Marine Conservation

Science, Policy, and Management

G. Carleton Ray
Jerry McCormick-Ray

Illustrations by Robert L. Smith, Jr.

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CHAPTER 13

FROM BEING TO BECOMING: A FUTURE VISION

. . . in practice, possibilities for national action are now constrained by the increasing power of international forces, the declining influence of federal agencies over state and local government actions, an unmanageable workload, and an aging system of laws and regulations sometimes out of sync with new science and new issues.

Graham (1999) *The Morning After Earth Day*.

13.1 THE NEW NORMAL

The 21st century entered an era of limits for marine systems—from managing abundance to managing increasing scarcity. Marine policies that arose in the era of the Marine Revolution (Ch. 1) became instituted under social and environmental conditions different from today. Institutions were established to carry out fisheries management, species protection, regulation of shipping, oil, gas, and mining, and coastal zone management to resolve internal conflicts separately. This sector-based decision-making lacked clear authority to resolve cross-sector conflict and cumulative effects on coastal and marine systems.

Human civilization thrived during the last 10,000 years within a relatively narrow range of regular temperatures, freshwater availability, and biogeochemical flows, in a period when Earth was unusually stable (Dansgaard *et al*., 1993). With the global human population expected to reach 8 billion in 2024 and 9 billion in 2045, human activity may soon exceed the "safe operating space" for humanity (Rockström *et al*., 2009), especially in that narrow coastal fringe covering only 7.6% of the Earth's total land area that presently holds approximately 40% of the world's population, dependent in varying degrees on coastal resources for its livelihood.

Now, population growth, technological achievements, and improved social standards encompass a world society intimately connected to oceans, climate, and biogeochemical cycles. Twenty-six of the 33 world's megacities are located on the coast (Table 2.4), and have expansive ecological footprints (Folke *et al*., 1997). Through increasing use of fossil fuel energy and natural resources, and institutional capacity to resolve issues, the social system is transforming coastlines, marine ecosystems, and the global climate. The accelerating scale of human activity intertwines social and ecological crises (Walker *et al*., 2009) and increases synergistic effects that lead to mass ocean extinctions (Jackson, 2008).

The recognition of increasing frequency of deadly and costly natural disasters is alerting scientists, decision-makers, and the public to take precaution. New geospatial tools focus on large regional scales to foretell potential climate-related disasters. Scientists are now able to forecast the impact of climate change on major cities and urban land susceptible to high-risk coastal flooding (Strauss *et al*., 2012). Yet, fragmented policies and management directives continue to fail holistically to address the interconnected coastal-ocean system undergoing change. Under this "New Normal," marine conservation remains stubbornly dependent on past policy instruments and soft-policy agreements.

13.2 FROM BEING . . .

Ilya Prigogine, in his classic book *From Being to Becoming* (1980), explained from theoretical non-equilibrium thermodynamics how systems evolve from low-level chaos to high-level order, and that change is always accompanied by degradation into a more dispersed, chaotic state of greater disorder (Ch. 4). Panarchy theory describes four stages of ecosystem change: expansion, maturity, senescence, resilience, and back to expansion (Fig. 4.21). These explanations of system behavior become metaphors for the transition of marine conservation, from the necessary but insufficient protection of species and spaces and narrowly based regulations (fisheries, pollution, etc.) into the broader context of complex eco- and social-system behavior that ultimately governs the success of conservation effort.

Marine conservation is rooted in both social and environmental conditions, with expectations of building on the past. Our case studies illustrate that conservation issues extend throughout whole systems, evolving with the social-ecological system from past history that is moving into a dramatically different 21st century. As such, marine conservation remains a work in progress, encompassing present mechanisms to preserve biodiversity, ecosystem resilience, and human well-being, while working within the bounds of a changing socio-ecological system. That solutions are not yet "complete" has less to do with lack of scientific information than with social, economic, and political forces and ecosystem adjustments. Failure to treat conservation goals systemically, while socio-political forces exacerbate the global environmental deficit,

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risks the loss of socially and environmentally valued assets. According to Bormann (1990), "This deficit results from the collective and often unanticipated impact of our alteration of the Earth's atmosphere, water, soil, biota, ecological systems, and entire landscapes [and seascapes]. The social and economic costs to human welfare are ultimately greater than the short-term benefits that flow from this activity."

Especially in the vital area of the biosphere we call the coastal realm, societies at all governing levels require integrative conservation action to protect and restore species and environments. This narrow land-sea region of Earth, where social and economic uses impinge most strongly on ecosystem integrity, is increasingly exposed to intense droughts, floods, earthquakes, and storms from human-induced climate change. "Natural disasters" are increasingly affecting urbanized coasts and industrialized seas. Most significant was the 2004 Indian Ocean earthquake and its tsunami that shocked the world when it caused the deadliest natural disaster in recorded history. In 2011, Japan experienced the most costly powerful earthquake on record, revealing the vulnerability of offshore waters to coastal nuclear power and to tons of debris that were added to the North Pacific "garbage patch" (Ch. 2, Section 2.2.2.4). In 2012, Hurricane Sandy became the costliest natural disaster in U.S. history when it struck the mid-Atlantic states, surpassing the horrific damage of Hurricane Katrina in the northern Gulf of Mexico in 2005. Under these new conditions, sector-based management continues to follow institutional frameworks that were created under different social and environmental conditions.

13.3 . . . TO BECOMING

Three historic arenas most prominent for marine conservation are fisheries, coastal management, and Marine Protected Areas. The following three sections describe their present states. The succeeding Section 13.4 offers arenas for change. New conditions suggest new strategies.

13.3.1 Managing fish, fisheries, and fishermen

Fisheries have long been acknowledged to be the most ubiquitous of human interventions into marine environments (NRC, 1995). Fish, fisheries, and fishermen are managed through established institutions influenced by the industrialization of capture fisheries, which generated enormous wealth in the 19th to 20th centuries. Modern fishing now supports about 20 million fishermen worldwide, 90% of which are small-scale fishers that remove an estimated 25% of the global catch (FAO, 2008). Fisheries support a global fleet of about 4.3 million vessels: 59% powered by engines and 41% by traditional craft operated by sails and oars, primarily in Asia (77%) and Africa (20%). About 40% of the total global fisheries catch is for human consumption in an expanding market that supports an industry that employs almost ten times as many persons as fishermen, including processors, shippers, and marketers. Fishers, along with aqua culturists and those supplying services and goods to them, sustain the livelihoods of about 540 million people, or 8.0% of the world population (FAO, 2010). Small-scale, nearshore fisheries in the tropical Pacific are for subsistence, social and cultural purposes, and for food, trade, and recreational resources (e.g., Dalzell *et al.*, 1996). Among South Pacific islanders, coastal fisheries target reef fishes and coastal pelagic fishes, with a total removal of 100,000 tons per year and a value of $262 million dollars, 80% harvested for subsistence (Dalzell *et al.*, 1996). But as Ludwig *et al.* (1993) observed, ". . . the larger and the more immediate are prospects for gain, the greater the political power that is used to facilitate unlimited exploitation."

The principal, direct impact of fishing is that it reduces the abundance of target species, especially the largest, most reproductive, and ecologically valuable species (Pauly *et al.*, 2002). This process of "fishing down the food web" (Pauly *et al.*, 1998) selectively reduces economically valued top predators, such as the endangered Atlantic bluefin tuna (Ch. 2), Nassau groupers (Ch. 8), and others now in very reduced numbers and even threatened with extinction. Removal of top predators has strong effects on ecosystems and biodiversity (NRC, 1995); e.g., prey numbers increase to force an ecological shift toward short-lived species on lower trophic level species, thereby affecting biodiversity (Branch *et al.*, 2010) and ecosystem function (Choi *et al.*, 2004). Meanwhile, these species attract new fisheries, furthering a cascade of decline, appropriately termed a "March of Folly" (Sumaila and Pauly, 2011).

Fisheries management to date has most often been ineffective (Pikitch *et al.*, 2004). It has focused, until recently, on single-species, "maximum sustainable yield" management in which the natural histories of fish and habitat have only lately been included (Box 3.5). Management effectiveness within national jurisdictions varies greatly among nations, but high seas international management is in a state of crisis. This crisis relates to Garrett Hardin's (1968) resounding essay "Tragedy of the Commons" in which environmental disaster occurs in the public commons from individual decisions and too many people exploiting limited common-pool resources. This tragedy is particularly devastating for fisheries, which remains the last, large-scale "hunter-gatherer" activity of humans, affecting whole ecosystems, in many cases irreversibly, and also the economic prospects of numerous dependent fishermen worldwide. Fisheries management is also affected by investment policies of multilateral development banks for developing countries that aim to generate foreign exchange through expanding fisheries export capacity, as well as other environmentally destructive practices; e.g., aquaculture, larger vessels for increased capacity, and encouraging foreign access to fisheries. The management of wide-ranging, anadromous fish is especially contentious, for example high-profile icons such as Pacific salmon, because these fish are affected by nearly everything local people do (Box 13.1). Therefore, potential remedies impact traditional ways in which people extract water, generate electricity, transport goods, harvest fish, develop industrial, commercial, and private properties, and conduct their daily lives (Ruckelshaus *et al.*, 2002).

