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ViewPoint

Research challenges at the land–sea interface☆

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The land–sea interface, or Coastal Transition Zone (CTZ), is the area that links terrestrial and marine habitats. We use here the definition of Schaefer (1972): "the sea and the land adjacent to the interface, encompassing that region where terrestrial activities importantly impinge on the marine environment, marine resources and marine activities, and where marine activities importantly impinge on the environment, resources, and activities of the land". The precise spatial scale and extent of the interface in this definition is (appropriately, we feel) ambiguous, as it depends on both the attributes of the interface at any given location, as well as the processes or features being examined.

Like many ecotones, the CTZ is an area of intense interactions and enhanced productivity and biodiversity (Levin et al., 2001). The coastal zone is also a "keystone" habitat, providing human and ecosystem services out of proportion to its areal extent (e.g., Costanza et al., 1997). The coastal zone represents only 8% of the earth, but provides 20% of the oceanic production (Liu et al., 2000). Further, 60% of humans, 3.8 billion people, live within 100 kilometers of the sea (Vitousek et al., 1997). This region is a nexus for transportation, production of energy, and food resources for humans. The importance of this region, both to humans and to terrestrial and aquatic ecosystems, makes it crucial that we understand the processes and interactions in this habitat.

The coastal transition zone, however, presents a number of difficult research challenges. While these challenges are qualitatively similar to those faced by scientists in other habitats, they are magnified in the coastal transition zone. The goal of this paper is to describe the difficulties that confront the researcher interested in the CTZ, and to offer some ideas for ways in which we as scientists can approach these challenges more fruitfully.

1. Challenges

1.1. Anthropogenic effects

One of the most difficult issues in studying nature is the task of separating anthropogenic variability from

☆ The authors of this paper were brought together in October 2002 as part of the Dissertations Symposium for the Advancement of Coastal and Estuarine Science (DIACES; see http://aslo.org/phd.html). The meeting provided a venue for us to consider the unique challenges facing researchers working at the land–sea interface, and ways that they can be addressed. This paper is the result of that discussion.

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intrinsic or natural variability in the ecosystem (Dayton et al., 2000). This problem is particularly acute in the coastal zone, both because of the intensity of anthropogenic effects and the inherent natural variability within CTZ systems. Human-induced variability is difficult to quantify because it arises from a combination of the dense human populations within coastal areas (Vitousek et al., 1997), human exploitation of coastal zone organisms (Carlton et al., 1999), and the related impacts of habitat modification, nutrient input, and invasive species introduction (e.g., Kennish, 2002 and references therein). Human impacts have been pronounced throughout recorded history (e.g., Jackson et al., 2001), usually occurring long before large-scale environmental monitoring programs, making the identification of "baseline" conditions and natural variability particularly difficult.

1.2. Physical and biological variability

When a system is highly variable both spatially and temporally, discerning underlying patterns and processes is difficult. The land–sea interface is an exceptionally dynamic habitat, impacted by strong, non-linear, and often distant physical and biological forces from both the terrestrial and oceanic ecosystems. These forces are themselves variable on multiple spatial and temporal scales. Even the actual physical boundary between the land and the sea changes due to tides, waves, climatic conditions, geomorphology, and a host of other factors. These changes occur over timescales ranging from seconds to millennia, and across spatial scales from millimeters to entire continental shelves. Not only can this variability make it difficult to discern the mechanisms and patterns at work in the CTZ, but it complicates efforts to determine the "normal" state or range of the system, and obscures the difference between human-induced and natural variability.

1.3. Parochialism

Like many facets of science, CTZ interfaces are often studied in a highly parochial manner. Progress in understanding is hindered by lack of interaction between scientists of different disciplines (e.g., physicists and biologists), taxonomic fields (e.g., fish ecologists and plant ecologists), geographic regions (e.g., Pacific Northwest and Gulf of Mexico), and habitat specialties (e.g., salt marsh versus coastal scrub systems). This problem is particularly acute across the land–sea interface, where many scientific disciplines, often considered completely distinct, overlap. The tight coupling between land and sea within this environment necessitates collaboration among the many subdisciplines of terrestrial and aquatic science. Further, the social, economic, and political need for sound science in this region is particularly strong, due to the heavy use and importance of the habitats to various stakeholders (e.g., fishers, developers, industry, recreational users) and public services (drinking water collection, power generation, sewage treatment, food production). The CTZ is therefore a region that requires significant interaction among scientists, policy-makers, and the public.

These inherent challenges of working at the land–sea interface are not insurmountable, but require a broad range of efforts at the individual and institutional levels. Here we present some basic directions that would help mitigate the difficulties of conducting science at the land–sea interface.

