2016

Upgrading Marine Ecosystem Restoration Using Ecological-Social Concepts

A Abelson

BS Halpern

DC Reed

R J. Orth

GA Kendrick

See next page for additional authors

Recommended Citation

Abelson, A; Halpern, BS; Reed, DC; Orth, R J.; Kendrick, GA; and et al, "Upgrading Marine Ecosystem Restoration Using Ecological-Social Concepts" (2016). *VIMS Articles*. 817.
https://scholarworks.wm.edu/vimsarticles/817

Authors

A Abelson, BS Halpern, DC Reed, R J. Orth, GA Kendrick, and et al

Upgrading Marine Ecosystem Restoration Using Ecological–Social Concepts

AVIGDOR ABELSON, BENJAMIN S. HALPERN, DANIEL C. REED, ROBERT J. ORTH, GARY A. KENDRICK, MICHAEL W. BECK, JONATHAN BELMAKER, GESCHE KRAUSE, GRAHAM J. EDGAR, LAURA AIROLDI, ERAN BROKOVICH, ROBERT FRANCE, NADAV SHASHAR, ARIANNE DE BLAEIJ, NOGA STAMBLER, PIERRE SALAMEH, MORDECHAI SHECHTER, AND PETER A. NELSON

Conservation and environmental management are principal countermeasures to the degradation of marine ecosystems and their services. However, in many cases, current practices are insufficient to reverse ecosystem declines. We suggest that restoration ecology, *the science underlying the concepts and tools needed to restore ecosystems, must be recognized as an integral element for marine conservation and environmental management. Marine restoration ecology is a young scientific discipline, often with gaps between its application and the supporting science. Bridging these gaps is essential to using restoration as an effective management tool and reversing the decline of marine ecosystems and their services. Ecological restoration should address objectives that include improved ecosystem services, and it therefore should encompass social–ecological elements rather than focusing solely on ecological parameters. We recommend using existing management frameworks to identify clear restoration targets, to apply quantitative tools for assessment, and to make the re-establishment of ecosystem services a criterion for success.*

Keywords: social–ecological restoration; conservation; marine ecosystems; Ocean Health Index (OHI); marine spatial planning (MSP)

Marine ecosystems play a crucial role in supporting human well-being, from our food supply and coastal protection to the regulation of the Earth's climate (figure 1; e.g., Barbier 2012, Halpern et al. 2012, HLPE 2014). Nevertheless, contemporary marine ecosystems are changing, degrading, and disappearing (figure 1; e.g., Waycott et al. 2009, Beck et al. 2011, Burke et al. 2011), a consequence of intensive exploitation together with other anthropogenic local and global effects (e.g., Burke et al. 2011, IPCC 2013). Such rapid ecological degradation results in drastic declines in the value of marine ecosystem services and increasing consequential costs to humanity (Barbier 2012).

Current conservation and natural-resource management are the main countermeasures to this degradation of marine ecosystems (e.g., Gaines et al. 2010), and they operate primarily by regulating human behavior. These measures include rules crafted to reduce pollution (direct and nonpoint source); laws to protect threatened species (e.g., the US Marine Mammal Protection Act); rules to regulate resource extraction, such as offshore oil wells or seafloor mining; and fisheries regulations. The last include seasons, marine protected areas (MPAs) and other spatial closures, gear restrictions, catch limitations, and bycatch-mitigation measures. MPAs are designed to reduce human impacts—especially those caused by overfishing and habitat destruction—and to increase resilience to natural disturbances and indirect anthropogenic impacts (e.g., De'ath et al. 2012). However, in many cases, conservation and management as practiced are insufficient to maintain ecosystem health, much less reverse declines and restore ecosystem functions and services (e.g., Lotze et al. 2011, De'ath et al. 2012, Parravicini et al. 2013). For instance, De'ath and colleagues (2012) documented a dramatic decline (over 50%) in the cover of live coral (from 28.0% to 13.8%) on Australia's Great Barrier Reef in less than 30 years (between 1985 and 2012). This huge decline at the largest and one of the best-protected coral reef systems in the world is a prominent case that raises questions about the general adequacy of management and protection efforts (Knowlton 2012), as well as the use of MPAs as the primary tool for conservation and the optimal conditions for natural recovery.

Natural recovery, the process by which an ecosystem returns to a prior state following the cessation of some impact or alteration, is often a slow process that can take

BioScience 66: 156–163.

