Marine Conservation

Science, Policy, and Management

G. Carleton Ray
Jerry McCormick-Ray

Illustrations by Robert L. Smith, Jr.

WILEY Blackwell

MARINE CONSERVATION

The land-sea coastal realm from the tropics to polar regions, where the majority of marine conservation issues lie. See Chapters 2 and 4 for physical and biological/ecological characterization. Illustration © Robert L. Smith, Jr.

Cover image: created in Photoshop by Robert L. Smith, Jr., from separate pictures of the walrus and the ice floe, Bering Sea. Photographs © Ray & McCormick-Ray.

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To Sally Lyons Brown for her vision and support, and to Raymond F. Dasmann and F. Herbert Bormann who continue to inspire us.

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PREFACE

We are at a time in history when science allows us better to understand our global environment, and when human societies are beginning to recognize the urgency of marine conservation and the need for sustainable use of marine resources. As John A. Moore (1993) has put it: "We have reached a point in history when biological knowledge is the *sine qua non* for a viable human future . . . A critical subset of society will have to understand the nature of life, the interaction of living creatures with their environment, and the strengths and limitations of the data and procedures of science itself. The acquisition of biological knowledge, so long a luxury except for those concerned with agriculture and the health sciences, has now become a necessity for all."

During the past century, humans have acquired the ability to intrude, exploit, and better understand the last, previously unexplored portion of Earth—the contiguous global oceans. The rates and magnitude of change brought on by the Marine Revolution (Ray, 1970) followed 5–10,000 years of the Agricultural Revolution and two centuries of the Industrial Revolution, with dangers of repeating errors of the past. Observation of the quickening pace of change and the way that humans behave and manage themselves, and increasing knowledge of the way marine ecosystems function have made apparent major ecosystem instabilities and management incongruences. Approaches deemed feasible when marine conservation was emerging only a half-century ago no longer fulfill needs of the 21st century. That the world has become "hot, flat, and crowded" (Friedman, 2008) makes clear the need for new marine conservation approaches.

Our previous book, *Coastal-Marine Conservation: Science and Policy* (Blackwell Science, 2004) called attention to the fundamental role natural history and ecosystem-based science play in conservation policy and management planning. That is, conservation must be informed by the natural histories of organisms *together with* the hierarchy of scale-related linkages and ecosystem processes. This book continues that focus on a whole-systems approach to marine conservation, taking account of major advances in marine ecosystem understanding to guide marine conservation practice. Our objective is to expose students and other readers to the broad range of overlapping issues (Chapter 2) in the context of present conservation mechanisms that have been devised to achieve marine conservation goals (Chapter 3). Achieving these goals depends on understanding basic marine ecosystem science (Chapter 4) and the natural histories of marine organisms (Chapter 5), that is, how organisms make a living in dynamic and often stressful environments. In that process, we call attention to emergent and unexpected properties that are changing coastal and marine systems—climate change, ocean acidification, dead zones, and loss of biodiversity—that challenge the resilience of coast-ocean systems, hence also governance and human well-being. We present seven "real-world" case studies that exemplify coastal and marine conservation in action, each presenting a central issue or issues in the context of its biogeographic and social setting. Each combines theoretical ("pure") and applied science, and each concludes with challenges to governance that are not yet fully resolved.

A final synthesis chapter looks to the future, to transition coastal and marine conservation from the *being* of traditional, fragmented, protection, and management to the *becoming* of ecosystem-based approaches, intertwined in a social-ecological system, that propel marine biodiversity and society into the future. Overall, this book is an attempt to provide a framework for thoughtful, critical thinking in order to incite innovation in the new Anthropocene Era of the 21st century.

References, scientific terms, Latin names, and units. This book provides readers with a window into a massive literature on conservation science, policy, and management as a context for understanding the present state of knowledge of marine ecosystems, their life, and their current conservation and management. The language of science is enormous and similar terms often have different, even contradictory, meanings among disciplines. We have attempted to explain these terms by defining some of them in the text. We do not include a glossary, as definitions can be accessed in science dictionaries or through search engines on the Internet. We use the International System of Units (SI units) and metric measurements (e.g., m = meters, mt = tonnes, km = kilometers, nmi = nautical miles, etc.) throughout the text.

Species are referred to by their vernacular ("common") names (blue crab, herring, porpoise, etc.) with Latin names for proper identification. Care must be taken with vernacular names because for the great majority of species these names are not standardized (mammals, birds, and some fishes are notable exceptions). For example, "cod" is a common name for a valuable Atlantic fish of the cod family (Gadidae), but "cod" in Australia refers to groupers of the sea bass family (Serranidae), and for some species of the Southern Ocean "cod" refers to ice fishes of the family Nototheniidae; similarly, "rockfish" may refer to a number of fishes from a half dozen families of fishes; and, the "Dover sole" of the north eastern Pacific is not the highly valued Dover sole of the eastern Atlantic. Therefore, scientific names are essential for identification, and are given with the vernacular the first time the species is mentioned in each chapter, or if far separated.

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G. Carleton Ray and Jerry McCormick-Ray

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ABOUT THE COMPANION WEBSITE

This book is accompanied by a companion website:

www.wiley.com/go/ray/marineconservation

The website includes:

- Powerpoints of all figures from the book for downloading
- PDFs of tables from the book

CHAPTER 1

IN PURSUIT OF MARINE CONSERVATION

> There is a tide in the affairs of men
> Which, when taken at the flood, leads on to fortune . . .
> On such a full sea are we now afloat;
> And we must take the current when it serves
> Or lose our ventures.
>
> William Shakespeare *Julius Caesar*

Open-ocean systems may seem not to be so disturbed at their surface, but signs of ecological disruption are apparent. The lone walrus on our cover is a metaphor for Planet Earth's fragmented habitats, disrupted ecosystems, and diminished biodiversity. As oceans change, tropical reefs die, polar regions lose sea ice, and marine life that we hardly know is increasingly becoming vulnerable to extinction. Nowhere is this change more apparent than in the land-sea coastal realm (Frontispiece), where the majority of humanity lives, ecosystems are most productive, and biodiversity is greatest.

During the rise of human civilizations, societies have inherited the economics of resource exploitation from an ocean perceived as "limitless." Fisheries, shipping, and coastal settlement as old as civilization, have increasingly expanded to force conservation into defense of species and spaces. And as the ecosystems upon which species depend have changed, scientists have become increasingly involved. Modern science, which had moved from studies in natural history to environmental modeling and statistics to better understand marine systems, is returning to natural history, recognizing that it forms the basis for environmental and evolutionary science itself (Box 1.1). The advancing state of knowledge and the increasing need for sustainable ecosystems are forcing marine conservation science to become more proactive and to expand its scope to encompass whole regional seas. Recognition of depleted fisheries, coastal catastrophes, and consequences of natural events tied to human activities have led to new ways of thinking about how marine conservation may modify society's relentless pursuit of ocean wealth.

The past decades' tendency to compartmentalize marine conservation issues has changed. Marine conservation is now forced to embrace the totality of issues together, because the oceans are interconnected, dynamic, and complex. Knowing how marine life makes a living is fundamental in the vast, bioenergetic marine environment undergoing continual change. And the dynamic features of the global ocean and of the coastal realm make the pursuit of marine conservation different from that for the land.