In 2006, United Nations General Assembly Resolution 61/105 called "upon States to take action immediately to sustainably manage fish stocks and protect vulnerable marine ecosystems (VMEs) (Ch. 3; Section 3.5.2.3), including

Box 13.1 Pacific salmon: science policy

James H. Pipkin
[Retired, U.S. Department of State Special Negotiator for Pacific Salmon (1994 to 2001); U.S. federal Commissioner on the bilateral Pacific Salmon Commission (1999 to 2002); Counselor to the U.S. Secretary of the Interior (1993 to 1998); and Director of the Interior Department's Office of Policy Analysis (1998 to 2001)], Bethesda, Maryland, USA.

Historically, more than ten million salmon and steelhead trout (all *Oncorhynchu*s species) returned to the Columbia River basin each year to spawn. Now there are less than two million, and most of those originate from hatcheries, not from the wild. Some salmon populations are already extinct and others are headed that way.

Few people would deny that many stocks of wild salmon in the Pacific northwest are in trouble, or that an ecosystem approach must be taken if the problem is to be corrected. However, the application of ecosystem principles to the Pacific salmon issue is enormously complicated and requires the accommodation of a number of important, and often competing, interests. This is true from many standpoints—economic, ecological, social, cultural, institutional, and political.

Severe declines of wild salmon in the Pacific northwest are the product of many factors. The major contributing factors are sometimes referred to as the four "Hs": harvests, hydropower, hatcheries, and habitat. The first two require little explanation. The term "harvests" simply refers to the fact that salmon are caught by commercial, recreational, and tribal fishermen, both in the ocean and when they return to the stream in which they were born. "Hydropower" relates to the huge dams that have been constructed on important salmon rivers as part of our quest for cheap electricity. Those dams form barriers that make migration more difficult, as well as altering water temperatures and flow rates. The main issue concerning "hatcheries" is that salmon from hatcheries can reduce the genetic diversity of wild salmon or make them more susceptible to disease and predation. The fourth factor, "habitat," is complicated, since a wide variety of human activities have an adverse impact on salmon habitat. Clear-cutting of forests removes tree cover and increases siltation, which increases turbidity and raises water temperatures. Drawing water from rivers to irrigate agriculture lowers water levels in the river. Urban and agricultural runoff contains fertilizers, pesticides, herbicides, and other materials that result in habitat degradation in rivers and streams. Wastes produced by industries find their way into aquatic habitat. The building of homes along rivers removes tree cover and woody debris, as well as increasing runoff. Widespread diking of rivers to protect development in floodplains also affects salmon habitat adversely.

Because there are so many "culprits," the norm has been for each group to defend its actions and point fingers at the others. Fishermen say that they have sacrificed more than other sectors and that further cuts in their catch will not reverse the real problems, which are rooted in habitat degradation. Indian fishermen also point to their treaties (under which they ceded most of their land to the United States), which reserved to them the right to continue to fish in their "usual and accustomed" fishing places. Farmers say that they have relied on irrigation water for decades and cannot give it up without going out of business. Land developers say that their contribution to the problem is minuscule when compared to the other factors and that the economic costs of non-development are excessive. Some landowners also argue that the right to make maximum economic use of their properties is protected under the Fifth Amendment to the Constitution.

Many of the arguments about salmon restoration boil down to economics. Unfortunately, the economic consequences of various restoration strategies are rarely clear, and gaps in the science make the implications even more controversial. Beyond economics, in the Pacific northwest, salmon are cultural icons. This is especially true of Indian tribes for which the salmon has both cultural and spiritual significance. Even for non-Indian residents who have no intention of ever catching a fish, salmon represent part of their heritage. To many, salmon are like the canary in the coal mine: the serious decline in the abundance of wild salmon is an indication that streams are no longer healthy, that riparian habitat has been degraded, and that desirable recreational opportunities have been lost.

Politically, the salmon situation is also complex. On one level, an elected politician (state or federal) representing farmers who irrigate their fields will have a different perspective on the salmon issue than a politician whose constituents prize wilderness and sport-fishing opportunities. Both will differ sharply with a politician from another region who questions the large amounts of money being spent to restore salmon in an area that means little to his constituents. The approach of each will make it virtually impossible to find common ground, and in the end the political debate will likely be resolved through seniority and relative political power, rather than by a thoughtful weighing of the merits or a quest for a compromise solution. The same difficulty of achieving consensus exists in the international arena as well.

Jurisdictionally, the problem is equally complicated. No single governmental or other entity controls any one of the four Hs referred to above. Take harvests as an example. In general, each state regulates fishing within its borders

(*Continued*)

and off its coast to a distance of three miles. But unfortunately, salmon are not very good at respecting state borders. They swim across state lines, as well as into Canadian waters where harvests are regulated by the Canadian government, and into international waters where their principal protection is the *North Pacific Anadromous Fisheries Convention*. Beyond that, tribal governments have treaty rights that affect permissible harvests. The U.S. federal government can step in to regulate salmon harvests only when they affect species "listed" as threatened or endangered under the *Endangered Species Act* or when other federal statutes come into play. Similar dispersions of authority exist with respect to the other Hs.

Institutions that play a role in the Pacific salmon controversy include federal and state legislatures, state and federal fish and wildlife agencies, the courts, the Bonneville Power Administration, the Northwest Power Planning Council, the U.S. Army Corps of Engineers, the Environmental Protection Agency, federal and state land management agencies, harvest management organizations such as the Pacific Fishery Management Council and the U.S./Canada Pacific Salmon Commission, and tribal governments. Many institutions at different levels focus primarily on isolated issues that bear on salmon recovery—for example, how many fish can be caught and by whom, how timber will be harvested on national forest land, or how a hydropower facility will be managed to reduce the impact on fish. No existing institution has the mandate to determine answers to broader ecosystem-based questions, such as how a watershed will be managed. Current institutional arrangements are poorly suited to development of an ecosystem (or bioregional) perspective on the salmon problem. Indeed, the U.S. National Research Council concluded that the current set of institutional arrangements "contributes to the decline of salmon and cannot halt that decline."

In sum, it is hard to imagine a more complex problem than what to do about Pacific salmon. Does that mean we should throw in the towel and schedule funeral services for the remaining wild salmon? For all but the hardened pessimist, the answer to that question has to be "no." The sharp declines in salmon abundance, the "listings" of salmon populations under the *Endangered Species Act*, and the economic dislocations to commercial fishermen and to the recreational infrastructure of the Pacific northwest, have dramatically increased the general awareness of the problem and the willingness of many residents of the region to make economic sacrifices to ensure the survival of remaining salmon populations.

A few encouraging signs have appeared. Among them, plans being developed at the federal, state, and tribal levels attempt to take an ecosystem approach to salmon recovery. Long-term arrangements for ocean salmon fisheries put into place by the United States and Canada, together with harvest limits being imposed under the *Endangered Species Act*, provide some confidence that harvests will be under control. Moreover, restrictions have been imposed on timber activities in the northwest for the benefit of salmon and other anadromous fish.

Although some reasons for optimism exist, for that optimism to come to fruition will require a huge commitment, by many interested parties, during many years, to fill gaps in scientific information, to coordinate management, to provide funding, and to make and implement hard choices among painful alternatives that have serious and interrelated ecologic, economic, social, and cultural implications. We should not delude ourselves into thinking that the effort to restore wild salmon is anything other than an uphill struggle. Success will no doubt require a willingness on the parts of federal, state, and tribal governments to conclude that current institutional arrangements are not adequate and to establish a new decision-making framework that can address broad issues such as watershed management and fish governance.

These tasks are formidable, similar to the daunting obstacles faced by the juvenile salmon making the difficult and challenging journey to the sea. The salmon has no option but to begin the journey and to commit fully to completing its task. For that matter, if we are to bring salmon and back from the brink of extinction, neither do we.

seamounts, hydrothermal vents and cold water corals, from destructive fishing practices . . ." individually and through regional fisheries management organizations and arrangements consistent with precautionary and ecosystem approaches (UNGA, 2006). Nations and regional fishery management organizations are to manage fisheries so as to prevent significant adverse impacts to areas identified as VMEs. The European Union and the Northeast Atlantic Fisheries Commission have taken measures for action, including closing bottom fisheries in large areas of the high seas identified as VMEs, e.g., on the Mid-Atlantic Ridge. And in March 2011, North Pacific nations agreed to interim measures to curb expansion of destructive bottom trawling for more than 16.1 million mi^2 of seafloor habitat in accordance with the North Pacific Fisheries Commission (NPFC, 2012).