2. Recommendations

2.1. Increase interdisciplinary training and collaborations

While it is clearly beneficial for any scientist to enhance their understanding of other disciplines, it is a necessity when studying CTZ systems. We should encourage interdisciplinary education at the graduate student and post-doctoral level. This would enable these scientists to enter their field with a set of skills and vocabulary that facilitates interdisciplinary work. Good examples of this training include scientists who are willing to serve as graduate committee members for students in different disciplines, advisors who support interdisciplinary coursework, departments that encourage students to rotate among labs, and programs that promote collaborative research and information exchange (e.g., National Science Foundation's Integrative Graduate Education and Research Traineeship (IGERT) program, DIACES). Activities such as these should become standard for scientists and funding agencies whose mission includes training scientists and managers to work at the land–sea interface and addressing the challenges that face this inherently interdisciplinary system.

In addition to training the next generation of scientists and managers, we should make efforts to broaden our own understanding of related fields, and work to overcome the barriers that block interdisciplinary research. We can learn the language and etiquette of other disciplines by organizing informal discussion groups, inviting interdisciplinary seminar speakers, and attending seminars from other university departments. In addition, integrating scientists from diverse fields in our research programs and scheduling time for discussing and synthesizing ideas would enhance information exchange, push science in the CTZ forward, and may increase chances of proposal funding success. Finally, we could help ensure that interdisciplinary studies do not 'fall through the cracks' by agreeing to peer review interdisciplinary articles and support cross-cutting theme sessions at research conferences.

2.2. Work on multiple spatial and temporal scales

Since the CTZ integrates the additive and emergent effects of processes across a broad range of scales, it is particularly important that we are aware of the spatial and temporal scales of our studies, and the implications of scale on the processes investigated. We should also attempt to understand how processes might "scale up" from the experiment to the ecosystem (e.g., see Thrush et al., 1997). This involves specifically addressing issues of scale when designing investigations that encompass a broad range of spatial and temporal scales and/or generating and testing specific hypotheses about the potential to "scale up" processes to the ecosystem level. Explicitly addressing and reporting issues of scale will facilitate synthesis of interdisciplinary research and enhance our understanding of the dynamics of CTZ systems.

2.3. Support long-term monitoring programs and enhance data mining

Understanding the function and state of CTZ ecosystems requires long time-series data sets. These data help separate natural variation from human-induced impacts, and provide benchmarks against which future comparisons can be made. But long-term data collection programs are expensive and difficult to maintain. Members of the scientific community should convey the importance of long-term data sets to the public and encourage management agencies to maintain long-term monitoring programs. In places where long time-series data sets are lacking, we need to be creative about how to construct the best data sets possible using data mining approaches. These include utilizing the paleo-record, museum collections, unpublished (gray-literature) data sets, and archived theses. Further, using space-for-time substitutions is a valuable tool for inferring temporal patterns where time-series data are not available (e.g., Tyler and Zieman, 1999). All these methods will help in our efforts to understand the patterns and mechanisms of natural heterogeneity in these systems, as well as identify anthropogenic effects.

2.4. Incorporate research into restoration and mitigation projects

Mitigation, creation, and restoration projects are becoming increasingly common in coastal systems, as communities struggle to repair or replace lost or damaged habitat (Mitsch and Gosselink, 2000). Yet, the success of these projects is often 'hit or miss' because the critical physical and biological processes for creating healthy ecosystems are poorly understood (Ehrenfeld and Toth, 1997). Researchers studying the CTZ could integrate their work into restoration and mitigation projects. Incorporating sound research into large-scale restoration programs could help researchers identify critical processes and understand natural variability in the CTZ. In addition, these projects provide researchers with an opportunity to work on larger scales and more heterogeneous conditions than is often possible, while helping CTZ scientists inform management and policy decisions.

3. Conclusion

We recognize that some of these recommendations appear self-evident. For example, few would argue that it is not desirable to be interdisciplinary. Yet despite its obvious value, major professors often discourage students from taking classes outside of the immediate focus of their dissertation, and truly interdisciplinary projects are rare. Similarly, few researchers would claim it is a waste of time to study multiple spatial and temporal scales. Yet studies are often focused narrowly, because there is much more emphasis placed on certainty than on generality, and a narrowly focused study is more likely to generate confidence in the results (Thrush et al., 1997).

We propose that the key to facing the difficult challenges of studying the land–sea interface is to integrate these suggestions into our daily efforts and future research plans, and to recognize that what appear to be idealized and unattainable goals are met by many individuals taking one small step at a time.

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