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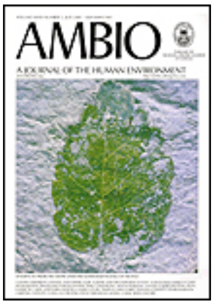

The Importance of Marine Sediment Biodiversity in Ecosystem Processes

Paul V. R. Snelgrove
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The Importance of Marine Sediment Biodiversity in Ecosystem Processes

Sedimentary habitats cover most of the ocean bottom and therefore constitute the largest single ecosystem on earth in spatial coverage. Although only a small fraction of the micro-, meio- and macroscopic benthic organisms that reside in and on sediments have been described and few estimates of total species numbers and biogeographic pattern have been attempted, there is sufficient information on a few species to suggest that sedimentary organisms significantly impact major ecological processes. Benthic organisms contribute to regulation of carbon, nitrogen, and sulfur cycling, water column processes, pollutant distribution and fate, secondary production, and transport and stability of sediments. Linkages between groups of organisms and the level of functional redundancy is poorly known, however, there is probably substantial redundancy within groups. There is little evidence that biodiversity *per se* is necessary for benthic systems to contribute to ecosystem services, but because linkages are so poorly known and predictive knowledge confined to a few species, it is not presently possible to predict exactly how species loss will impact these services and ecosystem health. Thus, a precautionary approach of "assume the worst" is advised, and every effort should be made to curtail the species and genetic diversity loss resulting from fishing, pollution, habitat destruction, introduction of non-native (exotic) species, and global warming. Concurrently, scientists must take advantage of exciting, rapidly evolving technology and a rejuvenated interest in biodiversity to provide more concrete and thorough information on benthos and ecosystem processes.

INTRODUCTION

Oceans cover 70% of the Earth, and most ocean bottom is covered in sediments ranging from gravel to fine muds; this makes it the largest habitat on our planet in areal coverage. Some sediments are uniform in grain size, some are mixed, some are biological in origin and others are geological. Much of this habitat (~ 83%) is greater than 1000 m depth (1), so most marine sediments are located in a cold, lightless, high pressure habitat where food is supplied from distant surface waters. Surprisingly, the benthic (bottom) organisms that reside within marine sediments are extremely diverse. For example, of the known 29 nonsymbiont animal phyla, all but one occurs in marine habitats and 13 are solely marine (2). There are some 10^5 species described from marine sediments and perhaps 10^8 that remain important. More specifically, we investigate the importance of sedimentary biodiversity in these processes to evaluate whether species loss will have a major impact on ecosystem health and ecosystem services that oceans provide.

BIODIVERSITY IN MARINE SEDIMENTS

Efforts to evaluate biodiversity on a global scale pale in comparison to the effort that remains. This is largely a problem of logistics. For metazoan taxa there are sampling techniques that scientists agree are sufficiently quantitative (30), and the challenge is in finding resources to sample and process material representative of the 3.6 x 10^8 km^2 of ocean bottom. For the phylogenetic domains bacteria, archaea, protozea, and fungi there is an additional problem defining species. The reproductive biology of these groups does not allow application of a metazoan species concept, and species must therefore be defined on genetic, chemotaxonomic, physiological, and ecological criteria. The task becomes even more daunting because this approach requires culturing microorganisms, and only a small percentage can presently be grown (31). Thus, our discussion of microbial diversity is very preliminary.

There are few syntheses on patterns of global biodiversity, and those that exist include only a subset of all species. Because marine scientists often specialize on one of the size groupings of sedimentary organisms (macrofauna, meiofauna, microbes), biodiversity tends to be treated accordingly. This division is not strictly one of convenience and size because there are major differences between groups. Global biodiversity estimates for any given taxon are also very tenuous, and this is particularly true for benthic marine organisms given the relatively small proportion of habitat and organisms that has been sampled (8). Nonetheless, we have estimated global numbers of described and undescribed benthic species based on existing data (Table 1) for individual phyla. Regional commmunity-level studies have extrapolated species number to a global estimate for several groups. Marine sediments may contain up to 10^8 nematode species (8) and deep-sea macrofauna have been estimated at 10^7 species globally (1). Others argue that macrofaunal estimates of 500 000–5 million (32) are more appropriate. Suggestions that the deep sea is more diverse than shallow habitats (1) have been questioned, indicating that the North Atlantic study (1) may not be globally representative (18, 33). Proposed latitudinal gradients with high tropical and low polar diversity for deep-sea macrofauna (34) have also been debated (9).

Global syntheses of benthic species distributions and compoundescribed (Table 1). But is consideration of and inventoring biodiversity little better than stamp collecting as was once suggested by the physicist Ernest Rutherford? Among the many reasons for considering living organisms differently from stamps are their roles in maintaining the Earth's life support system. Indeed, a recent study suggested that oceans account for ~ 2/3 of the value of global ecosystem services (29). They play a major role in climate regulation, provide protein for human consumption, and regulate global water, nutrient and carbon cycling. They absorb and dilute pollutants, provide recreation and employment, and bear ~ 2/3 of human populations on their shores. The purpose of this review is to evaluate how organisms in marine sediments impact the many processes in which oceans are so

sition are generally limited to regional monographs (Table 1), but we can draw generalizations that are common to all groups. Species patterns correlate well with historical disturbance (e.g. glaciation), sediment grain size, organic content, depth and temperature. Global syntheses of species patterns in relation to these factors could be extremely illuminating. Many benthic species, from bacteria (35) to macrofauna (36), are considered cosmopolitan in distribution, but increasing evidence suggests some "species" may in fact be species complexes (36). The large proportion of undescribed species (Table 1) and other taxonomy problems (8) impede estimates of global diversity patterns; science must use all available data and generate new data to improve estimates. For example, changes in distribution and diver-

Abstract:

Sedimentary habitats cover most of the ocean bottom and therefore constitute the largest single ecosystem on earth in spatial coverage. Although only a small fraction of the micro-, meio- and macroscopic benthic organisms that reside in and on sediments have been described and few estimates of total species numbers and biogeographic pattern have been attempted, there is sufficient information on a few species to suggest that sedimentary organisms significantly impact major ecological processes. Benthic organisms contribute to regulation of carbon, nitrogen, and sulfur cycling, water column processes, pollutant distribution and fate, secondary production, and transport and stability of sediments. Linkages between groups of organisms and the level of functional redundancy is poorly known, however, there is probably substantial redundancy within groups. There is little evidence that biodiversity per se is necessary for benthic systems to contribute to ecosystem services, but because linkages are so poorly known and predictive knowledge confined to a few species, it is not presently possible to predict exactly how species loss will impact these services and ecosystem health. Thus, a precautionary approach of "assume the worst" is advised, and every effort should be made to curtail the species and genetic diversity loss resulting from fishing, pollution, habitat destruction, introduction of non-native (exotic) species, and global warming. Concurrently, scientists must take advantage of exciting, rapidly evolving technology and a rejuvenated interest in biodiversity to provide more concrete and thorough information on benthos and ecosystem processes.