doi:10.1093/biosci/biv171

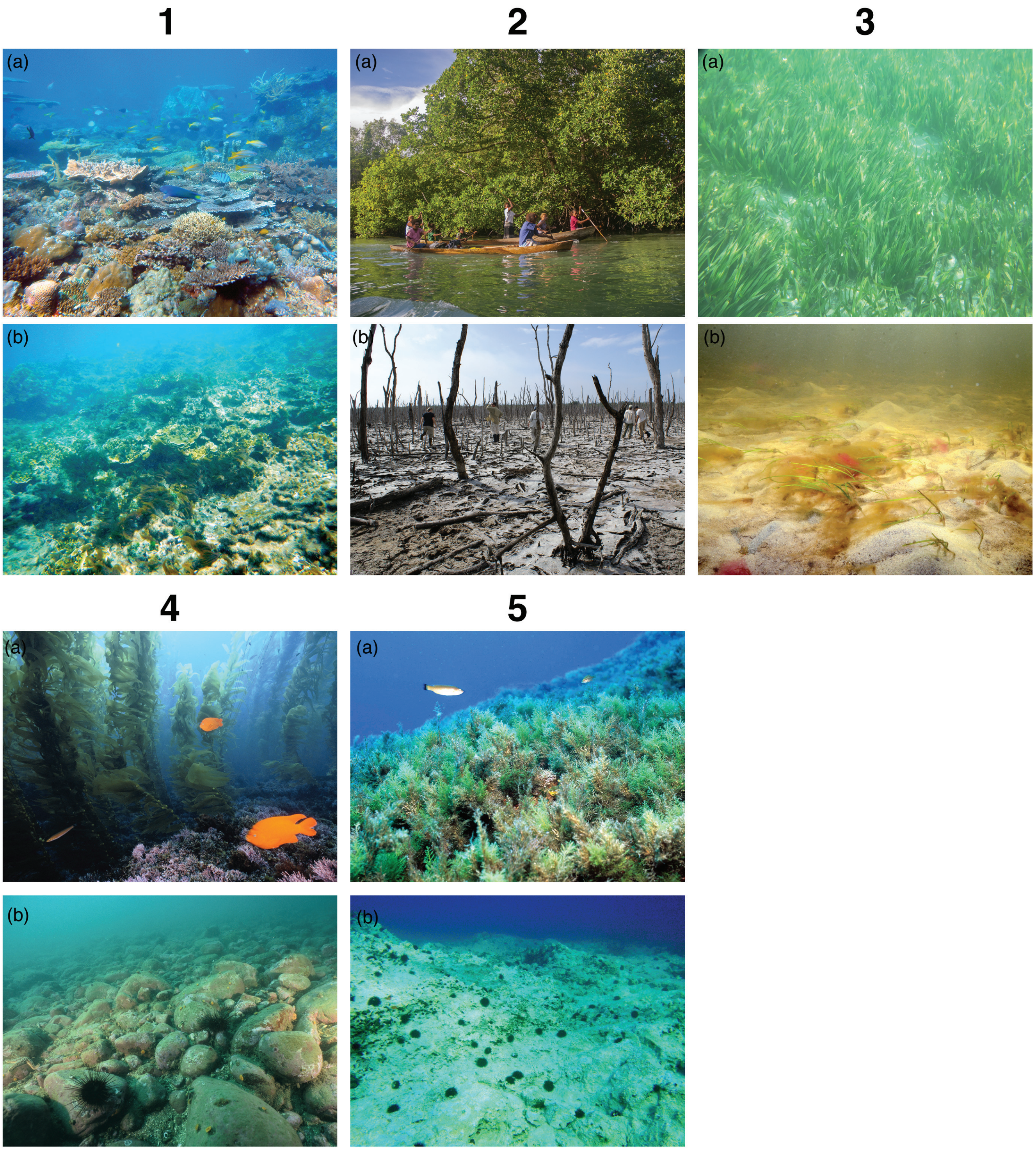

Figure 1. Examples of healthy (rich ecosystem services; e.g., food supply, nursery grounds, coastal protection) versus degraded (poor ecosystem services) marine ecosystem sites. (1) Tropical coral reefs: (a) a high-structural-complexity reef, dominated by reef-building corals (Kota Kinabalu, Malaysia), (b) a degraded reef (Ulithi, Yap, Federated States of Micronesia); (2) Mangrove forests: (a) a fully developed forest (Mangal; Solomon Islands), (b) a degraded mangrove site (Rookery Bay, Florida); (3) Seagrass meadows: (a) a Posidonia australis *meadow (King George Sound, Australia), (b) a stressed* Zostera muelleri *meadow (Tasmania, Australia); (4) Kelp forests: (a) a highly productive giant kelp forest (California), (b) a deforested kelp reef with low productivity and diversity (California); (5) Canopy-forming algal forests: (a) a* Cystoseira balearica *forest (Scandola, Corsica), (b) urchin barrens (Porto Cesareo, Italy). Photographs: 1a C. Storlazzi; 1b A. Abelson; 2a E. Brokovich, 2b C.J. Sapp; 3a G. Kendrick, 3b G. Edgar; 4a,b R. McPeak; 5a E. Ballesteros, 5b P Guidetti.*

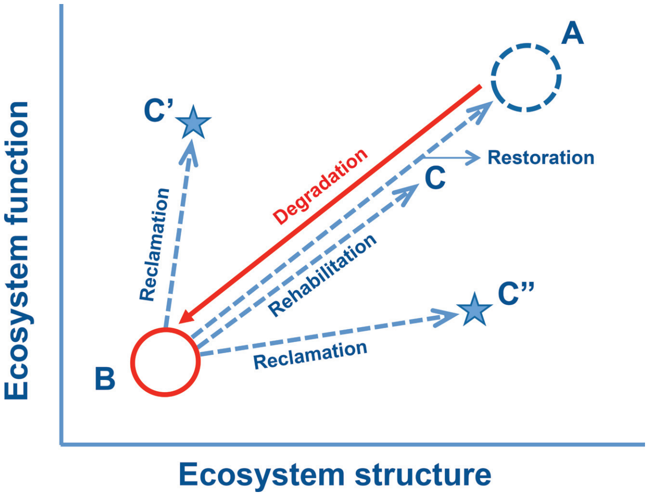

Figure 2. A schematic illustration of the effects of restoration interventions (e.g., restoration, rehabilitation, and reclamation) on ecosystem structure (e.g., species diversity and structural complexity) and ecosystem function (e.g., nutrient content and cycling as well as productivity), illustrating changes that occur as a degraded ecosystem (State B) recovers toward its original state (A). Practices which lead to partial recovery are termed **rehabilitation** *(C), in which practices that improve either or both the ecosystem structure or function—but not toward the original state (A)—are termed* **reclamation** *(C’ and C”; after Dobson et al. 1997).*

decades or even centuries (Dobson et al. 1997, Lotze et al. 2011). For example, the recovery of fished stocks relies on the natural system to recover at its own rate, and in some cases (e.g., North Atlantic cod), recovery has not occurred. In severe cases, a return to the “historic natural” state is not likely to occur in a reasonable time scale (e.g., Lotze et al. 2011). However, if we are able to identify the specific recovery inhibitors (e.g., phase-shift attractors) and these can be overcome by certain interventions, then this lengthy process may be dramatically shortened. Such identification and intervention are the essence of ecological restoration (e.g., Dobson et al. 1997, Suding 2011), in which *ecological restoration* is defined as the process of assisting the recovery of damaged, degraded, or destroyed ecosystems (e.g., Hobbs 2004).