1.1 THE EMERGENCE OF MODERN MARINE CONSERVATION

Modern marine conservation arose after World War II when the oceans took on greater political, economic, and social importance. The oceans became viewed as a "supplier" to meet expanding human wants for food, resources, and wealth. Humans rapidly began to acquire the ability to explore and exploit this last, previously unavailable portion of Earth—the oceans—to fish and seek petroleum and minerals facilitated by new technology that allowed humans to invade, and also better to understand the oceans to their utmost depths. We call this era of emerging ocean importance the "Marine Revolution" (Ray, 1970). It followed the Industrial Revolution of about two centuries before, which had expanded the human footprint with the invention of the steam engine, electric power, industrialization, and urbanization. And the Industrial Revolution followed the Agricultural Revolution, circa 10,000 to 5000 BP, that transformed landscapes into patches of farmland on such massive scales as to alter Earth processes, including climate (Ruddiman, 2005). Each successive revolution promoted human well-being and population growth as it also depleted natural resources, and as land resources became depleted and consumption grew, societies looked to the oceans for food, energy, and economic benefits. Today, human activities are globally pervasive, marked by resource shortages and the need to conserve what remains in the new age of the Anthropocene (Crutzen and Stoermer, 2000; Steffen *et al.*, 2007).

The economic value that humans place on coastal and marine systems and their workings no doubt arose during the earliest of human cultures. The need for conservation that scientists and writers called attention to focused on overexploited commercial species as early as the 18th and 19th centuries with the squandering of Steller sea cows, fur seals, and others. George Perkins Marsh's *Man and Nature* (1864) was first to link culture with nature, science with society, and landscape with history, and spearheaded nature conservation by leading to forest conservation and establishment of the first

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Box 1.1 The importance of studying nature outdoors

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> The most basic rules of the world—the ones we all live by—are ecological rules. You can't study them or even perceive them very well in a classroom or laboratory. It is imperative to go out on the mountainside, watch the rain fall over a valley, dig into the earth beneath a fallen tree, or wade a creek for cobbles with sources upstream. The best work in the natural disciplines all starts with observations in nature.
>
> Kenneth S. Norris, in Dayton (2008)

Ken Norris wrote this, in late 1960, making a pitch to the University of California Regents to create a natural reserve system. He was successful and the UC Natural Reserve System has grown into the best such system in the world. But to what avail are patches of nature if people do not immerse themselves in those natural systems?

In the past few decades the powerful tools of molecular biology and capacity of modern computers have joined with technical advances that allow us to monitor and analyze the world around us with unprecedented precision. These new and powerful tools have seduced would-be ecologists into the comfortable idea that they can do good ecology in the laboratory or at a computer terminal without bothering to actually study nature. Indeed, the tools are so complicated that there has been strong selection for ecologists to become increasingly specialized with a laser-like focus. We have thus deprived ourselves of a sense of place of nature that comes from personal experiences, smelling, feeling, and seeing important if episodic relationships. Many ecologists and especially universities have lost respect for the broad view of nature, the understanding of the components and processes of the whole natural world or "natural history" of the systems we study. These specialists fail to perceive the critical relationships and ecosystem workings that their powerful machines were not designed to study. Deprived of personal experience in nature, many forget natural history and accept habitats and systems that are a pale shadow of their former selves and substitute simplistic models for understanding of nature.

Here we are concerned with the conservation of these habitats. We understand that we are reducing populations and losing species, and we are disrupting the important relationships that define our ecosystems. As populations decline, the relationships that define the ecosystems are lost long before the species go extinct, and it is precisely these relationships that we most need to protect. The damage to these relationships and ecosystems is often so persuasive that it may be impossible to understand what has been lost because generations of biologists have reduced expectations of what is natural. This sliding baseline of reality is exacerbated by the lack of personal experience in nature. Without a deep understanding of the history of their systems, ecologists can be beguiled by short-term events or introduced, inappropriate imposters that replace and mask the traces of the natural systems we hope to study and protect. The natural relationships simply disappear, leaving no conspicuous evidence of what has been lost. This loss is paralleled by the loss of human cultures and languages with the passing of elders; we, too, have lost the ecological cultural wisdom of the ages as well as the evolutionary wisdom found in intact ecosystems.

Conservation biologists face extremely difficult problems much more complex than most realize. For example, we need to understand ecosystem stability, recoverability, and resilience. How do we define stability, and what processes maintain it? What spatial and temporal scales are optimal for the analyses of trends? How do we define ecosystem stress? How can we understand when "natural" disturbances ratchet into new "stable states" that resist recovery? What relationships are most critical, what processes define strong and weak interactions, and how do we evaluate the most critical interactions? How do we define multispecies relationships important to ecosystem resilience? Can we predict thresholds in these relationships?

Sustainable ecosystem-based management is an ecological mantra, but how does "single-species management" morph into ecosystem-based management? What do we need to protect and how can we prioritize the relationships? People perturb all ecosystems, but how do we evaluate cumulative effects and understand how much is too much? That is, all ecological relationships have thresholds defined in the context of ongoing natural interactions, but which thresholds are most critical and how do we measure them?

The above questions focus on difficult science that cannot be done without a very deep sense of place that only comes from intimate familiarity with the natural world. But consider also the great importance of social values in addition to the natural sciences. The scientific focus is on important relationships critical for management, but how do we evaluate the value of species? Do we also need to protect weak interactions? Ecologists lose credibility when they claim that every species and interaction is critical to the ecosystem, because this assertion simply is not true. Most systems are comprised of many populations that can be altered without much ecosystem effect. There are many rare and very obscure species with no discernible interactions, and there are charismatic species such as pandas or leatherback sea turtles with roles that are hard to evaluate. Thus, we are asked whether some species are expendable, and we must learn to shift seamlessly from our scientific value systems to cultural value systems that define human values. It is very hard to argue for aesthetic or cultural values for nature without having an intimate understanding of the natural world. If you have not experienced first hand the awe and wonder of nature, it is very hard to communicate it!

Finally, you went into biology because you love nature, and this involves regular contact with nature. The intuitive sense of place so very important to ecological understanding must come from personal experience—smelling, feeling, and seeing the important lessons nature offers an open and prepared mind. It is easy to be seduced by the demands of everyday life and to forget to visit nature and fuel your passion and sense of self as well as a sense of place necessary for your science.

U.S. Commissioner of Fish and Fisheries. But only since the 1940s did conservation become an ethic among the wider public. Aldo Leopold's *Sand County Almanac* (1960), Fairfield Osborn's *Our Plundered Planet* (1947) and *Limits of the Earth* (1953), Raymond Dasmann's *A Different Kind of Country* (1968) and *No Further Retreat* (1971), and others inspired a conservation movement that saw the founding of governmental agencies and non-governmental organizations dedicated to wildlife management and environmental protection. Rachel Carson's *Silent Spring* (1962)—on the *New York Times'* best-seller list for 31 weeks—served as an indictment of the pesticide industry and helped to catalyze ecological awareness and action. However, opposition to ocean abuse—a major feature of the Marine Revolution—has been relatively new.

Little had been said for the marine world until Rachel Carson's *The Sea Around Us* (1951) and, especially, Jacques-Yves Cousteau and Frédéric Dumas' The *Silent World* (1953) made the oceans and their life familiar to the public. Cousteau and Dumas' invention of the "Aqualung" (self-contained underwater breathing apparatus or scuba) allowed anyone in reasonably good health to explore and find value in the sea and marine life "up-close and personal." This self-conscious awareness of the sea's value, beyond only "resources," had immense, global impact. Under a new sense of urgency, Marine Protected Areas began to be established and charismatic species to be protected. Whales, sea turtles, and others that had suffered from over-exploitation, and dolphins and killer whales that were displayed in oceanaria became icons of the ocean's value.