To further remedy fisheries problems, NGOs, national agencies, and international institutions are forming collaborative partnerships. And formally separate fisheries science and ecosystem science are seeking common ground to ensure that fishing remains a viable occupation and that ecosystems are viable enough to maintain productive fisheries (see EBFM, Section 13.4.4.1). For rebuilding fisheries in many poorer regions, co-management involves collaboration of local communities with government or non-governmental organizations. And because of the impacts of international fleets, lack of fishing alternatives, and poor documentation that complicate recovery, a global perspective is required; 63% of assessed stocks worldwide still require rebuilding (Worm *et al.*, 2009). Large Marine Ecosystems (LMEs, Ch. 3, Section 3.5.1) lend particular opportunities for nations to integrate fisheries and ecosystem principles into effective fisheries management (Pauly *et al*., 2008). LMEs occur in nations' Exclusive Economic Zones where overfishing is most severe, marine pollution is concentrated, and eutrophication and anoxia are increasing (Sherman *et al*., 2009).

13.3.2 Managing uses along congested coasts

The coastal economy is big business, in which expanding marine transportation and ports, coastal fisheries, coastal forestry (mangroves, etc.), aquaculture, offshore energy, minerals, tourism, and recreation are in conflict with human health, biodiversity, ecosystem function, coastal real estate values, and other interests, further exacerbated by exponential population growth, climate change, and rising sea levels. Coastal management is being undertaken in multiple dimensions, first in the full extent of the coastal realm, including the nation's Exclusive Economic Zone (Ch. 4), as in the case of anadromous fishes, and second in the narrower land-sea boundary zone (Fig. 4.7). In both cases, management and conservation efforts are confronted by jurisdictional, social, and economic conflicts. Additionally, all coastal nations are facing significant global pressures, escalating risks, and issues of private ownership. Ports that were once considered public entities are today either privately owned or operated by maritime shipping companies and port terminals (Rodrigue, 2010). Any attempt to maintain marine biodiversity and protect natural habitats must address issues of natural disasters, coastal degradation, and destruction of natural landforms (marshes, beaches) and seascapes (reefs, seagrasses) to resolve multiple-use conflicts brought on by intensifying population growth.

Changes of ecosystems, demography, institutions, and high costs of ecosystem restoration are forcing coastal management to undergo a major transformation (Olsen, 2000). Integrated Coastal Zone Management (ICZM) is being undertaken by many nations through an approach that attempts to incorporate natural-resource management, conservation of biodiversity, maximization of socio-economic benefits, and protection of life and property from natural hazards within existing institutional and organizational frameworks of individual nations' particular characteristics (Clark, 1996). Nations are mostly undertaking ICZM through the power of their constitutions or laws without a comprehensive context, delegating such authority to subnational levels. As the practice of ICZM moves from developed to developing nations, it is also being promoted by international assistance; at least 142 ICZM efforts had been established by about 57 sovereign and semi-sovereign states by the 1990s (Sorensen, 1993). The accomplishments to date are modest, having only modulated some localized impacts of anthropogenic change. The institutions involved often protect and promote jurisdictional interests without cross-sector collaboration, while weak public constituencies strive for better equity and accountability. These institutions often succumb to private interests. For example, some owners on eroding shores have gained court permission to build expensive barriers to protect their threatened homes from the advancing ocean, defying state officials and scientific advice that such activities accelerate erosion, thus burdening their neighbors with the erosion problem (Dean, 2005). Olsen (2000) suggests that to promote sustainable development through a governing process that is rooted in participatory democracy, ICZM needs to integrate scientific principles within a curriculum that includes a diverse mixture of knowledge and skills, and where public education plays an increased role.

Land-based activities are major drivers of coastal-marine change. Nevertheless, agencies and institutions that manage land and sea traditionally operate under separate legislative mandates and generally lack adequate communication among them. This situation is well recognized, bolstered by cases where only changes in land management will solve coastal-marine issues; e.g., for estuaries (Ch. 6), pollution (*Deepwater Horizon*, Ch. 2, Section 2.2.2.2), and dead zones (Box 2.5). Thus, heightened awareness and economic incentives are inspiring hope for significant change in governance at national and local levels. The international community has also taken significant action (albeit without regulatory power) by agreeing on the *Global Programme of Action for the Protection of the Marine Environment from Land-based Activities* (GPA) in 1995. The Program is designed to assist nations to preserve and protect the marine environment by preventing, reducing, controlling, and/or eliminating degradation, and to recover from land-based impacts, with assistance from UNEP's Regional Seas Program (Ch. 3). UNCLOS obligates signatories to protect and preserve the marine environment through regional and global cooperation by adopting laws and regulations to deal with land-based sources of marine pollution. Also, the World Bank in 2001 launched a new global partnership for the oceans, *Oceana*, intended to become the largest international organization on ocean conservation, involving the world's top conservation organizations, and private sectors (Oceana.org).

In sum, these activities offer ways to confront the socio-economic and ecological dilemma of protecting coastal-marine systems while also maintaining healthy economies. Solutions are bound to be case-dependent due to the huge array of differing mixes of social, legal, and ecological conditions.

13.3.3 Protecting species and spaces

Iconic species—whales, walruses, sea turtles, manatees, penguins, great white sharks, tuna, marlins, groupers, oysters, corals, seabirds, and many other marine and coastal species—are seen by the public at large as the primary symbols of ocean well-being, and many NGOs promote their protection. Indeed, without that recognition, species' protection, even their survival, would be immeasurably more difficult, as the public would be less involved. Consequently, major efforts are devoted to listing depleted species as threatened, endangered, or vulnerable to extinction by international, national, provincial, and in a few special cases, by local and native institutions and cultures (Fig. 3.1). It is less well recognized that these icons of the seas are also often the fish that fishermen target, that depend on habitats coveted by developers (seagrass beds, coastal marshlands, reefs, mangroves, kelp forests, etc.), or that are most threatened by human activity (pollution, invasive species, disease, global climate change, ocean acidification, and ocean warming). The case studies highlight the vulnerability of these icons to human pressures in a changing ocean system, where increasing noise, disturbance, pollutants, and anthropogenic change threaten their ability to make a living. For recovery, these species depend on increasing understanding of their geographic distributions, their natural histories, their sensitivities to disturbance, and their resilience. All have coevolved during decadal to century-long periods of interconnected ecosystems, characterized by various degrees of ecological complexity and biomass production. Many are top-predator, "keystone" species (Ch. 5) that exert significant effects on their ecosystems, while others are forced to adapt to change, if possible.

Designated Marine Protected Areas (MPAs; Ch. 3) constitute a major form of protection for species and spaces. They have formed the foundation for marine conservation in many areas of the world, being scientifically proven for effective fishery management and biodiversity protection and vital for protecting habitat, maintaining food-web integrity, and enhancing biodiversity when appropriately managed. Within designated locations, MPAs can address both specific and multiple objectives, ranging from strict nature conservation and scenic beauty, to protecting specific life-history stages and biodiversity, controlling fishing mortality, and facilitating fish recruitment outside their boundaries. MPAs can also serve as a hedge against the uncertain outcomes of environmental change. And because of their value, signatory nations to the *Convention on Biological Diversity* (Ch. 3) agree to establish national and regional systems of protected areas that are comprehensive, effectively managed, and ecologically representative, leaving to nations the establishment of target goals. This Convention brought incentives to support systematic conservation planning in which to develop ecologically representative MPA networks (UNEP-WCMC, 2008). Among the first general models proposed for a MPA network design was by Sala *et al.* (2002) for the Gulf of California.

Some MPAs are included in networks to help achieve regional or target goals. Worldwide, there are at least 30 national and 35 subnational ecological MPA network initiatives, most still under development and none yet fully managed (UNEP-WCMC, 2008). Networks of MPAs help achieve regional or target goals through a range of different types of MPAs that include both no-take areas (NTAs) and multiple-use sites (U.S. marine sanctuaries). Some involve hierarchical approaches, with small networks nested within larger national networks, as in Mexico, Indonesia, Australia, and the U.S. However, implementing a coherent network of MPAs can prove challenging. In California, for example, the *Marine Life Protection Act* of 1999 aimed to develop and apply the best available science in resource management and decision-making to improve ecosystem protection (Carr *et al.*, 2010). The task took seven years with an investment of about $38 million (Gleason *et al.*, 2012), but aroused much controversy. Thus, despite growing awareness of the need to curb biodiversity loss and protect ecosystem function at regional scales, MPA management plans must often be accompanied by complex governing structures that accommodate strong differences of opinion.

13.4 EMERGING CONCEPTS FOR MARINE CONSERVATION

The global ecological crisis stems from a political-economic organization of societies increasingly out of balance with ecological systems. Thus, global societies are being propelled into a future of intractable ocean and global change. The nexus of system behavior (Ch. 4) with species natural history (Ch. 5) makes clear the complex nature of marine systems. As the case studies illustrate, conservation principles are being applied in the attempt to transition into a coevolving, interdependent social/ecological system. And when such principles are incorporated into a spatial matrix of integrative planning, conservation targets are more likely to succeed. Thus, new ocean policies are being advocated that can be based on scientific models, spatial tools, system science, and a better-informed public (Crowder *et al.*, 2006).