Given that conservation and sustainable management likely require more than MPAs or fisheries regulations alone to be effective, we suggest that the scientific discipline of *restoration ecology*, defined as the science underlying the concepts and tools needed to restore ecosystems (SER 2004), needs to become an integral element for marine conservation, natural resource management, and sustainable development (MEA 2005, Suding 2011). Restoration ecology is a relatively young scientific discipline (e.g., Suding 2011), especially so in the marine environment, and wide gaps still exist among current implementation methods, approaches and standards, and the supporting science (e.g., Elliott et al. 2007, Suding 2011, Duarte et al. 2014). In the marine context, this misalignment is exacerbated by (a) real or apparent inequalities between project cost and economic benefits (e.g., Cesar 2000) and the consequent inability to scale-up projects (e.g., Adger et al. 2005, Mumby and Steneck 2008); (b) treating symptoms rather than the causes (e.g., Mumby and Steneck 2008); and (c) confusing the semantics of *restoration* with inconsistent, conflicting, and sometimes overlapping terms (Elliott et al. 2007, Duarte et al. 2014).

Vague or undefined restoration evaluation criteria present further obstacles to linking marine science with the practice of ecological restoration (e.g., Ruiz-Jaen and Aide 2005, Elliott et al. 2007). Restoration evaluations typically are carried out by measuring state variables and ecological processes, which are based on scientific methods indicating ecosystem performance (Palmer and Filoso 2009). Such measurements are often complicated, and the evaluation of many restoration projects often falls short of reliable (Palmer and Filoso 2009). Moreover, using ecological metrics (e.g., species diversity) has proven to be inefficient for restoration assessment in many cases (Palmer and Filoso 2009). These shortcomings should be tackled if we are to realize the potential for using ecological restoration as an effective management tool and reversing the decline of numerous degraded marine ecosystem sites and their deteriorating services.

Marine ecosystem restoration: Basic ecological goals

Ecological restoration encompasses multiple forms of intervention (e.g., restoration, rehabilitation, and reclamation—or replacement; points A, C, C’, and C” in figure 2; for further definitions, such as of *remediation*, *mitigation*, and *compensation*, and recommended terminology, see Elliott et al. 2007). These various forms differ in the way they affect the biota and/or physical conditions at a site in order to restore the structure and function of the original state (figure 2; e.g., Dobson et al. 1997). The ideal aim of many ecological-restoration projects is to return the system to its past *natural* state (i.e., a state comparable to one unaffected by modern anthropogenic disturbance; point A in figure 2; e.g., Dobson et al. 1997). Alternatively, the goal of restoration may be to bring the target habitat to a healthier state (i.e., a “self-maintaining, vigorous, resilient state to externally imposed pressures, and able to sustain services to humans…”; points C,C’,C” in figure 2; Tett et al. 2013). Under other circumstances, restoration may focus on repairing the structure and function of degraded systems to some extent (figure 2; see Dobson et al. 1997 and Elliott et al. 2007 for different definitions) or providing some function where missing (e.g., ports or other marine urban environments; Dafforn et al. 2015). A key question, then, is, “What can be done in those common cases where neither natural processes nor changes in resource management will return the ecosystem to its original state in a reasonable time frame?” (figure 2). Examples of slow-recovering, or stable, degraded states may include: (a) the physical destruction of habitat-engineering

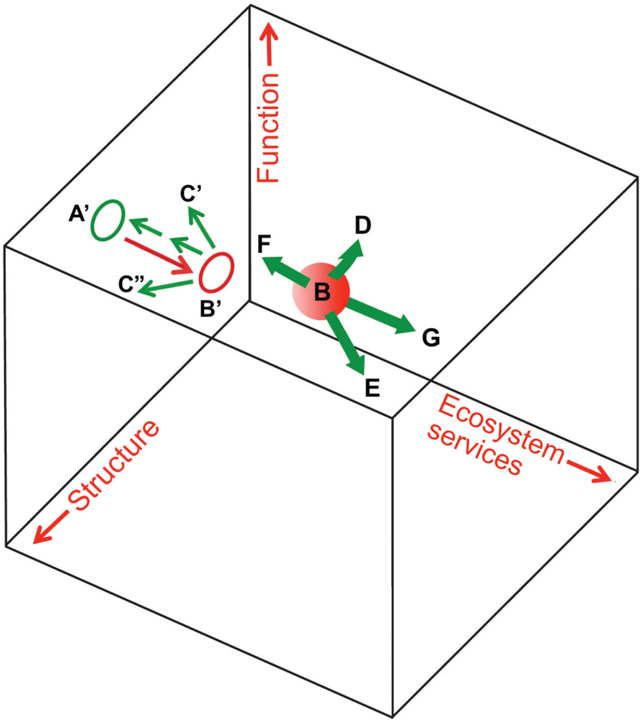

Figure 3. A schematic illustration of the effects of restoration interventions on ecosystem structure, ecosystem function, and ecosystem services, illustrating the hypothetical scenarios that may occur as degraded ecosystems either recover toward their original state or shift toward other improved directions (C–F). Arrays A' to C', correspond to figure 2; B,B' to the degraded ecosystem; D to improved function, structure, and services (e.g., the removal of stressors, which enables the partial or complete recovery of the ecosystems); E to the declined function and slight improvement of structure and services (e.g., the transplantation of a single habitat-engineering species); F to improved function and structure but no significant change in services (e.g., the restoration of a reef-table community with species that cannot improve coastal protection); G to no improvement of the structure and function of a given ecosystem site but improved locally needed services (e.g., enhanced food supply related to the creation of alternative habitat sites, such as artificial reefs).

species (e.g., a flattened reef area after years of blast fishing or severe storms), with natural recovery expected to take many years or decades (e.g., reef-building corals, mangroves, and seagrasses; Lotze et al. 2011); (b) extreme biotic changes (e.g., invasive pest species, overfished stocks, or replacement by new ecological engineering taxa), which can shift the system to a different state (i.e., phase shift; e.g., coral to macroalgae; Graham et al. 2015); or (c) extreme abiotic changes of either water quality (e.g., from oligotrophic to eutrophic) or substratum type (hard substrate, soft bottom, or change of sediment grain size) due to off-site activities, such as those occurring upstream or in adjacent watersheds.