The immediate responses for ocean protection were based on practices that had long proved appropriate for terrestrial environments, namely protection of *species*—overwhelmingly charismatic ones deemed threatened or endangered—and protection of *spaces* that served as habitats for unique, endemic, or threatened plants and animals, or as scenic inspirations. Marine conservation had finally joined an era of environmental concern that reached a climax, fervently expressed on Earth Day, 1970, that aroused the necessary social and political will to make transformational change (Graham, 1999): "In 1965 the environment was not a leading issue. Five years later it was the national problem Americans said they worried about most, second only to crime. Earth Day 1970, celebrated just as that crescendo in public concern was reaching its peak, became the lasting symbol of past frustrations and future hopes." Increased awareness of coastal impacts and recognition of failures to conserve marine resources brought on a quickening pace of change. The public opposed the ruthless slaughter of marine mammals, impacts of polluted water, and shores tarnished by oil spills. The result was a suite of environmental legislation, particularly in the U.S., that set standards that became adopted globally. U.S. legislation centered on species protection, coastal zone management, fisheries management, curbing ocean dumping, and establishment of marine sanctuaries. Marine Protected Areas became institutionalized, albeit operationally stalled by difficulties of designating environmentally or legally defensible boundaries, sizes, and locations, compounded by jurisdictional conflicts, established national priorities, and deficiencies of international ocean law. Internationally, the first effort (mid-1970s) specifically directed towards marine conservation became the *Marine Programme* of the *International Union for the Conservation of Nature and Natural Resources* (IUCN), which persists to this day. This program helped direct efforts towards regional-seas agreements organized and promoted by the United Nations Environmental Program (UNEP). Conservation focus remained on charismatic marine species—whales, seals, walruses, albatrosses, sea turtles, etc.—and natural areas of high biodiversity (coral reefs) and/or scenic beauty, which served to promote marine conservation to the vast majority of humankind that had little direct experience *in* the sea.

However, these programs lacked appropriate mechanisms for addressing new and emergent issues, which made obvious the enormity of the task confronting marine conservation. A cadre of non-governmental organizations (NGOs) began to expand, each with its own interests and goals. At this same time, marine ecology was advancing, generated by new technologies for undersea exploration; satellites allowed "world views" of the coasts and oceans, computers analyzed large data sets, and models revealed insights into system-level phenomena. A principal finding was that change is a fundamental property of ecosystems, at all scales from local to global, and that such change responds to ecological and social domains beyond protected-area boundaries. That is, "protection" of valued or threatened species and spaces—presumably isolated from harm—would not suffice. Marine boundaries are continuously on the move.

From about 1980 to the turn of the 21st century, human-caused ocean change deepened, grew wider, and became more complex, along with the public recognition that "biodiversity" was seriously under threat (Wilson and Peter, 1988). Conservation gradually began to take on a new role—that of protecting biodiversity "hot spots" and restoring diminished natural systems in a shrinking world dominated by human needs.

Additionally, a host of independent initiatives arose, but too many individually directed and often-conflicting laws, regulations, agreements, and treaties added up to challenge conservation—a "tyranny of small decisions" (Odum, 1982). By protecting one part of a whole system, another part unexpectedly reacts, often resulting in consequences that no one wanted or intended, including species depletion and ecological degradation.

We are now at a time in history when science allows better opportunities to understand our global environment and to more clearly recognize the limits of the oceans and the urgency of marine conservation. The need for a comprehensive "systems" approach to protect species and spaces has become increasingly apparent. Coherent national ocean policies are being called for, and international policies are being formulated, but the challenge of implementing comprehensive conservation policy remains. But as Graham (1999) warned: "A generation later, the political and economic ground has shifted . . . The public's sense of crisis has been replaced with enduring support for improving pollution control and conservation, but also with a frequent reluctance to pay the public costs of increased protection or to change everyday habits."

1.2 DEFINING "MARINE CONSERVATION"

Marine conservation is an elusive concept to grasp. What exactly is it? "Conservation," as defined in *Webster's Third New International Dictionary*, is "deliberate, planned, or thoughtful preserving, guarding, or protecting . . . planned management of a natural resource to prevent exploitation, destruction, or neglect . . . wise utilization of a natural product . . . a field of knowledge concerned with coordination and plans for the practical application of data from ecology, limnology, pedology, or other sciences that are significant to preservation of natural resources." These definitions presume a basic understanding of natural-resource science and illustrate that conservation is an issue-directed activity towards which science can provide a guide to inform decision-makers at all levels. However, solutions to sector-based conservation problems have proved elusive for reasons that are not always straightforward, not for want of a plethora of laws, regulations, agreements, organizations, and procedures that have been adopted, but for their applications in a society divided by priorities. Many difficulties also relate to recognizing the differences between land and sea and their respective conservation needs.

The oceans are not like the land. Physically, the three-dimensional ocean is driven by interactions of fluid dynamics, light, nutrients, and temperature. Biologically, ocean volume exceeds the land by almost two orders of magnitude, being dominated by small, non-charismatic microbes and plankton that support larger invertebrates and fishes and a few highly developed, charismatic air-breathing reptiles, birds, and mammals. Phyletic diversity and total biomass in the sea far exceeds that of the land, although large plants are few and restricted to shallow, nearshore waters. Functionally, marine ecosystems are continuous and connected across huge spatial extents, as exhibited by planktonic larvae, billfishes, sharks, sea turtles, and whales. Yet the ocean has boundaries to which species respond. Many widely distributed species exhibit taxonomic and genetic differences in biogeographic patterns and in metapopulations (Ch. 5). Ocean boundaries can move, and can change unexpectedly and unpredictably over decadal time scales or less, and at spatial scales rarely known for terrestrial environments. Such boundary changes are difficult to know, often being observed through natural history and genetic studies of species. Furthermore, the distributions and behaviors of species depend not only on the physical environment, but also on species that can affect and change environments. Species–environment feedbacks modify ecosystems and create conditions that support many other species. Many marine species are opportunistic, depending on chance or changes in response to highly dynamic marine systems. Furthermore, species and environments are interdependent and may coevolve. Such relationships are particularly difficult to observe in the moving fluid of the marine environment. Thus, defining species–environmental interdependencies under conditions of continual change and lack of natural-history knowledge for most of them remains a critical conservation arena. As Levin (2011) put it: "Sustainable management requires that we relate the macroscopic features of communities and ecosystems to the microscopic details of individuals and populations." But how?

1.3 MARINE CONSERVATION'S SCOPE

The rise of ecology, globalization, and the ubiquity of human activities makes obvious the fact that by the later 20th century humans had so altered global ecosystems that the rapidly decreasing number of natural spaces on Earth left to defend may soon be few. This raises the ambiguous issue of "scope." Does scope simply mean size, as established through spatially designated protected or managed areas, i.e., that the larger the boundaries or percentage of protected areas designated means that *more* is protected? Conversely, should preference be given to those species that we believe to be "charismatic"? Or does scope imply a greater suite of procedures, regulatory or otherwise, which translates to *how* conservation is conducted? Answers are not as simple as they may seem.

Currently, marine conservation draws public support and legislative action more from emotional and personal preferences and less from scientifically based information on marine system processes. Hardly anyone would not wish to save a whale, but what about its food supply of very small copepods and krill? And how do ocean processes operating over huge scales support those foods? Clearly, marine conservation is drawn into a large spatial context, as well as being subject to socio-economic conflicts. If marine conservation is to be about biodiversity maintenance, resource sustainability, and human well-being—and all at once—it should become fundamentally hierarchical, from protecting the rarest and most valued (in human and ecological terms) species and spaces, to sustainable use, and to enable the resilience of ecosystems; that is, conservation needs to become "systemic" in its approaches. The crisis is this: as the increasing human population demands ever more marine natural resources, the environmental deficit also grows (Ch. 13; Bormann, 1990). The objective of marine conservation, then, is to slow and eventually stop the ecological cascades resulting from social/ecological imbalances by protecting, restoring, and sustainably using resilient ocean systems and their living components as Earth's last frontier. This objective requires a better understanding of the living and physical components that marine conservation aims to address holistically. As Franklin (1993) has said in another context: "We must see the larger task—stewardship of all the species on all of the landscape with every activity we undertake as human beings—a task without temporal and spatial boundaries."

1.4 ADAPTING MARINE CONSERVATION TO THE 21ST CENTURY

The 21st century is much different from preceding centuries. The Earth is now "hot, flat, and crowded" (Friedman, 2008) and marine issues are converging, thus requiring new approaches. As this century advances, a systems approach is needed for improving society's ability to take effective action through improved understanding of the physical and biological worlds under an accelerating pace of environmental change (Forrester, 1991). Such an approach requires identifying and understanding the components in the system, and how system behavior arises from their interactions over time (Sweeney and Sterman, 2000).