Three emergent conceptual applications offer high potential for addressing this current situation: ecosystem-based management, marine spatial planning, and resilience thinking.

13.4.1 Ecosystem-based management (EBM)

EBM recognizes that all forms of resource use are interrelated and that humans form an integral part of ecosystems (McLeod and Leslie, 2009a). EBM also recognizes the utility of sound ecological models to address complexity, connectivity, and the dynamic, heterogeneous nature of ecosystems (Thrush and Dayton, 2010). Thus, the application of EBM has the potential to establish a commitment to adaptability, accountability, and inclusive decision-making, in which MPAs and marine spatial planning can play important roles and resilience practice offers adaptation to changing conditions.

Essential to EBM is recognizing the hierarchal scales in which both ecosystems and societies are organized. The self-organizing capacity of coastal-marine ecosystems operates over a range of different spatial and temporal scales, not always easy to identify. Each scale moves through its own adaptive cycle, building capacity to absorb disturbance and to maintain function (Walker and Salt, 2006, 2012). For a particular conservation target, choice of spatial and temporal dimension defines the scale, and multiple scales define the target holistically in a broader context of change and availability of conservation tools (Swaney *et al.*, 2012). Conserving coastal seagrass, for example, requires management not only of the aquatic area it occupies, but also the patterns and regulation of water flows and substrate quality that affect it. Thus, the target (i.e., a seagrass bed) is the smallest spatial unit (grain, patch) set within a larger region that defines the total area occupied ("extent") (O'Neill *et al.*, 1996). This consideration of multi-scale hierarchy also encompasses the concept of "panarchy" (Fig. 4.21). Panarchy describes the adaptive cycles that define ecosystems across scales at various stages of development (Holling, 2001) and how, through self-organizing capacity, a healthy system can "invent" and "experiment," and create opportunity while being kept safe from destabilization or "excessive exuberance." This is a concept applicable to sustainable development in which multi-scale, panarchy concepts can help foster approaches for adaptive management by using fine-scale, mechanistic understanding to screen hypotheses to be tested at large scales (Hobbs, 2003).

It is no small coincidence that social-economic systems operate in much the same cyclical way as ecosystems in reacting to environmental or other conditions on which both society and ecosystems depend. Thus, EBM embraces human activities and explicitly deals with trade-offs among human activities and ecosystem services (McLeod and Leslie, 2009b). Yet, current management strategies have rarely been designed to incorporate sectors of human activity *holistically with the ecosystem*. Hence, a necessary condition for implementing EBM is moving from sector-specific mandates to comprehensive planning, to be carried out by managers under comprehensive and clear legal mandates, in a forum for comprehensive ocean planning (Rosenberg and Sandifer, 2009). No better examples of this transition may be found than for fisheries and MPAs in their quests for sustainable resource management.

13.4.1.1 Ecosystem-based fisheries management

The paradigm for sustainable fisheries is becoming ecosystem-based fisheries management (EFBM; Pikitch *et al*., 2004; Box 3.5). This approach has evolved from the uncertain results of single or multispecies management and the acknowledged interactions between fisheries and ecosystems (FAO, 2011). EBFM goes beyond traditional management of fish, based on simplistic, yield-based models, to involve interactions with the human system and ecosystem. Most significantly EBFM aims to ensure that total biomass removed by all fisheries in an ecosystem does not exceed a total amount of system productivity, *after* accounting for the requirements of other ecosystem components (e.g., non-target species, community interactions, habitat dependencies, etc.). For example, sessile, estuarine-dependent shellfish species, e.g., oysters, requires that sustainable management involves recognition of an historical legacy of overfishing and present depletions related to habitat loss, pollution, and disease in an estuarine system undergoing change (Ch. 6). A management plan for a single species that meets both fisheries-use needs and ecological restoration involves cooperation among numerous agencies in order to safeguard a mutually shared resource. Rebuilt oyster beds in a semi-enclosed, tidally controlled system require appropriately designated locations protected from harvest. Identification of such locations could provide a "free service" in a regional setting, ensuring natural recruitment through life-history dispersals, and for establishing restoration sites selected for a marine reserve network (Box 13.2). Ecosystem-based shellfish management is entering U.S. national and state-agency programs in which to enhance commercial, ecological, and social benefits. NOAA, a federal agency, has established National Shellfish Initiatives to build partnerships with states that will increase shellfish populations and encourage EBM to optimize economic and ecologic benefits. This comprehensive approach is embraced by Washington State, whose oyster protection plan involves global concerns for ocean acidification and climate change while also focusing on local management action.

Protected-area designation, fisheries initiatives, and EBFM, together, provide potential means for restoring fisheries into ecologically and economically sustainable enterprises, while also sustaining biodiversity and ecosystem function. This requires a significant paradigm shift in fisheries management. To stimulate discussion and bridge the gap between principles and methodology, Francis *et al*. (2007) propose "ten commandments" for EBF scientists that include: "characterize and maintain viable fish habitats"; "account for ecosystem change through time"; and "characterize and maintain ecosystem resilience." The intention is to integrate EBFM with natural and social sciences. Application is challenging, requiring "an expanded empirical basis as well as novel approaches to modeling." Under present circumstances, there appears to be no viable alternative, as scientific understanding, social support, and public understanding, *operating together*, are key factors for EBFM success.

13.4.1.2 Ecosystem-based Marine Protected Area management

EBM is also being extended to apply to MPAs, but how MPAs fit into the "ecosystem," where they have been established and for what purpose, is rarely apparent. In almost all cases, MPAs are islands in a sea of economic use, therefore highly vulnerable to outside influences. Thus, their designation requires "agonies of choice" (Ray, 1999) and careful consideration (Agardy *et al*., 2011). MPAs designed solely around the distribution and apparent resource needs of particular species are likely to fall short of their intended purpose (Box 13.3). And unless they serve the public good and are locally acceptable to the user community (stakeholder), they may also fail to be viable entities for conservation. Justification for their selection involves opportunities, funding, planning, and community involvement and acceptance. As criteria for selection, biogeography of "key" species and biological associations can help address selection issues about which and how many protected areas are required to meet a conservation goal, where they should be placed, how big they should be, and what legal, social, and economic constraints affect their success. Nevertheless, exclusively protected habitats will lose species and fail to protect valued social functions, such as sustainable fishing and attraction of tourism, if not ecologically selected, established, and managed *within a wider ecosystem context*. By incorporating ecosystem principles, MPAs have the potential to fit well within an ecosystem-based approach (Lubchenco *et al*., 2003).

MPAs, at present, have proved to be limited in their applications. First, only rarely are their boundaries based on ecological characteristics, and many have been designated opportunistically. Furthermore, many are "set aside" from outside, human-caused, deleterious influences, in which case sustainability is questionable. Despite such problems, there are signs among the scientific community and conservation biologists especially, that perspectives are changing towards broader applications, as the case studies exemplify. A fundamental part of this is a paradigm shift in both policy and management towards more comprehensive ways to protect biodiversity and marine space—a move towards EBM and marine spatial planning, with special attention given to

Box 13.2 Demography and connectivity: metapopulation dynamics guide the design of a marine reserve network

Brandon J. Puckett and David B. Eggleston
Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, North Carolina, USA

Application of the metapopulation concept and identification of source and sink populations is key to designing marine reserve networks—multiple Marine Protected Areas connected by dispersal. Many marine populations are open, whereby larval settlement is uncoupled from local reproduction. At sufficiently large spatial sales, local populations characterized by demographic rates that vary in space and time are connected to one another via larval dispersal forming a closed metapopulation. Within a metapopulation, local populations can be classified as sources, which contribute more births than deaths to the metapopulation, or sinks if the converse is true. Metapopulation analyses require data on local demographic rates—growth, survival, and reproduction—and connectivity, i.e., the probability of local populations dispersing offspring among them.

Herein, we illustrate how metapopulation dynamics can guide reserve network design and evaluation using the eastern oyster (*Crassostrea virginica*) and Pamlico Sound, North Carolina, USA, as the model system. Specifically, we conducted mark-recapture studies and fecundity analyses to measure demographics and used a three-dimensional water circulation model to estimate larval connectivity among a network of no-take oyster reserves. Ultimately, we were interested in (i) identifying source and sink reserves; (ii) assessing the potential for reserves to function as a self-sustaining network (i.e., positive metapopulation growth, $\lambda \geq 1$); and (iii) comparing network sustainability among reserve size-increase design scenarios. The eastern oyster is particularly amenable to metapopulation analyses because adults are permanently attached benthic organisms representing discrete local populations only capable of dispersing via weakly swimming planktonic larvae. Unfortunately, populations of this commercially and ecologically important bivalve are at historic population lows along the Atlantic and Gulf coasts of the USA.