Given these dramatic adverse changes, ecological restoration, if appropriate, should be applied to address any of three potential overall goals: (1) to accelerate recovery in the case of slow natural recovery processes, (2) to enable recovery when systems are stuck in alternative, less desirable states, or (3) to change the structure and/or function in cases of extreme decline of ecosystem services to form a healthy ecosystem, even if it differs from what we understand to have existed prior to human interference, and to enable the renewal of services in the form of a "target-designed novel ecosystem." All three objectives include the expectation of improved ecosystem functionality and the attendant ecosystem services. If improved ecosystem services are defined as a key goal, then the restoration efforts should focus on social–ecological elements rather than solely on ecological-restoration ones (figure 3).

The concept of social–ecological restoration

Marine ecosystems are tightly linked to coastal human communities (social–ecological systems, *sensu* Berkes and Folke 1998, Kittinger et al. 2012), which reciprocally affect each other. By the term *marine ecosystems*, we refer here to a wide range of benthic marine ecosystems, from supralittoral and intertidal environments to subtidal environments. The overexploitation of marine ecosystems and natural resources can degrade life-supporting systems, such as coral reefs and mangrove forests, which, in turn, dramatically influence the quality of life and well-being of associated communities. Poverty in fishery-supported communities in developing countries, for example, is correlated with the decline of coastal ecosystems and their services (Béné 2003, 2009, Leisher et al. 2013). The strong interactions between human societies and marine ecosystems that define a social–ecological system should be considered in developing operative restoration plans, integrating effective tools and focused goals where degradation has led to declines in ecosystem services (e.g., the three examples of slow-recovering degraded states that we described above).

There is a growing literature on the socioeconomic aspects of the resilience, recovery, and ecosystem services of marine systems (e.g., Adger et al. 2005, Elliott et al. 2007, Duarte et al. 2014). Within this literature, attention has focused on the social aspects of fishery management and establishing marine reserves (e.g., Hilborn 2007, Pollnac et al. 2010, Unsworth and Cullen 2010), whereas relatively few studies have dealt with the social aspects of marine ecological restoration (e.g., Elliott et al. 2007). Nevertheless, a disregard for the socioeconomic components in conservation projects can lead to failures (Bode et al. 2008, Polasky 2008), such as "paper parks." These situations typically result when MPA planners fail to address stakeholder conflicts or disregard their values in the planning process; in these instances, local communities often ignore reserve boundaries, leading to a "failed" reserve (e.g., Bode et al. 2008). Similar outcomes can also occur when ecological-restoration projects lack socioeconomic dimensions. That is, restoration efforts that only

