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A Practitioner's Guide to Planning for Biodiversity

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CHAPTER ELEVEN

The Sea Around: Conservation Planning in Marine Regions

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The oceans, unlike forests, still look like the oceans after we've removed their contents, and even scientists are susceptible to being seduced to ignore phenomena that are out of sight.

—CARLTON (1998)

The importance of marine diversity, the threats it faces, and the need for better conservation in the marine environment have become increasingly clear. Marine conservation may be as much as two decades behind terrestrial conservation. Fortunately, the identification of priority areas for marine conservation, through marine regional planning, is comparatively advanced. Indeed, many advances in regional planning in general have been made in marine environments. This chapter provides an overview of marine regional planning with an emphasis on points that would not be obvious in terrestrial planning efforts. However, between the two environments, there are mostly similarities in regional planning, and a separate chapter is therefore more a matter of accessibility, not necessity. The most important point is that marine planners should be aware of the methods discussed throughout the book. In turn, terrestrial planners need to be aware of planning advances in marine environments.

This chapter is primarily concerned with planning in coastal marine or nearshore environments. While there is no specific seaward boundary for these regions, the continental shelf is often a reasonable dividing line, as there are strong breaks between the shelf and the rest of the ocean when considering species' ranges, ecological processes, threats, and conservation strategies. In some places, strong current patterns, such as the California and Humboldt currents in northern California (U.S.), create the most obvious dividing lines between nearshore and offshore environments and have strong influence on coastal diversity patterns. Approaches for conservation in far offshore areas (e.g., the "high seas") are much less likely to be area-based than those nearshore. In nearshore areas, planners must pay greater attention to the importance of the integration of planning and action across terrestrial, freshwater, and marine environments.

A Brief Overview of Marine Diversity and Threats: Facts and Myths

A significant amount of the world's diversity is marine. At higher taxa levels (e.g., orders and phyla), most of the world's biological diversity is marine. This diversity is often overlooked in regional conservation and management plans, perhaps because the threats are not as obvious, nor are the losses in diversity as easily observed as they are in many terrestrial ecosystems. While not as apparently fragmented as many terrestrial environments in the world, the marine environment is highly threatened.

Underlying most of the threats to marine diversity are three main factors. First, burgeoning human populations along coasts, with their requirements for housing, food, and income, are causing harmful effects on nearshore estuarine and marine species and ecosystems. More than one-third of the world's human population lives in coastal areas, and that proportion is growing (United Nations Environment Programme 1999). In the United States, coastal counties make up only 11% of the land area in the lower 48 states, but population density in coastal counties is nearly five times that in the rest of the country. By 2010, 75% of the U.S. population is expected to live within 80 km (50 mi) of the coast. Coastal ecosystems have been and will be increasingly threatened by development and shoreline modification.

Second, even more distant human activities on land and in freshwaters have significant, although often overlooked, effects on coastal and marine ecosystems. Watersheds link the land to the sea, and such linkages can traverse very large distances (Goolsby et al. 2000, Mitsch et al. 2001). This link between land and sea is acknowledged but has not been well addressed by most federal agencies and nongovernmental organizations (NGOs). Estuaries may be some of the most anthropogenically degraded

environments on Earth, in part because the harmful effects of misguided land and river management decisions accumulate downstream in estuaries (Edgar et al. 2000). For example, the excessive input of nutrients, particularly nitrogen, in the watersheds of the Mississippi River foster algal blooms that deplete oxygen and create a zone of hypoxia (often referred to as the "dead zone") in the summer off the coast of Louisiana. The primary source of this nitrogen is in the intensively farmed lands of Minnesota, Iowa, Illinois, Indiana, and Ohio (Figure 11.1) (Goolsby et al. 1999, 2000). To conserve diversity in the Gulf of Mexico, it is necessary to increase wetland restoration and develop more environmentally friendly farming practices on these lands in the American Midwest, some 1500 km (1000 mi) from the Gulf of Mexico (Mitsch et al. 2001). In Latin America and the Caribbean, incompatible development and farming practices have caused erosion and excessive sedimentation in coastal waters, threatening diverse mangroves and coral reefs.