An increasingly popular strategy (and one used in North Carolina) for oyster restoration is to establish reserves that contain artificial reefs to provide hard settlement substrate for oyster larvae. In Pamlico Sound, which is a shallow, well-mixed, predominately wind-driven estuary, there are 10 oyster reserves that range in size from 0.03 to 0.2 km^2 and are spaced anywhere from c. 20 to 105 km apart. Our field measurements indicated that oyster growth, survival, and reproduction varied from 30 to 90% among reserves, and not in the same manner, such that certain reserves could be classified as the “growers” (i.e., reserves with fastest growth), others the “survivors”, and yet others the “spawners” (Fig. B13.2.1a). Inter-reserve connections were rare—only 4 of a possible 90 connections were present, unidirectional, and relatively low in magnitude (<5%; Fig. B13.2.1a). Self-recruitment, while also rare (three of the 10 reserves self-recruited), was relatively high in magnitude (20–50%) when present (Fig. B13.2.1a). As a result of limited network connectivity via larval dispersal, only c. 6% of larvae released from reserves were subsequently retained within the reserve network. Limited connectivity and reserve-specific demographics resulted in only three of the 10 reserves functioning as sources (Fig. B13.2.1a) and an exponential decline in metapopulation size over time. Thus, we concluded that the network of oyster reserves in Pamlico Sound, as currently configured, is not self-sustaining or capable of persisting through time.

How can network connectivity be improved? One way is by increasing the size of reserves within the network. As reserve size is increased, a larger target for dispersing larvae is provided which should increase connectivity. However, socioeconomic and resource (e.g., artificial reef material or personnel) constraints prevent managers from indiscriminately increasing reserve size, so how should one prioritize reserves for expansion? To answer this question, we conducted computer simulations that increased reserve size under three scenarios: (i) uniform 10% size increase of all 10 reserves; (ii) size increase of three source reserves by 33.3%; and (iii) size increase of three worst sink reserves (i.e., lowest λ_C) by 33.3%. Model results for all three scenarios suggested that relatively small increases in reserve size led to rapid increases in larval retention within the network (i.e., increased network connectivity), as well as metapopulation growth rate (Fig. B13.2.1b). Of the three scenarios, increasing all reserves uniformly in size led to the largest improvements in larval retention and metapopulation growth rate, and thus was deemed the best strategy. Counter intuitively, increasing the size of the three source reserves ultimately resulted in the lowest larval retention and metapopulation growth rate (Fig. B13.2.1b), suggesting that a reserve’s source strength is dependent on the location and size of surrounding reserves within the network (Fig. B13.2.1b). Given the current number, spatial configuration, and a uniform reserve size-increase strategy, approximately 5% of Pamlico Sound needs to be designated as reserves—an increase of two orders of magnitude from current size—for the network to be self-sustaining.

Spatial variation in oyster demographic rates in Pamlico Sound, as well as rare, but non-trivial larval connections, provided proof of the metapopulation concept in this reserve system, which enabled us to develop a metapopulation model to evaluate and guide reserve network design. Based on this analysis, we offer three concluding remarks: (i)

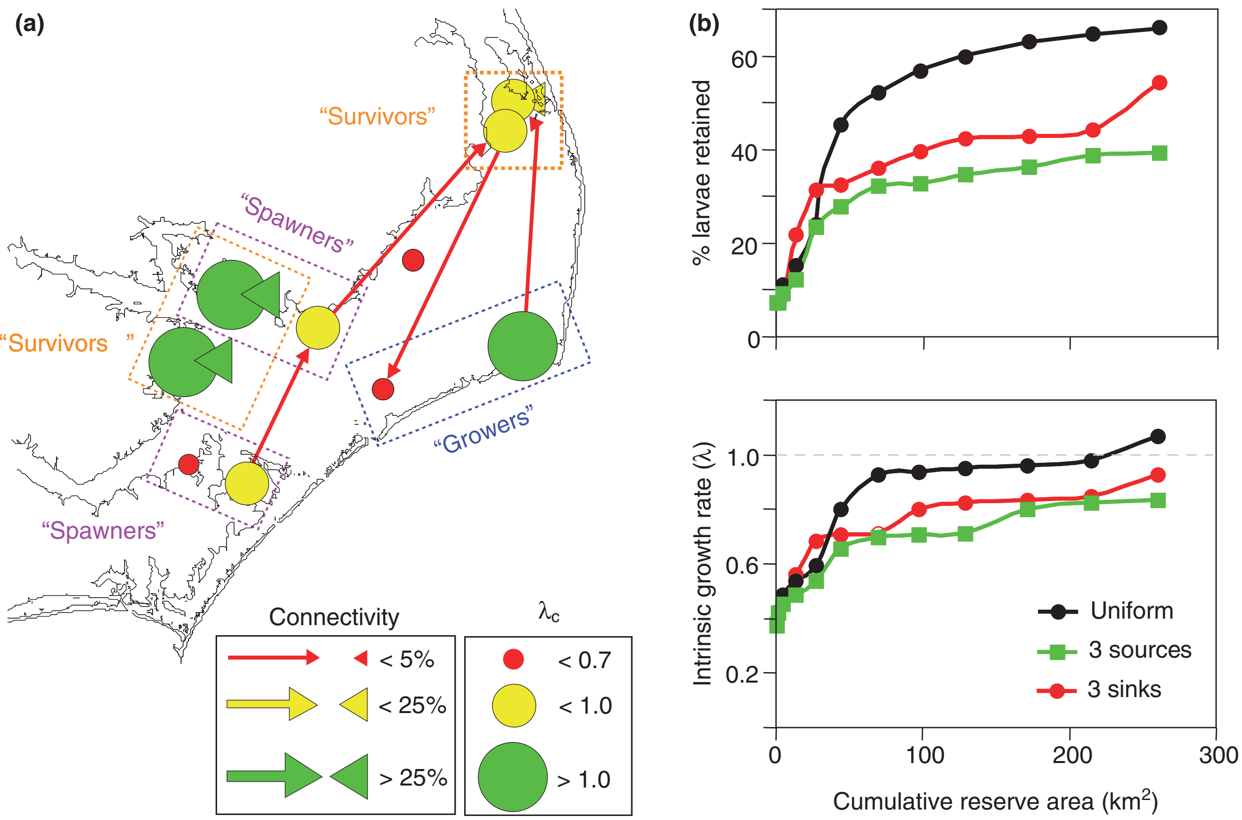

Fig. B13.2.1 (a) Map of no-take oyster reserves (circles) in Pamlico Sound, North Carolina, USA. Oyster demographic superlatives (e.g., fastest-growing oysters) are indicated by the dashed boxes. Larval connectivity is proportional to the thickness of the arrows and triangles, which depict inter-reserve dispersal and self-recruitment, respectively. Metapopulation source (largest circle, $\lambda c > 1$) and sink reserves ($\lambda c < 1$) are denoted by the circle size at each reserve. (b) Results of model simulations to determine the impact of increasing reserve size (measured as cumulative reserve area) on the percentage of larvae retained within the metapopulation (top panel) and growth rate of the metapopulation (bottom panel) for three scenarios whereby size increases were allocated (i) uniformly among all reserves (black); (ii) among the three source reserves (green); and (iii) among the three worst sinks (red). The initial points on each panel represent the current state of the reserve network.

not all habitats, local populations, or reserves function equally (i.e., source-sink dynamics); (ii) marine reserves and reserve networks do not guarantee restoration or conservation success and only when they are evaluated and designed at appropriate scales can they achieve management objectives; and (iii) metapopulation-based analyses that integrate demographic rates and population connectivity provide decision support tools that are essential for effective conservation and management.

Sources: Caley *et al*. (1996); Figueira and Crowder (2006); Gaines *et al*. (2010); Hanski and Gilpin (1991); Lester *et al*. (2009)

ecosystem resilience (see Section 13.4.3). That is, as MPAs are an essential part of marine conservation and must increase in number and magnitude, they also need to be implemented and managed in the context of the ecological and social dynamics of their surroundings at larger scales. Thus, to protect entire biotic communities, MPA strategies must seek a nested, hierarchical approach, from species and habitat protection at local scales to regulatory procedures for communities and ecosystems at regional scales.

13.4.2 Marine spatial planning

Marine spatial planning (MSP) is a recent attempt to move from sector-specific area protection (e.g., MPAs) and human uses of the coasts and oceans towards integrated multiple use through ocean zoning over large spatial scales. Sustainable use is a fundamental guiding principle (Douvere and Ehler, 2008; Gilliland and Laffoley, 2008). Mapping and analysis of biophysical features, socio-economic uses and values, and

Box 13.3 How not to design a sea otter reserve

James A. Estes
Center for Ocean Health, University of California, Santa Cruz, California, USA

The Bering Sea/North Pacific Ecosystem (BSNPE, south of the shelf, Ch. 7) is in a state of spectacular change, characterized in particular by precipitous population declines of various marine birds and mammals. Sea otters are the most recent addition to the list of dwindling species, having declined by >90% or more across large regions of western Alaska since about 1990. In contrast to the situation with most of the region's other declining species, the immediate cause of sea otter decline is reasonably well understood. But for the moment, let us imagine that we know little more than its pattern, other than to suspect that the cause is in some important way anthropogenic. These conditions define our present understanding for most of the BSNPE's declining species.