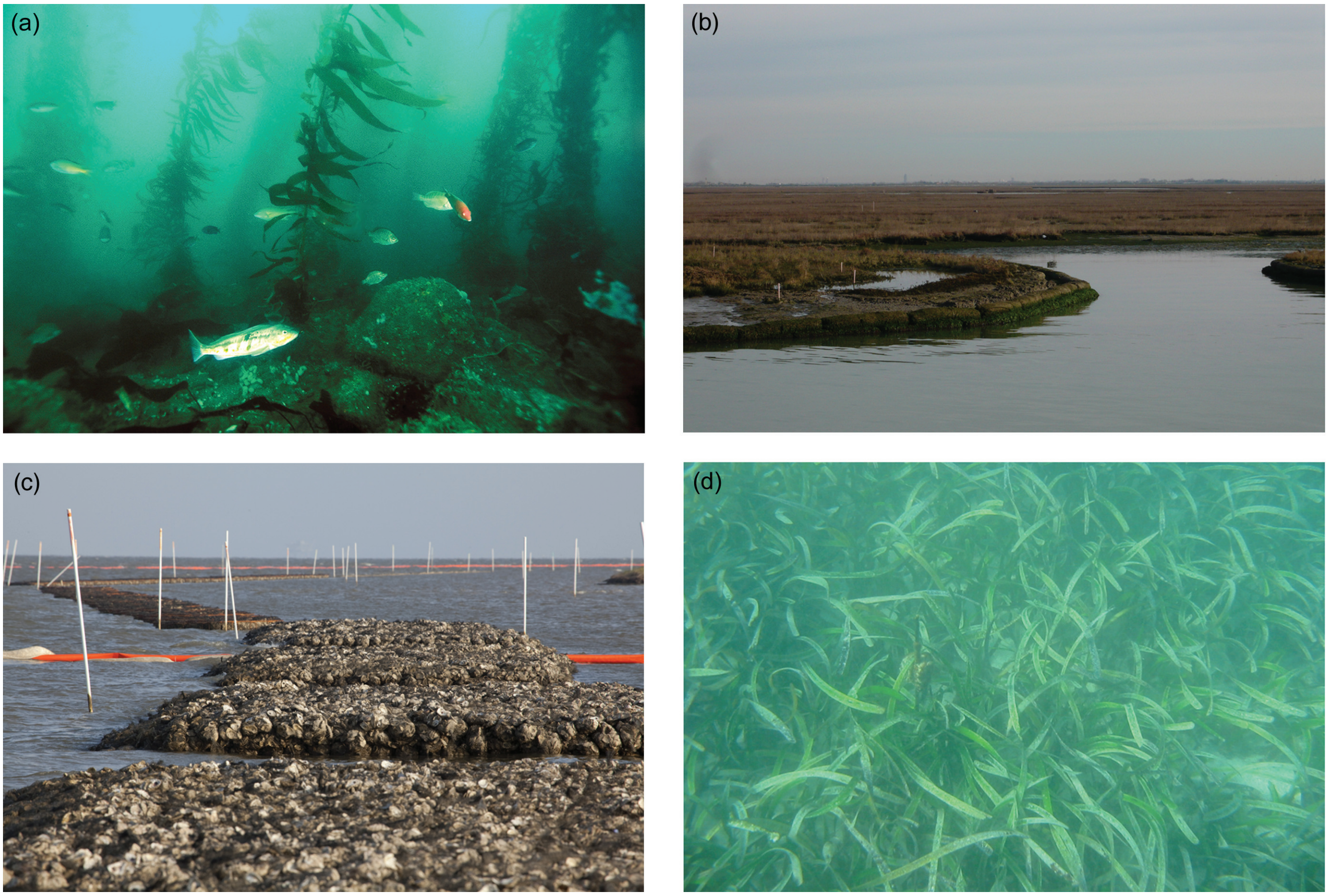

Figure 4. Case studies of marine ecosystem restoration projects designed to restore or mitigate for lost ecosystem services, notably coastal protection, seabed stabilization, food supply, nursery habitats, carbon sequestration ("blue carbon"), and tourism attractions. (a) A replaced kelp forest, established on an artificial reef (i.e., deployed rocks) on a sandy seabed, in an alternative site to mitigate for the loss of a kelp forest damaged by a power plant, the San Onofre Nuclear Generating Station (California; a project by UCSB). (b) Restored salt marshes, which are part of the coastal defense strategy to protect the city of Venice and the Venetian Lagoon from flooding (Italy; the MOSE project by Consorzio Venezia Nuova). (c) A constructed oyster reef in the Gulf of Mexico as part of the living shoreline efforts (Alabama; a project by The Nature Conservancy). (d) A seagrass meadow of **Posidonia australis** ***restored three decades after having been heavily affected by eutrophication (Cockburn Sound, Perth, Western Australia; a project by Murdoch University). Photographs: (a) Richard Herrmann, (b) Laura Airoldi, (c) Jeff DeQuattro, and (d) Jennifer Verduin.***

focus on improving the structure and function of ecosystems while disregarding the needs of relevant stakeholders who are often the most direct recipients of ecosystem services will rarely succeed.

We recommend the use of ecosystem services (figure 3; presented as a third axis in the model of restoration effects on ecosystem structure and function) and socioeconomic aspects as part of an integrated approach for planning, executing, and evaluating or monitoring restoration projects. The *ecosystem-services* concept describes and emphasizes the diverse benefits and uses of ecosystems to human society (see figure 4 for examples; MEA 2005). The application of this concept, which is gaining interest among scientists and policymakers, can facilitate collaboration between them and relevant practitioners and reduce conflicts among stakeholders (Tallis et al. 2012, Kelble et al. 2013). An example of the increased interest in including ecosystem services in decisionmaking processes is The Economics of Ecosystem Services and Biodiversity (TEEB) initiative, a global initiative focused on drawing attention to the economic benefits of biodiversity, including the growing cost of biodiversity loss and ecosystem degradation. The TEEB approach consists of recognizing value, demonstrating value, and capturing value (Sukhdev et al. 2014). Objections to the approach have been raised but have been well addressed (see Schröter et al. 2014). Another example, specific to marine ecosystems, that represents a shift from an exclusive focus on adverse anthropogenic impacts on ecosystems to a holistic management approach and includes ecosystem services is presented by Kelble and colleagues (2013). In their conceptual model, they combine the widely applied conceptual model of driver, pressure, state, impact, and response

(DPSIR) with an ecosystem-based management model that also incorporates positive changes in the ecosystem and its services (i.e., driver, pressure, state, ecosystem service, and response; EBM-DPSER; Kelble et al. 2013).

Ecosystem services can be linked to ecosystem structure and function (Tett et al. 2013) but are also interconnected to human behavior and resource-exploitation levels, both of which affect the two former parameters. It is important, however, to distinguish between ecosystem services and ecosystem functions (figure 3; Schwerdtner Manez et al. 2014): *Ecosystem functions* are the chemical, physical, and biological interactions associated with ecosystems, whereas *ecosystem services* depend on these functions but are different—they are the aspects of the ecosystem valued by people (Boyd and Banzhaf 2005) and do not necessarily present the same trends as the ecosystem structure and function (figure 3).

The translation of ecosystem structure and function into ecosystem services requires an interdisciplinary approach (Daily et al. 2009). The structure and function of ecosystems expressed by the provision of ecosystem services can be described by ecological production functions (Daily et al. 2000). A better-informed decisionmaking process for restoration management can be made by making explicit all of the costs and benefits that affected people obtain from restored versus nonrestored marine ecosystems. This approach may be implemented using *ecological production functions* (Daily et al. 2009), which includes (a) the translation of the structure and function of ecosystems into the possible provision level of the services to humans; (b) the assessment of the real provision of these services, which depends on the human demand for these services and on identifying the stakeholders who are expected to benefit from the ecosystem restoration; and (c) the implementation of economic valuation methods to make different costs and benefits comparable in monetary terms.