Marine management institutions that arose in the 20th century are today challenged by the interactions among resources, the environment, critical habitats, and conflicts among institutions that undermine their mandated goals. The organisms that institutions aim to protect inhabit a dynamic world in which feedbacks and complex interdependencies sustain them. While the history of ecology is firmly grounded in natural history, understanding ecological patterns and being able to conserve resources requires understanding dynamics (Levin, 2011). This understanding requires a process that starts with a problem to be solved, and advances with better knowledge about the situation and the wealth of information available (Forrester, 1991). For conservation to advance, this wealth of information needs to: (i) place conservation issues in the context of environmental-social systems; (ii) connect species natural history to interconnected natural and human systems; and (iii) place ecosystem resilience in the forefront of conservation action (Walker and Salt, 2012). These goals relate to the art of systems thinking, which involves the ability to represent and assess dynamic complexity. Implicit in thinking about systems is the ability to have good science and quantitative data in order to see relationships between the issue to be addressed and the conservation tools to address it.

Marine conservation is confronted by an overwhelming array of complex issues and an astonishing amount of information. Categories of issues confronting marine conservation are introduced in Chapter 2 to help sort out this complexity. While solutions to many issues are being sought (Ch. 3), most of them have been addressed singly, as if in isolation. Yet some issues are emergent, have arisen suddenly and unexpectedly to catch both science and society unprepared, notably climate change, ocean acidification, and anoxia. Such issues relate to the nature and properties of the ocean's ecological systems, the natural histories of marine species, and their interactions, which requires relating dynamics and linkages of organisms to each other and to their environment. A conceptual level of ecosystem understanding helps make these connections real (Chs. 4, 5).

The book introduces seven case studies that exemplify pursuit of marine conservation. They illustrate an array of attempts to address specific conservation issues in geo-social-ecological contexts. Implicit in each case study is the relationship of social and ecologic systems to each other and to the task of conservation.

Some questions to consider along the way:

- How can marine conservation be framed to protect, restore, and accommodate both a dynamic marine environment and expanding human needs?
- How does systems thinking relate the environmental debt to social well-being and economics?
- How can a focus on "charismatic" iconic species be expanded to encompass biodiversity protection?
- How big, how many, and where should Marine Protected Areas be placed to maximize benefits for marine conservation?
- What lessons can be learned from real-world cases that can be extrapolated to other situations?
- How do 21st century needs fit within 20th century mandates?

Ecosystem approaches to marine conservation focus on issues holistically, rather than repeating fragmented approaches that fail to account for unexpected changes that arise from complex system behavior. Maintaining the status quo through sector-based decisions (e.g., fishing, coastal development, water quality, and energy) needs reconsideration, which requires thinking differently about solutions in order to better fit future policies with procedures. Successful alternatives are being sought (Ch. 13) to protect and sustain biodiversity and the species that both serve society's needs and refresh human minds. As complex systems defy intuitive solutions, it is time to explore new frontiers for marine conservation practice.

Marine conservation itself is now at a crossroads, transitioning from "protection" and sector-based regulations to a wider context. That marine conservation has lagged behind its terrestrial counterpart gives it the potential to be innovative by devising a "best mix" of old ways to new ones, taking historic successes and failures into account. Aware that the oceans are no longer "out of sight, out of mind" to most people, as in the recent past, and armed with "science as a way of knowing," as John Moore put in the title of his seminal book (1993), marine conservation should be capable of avoiding future pitfalls. Humans are not to be faulted for lack of caring. Rather, future progress lies in perceiving connectedness and feedbacks to and from the environment and human societies, leading to the hopeful well-being of both.

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CHAPTER 2

MARINE CONSERVATION ISSUES

> . . . man has greatly reduced the numbers of all larger marine animals, and consequently indirectly favored the multiplication of the smaller aquatic organisms which entered into their nutriment. This change in the relations of the organic and inorganic matter of the sea must have exercised an influence on the latter. What that influence has been, we cannot say, still less can we predict what it will be hereafter; but its action is not for that reason the less certain.
>
> George Perkins Marsh (1864) *Man and Nature: Or Physical Geography as Modified by Human Action*.

2.1 IGNITING MARINE CONSERVATION CONCERN

Issues attract conservation concern for changes threatening marine biological richness and ecosystem function. Marine ecosystems sustain the largest species on Earth (blue whale), the fastest swimmers (mako shark, marlins), the most bizarre (octopus), most serene (kelp forests, coral reefs), most intriguing (dolphins, orcas, sea horses), most fearsome (great white shark), and most tasty (shellfish, salmon). Depletion of some species, overabundance of others, ill health, and degradation of habitats are *primary* issues for concern, followed by *secondary issues* that illustrate the concentration of human activities impinging on marine ecosystems. *Tertiary issues* focus on fundamental changes in marine ecosystems that are global in scope and propelling marine ecosystems toward unexpected and unintended outcomes. These issues, largely hidden beneath the undulating waves, contrast with a seemingly resilient ocean undergoing change, with major social and economic consequences.

2.2 PRIMARY ISSUES: LOSS OF MARINE BIODIVERSITY

Scientific evidence makes clear that marine ecosystems are losing some of their largest, most charismatic and most productive species. Overabundance of nuisance and toxic species, ill health and pandemics, abnormal behaviors, and deteriorating critical habitats highlight biological changes in the marine environment. This set of issues focuses conservation concern on the ethical and ecological loss of species and marine biological diversity, moving marine environments increasingly toward biological homogenization with consequences for ecosystem integrity and function.

2.2.1 Species extinctions and depletions

Many of the largest and most charismatic marine species, the icons of the oceans, are being depleted worldwide and/or risk extinction. The IUCN 2008 *Red List of Threatened Species* documents about 1500 marine species (Polidoro *et al*., 2008; Fig. 2.1). Documented extinctions of less obvious species are few (e.g., sediment fauna; Snelgrove *et al*., 1997), but ramifications could be significant (Emmerson *et al*., 2001). The ability of scientists to anticipate extinction is elusive, and understanding the causes is a central problem in biology (Ludwig, 1999).

Of the more than 120 species of marine mammals, at least a quarter is presently depleted (Polidoro *et al*., 2008), and a few have gone extinct. The Steller sea cow (*Hydrodamalis gigas*) was wastefully hunted to extinction 27 years after its discovery in 1741 (Stejneger, 1887; Fig. 2.2); its living Sirenian relatives, the dugongs (*Dugong dugon*) and manatees (*Trichechus* spp.), face potential extinction. Whaling drastically reduced the great whales and recovery of some is slow. The North Atlantic gray whale (*Eschrichtius robustus*) population went extinct in the 18th century, but the relatively rare, iconic blue whale (*Balaenoptera musculus*) appears to be recovering. Right whales (*Eubalaena glacialis*) remain at risk in the North Atlantic and North Pacific (the latter was victim of illegal whaling, Box 3.1), but the Southern Hemisphere population is rapidly recovering (FAO, 2011). The sperm whale (*Physeter macrocephalus*) of *Moby Dick* fame has recovered to 32% of pre-whaling levels (Whitehead, 2002). A declining population of the iconic orca or "killer" whale (*Orcinus orca*) in Washington State is in danger of extinction due to reduced prey and toxic pollution (Wiles, 2004). The Gulf of California porpoise (*Phocoena sinus*) and all river dolphins (family Platanistidae) are greatly depleted and near extinction; the Chinese Yangtze River dolphin (*Lipotes vexillifer*) is considered extinct (Turvey *et al*., 2007). The seriously depleted Mediterranean (*Monachus monachus*)

Marine Conservation: Science, Policy, and Management, First Edition. G. Carleton Ray and Jerry McCormick-Ray.

and Hawaiian monk (*M. schauinslandi*) seals may be following the now extinct Caribbean monk seal (*M. tropicalis*) that was last reliably sighted in the 1950s near Jamaica. International protection of fur seals (*Callorhinus* and *Arctocephalus* spp.) and sea otters (*Enhydra lutris*) prompted their recovery from near-extinction during the 19th century's fur and oil exploitation, although some are currently declining for unknown reasons (Ch. 7). Atlantic walruses (*Odobenus rosmarus rosmarus*) remain depleted to this day, following a centuries-long period of exploitation; the Pacific subspecies (*O.r. divergens*) recovered following the collapse of Bering Sea whaling, but appears now to be declining (Ch. 7).