Given this state of affairs, how might one design a marine reserve for sea otters? We may begin by defining the goal, which is to protect a sufficiently large segment of habitat from human impacts to provide for a viable sea otter population. One approach is to identify an area capable of supporting an effective population size (*N*) of 500 individuals at an ecologically effective population density. Recent analyses indicate that about 6.5 sea otters km^{-1} is the minimum density required to prevent the coastal ecosystem from undergoing a phase shift from healthy kelp forests to deforested sea urchin barrens. Based on known features of the sea otter's mating system, sex ratio, and demography, this population size translates to an actual population (*N*) of about 1850 individuals. Armed with this figure and knowing the minimum effective population density of sea otters (*D*), the area (*A*) needed to support a viable population is estimated by *N/D*. These figures lead to values of A in the minimum range of about 300 km^2, roughly the size of the larger-sized islands in the Aleutian archipelago.

Although the reserve size specified by this scenario is large by existing average sizes of coastal-marine protected areas, in this case it would almost surely fail. The problem is that the ultimate cause of the sea otter decline has little or nothing to do with events in the protected area, but rather with those in far-removed oceanic waters. Tagging studies show that the demographic cause of the decline is elevated mortality, not reduced fertility or redistribution. Increased killer whale predation is one apparent reason for elevated mortality.

What may have caused killer whales to do this is less clear. Perhaps killer whales have hunted otters for years and killer whale numbers are on the rise. Or maybe a few killer whales fortuitously discovered sea otters as easy prey. The most likely explanation, in my view, is that killer whales turned to consuming sea otters as their preferred prey, as harbor seals and Steller sea lions have declined. The apparent fact that the otter declines occurred on the heels of the pinniped declines fits this explanation although it leaves the question of why pinniped populations have declined unanswered. Some suspect that pinniped declines were caused by negative interactions with local fisheries (Ch. 7), others favor oceanic regime shifts, and still others suspect that, as with the sea otter, predation had a lot to do with it.

This example serves to make the general points that marine reserves, even when very large, may not serve their intended purposes of when adjoining ecosystems are not considered. Marine ecologists recognize that functionally important linkages occur through such processes as larval dispersal, physical and biological transport of food and nutrients, and the movement of apex predators. However, the fact that marine reserves must be large enough to capture these diverse linkages remains underappreciated. Although one can argue the details, the take-home message is that marine reserves designed solely around the distribution and apparent resource needs of species targeted for protection are likely to fall short of their intended purpose.

Can marine reserves stem the tide of species decline in the BSNPE? Probably, but only *if* human impacts are instrumental in causing the declines and *if* the reserves are large enough to buffer populations against these impacts. The problem is that the burden of proof traditionally falls on scientists and resource managers to first demonstrate human cause and then to engineer the details of an explicit solution. Time is too short and the system is too complex for that approach to work in most cases. For the BSNPE, we might begin by establishing one or more very large Marine Protected Areas together with the time and resources to demonstrate their effects. These areas must be large because of the demographic characters and ecosystem linkages described above. If overfishing is responsible, either wholly or in part, for the declines of marine birds and mammals in the BSNPE, this approach has the potential to both demonstrate and begin to mitigate those effects. If killer whale predation turns out to be a factor, however, a management dilemma is raised that may be beyond human control.

Sources: Anderson and Piatt (1999); Estes *et al*. (1998); Estes *et al*. (2010); Ralls *et al*. (1983)

jurisdictional arrangements provide a first step toward producing meaningful mosaics of spaces suitable for place-based, marine ecosystem protection and resource management (Ray *et al*., 1979, 1980; NOAA/NOS, 1988; Crowder and Norse, 2008). Principles of land- and seascape ecology have the potential to be applied as useful frameworks to guide managers in addressing multiple goals and to communicate with major stakeholders on shared responsibilities. MSP has entered national and international policy development, being one among nine priority objectives of the U.S. Ocean Policy Task Force (CEQ, 2010). The goal is to reconcile overlapping and conflicting management practices carried out by numerous agencies with conflicting mandates, rules, and management. MSP provides a transparent communication and application tool to address coastal and ocean-space zoning according to uses—e.g., fisheries, shipping, recreation, species protection, mineral extraction, and maintenance of biodiversity, among others. While MSP goals may be explicit, constraints lie in how boundaries may be set in highly dynamic ocean space. From a management point of view, a strategy is required that involves a balancing act: i.e., understanding the management cycle that links strategy with operations and the tools that apply at each stage of cycle (Kaplan and Norton, 2008). Furthermore from an ecosystem point of view, natural cycles of change (Section 4.8) need accounting. Yet, recognizing cumulative effects of development and application of zoning for use is moving marine conservation in a more realistic direction.

Any newly proposed ocean zoning will have to accommodate the past with future jurisdictions. It is not yet clear how existing zonation of the coasts and oceans (Fig. 3.4), or land-sea interactions, can be accommodated. Virtually the entire open ocean and coastal realms are captured in some sort of regulation or agreement, nationally and/or internationally. Ocean zones have been designated for a host of purposes, exclusively for specific uses and economic benefits, or to permit multiple uses within designated boundaries under varying sets of rules. To date, these zones have been almost exclusively directed towards human uses and endeavors, but overlapping uses have led to the recognition that more than jurisdictional zoning is required to resolve increasing conflicts, as between renewable and non-renewable resource extraction, marine transportation impacts, sensitivity of established protected areas, fisheries, mariculture, recreation and tourism values, and recovery of endangered species and habitats. More often than not, such zoning does little to address such emergent issues as climate change, sea-ice diminishment, acidification, anoxia, etc., all of which require changes in geopolitical thinking and improved administrative performance. Although jurisdictional boundary designations too often lack ecological context, thereby often hindering and complicating efforts for natural-resource sustainability, the question is not that zoning is not necessary, but how it can accommodate ever-changing and dynamic coastal and ocean systems (Ray, 2010; Spalding, 2011). For solutions to become workable, central government and intergovernmental policies need to be in place to guide decision-making in resolving competing goals among all stakeholders, addressing mismatches in ocean governance, and protecting common-pool resources.

The biosphere reserve is a spatial planning concept that addresses the above issues (Ch. 11). It was proposed in the mid-1970s, with coastal-marine conservation, conflict resolution the dynamic nature of marine systems, and boundary limitations of MPAs in mind (Ray and McCormick-Ray, 1987; Batisse, 1990). The first step in considering a biosphere reserve is to identify a "core" protected area that has legal protection, and the purpose for which it has been, or will be, established. Surrounding a core is a "buffer" area for the purpose of maintaining ecological and social support. Outside the buffer zone is a zone of "transition" that inhibits intensive, potentially deleterious human activities. Thus, the area a biosphere reserve potentially encompasses is large enough to maintain the identity and resilience of the designated core protected area. This "idealistic" solution has proved difficult to implement (Ch. 11). Nevertheless, the biosphere reserve concept offers an excellent model for the development of ecosystem-based marine spatial planning, particularly as it incorporates land-sea interactions, which, as yet, MSP does not.

13.4.3 Achieving resilience practice

The concept of "resilience practice" arises from the fact that resilience is an emergent property of ecosystems (Fig. 4.21). Walker and Salt (2006) clarified resilience as: "the capacity of the system to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks—to have the same identity." Put more simply, resilience is "the ability to cope with shocks and keep functioning in much the same kind of way," being analogous to how healthy humans maintain health or recover from disease. Thus, given that ecosystems naturally change, and that human activities can disrupt this process, resilience is a necessary concept for conservation. Regeneration, or restoration following disturbance, depends on sources of resilience that operate at multiple scales, wherein ecosystems can absorb recurrent perturbations and cope with uncertainty and risk (Hughes *et al*., 2005). Walker and Salt (2012) describe three broad activities for incorporating resilience into practice: describe the system, assess its resilience, and manage for resilience.

In the present situation of biodiversity loss and perturbed ecosystems, a fundamental aspect of resilience is restoration. Keeping in mind the above definition, this means restoring ecosystems to states that *have the same identity*, i.e., that processes are intact. As ecosystems progress through cycles of change, the likelihood is that community composition will shift along a trajectory of change. Jackson *et al*. (2011) call attention to "shifting baselines" as "a truly fundamental and revolutionary idea, but the revolution has not yet happened because the challenges are enormous." Which is to say that restoration to any precondition along a continuum of change may not be realistic or even possible absent knowledge of its history. Therefore, conservation for ecosystem resilience means keeping ecosystem function in mind when undertaking EBM, MPAs, and/or MSP. There are a number of ways this can be approached. A first step lies in recognizing that the system is self-organizing, moves through adaptive cycles in constant states of change, reaches limits (thresholds), and is linked to social, economic, and biophysical domains. In this context, one needs to consider what A.N. Whitehead termed the "fallacy of misplaced concreteness" in which attention is diverted from the underlying causes that drive change (Daly and Cobb, 1989).