Implementing and assessing social–ecological restoration

Restoring single species or particular ecosystem functions can in theory be straightforward but may succeed at the cost of other ecosystem elements. Understanding such trade-offs and helping guide restoration toward outcomes that meet multiple objectives require focusing on healthy ecosystems, but it can be difficult to quantitatively define a healthy ecosystem. If *healthy ecosystems* are those able to supply a full range of ecosystem services (e.g., Palmer and Filoso 2009, Tett et al. 2013; see also Schröter et al. 2014), then the social–ecological concept can provide a framework for setting realistic restoration goals and effective and reliable assessment parameters. Alternatively, if there is an easy-to-assess and high-value service that a given ecosystem provides, restoration interventions are likely to be funded and implemented, regardless of the expected health state—or the full range of ecosystem services—of the restored ecosystem (see figure 4 for examples).

The current focus on integrated coastal zone management (ICZM; European Commission 2007), ecosystem-based management (EBM; McLeod and Leslie 2009), and marine spatial planning (MSP; Gilliland and Laffoley 2008; also termed as coastal and marine spatial planning, CMSP) offers existing management frameworks within which to embed social–ecological restoration and helps to refine restoration targets and provide quantitative tools for assessment. The MSP concept can serve as a framing platform that directs restoration intervention toward specific focused goals; thus, the social–ecological restoration outcomes are expected to improve ecosystem services, which in turn will improve the MSP achievements by alleviating conflicts and enhancing the services supplied to society. Specifically, we believe that social–ecological restoration can help to achieve the goals of MSP in parallel with the ecosystem-services framework approach in two ways: First, this combined approach provides the tools to improve the ecosystem-services value by enhancing supply or by lowering the impact of exploitation via mitigation and therefore may enable enhanced direct and/or indirect use. Second, it can help by creating alternative incentives to conserve and restore ecosystem services and improve their sustainable supply. To be applicable, the MSP concept needs a comprehensive framework that considers a broad range of uses and accurately evaluates the suite of benefits (ecosystem services) humans receive from the oceans. However, at present, marine ecosystem services are often categorized under broad definitions and are roughly estimated or measured in different ways (Tallis et al. 2012, Schwerdtner Manez et al. 2014). A novel approach suggested by Tallis and colleagues (2012) addressed many of the shortcomings noted above by using a three-step framework that, in addition to creating a refined classification of ecosystem services, emphasizes the importance of measuring ecosystem services at three distinct points along the ecosystem-services production chain: supply, service, and value. We suggest taking this approach further by incorporating social–ecological restoration as an additional tool in a reciprocal framework.

Assessing the success of social–ecological restoration in turn requires metrics of overall ocean health. The recent development of the Ocean Health Index (OHI; Halpern 2012) provides one such metric. The OHI is a systematic approach for measuring the overall condition of marine ecosystems and treats nature and people as integrated parts of a healthy system (Halpern et al. 2012). It can provide a powerful tool to direct resource management and improve policy, which also may include restoration interventions, if needed (Halpern et al. 2012). With repeated assessments over time, the OHI can be used to assess whether or how restoration actions affect each dimension of ocean health (e.g., ecosystem service) separately and altogether. In combination with other tools that model ecosystem-service provision under different management scenarios (such as InVEST; Daily et al. 2009) or evaluate likely change in ecosystems (such as Bayesian network based risk assessments), the OHI can also be used to evaluate how restoration activities may alter ocean health in the future.

Conclusions

Marine ecosystems are degrading at accelerated rates that jeopardize essential ecosystem services for human society. Unfortunately, our present management approaches and tools are inadequate to address the problem, and an urgent need exists to bridge the gaps among science, policy, and on-the-ground practice.

Ecological restoration cannot provide a substitute for the conservation of ecosystems, but where ecosystems are already heavily degraded, it may be a necessary and even a more effective management strategy. Natural recovery is preferred (ecologically and economically) over active restoration interventions. If, after the removal of significant stressors, natural recovery is expected to occur in a reasonable time scale, this is likely to emerge as the management priority. However, in cases in which the major stressor(s) cannot be removed or significantly reduced, when changes are beyond recovery because of the different trajectories of degradation and recovery (e.g., Lotze et al. 2011, Suding 2011), or when economic or social reasons motivate accelerating the recovery (even if the system would recover on its own), restoration interventions should be considered and implemented as essential elements of ecosystem management.

The strong link between human societies and marine ecosystems is a key element in applied ecological restoration and therefore should be integrated in restoration plans, especially in developing countries, where local stressors often play a stronger role than global stressors (e.g., Burke et al. 2011). In this regard, we propose testing the application of management frameworks (e.g., the OHI and MSP) as potentially effective tools for focusing restoration goals and providing more effective and reliable assessment. Incorporating the social–ecological restoration element is expected to compensate for the relatively low supply of ecosystem services, which is drastically below its potential (or former supply) because of misuse and overexploitation.

Overall, the development of effective, scalable restoration tools and approaches will inevitably be complicated by its broad multidisciplinary nature. Therefore, whatever the future direction, if ecological restoration is to result in reliable applied science, then strong collaboration will be required among ecological, economic, and social experts, as well as with private and public stakeholders, to encompass a diverse array of fields into a transdisciplinary co-designed approach.

Acknowledgments

This study was conducted as a part of the Marine Ecological Restoration Working Group (MER-WG) workshop held in Eilat, Israel, by the Red Sea. Thanks are due to Israel's Ministry of Environmental Protection and the Israel Society of Ecology and Environmental Sciences, whose support enabled the workshop and the US National Science Foundation (OCE-1232779) for assistance with publication costs. The MER workshop was held at the InterUniversity Institute (IUI) for Marine Sciences, in Eilat. We wish to thank the Dolphin Reef, in Eilat, for their help and support; Dr. Sinaia Netanyahu for her support; and the directors and staff of the IUI for their help and hospitality. This article is contribution no. 3501 of the Virginia Institute of Marine Science at the College of William and Mary. Gary Kendrick's travel to the workshop was funded through an Australian Research Council Linkage grant (no. LP130100155). Thanks are due to Ron McPeak, Cynthia Sapp (courtesy of Coastal Resources Group, Inc., in Venice, Florida), Enric Ballesteros, Paolo Guidetti, Richard Herrmann, Jeff DeQuattro, and Jennifer Verduin for their contributed photos. We gratefully acknowledge the efforts of the two anonymous reviewers; these contributed significantly to improving this article.