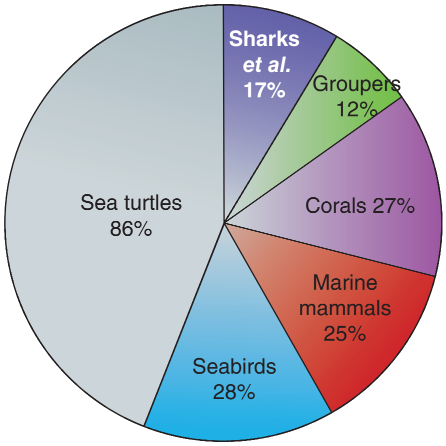

Fig. 2.1 Percent marine species in taxonomic groups are listed in the *Red List of Threatened Species* as Critically Endangered, Endangered, and Vulnerable to extinction (IUCN, 2012). The number of marine species assessed for extinction lags far behind those on land. Percents of Red-Listed species of sharks and rays, groupers, reef-building corals, seabirds, marine mammals, and sea turtles have been calculated from data in Polidoro *et al*. (2008).

Many seabirds are in serious decline. Some 312 species (albatrosses, penguins, puffins, auks, etc.) in 17 families are vulnerable to extinction due to their dual dependence on land and sea, which subjects them to both terrestrial development and marine fishing activities (Ballance, 2007). Of particular concern are petrels and albatrosses that migrate over great ocean distances to feed and return to land to breed. Coastal pollution and climate change increase the threat.

Sea turtles are also threatened with extinction due to dual dependence to breed on sandy beaches and long-life ocean feeding (NRC, 2010a). Their sea migrations cover whole ocean basins (Ch. 8) where fisheries bycatch is an especially serious form of mortality. All seven species of these air-breathing reptiles face direct and indirect human impacts: loggerhead (*Caretta caretta*); green (*Chelonia mydas*); hawksbill (*Eretmochelys imbricata*); Kemp's ridley (*Lepidochelys kempii*); olive ridley (*Lepidochelys olivacea*); leatherback (*Dermochelys coriacea*); and flatback (*Natator depressus*).

Fishes are by far the most diverse and numerous of vertebrates, and the list of threatened and depleted species is long and growing. Many of the largest are targeted by commercial and sports fisheries, and examples are many. The largest and fastest tuna and billfish are depleted as a result of high market

Fig. 2.2 Extinct Steller sea cow (*Hydrodamalis gigas*) as conceived from existing sources. This herbivorous marine mammal, exploited to extinction, was the largest member of the order Sirenia, a group that includes dugongs (*Dugon dugon*) and manatees (*Trichechus* spp.). All four extant species of this group are listed by IUCN as Vulnerable to extinction. Illustration © R. L. Smith, Jr.

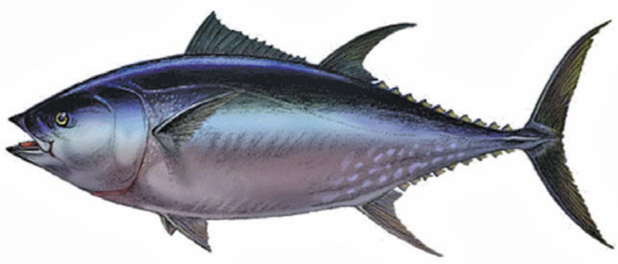

Fig. 2.3 Atlantic bluefin tuna (*Thunnus thynnus*), is the largest of tuna (4 m long and weighing up to nearly 900 kg), a prime target for game and longline fishing, and a favorite for sushi. This highly migratory, top predator has declined more than 80% since the 1970s and is listed by IUCN as "Endangered" (IUCN, 2012). Illustration © R. L. Smith, Jr.

value that encourages overfishing. The largest of them, the Atlantic bluefin tuna (*Thunnus thynnus*; Fig. 2.3), is subject to intense fishing pressure and may be on the path to extinction (IUCN, 2012). The depleted great white shark (*Carcharodon carcharias*) has a low reproductive potential (Smith *et al.*, 1998). Other sharks (e.g., scalloped hammerhead (*Sphyrna lewini*), thresher shark (*Alopias vulpinus*), etc.) have declined more than 75% just in the last 15 years (Baum *et al.*, 2003); coastal sand tiger sharks (*Carcharias taurus*) of the Atlantic, Caribbean, and Gulf of Mexico are threatened by poor water quality, fishing, and fisheries bycatch (Meadows, 2009). Sawfishes (*Pristis* spp.) and some species of skates and rays (order Rajiformes) are threatened worldwide due to fisheries bycatch and gill-net fishing. The 5.5 m shallow-water smalltooth sawfish (*P. pectinata*) is in a critical state. Estuarine fishes that travel between land and sea to breed and feed (salmons, sturgeons, anguillid eels) are particularly vulnerable; natural populations of Atlantic salmon (*Salmo salar*) are seriously depleted, as are southerly northwest Pacific populations of five species of salmon (*Oncorhynchus* spp.). Groupers as a whole, especially the tropical West Atlantic Nassau grouper (*Epinephelus striatus*), are much depleted (Ch. 8). Deep-living ocean fish are also especially vulnerable; the slow-growing, late-to-mature orange roughy (*Hoplostethus atlanticus*), which lives below 200 m in the deep sea, is especially vulnerable to fishing, due to a low reproductive rate, and is greatly depleted.

Invertebrates are particularly difficult to assess due to their overwhelming numbers, variety, and lack of high conservation priority. Iconic corals and some shellfish are approaching extinction from a variety of causes. Tropical corals, especially the historically abundant Caribbean reef-building elkhorn (*Acropora palmata*) and staghorn (*A. cervicornis*) corals are now much reduced (Ch. 8). Two rare endemic coral species of the Galápagos Archipelago (*Tubastraea floreana* and *Rhizopsammia wellingtoni*) are declining, presumably due to climate change. Abalone, in particular white (*Haliotis sorenseni*) and black (*Haliotis cracherodii*) abalones of the Northwest Pacific, as well as the perlemoen (*Haliotis midae*) of South Africa (Ch. 11), are prized food items and key members of coastal ecosystems, and face high risk of extinction.

2.2.2 Overabundant species

Conversely to depletion, some species are flourishing beyond expected levels. Overabundance reflects a species' ability to dominate a natural community and become a nuisance or harmful. This situation is often the result of an unnatural (deliberate or accidental) transfer of a species (termed alien, exotic, invasive) into a new location, where it can thrive with few natural controls, and outcompete native species. Even relatively uncommon species in their native environments can prove successful in changed environments or when their predators are absent, reproducing in such massive numbers that they can deplete their own food resources (e.g., sea urchin "barrens"; VanBlaricom and Estes, 1988). And some native species may thrive, for example, the common reed (*Phragmites*) in North American wetlands (Box 2.1). Others may transform ecosystems into monocultures, later to crash and leave barren seascapes.

Increasingly, exotic species introduced by human activities into new locations are transforming environments; coastal waters appear to be particularly vulnerable (Preisler *et al.*, 2009). About 329 marine invasive species are documented for 84% of the world's 232 marine ecoregions (Molnar *et al.*, 2008). Most are benign, but some can transform marine habitats, displace native species, alter community and ecosystem structure through nutrient cycling and sedimentation patterns, damage fisheries, and clog ship hulls and power plants. A particularly severe invasion is that of the lionfish (*Pterois volitans*) in The Bahamas (Ch. 8). The social and economic consequences are major national and global concerns (Vitousek *et al.*, 1996).

