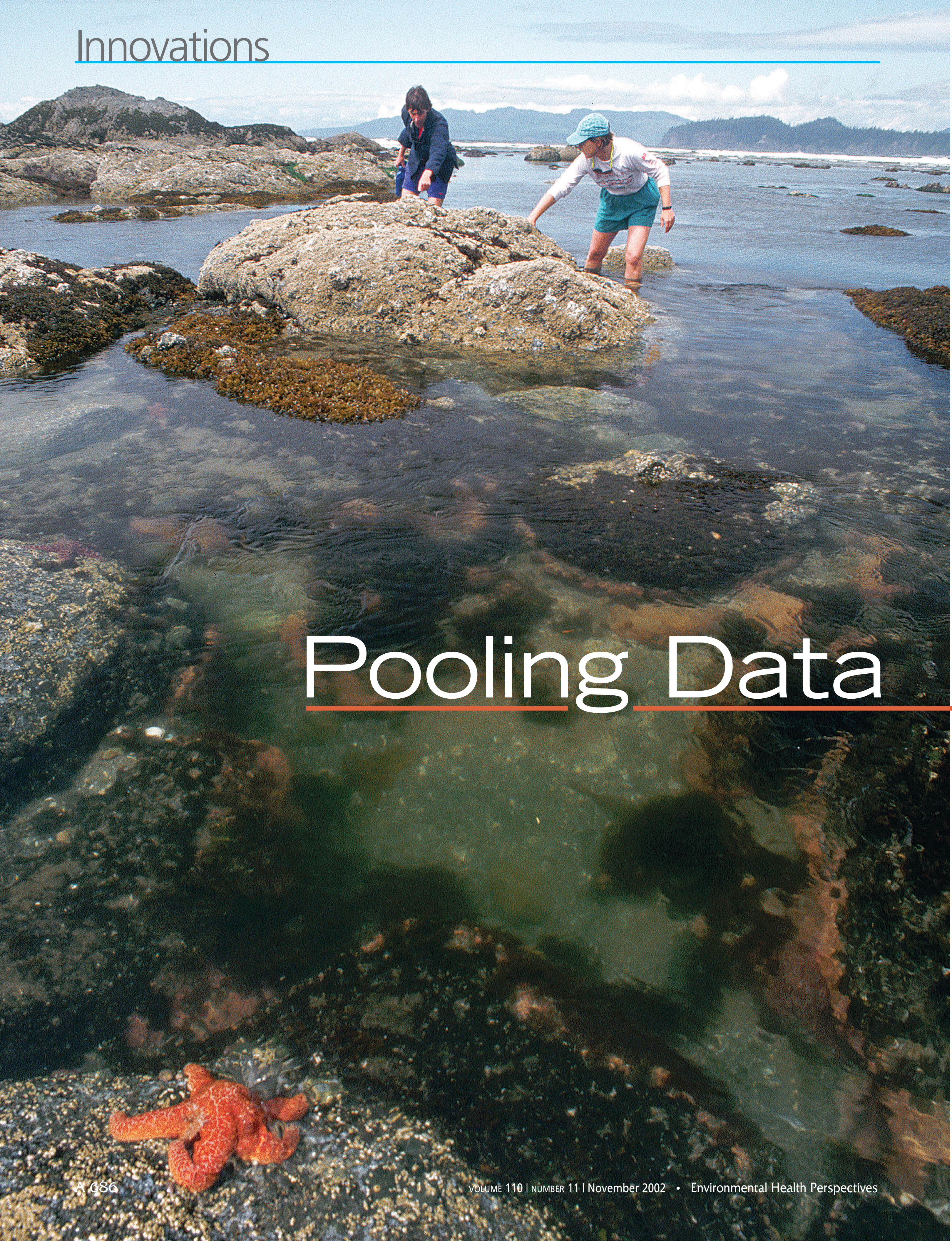

Pooling Data

Corbis

on Coastal Zones

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 Wulff, a professor of marine systems ecology at Stockholm University. The LOICZ budget model is extremely simple, says Swaney, yet the common methodology can be applied anywhere and provides uniform results to compare coastal zones around the world.

Materials enter or leave coastal zones by precipitation, evaporation, surface water drainage, groundwater discharge, ocean tides, oceangoing vessels, dumping of sewage, and sedimentation. Although the open oceans remain fairly homogenous in composition, the estuaries and bays of coastal zones vary greatly, depending on the amount of agricultural and industrial runoff occurring upstream, which impacts the quality of water flowing into them. Coastal zones also serve as traps for pollutants, because they so closely border human activities that generate pollutants such as fossil fuel combustion products, sewage, and farm runoff. "Estuaries and other coastal environments are the most heavily used and abused part of the ocean," says Stephen V. Smith, an oceanographer at the Center for Scientific Research and Higher Education in Ensenada, Mexico, and project collaborator. "If we want to preserve the health of the world's oceans, we have to start here."

Methods and Strategies

The LOICZ budget model considers the flow of water, and that of the dissolved nutrients carbon, nitrogen, and phosphorus, to produce a so-called nutrient budget. Basically, a budget 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 need to target [developing] countries to find out what's happening in their coastal zones," says Swaney. Members of the LOICZ project have conducted 15 workshops around the world to teach local experts how to develop nutrient budgets for their regions. Two recent workshops in the series were held in Goa, India, and Cape Town, South Africa.

The LOICZ database of detailed information about coastal ecosystems is maintained at Stockholm University in Sweden. The LOICZ project is largely administered from its website (**http://www.nioz.nl/loicz**). Researchers worldwide plug local data into the LOICZ modeling webpage (**http://data.ecology.su.se/MNODE/**). About 150 people have contributed budget information for some 170 sites; the ultimate goal is to collect information from 200 sites.

Data obtained from global collaborators are being compiled into a typology, or classification, of coastal zones. The LOICZ webpage also summarizes and updates the budgeting procedure, provides tools for carrying out the process, offers teaching materials, and posts existing budgets as they become available. Visitors can view and download PowerPoint presentations that contain a summary of the budgeting process, information for estimating river discharge, aspects of the budgeting methodology, tutorials on estimating nutrient loads to coastal areas from waste streams of various human activities, and spreadsheets for estimating nutrient loads.

An early overview by Smith, presented at the annual Ocean Sciences Meeting of the American Geophysical Union, held 11–15 February 2002 in Honolulu, Hawaii, found that nutrient loads vary up to 10,000-fold and represent everything from pristine river conditions to direct sewage discharge. The time it takes an estuary to exchange nutrients with its adjacent ocean ranges from less than one day to several years. This helps researchers put things into persepective—it may be hard to believe that any coastal zone is still pristine; on the other hand, some areas heavily impacted by humans are not as damaged as assumed.

Although many of the world's estuaries are polluted, there has been no uniform information to compare them. Now the budget model allows for such comparisons. For instance, Chesapeake Bay, which American environmentalists consider troubled due to its large drop in fisheries, carries a nitrogen load of about 1.6 millimoles per square meter per day. The nitrogen load in Tokyo Bay in Japan runs 10 times higher, at 16 millimoles per square meter per day. "This is an enormous load," says Swaney. Comparing Chesapeake Bay to the Gulf of Gdansk in Poland, a heavily populated region surrounded by agricultural land, finds that the nitrogen load runs 3 times higher for Gdansk than for Chesapeake Bay. This 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 size 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 in to 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 downstream, 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 policy makers 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

Suggested Reading

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