Vol. 264: 173–175, 2003 | MARINE ECOLOGY PROGRESS SERIES Mar Ecol Prog Ser | Published December 15

THEME SECTION

Restoration scaling in the marine environment

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Scaling restoration actions in the marine environment to meet quantitative targets of enhanced ecosystem services

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Recognition of the critical importance of the sustainable delivery of goods and services from natural ecosystems to human welfare, health, and economic systems is rapidly growing (e.g. Lubchenco et al. 1991, Daily 1996). Because the degradation of natural ecosystems is so pervasive both on land (Vitousek et al. 1997) and in the sea (Botsford et al. 1997), especially in coastal systems (Jackson et al. 2001), interest in restoration of natural resources, habitats, and services is also increasing (Thayer 1992, Wilson 1992). Restoration ecology may even become the dominant discipline in environmental science during the 21st century (Hobbs & Harris 2001).

Restoration ecology and conservation biology share the broad goal of managing human impacts on natural resources and ecosystems (Young 2000). Although seminal books on the 2 disciplines appeared almost simultaneously (Jordan et al. 1987, Soule 1987), subsequent conceptual growth in conservation biology has exceeded that of restoration ecology (Young 2000). Consequently, technical restoration activity in both terrestrial and marine environments has progressed faster than the fundamental conceptual support for it (Allen et al. 1997, Palmer et al. 1997, van Diggelen et al. 2001). A major goal of this Theme Section is to expose to wide review the conceptual bases for various types of restoration projects so as to stimulate further growth of the ecological theory required to advance and improve restoration practices.

One active and growing area of marine restoration ecology involves government-mandated restoration of natural resources injured by environmental incidents, such as oil and chemical spills, pollutant releases, or physical destruction of habitat (e.g. NOAA 1997). Federal laws in the USA, notably the Comprehensive Environmental Response, Cleanup, and Liability Act (CERCLA) of 1980, and the Oil Pollution Act (OPA) of 1990, dictate that restoration actions be taken to provide equivalent compensation for losses or injuries to natural resources held in public trust and to the services that those resources would have provided (Burlington 1999). Natural resources under public ownership include the air, water, and habitats, together with the plants and animals within them. The federal and state trustees of those resources are charged with the responsibility to assess losses and injuries, to restore, replace, rehabilitate or acquire their equivalent, and to obtain a monetary settlement from the responsible party to achieve this end. As an example of the development of such compensatory restoration, Fonseca et al. (2000) describe a process for quantitative matching of injury to seagrass habitat against benefits flowing from seagrass restoration projects.

Both CERCLA and OPA depend upon the natural science of ecology in 2 contexts: first for a natural resources damage assessment (NRDA) and second for a comprehensive restoration program that fully compensates for those damages. Scientific challenges exist for

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each task. In damage assessment, the greatest challenges involve determining the metrics that best characterize the health and services provided by the ecosystem and then assessing the degree of departure from and rate of progression of natural recovery to conditions that would have prevailed in the absence of the environmental incident. Progress has been made in resolving many of the fundamental challenges in assessing impacts (e.g. Schmitt & Osenberg 1996). However, much new research is needed in developing rigorous and reliable scientific methods for restoring injured or lost natural resources and their ecosystem services to targeted levels. Predicting the quantitative consequences of any intervention into an ecosystem represents a challenge for the discipline of ecology (Lawton 1996). The demands for application of natural science to fulfill governmental mandates for compensatory restoration that is ecologically meaningful, scientifically sound, cost-effective, and reliable may drive further development of the conceptual foundation for restoration interventions and thereby enhance the capabilities of ecological science (Zedler 2000).

In this Theme Section, we intend to advance the conceptual basis of restoration ecology by publicizing recent analyses of restoration actions to achieve compensation for injuries to, and losses of, natural marine resources and the services that they provide. The papers illustrate multiple approaches to restoration, developing the conceptual basis for choosing specific restoration approaches and for scaling the intervention to match the quantitative injuries. The studies were conducted in response to 2 recent environmental incidents, the 1996 tanker barge 'North Cape' oil spill in Rhode Island and a 1997 process water spill from a phosphate plant into the Alafia River estuary near Tampa Bay in Florida.

Foci of the following papers in this Theme Section range from restoration of individual species populations to rehabilitation of entire communities and habitats. The contribution by French McCay et al. (2003a) uses the American lobster to illustrate how compensatory enhancement of a harvested (exploited) species can take advantage of a typically extensive body of research to determine the factor(s) that limit population size and also how changing fishery regulations provide unique opportunities for restoration. French McCay et al. (2003b) demonstrate for other exploited species, bivalve molluscs, how past scientific studies of resource enhancement, including development of hatchery technologies, permit juvenile seeding and adult transplantation to achieve compensation for losses. Donlan et al. (2003) assess the special challenges implicit in developing rigorous restoration options for a threatened or endangered species, the piping plover. Sperduto et al. (2003) synthesize available information on population limitation of loons, seaducks, and other seabirds in New England, and construct defensible restoration scaling. French McCay & Rowe (2003) develop a logical conceptual basis for scaling habitat restoration to compensate for the loss of several species at multiple trophic levels. Peterson et al. (2003) review available empirical data on quantitative enhancement of nekton populations by restoring oyster reefs in the southeast USA and apply demographic and growth models to estimate the species-specific augmentation of fish and crustacean production that is expected per unit area of oyster reef restoration. Powers et al. (2003) present an analogous synthesis and quantitative model to establish how installation of an offshore artificial reef is expected to affect fish production in the southeast USA. Kneib (2003) combines a bioenergetic approach with a landscape perspective to develop realistic expectations for augmentation of nekton associated with restoration of salt marsh habitat. Finally, Peterson & Lipcius (2003) use the preceding papers in the Theme Section to suggest how the discipline of restoration ecology has been and can further be advanced to better predict (e.g. Zedler 2000) the consequences of ecosystem interventions to restore natural living resources.

Acknowledgements. Development of this manuscript was supported by the NOAA Damage Assessment Center.

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