References cited

Adger WN, Hughes TP, Folke C, Carpenter SR, Rockstrom J. 2005. Social–ecological resilience to coastal disasters. Science 309: 1036–1039.

Barbier EB. 2012. Progress and challenges in valuing coastal and marine ecosystem services. Review of Environmental Economics and Policy 6: 1–19.

Beck MW, et al. 2011. Oyster reefs at risk and recommendations for conservation, restoration, and management. BioScience 61: 107–116.

Béné C. 2003. When fishery rhymes with poverty: A first step beyond the old paradigm on poverty in small-scale fisheries. World Development 31: 949–975.

———. 2009. Are fishers poor or vulnerable? Assessing economic vulnerability in small-scale fishing communities. The Journal of Development Studies 45: 911–933.

Berkes F, Folke C. 1998. Linking Social and Ecological systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge University Press.

Bode M, Watson J, Iwamura T, Possingham HP. 2008. The cost of conservation. Science 321: 340.

Boyd JW, Banzhaf HS. 2005. Ecosystem services and government accountability: The need for a new way of judging nature's value. Resources 158: 16–19.

Burke LM, Reytar K, Spalding M, Perry A. 2011. Reefs at Risk Revisited. World Resources Institute.

Cesar HSJ. 2000. Coral reefs: Their functions, threats, and economic value. Pages 14–39 in HSJ Cesar, ed. Collected Essays on the Economics of Coral Reefs. CORDIO.

Cowling RM, Egoh B, Knight AT, O'Farrell PJ, Reyers B, Rouget M, Roux DJ, Welz A, Wilhelm-Rechman A. 2008. An operational model for mainstreaming ecosystem services for implementation. Proceedings of the National Academy of Sciences 105: 9483–9488.

Dafforn KA, Glasby TM, Airoldi L, Rivero NK, Mayer-PintoM, Johnston EL. 2015. Marine urban sprawl: An ecological framework to inform the design of multifunctional artificial structures. Frontiers in Ecology and the Environment 13: 82–90. (11 November 2015; *http://dx.doi.org/10.1890/140050*).

Daily GC, et al. 2000. The value of nature and the nature of value. Science 5478: 395–396.

Daily GC, Polasky S, Goldstein J, Kareiva PM, Mooney HA, Pejchar L, Ricketts TH, Salzman J, Shallenberger R. 2009. Ecosystem services in decision making: Time to deliver. Frontiers in Ecology and the Environment 7: 21–28.

De'ath G, Fabricius KE, Sweatman H, Puotinen M. 2012. The 27-year decline of coral cover on the Great Barrier Reef and its causes. Proceedings of the National Academy of Sciences 109: 17995–17999.

Dobson AP, Bradshaw AD, Baker AJM. 1997. Hopes for the future: Restoration ecology and conservation biology. Science 277: 515–522.

Duarte CM, Borja A, Carstensen J, Elliott M, Krause-Jensen D, Marbà N. 2014. Paradigms in the recovery of estuarine and coastal ecosystems. Estuaries and Coasts 38: 1202–1212.

Elliott M, Burdon D, Hemingway KL, Apitz SE. 2007. Estuarine, coastal, and marine ecosystem restoration: confusing management and science: A revision of concepts. Estuarine, Coastal, and Shelf Science 74: 349–366.

European Commission. 2007. Report to the European Parliament and the Council: An Evaluation of Integrated Coastal Zone Management (ICZM) in Europe. European Commission. (11 November 2015; *www.ipex.eu/IPEXL-WEB/dossier/document/COM20070308FIN.do*).

Gaines SD, White C, Carr MH, Palumbi SR. 2010. Designing marine reserve networks for both conservation and fisheries management. Proceedings of the National Academy of Sciences 107: 18286–18293. doi:10.1073/pnas.0906473107.

Gilliland PM, Laffoley D. 2008. Key elements and steps in the process of developing ecosystem-based marine spatial planning. Marine Policy 32: 787–796.

Graham NAJ, Jennings S, MacNeil A, Mouillot D, Wilson SK. 2015. Predicting climate-driven regime shifts versus rebound potential in coral reefs. Nature 518: 94–97.

Halpern BS, et al. 2012. An index to assess the health and benefits of the global ocean. Nature 488: 615–620.

Hilborn R. 2007. Managing fisheries is managing people: What has been learned? Fish and Fisheries 8: 285–296.

[HLPE] High-Level Panel of Experts on Food Security and Nutrition. 2014. Sustainable Fisheries and Aquaculture for Food Security and Nutrition. Committee on World Food Security, Food and Agriculture Organization of the United Nations.

Hobbs RJ. 2004. Restoration ecology: The challenge of social values and expectations. Frontiers in Ecology and the Environment 2: 43–44.

[IPCC] Intergovernmental Panel on Climate Change. 2013. Climate Change 2013: The Physical Science Basis. Cambridge University Press.

Kelble CR, Loomis DK, Lovelace S, Nuttle WK, Ortner PB, Fletcher P, Cook GS, Lorenz JJ, Boyer JN. 2013. The EBM-DPSER conceptual model: Integrating ecosystem services into the DPSIR Framework. PLOS ONE 8 (art. e70766). doi:10.1371/journal.pone.0070766.

Kittinger JN, Finkbeiner EM, Glazier EW, Crowder LB. 2012. Human dimensions of coral reef social–ecological systems. Ecology and Society 17 (art. 17).