Sea plants globally have invaded new environments in unprecedented numbers. A fast-growing exotic alga (*Caulerpa* sp.) is transforming parts of the Mediterranean Sea's benthos into dense, single-species cover; *Caulerpa* has also invaded southern California and Australia. Sea lettuce (*Ulva prolifera*) formed a massive green tide on the popular tourist beaches of Brittany, France (June 2008), that killed dogs, a horse, and a clean-up worker. This alga reappeared in 2011 to rot en masse, releasing massive amounts of hydrogen sulfide gas (H_2S) that killed 36 wild boars (Hu *et al.*, 2010). Sea lettuce also blooms massively in the East China and Yellow seas; another green alga (*Enteromorpha prolifera*) covered 13,000–30,000 km^2 in the Yellow Sea (Sun *et al.*, 2008).

Exotic species can disrupt flows of energy and materials and biogeochemical pathways important to nutrient recycling, thus altering whole ecosystems. Such species may also alter evolutionary routes important to biodiversity, habitat stability, and ecological biomass (Crooks, 2009). For example, the European intertidal common periwinkle (*Littorina littorea*) that invaded New England shores changed mud flats and salt marshes into rocky shores by grazing on stabilizing algae and marsh grass (Williamson, 1996).

Natural phytoplankton blooms described as "red tides" (dinoflagellates; Fig. 2.4), "green films" (cyanobacteria), "brown tides" (chrysophytes), and micro-planktonic algae (dinoflagellates, blue-green algae, diatoms) are increasingly discoloring coastal waters and some are toxic, e.g., harmful algal blooms (HABs; Anderson, 2004). Blooms may remain localized or

Box 2.1 Invasion of common reed (*Phragmites*) in North American wetlands

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Wetlands are often sites of invasion by non-native species of plants (Zedler and Kercher, 2004). In the U.S., one of the most abundant, conspicuous, and notorious invaders is common reed, *Phragmites australis*, a grass that grows in dense stands up to 3–4 m tall, effectively blocking the growth of other potential plant competitors (Meyerson *et al*., 2009). *Phragmites* is considered a "cryptic invader" (Saltonstall, 2002) because an invasive genotype, introduced from Europe around the advent of the Industrial Revolution (Saltonstall *et al*., 2004), can displace the native subspecies. The native typically is a minor component of wetland communities, so the expansive growth of exotic *Phragmites* monocultures eliminates many other species as well.

The negative consequences of invasion and subsequent expansion of *Phragmites* into both tidal and non-tidal wetland environments include loss of wetland biodiversity and shifts in ecosystem structure and function (Chambers *et al*., 1999). With significant assimilation and storage of water and nutrients (Mozdzer and Zieman, 2010), a *Phragmites*-dominated wetland exhibits patterns of energy flow through food webs and nutrient cycling different from that of the native plant community. *Phragmites*-dominated wetlands tend to be drier than those they displace, with consequences for fish use of these habitats (Osgood *et al*., 2006). Further, bird use of *Phragmites* wetlands tends to include more generalist species than wetland specialists.

Exotic *Phragmites* invades open space in wetlands via both seed and rhizome dispersal (McCormick *et al*., 2010). During the 20th century, U.S. *Phragmites* invasion was tied to human activities in wetlands (Bart *et al*., 2006). Shoreline development that extended from uplands to wetland borders created nitrogen-enriched habitat into which *Phragmites* could establish (Silliman and Bertness, 2004). Some researchers suspect that eutrophication of waterways in North America creates conditions that encourage the introduction and spread of *Phragmites*. Interestingly, however, those same nutrient-rich conditions have been cited as a possible cause of *Phragmites* die-back in some parts of Europe.

Owing in part to the "no net loss" policy of wetland mitigation in the U.S., created wetlands provide additional open space for invasion and expansion of *Phragmites*, as *Phragmites* is one of the first species to arrive and thrive in these sites (Havens *et al*., 2003). At present, even undisturbed, pristine wetlands are susceptible to invasion, perhaps due to nitrogen enrichment via atmospheric deposition. *Phragmites* now occurs in wetlands from all 48 of the conterminous United States. Along the middle Atlantic seaboard, a broad invasion "front" appears to be working south through Virginia and the Carolinas. Some wetlands are taken over by *Phragmites* quickly, whereas others seem more resistant to invasion. *Phragmites* has also spread northward into eastern Canada, where yet another invasive species (purple loosestrife, *Lythrum salicaria*) is considered a bigger threat to native biodiversity.

Efforts to stop *Phragmites* expansion using controlled burning, chemical spraying, and physical removal have been largely unsuccessful. Without chronic application of these methods every growing season, *Phragmites* stands tend to recover more quickly than other species. Bio-control methods are under development but run the risk of non-specific actions by the control agents; a number of rhizome-boring insects have been introduced accidentally from Europe, but their North American impacts on *Phragmites* and potentially on other species have not been assessed (Tewksbury *et al*., 2002). From a management perspective, most invaded wetlands cannot be restored to a pre-*Phragmites* condition. Many coastal wetlands that once were restricted to tidal flows have been re-opened, allowing extended flooding by anoxic saltwater sufficient to kill *Phragmites* and encourage re-establishment of natives. However, managers often cannot exercise this option and must accept ecological changes brought on by a new wetland dominant.

Managing non-native *Phragmites* invasion is also complicated by the presence of the native, less aggressive genotype of *Phragmites* that is losing ground. How can *Phragmites* be managed to maintain the native and kill the exotic? Recent research has demonstrated that hybridization between native and non-native genotypes is possible (Meyerson *et al*., 2009), further limiting the available options for control of the abundant invader. Despite the negative impacts of having such an aggressive species in wetlands of North America, non-native stands are significant sinks for nutrients and may be important in mitigation of polluted, non-point source runoff to waterways. Because of rapid, extensive root and rhizome growth, *Phragmites* may also serve to stabilize shorelines in the face of coastal erosion and rising sea level. Additionally, in European and Asian wetlands where it has grown for centuries, *Phragmites* is used for thatching roofs and for paper production; this practice also occurs in portions of the U.S. by immigrants. Because of these positive qualities valued by humans, the new invasion and overabundance of exotic *Phragmites* cannot be easily categorized as either a bane or a blessing. Appropriate policy and management decisions regarding the invasion and spread of *Phragmites* must be considered within site-specific social and ecological contexts.

Fig. 2.4 Algae bloom, popularly known as "red tide." Small inserted picture illustrates two microscopic toxic dinoflagellates that cause red tide blooms. Photograph © Ray & McCormick-Ray. Dinoflagellates from U.S. Public Health Service online.

cover thousands of square kilometers for weeks; some occur at the same time and place each year and others are unpredictable, as for example: *Alexandrium fundyense* in the Gulf of Maine (Anderson *et al*., 2005); *Karenia brevis* in the Gulf of Mexico (Steidinger *et al*., 1998; Vargo, 2009); cyanobacteria in the Baltic Sea (Kononen, 1992; Bianchi *et al*., 2000); and others (Pitcher and Pillar, 2010). HABs produce toxins, noxious gases, or anoxic water that kill marine life, and are becoming more frequent. Some produce a neurological biotoxin (domoic acid) that causes amnesic shellfish poisoning that affects people and a variety of sea life from fish to blue whales (Grant *et al*., 2010). Some dinoflagellate HABs (e.g., *Alexandrium* sp., *Gymnodinium* sp., *Pyrodinium* spp., etc.) produce saxitoxin, also a neurotoxin that caused massive humpback whale mortality in 1987 (Geraci *et al*., 1989). A toxic dinoflagellate (*Noctiluca scintillans*) bloom stretched more than 20 miles along the California coast in 1995 (Anderson, 2004); another killed more than 1600 New Zealand sea lion pups (*Phocarctos hookeri*) at Auckland Island in 1998. And the first known toxic dinoflagellate bloom (*Gymnodinium* sp.) in the Arabian Sea in 1999 killed fish, closed aquaculture facilities, and caused significant economic impact (Heil *et al*., 2001). Toxic algae not only affect sea life, but also alter marine food-chain structure and habitats, and are linked to public health, seafood safety, and aquaculture, causing human deaths and illnesses and threatening coastal areas (Stommel and Watters, 2004).