Resilience practice requires flexibility and adaptability. Feedbacks between the manager and what is being managed may offer surprises and unexpected outcomes. Most importantly maintaining or restoring ecosystem resilience involves *assessing the sources of resilience in the system* (e.g., biodiversity, biophysical properties, evolutionary processes, etc.), monitoring them to determine a trend towards any new state, determining the extent and cause of change, and assessing costs and benefits socially, economically, and environmentally. Fundamentally, conservation for resilience allows engaging with the issue of complexity while focusing on what is important (Walker *et al*., 2012). Goals to conserve biodiversity and valued species and species diversity, and to maintain or restore ecological services depend on the resilience of the interdependent socio-ecological system.

13.4.4 Engaging the social system

The human-ecological system is coupled to interactions and feedbacks that promote change in time, space, and organization; insights into this complexity cannot be gained through ecological or social research alone (Liu *et al*., 2007). Different, interacting sectors of the human system play key roles in advancing integrative associations among coastal and marine systems, species, and their habitats that are needed to optimize goals of sustainable development and ecosystem resilience and also to promote social well-being (Box 13.4). This situation emphasizes the underlying role of governance, defined as the act or process of governing, taking account of social, economic, and ecological inputs, outputs, and functions.

13.4.4.1 The role of good environmental governance

There is a need for improved collective consciousness for making better decisions that impact ocean systems. The lifeboat metaphor (Hardin, 1974) exemplifies how human activities might be better managed to conserve ecosystem resilience for the common good. The globalization of opportunistic species that are homogenizing the planet into simpler forms of biodiversity and the disempowerment of people trying to manage their own affairs locally result from human-accelerated environmental change and eroding social, political, and jurisdictional boundaries that make up traditional governing practice (Swaney *et al*., 2012).

The tools of good governance depend on law, science, economics, and public education entering into a process of decision-making, and of making decisions that affect outcomes of marine conservation. This process occurs where political authority facilitates resource management through a clear and legitimate process applied at all levels of governance, including the way the nation is governed or not. Marine and coastal protection, conservation, and restoration can only take place within a framework of good governance, respect for the rule of law, an environmentally sensitive legal system, and consent of people affected.

13.4.4.2 Roles of law, science, economics, and universities

Environmental law and policy are presently plagued by policy and jurisdictional mismatches (Alder, 2005). A mismatch is also evident between the nature and scope of coastal-marine issues and those of the institutions charged with solving them (Crowder *et al*., 2006). Division of authority and responsibility for environmental protection among federal, provincial, and local governments has led to lack of cohesive rationale or justification for conservation action. Inevitably, these mismatches produce suboptimal levels of environmental protection, waste resources, discourage innovation, and inhibit the adoption and evolution of more effective measures for environmental protection.

Classic economics provides yet another critical mismatch, supporting a "growth economy" that runs into limits of finitude, ecological interdependence, and system entropy. The first and second laws of thermodynamics play key roles in economics (Georgescu-Roegen, 1971; Ch. 4). As the economist Herman Daly (1996) explained: "Finitude would not be so limiting if everything could be recycled, but entropy prevents complete recycling. Entropy would not be so limiting if environmental sources and sinks were infinite, but both are finite. That both are finite, plus the entropy law, means that the ordered structures of the economic subsystem are maintained at the expense of creating a more than offset amount of disorder in the rest of the system." This is to say that current economic processes and practices serve to degrade natural systems, deplete resources, and pollute the environment. As water and air are priced at zero to benefit markets, natural resources priced at market values become undervalued economic commodities and expose coastal and marine systems to exploitation, alteration, and degradation. As the economic system has advanced, the Earth has moved toward greater disorder (entropy), and as resources become scarce, their values rise and illegal trade advances. Therefore, market indicators are not good indicators of long-term social benefit. Robert Johnson, Executive Director of the Institute for New Economic Thinking recognized: "there's something amiss in a theory of value that doesn't value these common resources, the common pool on which we all base our lives" (Institute for New Economic Thinking, online).

Environmental degradation, pollution, climate change, and energy extractions cumulatively reduce the social values of coastal recreation, tourism, and renewable, common resources that most developing nations and individuals depend on. Furthermore, scientific evidence makes clear that coastal and marine systems cannot be managed for stakeholder benefits while ignoring ecosystem behavior. Present uses of these systems, as observed in the expanding human ecological footprint, are unsustainable (Jackson, 2010). Strauss *et al*. (2012) show that global warming has raised sea level about 20 cm since 1880, and the rate of rise is accelerating. How society may decide on reducing heat-trapping pollution will ultimately determine the fate of millions of people that live only 1 m above

Box 13.4 Well-being assessment

Robert Prescott-Allen
[Retired, International Union for Conservation of Nature and Natural Resources, author of *The Wellbeing of Nations*, co-author of *Blueprint for Survival, World Conservation Strategy*, and *Caring for the Earth: a Strategy for Sustainable Living*], Victoria, British Columbia, Canada

Well-being means a good condition or quality of life, both human life and the rest of the living world. Assessment means measurement and evaluation. Hence well-being assessment is the measurement and evaluation of human and ecosystem conditions and of the factors that produce them. Coastal-marine conservation needs to be guided by periodic assessments of human and ecosystem well-being to determine the socio-ecological state of a particular coastal or marine area, priority issues for action, and the effectiveness of the actions. This box reviews the dimensions of human and ecosystem well-being and how to assess them.

Human well-being

Depending on how it is defined, human well-being more or less equals human development or human happiness. Perhaps the simplest yet most encompassing definition is “human flourishing in its fullest sense” (Alkire, 2002). But no definition gives more than an inkling of human well-being. We need to know its dimensions—that is, the basic values or ends to be fulfilled for people to be well.

Over millennia, philosophers and spiritual leaders have proposed many sets of dimensions, addressing “being good” rather than “being well” or the proposition that “well being” comes from “well behaving” or “right conduct.” In the 20th and 21st centuries, these have been joined by economists, sociologists, and psychologists with a focus on “well being” only, split into objective well-being and subjective well-being (or “well feeling”). The former tends to be examined through a process of argument. The latter is discovered through surveys of populations. Ends shared by many studies of objective well-being (e.g., Grisez *et al*., 1987; Max-Neef *et al*., 1991; Centre for Bhutan Studies, 2008) and of subjective well-being (e.g., Narayan *et al*., 2000; Diener and Biswas-Diener, 2008; Rath and Harter, 2010) include health, wealth, rich use of time (work and play), inner well-being, and good relationships. Less common are freedom and rights, knowledge, aesthetics, and relationships with the supra-human. These broad ends give plenty of room for interpretation; different cultures value some aspects more than others.

Ecosystem well-being

Interest in human well-being is as old as people. The idea of its ecological equivalent is new, originating in the 20th century. It’s not an exact equivalent. Ecologists are uncomfortable with “ecosystem well-being” (or “ecosystem health”), wary of its apparently teleological, Gaian suggestions. They prefer the more neutral “condition” or “state” or no label at all. Regardless of label, review of this book and the Millennium Ecosystem Assessment (2005) suggests that five essential features—or dimensions—need to be examined to determine the state of any ecosystem: (i) biophysical structure (structure of land, shore, and seafloor forms and of fixed biota); (ii) energy transformation (food chains and webs and production and productivity); (iii) biogeochemical processes (biogeochemical recycling and retention); (iv) diversity (species diversity, variability within species, and community diversity); and (v) ecosystem services (provisioning services such as food, biochemicals, ornamentals, and regulating services such as climate regulation, erosion regulation, waste treatment, natural hazard regulation, and other services such as heritage, recreation, aesthetic, spiritual, and intellectual).

Assessment

To be a reliable and useful guide for policy-making and action, a well-being assessment of a coastal and/or marine area has to follow some rules. First, combine measurement and narrative. *Measurement* provides a common language, an unambiguous account, enabling analysis of change over time and space. But not everything is measureable; and much that is measureable may not matter. *Narrative* is needed to tell the whole story, to interpret what is measured and put it in context; and to cover important aspects that cannot be measured without distortion.

Second, assess separately states (outcomes) and influences (inputs). One cannot tell how much, or in what ways, an influence such as economic performance or governance or education affects human well-being if it is included as a component of well-being. Nor can one learn the impact of energy use or resource extraction or emission rates on an ecosystem if it is part of the measurement of the ecosystem’s condition. The four domains of well-being assessment are, therefore, human well-being, ecosystem condition, influences on human well-being, and influences on ecosystem condition (Fig. B13.4.1).

Third, develop an assessment protocol (*what* to assess) before designing the assessment (*how* to assess). This asks the questions: For the various groups of people in our area, what are the dimensions of human well-being?