Knowlton N. 2012. Iconic coral reef degraded despite substantial protection. Proceedings of the National Academy of Sciences 109: 17734–17735.

Leisher C, Sanjayan M, Blockhus J, Larsen SN, Kontoleon A. 2013. Does conserving biodiversity work to reduce poverty? A state of knowledge review. Pages 143–159 in Roe D, Elliott J, Sandbrook C, Walpole M, eds. Biodiversity Conservation and Poverty Alleviation: Exploring the Evidence for a Link. Wiley.

Lotze HK, Coll M, Magera AM, Ward-Paige C, Airoldi L. 2011. Recovery of marine animal populations and ecosystems. Trends in Ecology and Evolution 26: 595–605.

McLeod KL, Leslie H. 2009. Ecosystem-Based Management for the Oceans. Island Press.

[MEA] Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-Being: Synthesis Report. Island Press.

Mumby PJ, Steneck RS. 2008. Coral reef management and conservation in light of rapidly evolving ecological paradigms. Trends in Ecology and Evolution 23: 555–563.

Palmer MA, Filoso S. 2009. Restoration of ecosystem services for environmental markets. Science 325: 575–576.

Parravicini V, Micheli F, Montefalcone M, Morri C, Villa E, Castellano M, Povero P, Bianchi CN. 2013. Conserving biodiversity in a human-dominated world: Degradation of marine sessile communities within a protected area with conflicting human uses. PLOS ONE 8 (art. e75767). doi:10.1371/journal.pone.0075767.

Polasky S. 2008. Why conservation planning needs socioeconomic data. Proceedings of the National Academy of Sciences 105: 6505–6506.

Pollnac R, Christie P, Cinner JE, Dalton T, Daw TM, Forrester GE, Graham NAJ, McClanahan TR. 2010. Marine reserves as linked social–ecological systems. Proceedings of the National Academy of Sciences 43: 18262–18265.

Ricketts T, et al. 2008. Landscape effects on crop pollination services: Are there general patterns? Ecology Letters 11: 499–515.

Ruiz-Jaen MC, Aide TM, 2005. Restoration success: How is it being measured? Restoration Ecology 13: 569–577.

Schröter M, van der Zanden EH, van Oudenhoven APE, Remme RP, Serna-Chavez HM, de Groot RS, Opdam P. 2014. Ecosystem services as a contested concept: A synthesis of critique and counterarguments. Conservation Letters 7: 514–523.

Schwerdtner Máñez K, Krause G, Ring I, Glaser M. 2014. The Gordian knot of mangrove conservation: Disentangling the role of scale, services, and benefits. Global Environmental Change 28: 120–128.

[SER] Society for Ecological Restoration International, Science and Policy Working Group. 2004. SER International Primer on Ecological Restoration. (11 November 2015; *www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration*).

Suding KN. 2011. Toward an Era of Restoration in Ecology: Successes, Failures, and Opportunities Ahead. Annual Review of Ecology, Evolution, and Systematics 42: 465–487.

Sukhdev P, Wittmer H, Miller D. 2014. The economics of ecosystems and biodiversity (TEEB): Challenges and responses. Pages 135–152 in Helm D, Hepburn C, eds. Nature in the Balance: The Economics of Biodiversity. Oxford University Press.

Tallis H, et al. 2012. New metrics for managing and sustaining the ocean's bounty. Marine Policy 36: 303–306.

Tett P, et al. 2013. Framework for understanding marine ecosystem health. Marine Ecology Progress Series 494: 1–27.

Unsworth RK, Cullen LC. 2010. Recognizing the necessity for Indo–Pacific seagrass conservation. Conservation Letters 3: 63–73.

Waycott M, et al. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences 106: 12377–12381.

Avigdor Abelson (avigdor@tauex.tau.ac.il) is with the Department of Zoology at Tel Aviv University, in Israel. Benjamin S. Halpern is with the Bren School of Environmental Science and Management at the University of California, Santa Barbara. Daniel C. Reed is with the Marine Science Institute at the University of California, Santa Barbara. Robert J. Orth is with the School of Marine Science at the Virginia Institute of Marine Science at the College of William and Mary, in Gloucester Point, Virginia. Gary A. Kendrick is with the School of Plant Biology at the University of Western Australia, in Crawley. Michael W. Beck is with the Global Marine Team of The Nature Conservancy at the Institute of Marine Sciences at the University of California, Santa Cruz. Jonathan Belmaker is with the Department of Zoology at Tel Aviv University. Gesche Krause is with the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Earth System Knowledge Platform (ESKP), in Bremerhaven, Germany. Graham J. Edgar is with the Institute for Marine and Antarctic Studies at the University of Tasmania, in Australia.Laura Airoldi is with the Centro Interdipartimentale di Ricerca per le Scienze Ambientali and the Dipartimento di Scienze Biologiche, Geologiche ed Ambientali at the Università di Bologna, in Ravenna, Italy. Eran Brokovich is with the Israel Society of Ecology and Environmental Sciences, Israel. Robert France is with the Department of Environmental Sciences at Dalhousie University, in Truro, Nova Scotia, Canada. Nadav Shashar and Noga Stambler are with the Eilat Campus at Ben-Gurion University, in Eilat, Israel; NS is also with the Israel Society of Ecology and Environmental Sciences. Arianne de Blaeij is with the LEI at Wageningen University and Research Centre, in The Hague, The Netherlands. Pierre Salameh is with the Department of Fisheries at the Ministry of Agriculture, in Kiryat Haim, Israel. Mordechai Shechter is with the Natural Resource and Environmental Research Center at the University of Haifa, in Israel. Peter A. Nelson is a senior fish ecologist at H. T. Harvey and Associates, in Los Gatos, California.