Dense aggregations of jellies ("jellyfish") are increasing in severity and frequency worldwide (Parsons and Lalli, 2002; Graham and Bayha, 2007; Richardson *et al*., 2009). Overabundant jelly animals (pelagic cnidarians, ctenophores) may cause severe threats to ecosystem function on massive scales (Graham *et al*., 2003), with most notable blooms occurring in the Far East and East Asian marginal seas (Uye, 2008; Dong *et al*., 2010). Jellies are a natural feature of healthy pelagic ecosystems; in the Far East three species (*Aurelia aurita, Cyanea nozakii, Nemopilema nomurai*) naturally form large blooms. However, the population of the giant jellyfish *N. nomurai* (2 m maximum bell diameter, 200 kg wet weight) in Southeast Asia increased 250% between 2000 and 2003 with 300–500 million medusae being observed in 2005 (Uye, 2008). In Japan, moon jellyfish (*Aurelia* sp.) clog power plant intake lines (Purcell, 2005). The American comb jelly (*Mnemiopsis leidyi*) that invaded the Black Sea bloomed in the late 1980s to reach concentrations of 300–500 animals per m^3, with a biomass in some regions of over a billion tons (Mills, 2001); it also spread into other European seas, including the central Baltic, causing concern for fisheries. Overfishing, eutrophication, climate change, translocation, and habitat modification may contribute to blooms of jellies. Such abundance reduces food for fishes, alters food webs, and collapses fisheries to impact fishermen and national economies.

2.2.3 Ill health

Diseases of sea life, expressed as lesions, deformities, and infections, are collectively referred to as "ill health." Region-wide epidemic diseases of a wide variety of taxa have caused massive die-offs. Such phenomena appear to be increasingly frequent globally (Harvell *et al*., 1999). Examples are numerous. Corals worldwide exhibit "bleaching" due to loss of zooxanthellae (Fig. 2.5a). Caribbean corals exhibit microbial infections in epidemic proportions described as "white pox," "black line," and fungal diseases (Goreau *et al*., 1998; Fig. 2.5b). Reef-building Caribbean corals are also infected by the bacterium *Vibrio* sp. (Cervino *et al*., 2004). High mortalities of Caribbean sea fans (*Gorgonia ventalina*) caused by a worldwide terrestrial fungus (*Aspergillus sydowii*) carried on airborne dust from Africa (Weir-Brush *et al*., 2004) were related to ocean warming and nutrient enrichment (Ellner *et al*., 2007). Sponges worldwide are exhibiting significantly more diseases, with decimated populations throughout the Mediterranean and Caribbean seas (Webster, 2007). A "wasting disease" caused by a slime mold (*Labyrinthula macrocystis*) extirpated North Atlantic eelgrass (*Zostera marina*) in 1931–2, and 10 other species are

Fig. 2.5 Examples of diseased marine species. (a) Bleached fire coral (*Millepora* sp.). Photograph © Ray & McCormick-Ray. (b) Blackline coral disease (*Montastrea* sp.). Photograph © Ray & McCormick-Ray. (c) Green sea turtle with viral tumors, fibropapillomatosis, Andros Island, Bahamas. Photograph © Karen Bjorndal. (d) California sea lion (*Zalophus californianus*) with poxvirus (parapox). Reproduced with permission of The Marine Mammal Center, Sausalito, California. Disease patterns in the ocean are diverse, making it difficult to discern a clear increasing trend (Lafferty *et al*., 2004).

at elevated risk of extinction with three more qualifying as endangered (Short *et al*., 2011). Only recently have some species shown signs of slow recovery (Godet *et al*., 2008).

Vertebrates are also affected. Fishes exhibit a wide variety of well-studied diseases, some caused by humans (Noga, 2000). Sea turtles are infected by a herpes virus that causes multiple cutaneous masses called fibropapillomatosis, associated with heavily polluted coastal areas, areas of high human density, or where agricultural runoff and/or biotoxin-producing algae occur (Fig. 2.5c; Aguirre and Lutz, 2004). Marine mammals, e.g., seals and polar bears, also exhibit epidemic diseases, including a highly contagious, incurable, and often deadly disease called canine distemper virus (CDV) caused by a morbillivirus (de Swart *et al*., 1995), which is a leading cause of death in unvaccinated dogs. In 1987, many freshwater Baikal seals (*Phoca sibirica*) died from CDV. Other significant morbillivirus species include dolphin morbillivirus (DMV), porpoise morbillivirus (PMV; Saliki *et al*., 2002), and in pinnipeds, phocine distemper virus (PDV). PDV killed more than 23,000 harbor seals (*Phoca vitulina*) in Europe in 1988 and 30,000 in 2002 (Härkönen *et al*., 2006) and has been reported for sea otters (*Enhydra lutris*) in the North Pacific Ocean (Goldstein *et al*., 2009). DMV and PMV are now considered the same species, renamed cetacean morbillivirus (CMV). Viruses have also caused mortalities among striped dolphins (*Stenella coeruleoalba*), endangered Mediterranean monk seals (*Monachus monachus*), and fin whales (*Balaenoptera physalus*). Viral infections and pollutants were implicated in the deaths off U.S. mid-Atlantic shores of more than 700 bottlenose dolphins (*Tursiops truncatus*) in 1987–8, and in excess of 500 harbor seals in New England waters in 1979–80. This massive mortality caused by an influenza virus carried by birds killed 3 to 5% of the 10,000 to 14,000 seals along the New England coast (Geraci *et al*., 1982). Viruses also infect California sea lions (Fig. 2.5d).

Ill health brings into question: what is normalcy? Are diseases in the ocean increasing (Lafferty *et al*., 2004), are they new, or are they re-emergent (Harvell *et al.*, 1999)? Much remains to be known about the "normal state" of health for most marine species. Nevertheless, the magnitude of such phenomena and extent are difficult to ignore.

2.2.4 Abnormal behaviors

Although normal behaviors of most marine species are poorly known, changes in species distributions and behavior such as altered breeding times and places are being increasingly reported. For example, some migratory waterfowl that normally feed on shallow-water vegetation consume farm crop residues and no longer migrate. Expanding numbers of gulls opportunistically feed in garbage dumps and around fishing boats. California sea lions are choosing docks and piers rather than natural shores to rest, and Florida manatees seek the warm-water effluents of power plants during cold winters. Some cetaceans are hybridizing with other species (Zornetzer and Duffield, 2003), a phenomenon apparently unique among mammals (Willis *et al.*, 2004), but that may be normal for Cetacea.

Increasing interactions with humans are proving to be aggressive, mutualistic, positive, or learned. Shark attacks on humans are not common, but raise much public concern and speculation. Sharks' decreasing numbers do not translate into reduced attacks on humans, possibly because of increased numbers of swimmers and divers in nearshore waters (West, 2011). Sharks are not alone; dolphin (*Tursiops* sp.) interactions with humans in Monkey Mia in western Australia have turned aggressive (Orams *et al.*, 1996; Orams, 1997), betraying the illusion of their friendly behavior toward humans.