(*Continued*)

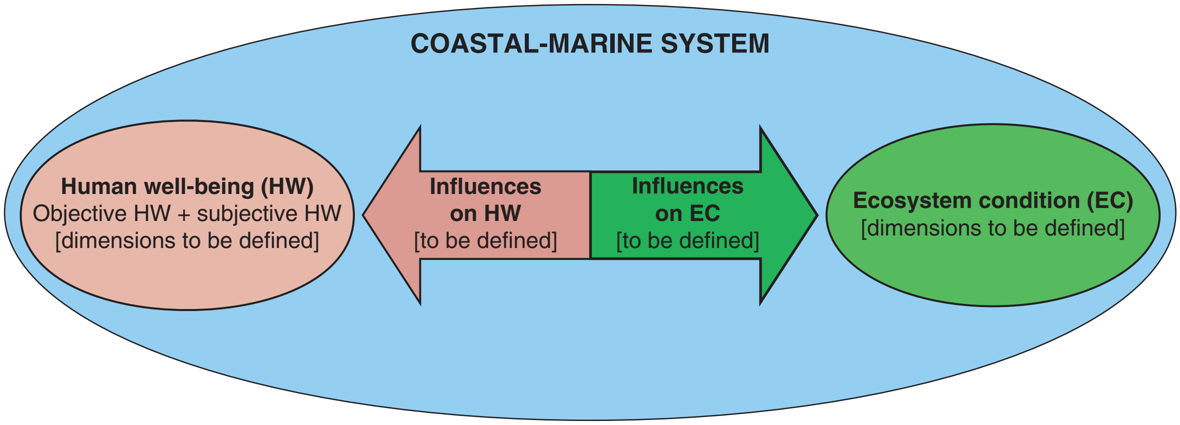

Fig. B13.4.1 The four domains of well-being assessment. Assessment participants decide the dimensions and influences to be assessed.

What features must we assess to determine the state of the ecosystem? What do we think are the main influences on human well-being and on ecosystem condition?

Fourth, construct a hierarchy of components of each dimension and influence, going from the general and unmeasurable (health, ecosystem services, economic performance, etc.) to the particular and measurable (indicators). For example, if level 1 is ecosystem services, level 2 might be provisioning services, regulating services, and other services, level 3 of provisioning services might be fisheries and others, and level 4 (the indicators) of fisheries might be the state of particular fishery stocks. Such systematic selection of indicators ensures they are representative of their dimension or influence and clearly reveals gaps in representation. In addition, the hierarchy of components provides a structure for the orderly aggregation of indicators should you wish to construct a human well-being index, ecosystem condition index, human influences index, and ecosystem influences index, to facilitate communication of the assessment's findings.

Sources: Alkire (2002); Centre for Bhutan Studies (2008); Diener and Biswas-Diener (2008); Grisez *et al*. (1987); Max-Neef *et al*. (1991); Millennium Ecosystem Assessment (2005); Narayan *et al*. (2000); Rath and Harter (2010)

high tide, saying nothing about the many lives that will be affected by increased storms, flooding, droughts, loss of food resources, and disease. Thus, managing the effects of such changes requires not only good governance, but also good science that brings to society an understanding of system behavior and natural history. Environmental change may be better understood through monitoring, creative synthesis of information, and continued research, all of which will ultimately determine the quality of coastal life in the 21st century and beyond (Swaney *et al*., 2012). In this context, universities are centers of learning that have the capacity to integrate reliable knowledge into democratic principles that address coastal and marine issues. Universities can also help generate thinking about integrating good science with good governance, and bring awareness to the need to integrate land and sea into ecosystem-based goals, e.g., fisheries, pollution abatement, and ecosystem resilience.

Social values play strong roles in achieving marine conservation goals. The ethics of protecting marine and coastal biological diversity presents a struggle between environmental beliefs and values held in competing worldviews for institutional recognition, including law. Because translating biodiversity into legally enforceable obligations requires major changes in traditional habits, marine conservation reflects a cultural divide in human values: those that see the world through value of individual autonomy and mastery of the physical world, and those whose values urge individual restraint in order to preserve a common good that fits within the "balance of nature" (Cannon, 2007). As political will reflects the values of society at the present time, these values intertwine the social and ecological system into a future of environmental risk, chance, change, or opportunity for which there is no turning back, and society must make adjustments. However, interpretations of the law and implementing regulatory authority reflect cultural value judgments (Fig. 13.1). In the coastal realm where economic and social issues are especially difficult for politicians to resolve, implementation of treaties and national programs remain unfulfilled, lagging behind scientific understanding and public perception.

Good governance is essential for improving resource management. At present, numerous agencies operating under traditional institutional structures cannot adequately address new challenges or move from single-sector, issue-by-issue management and toward EBM. The combined effect of too many agencies seeking prescribed mandates, often in conflict with others, can exacerbate rather than solve environmental

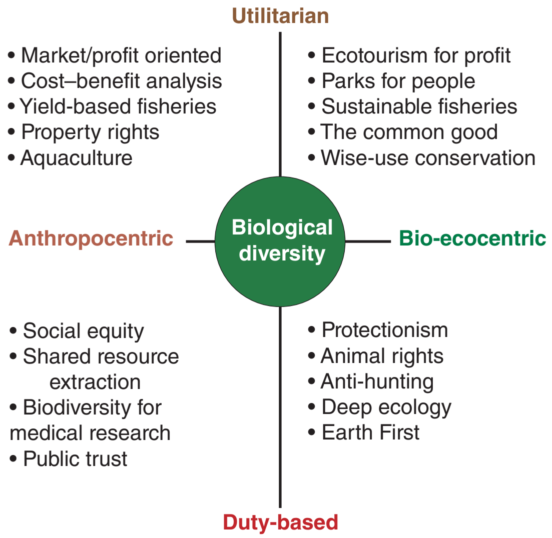

Fig. 13.1 Perceptions about values (e.g., biological diversity) are conceived in a decision matrix on two axes: from utilitarian to duty-based and from anthropocentric to bio- or ecocentric. Holders of various positions are exemplified in four segments, suggesting perceptual differences that are often difficult to resolve. Data from Beatley (1994).

problems. For example, the impact of many small decisions being made locally can accrete into big outcomes that no one intended, a phenomenon known as the "tyranny of small decisions" (Odum, 1982). Conservation goals confined to narrowly focused legal mandates are inhibited by lack of tools needed to meet intended goals, e.g., staff, funding, equipment, scientific data, etc. Management practices intended to do public good, such as government subsidies, may become "perverse" and need reform (Steenblik, 1998). In the case of fisheries, unintended and perverse consequences of governmental regulation of fishery resources that lack a uniform imposition of central regulations, or that ignore or contradict local regulations, exacerbate Hardin's "tragedy of the commons," where each person is trapped in a system that compels him to increase his profits without limits (Hardin, 1968; Davis, 1984).

13.5 LOOK TO THE FUTURE

F. Herbert Bormann (1996) observed, after long acquaintance with forestry management and acidification: "Never again would I be so naive as to think that natural resource decisions are based only on good scientific evidence. Social and economic factors will override science . . . if the public is not educated to understand the relationship of that science to their own long-term welfare."

Similarly, marine conservation faces its own set of social-scientific dilemmas. The ocean is a vast and powerful system that has entered into the human psyche for millennia. Its energy and productivity have nurtured the planet and have delivered benefits to humans that have seemed inexhaustible. Today, human activity no longer stops at the seashore, but encompasses huge arterial watersheds that deliver chemicals into the air and water to affect coastal and open-ocean systems. Intensifying human activities continue to alter the structure, timing, and recycling of marine ecosystems, systems that have self-organized into patterns of production over eons of time to sustain themselves and to provide resources to humans. As scientific evidence reveals, the diversity of life in the ocean is shifting toward smaller forms, undermining the leviathans that once roamed freely and that today must dodge human traffic, noise, and garbage in order to seek a decent meal.

Humans, as stewards of the oceans, are collectively pondering the need for marine protection and conservation. However, traditional beliefs that the oceans are too big to pollute, too productive to deplete, too out-of-sight to justify expensive actions, and too valued for their economic worth continue to hinder effective action. Our 20th century achievements have been enormous, having sent men to walk on the moon, created highways of information and communication, and provided nourishment for more people than Malthus ever thought possible. We have also achieved a social-political order through economic globalization, while also capturing fossil fuel energy by going deeper into the oceans, expanding global trade, and homogenizing a heterogeneous globe. Now, the extended human presence in the oceans, on land, and in the atmosphere faces challenges never before experienced in human history.

Conservation in general is a highly complex issue. Natural resources—water, food, air, and biota—are what the global society ultimately depends upon. The oceans, whether territorial or not, consist of a common pool of limited resources that require shared responsibility. This means that conservation is a social-scientific enterprise that needs to be put squarely on political and economic agendas. Addressing the ecological debt is as much a priority as the economic debt, as the latter is affected by the former. Thus, marine conservation can no longer be ignored without costing nations and the global society dearly. Marine conservation is no longer an option—it is the mandate for the 21st century.

The case studies exemplify the central role of governance, and the social tug-of-war for marine conservation. We may ask if we now know enough to proceed towards sustainable and resilient coastal and marine systems; the sole response has to be "possibly," but only if the coupled socio-economic-environmental system is addressed, and not only its components. And given the need for restoration of depleted species, disturbed spaces, and altered ecosystems under conditions of uncertainty, precaution is required. The "Earth Summit" (Rio Conference, 1992) suggested that the precautionary principle become operational as policy: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

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