2.2.5 Critical habitat degradation

Marine life depends on habitats, which are increasingly being modified, fragmented, and lost. Such changes worldwide are seriously threatening many species (Sih *et al.*, 2000). At the interface of land and sea, coastal habitats include salt marshes (Box 2.2), estuaries (Ch. 6), mangroves, reefs, and seagrasses (Ch. 7) that are particularly under severe threat worldwide, being increasingly exposed to poor water quality and erosion. Islands and sandy beaches are disappearing, exacerbated by interactions between human activities, tsunamis, hurricanes, and global warming. Most notably in the Indian Ocean, the 1200 islands and atolls composing the island nation of the Maldives are threatened by inundation due to sea-level rise. Loss of coastal habitats and islands is reducing critical ecosystem services that provide social benefits (Barbier *et al.*, 2011).

Estuaries are among the most productive of all ecosystems and vital to fisheries yet face worldwide decline (Lotze *et al.*, 2006). Deteriorating estuarine health is commonly due to poor water quality, depletion of native species (e.g., shellfish, estuarine fishes), and monocultures of invasive species. In the U.S., estuaries are typically over-enriched with nutrients (Bricker *et al.*, 2008). Once diverse and productive, estuaries and coastal seas have lost more than 90% of their formerly important species' populations and more than 65% of their associated seagrass and wetland habitats.

Seagrasses that provide key ecological services are in a global crisis (Orth *et al.*, 2006; Fourqurean *et al.*, 2012). An estimated 29% of their known global areal extent has disappeared since being first recorded in 1879, and losses have accelerated worldwide since 1980 at an annual rate of 110 km^2 (Waycott *et al.*, 2009). Fourteen percent of all seagrass species are at risk of extinction, with nearly one-quarter (15 species) in serious trouble (Short and Wyllie-Echeverria, 1996; Short *et al.*, 2011). Loss of seagrass habitat is attributable to a broad spectrum of anthropogenic and natural interactions—disease, destructive fishing practices such as dredging, nutrient pollution, natural dieback, etc.—affecting dependent fishes, invertebrates, waterfowl, dugongs, manatees, green turtles, and others.

Hard-bottom reefs (oyster, coral) are globally threatened. Temperate oyster reefs have been intensively depleted over a long period, those remaining being only vestiges of their former extents (Ch. 6; Beck *et al.*, 2009). Tropical coral reefs are threatened worldwide (Ch. 8; Box 2.3).

2.3 SECONDARY ISSUES: HUMAN ACTIVITIES

Secondary issues focus on human activities as agents of coastal change. Thirty-eight percent of the world's 6.5 billion people occupy only 7.6% of Earth's total land area—the narrow coastal fringe (UNEP/GPA, 2006). Fishing is the major agent of change, followed by chemical pollution, eutrophication, and invasive species (NRC, 1995). Such resource extraction, additions of novel substances, and physical alterations have historical roots imbedded in the social fabric of the global society. Expanding this level of coastal impact is the physical alteration of watersheds, new dam construction, wetland filling and/or drainage, and coastal armoring. These human activities act cumulatively over time to physically and functionally alter the coastal system on which so many species and a large portion of the global economy depend.

2.3.1 Extractions: over-harvesting natural coastal resources

Human civilizations extract many benefits from the oceans. With increasing technological advances driven by expanding human needs with increasing intensity, activities and impacts are moving ever deeper into the unknown realm of deep-ocean basins.

2.3.1.1 Overfishing

The limits of ocean bounty have been reached, and in some cases exceeded. Whaling drastically reduced the great whales when the International Whaling Commission stopped it in 1982 (Fig. 2.6; Ch. 3). But the seas continued to bring hope of meeting global food shortages (Idyll, 1978), and global fisheries in the 1950s extracted <20 million metric tons (mt) annually. By the late 1980s, expanding fisheries reached maximum global capacity (Pauly, 2008) and have since been declining (Fig. 2.7a); by 2004, 366 fisheries had collapsed, nearly one of four (Mullon

Box 2.2 Salt marshes under global siege

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Salt marshes are hugely productive intertidal grasslands that form in low-energy, wave-protected shorelines along continental margins. For over 8000 years, humans have benefited greatly from salt marshes and relied on them for direct provisioning of materials (Davy *et al*., 2009). For example, starting roughly 2000 years ago and to this day, marsh grasses are still purposely planted and protected by the Dutch so as to act as buffers against storm surges and as natural-engineering tools to reclaim shallow seas and build up sea barriers to facilitate greater human reclamation and development (Davy *et al*., 2009). Indeed, over 40% of the land in present-day Netherlands was once estuarine intertidal mud habitat and was reclaimed with the help of the engineering services of salt marsh plants (Davy *et al*., 2009). Besides this poignant service, salt marshes provide many other valuable benefits to humans, including water filtration, buffering of storm waves and surges, carbon sequestration and burial, critical habitat for both adult and juvenile fishes and birds, grasses for building houses and baskets, land for grazing ungulates and development, and for scientific and educational opportunities.

Despite this list of abundant and valuable critical services, salt marshes are under global siege from an impressive portfolio of human-generated threats (Gedan *et al*., 2009). Salt marsh coverage, as well as the structure of these ecosystems, continues to deteriorate drastically due to human-induced changes. The critical ecosystem services these systems support are likewise endangered. No longer can marshes be viewed in scientific, conservation, social, and political circles as one of the most resilient and resistant ecological communities. And no longer can they be championed as systems that can and should be used to buffer human impacts (e.g., absorption of nutrients in wastewater and terrestrial runoff). These systems are in desperate need of protection from human influence. Most of these threats are currently underestimated or even overlooked by coastal conservation managers because marsh preservation practitioners have historically worried most about stopping reclamation efforts (Silliman *et al*., 2009a). Current threats to salt marshes include human-precipitated species invasions, small- and large-scale eutrophication and accompanying plant species declines, runaway grazing by snails, geese, crabs, and nutria that denude vegetated marsh substrate over vast extents, climate-change induced effects including sea-level rise, increasing air and sea surface temperatures, increasing CO_2 concentrations, altered hydrologic regimes, and a wide range of pollutants, including nutrients, synthetic hormones, metals, organics, and pesticides (Silliman *et al*., 2009a).

Already about 50% of the value of services marshes provide have been lost as salt marsh ecosystems have been degraded or lost (Gedan *et al*., 2009). On some coasts, such as the West Coast of the U.S., this number rises above 90%, for both marsh area and their services (Bromberg and Silliman, 2009). Without proper conservation action, it is now predicted that this key coastal community will become a non-significant, ecosystem-service-generating habitat in <100 years (Silliman *et al*., 2009a). Key to saving salt marsh ecosystems and their services is recognizing a wide variety of threats and abating them through up-to-date conservation strategies (Silliman *et al*., 2009b) and providing justification of these conservation measures by both describing and valuing all of the critical services marshes provide.

One of the most important and effective acts that conservation practitioners can begin to do to ensure the long-term protection and persistence of salt marsh habitats is to champion the use of Marine Protected Areas in marsh management. This has been done widely for reefs, kelps, mangroves, and seagrasses, but not marshes and their surrounding waters. These protected areas must: (i) include associated marine habitats, such as seagrass beds and oyster reefs; (ii) incorporate extensive areas of undisturbed terrestrial border to buffer marshes from excessive eutrophication via runoff and allow for their landward migration as sea-level rises; (iii) account for the inclusion of positive interactions (Halpern *et al*., 2007) at all levels of biological association (e.g., between species—trophic cascades; and across ecosystems—nursery benefits); and (iv) be large, numerous, and appropriately spaced (See Halpern *et al*., 2007 for discussion). Around the world, coral and rocky reef conservation practitioners and scientists lead the field of marine conservation in this effort. Salt marsh conservationists and ecologists are far behind this work and, thus, should look to these fields for lessons-learned and guidance when establishing Marine Protected Areas for temperate coastal areas whose intertidal zone is dominated by salt marshes. Because of the conservation prestige associated with the designation of a site as a Marine Protected Area, using this method as a means to preserve marshes will also raise public awareness as to the critical role marshes play in the ecology and economy of local human communities.