Third, the exploitation and destruction of marine resources by humans is increasing. It is abundantly clear that the perceived limitlessness of the

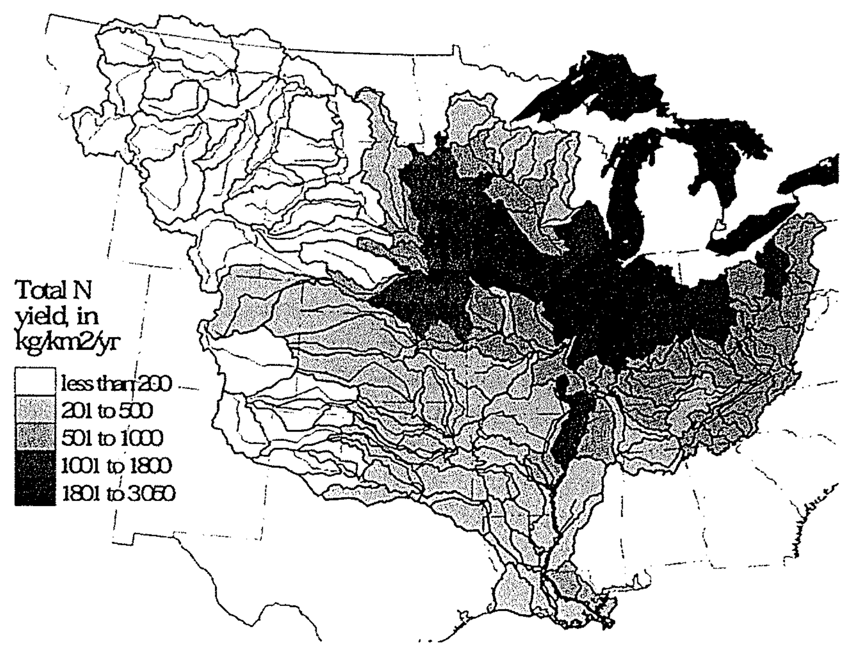


Figure 11.1 Input of nitrates in watersheds of the Mississippi Basin. These inputs help create the large zone of hypoxia or "dead zone" off the coast of Louisiana. (Modified from Goolsby 1999.)

resources of the seas is wrong. The most obvious direct exploitation is overfishing. Fishing impacts include the direct take of targeted individuals and the often overwhelming indirect take of individuals as bycatch. Recent and historical overfishing have drastically altered ecosystems (Jackson 2001, Jackson et al. 2001). Overfishing is also drastically altering marine trophic structure. As fisheries deplete higher trophic levels (e.g., top predators) to economic and ecological extinction, their effort is increasingly directed at lower trophic levels. In other words, fisheries fish down food webs (Pauly et al. 1998). Some of the most devastating effects of fishing come from the destruction of ecosystems from such practices as trawling (i.e., scraping the bottom), blast fishing, and cyanide fishing, which kills coral reefs (e.g., Watling and Norse 1998). There are, however, many other serious threats to the marine environment, ranging from the extraction of mineral resources (e.g., oil) to the impact from shipping in ship waste, noise, and accidental spills and to the introduction of exotic species. Even excessive tourism can be detrimental, as from snorkelers and divers who damage reefs (e.g., Plathong et al. 2000) and cruise ships that dump waste.

The limitlessness of the seas is but one myth being overhauled that requires planning in the marine environment with more foresight; there are others. For example, we commonly assumed that there would be little genetic diversity in marine compared to terrestrial species, because the larvae of many marine species have the potential to disperse widely. As we look more closely and with better techniques, we find that there is significantly more genetic variation in marine species than previously presumed (e.g., Palumbi 1994, Shaklee and Bentzen 1998, Barber et al. 2000, 2002).

We also assumed that there would be few, if any, extinctions in the seas. Several recent studies dispel this myth. Global extinctions have occurred and continue to occur in the marine environment. We have seen extinctions of species such as the Stellar sea cow (*Hydrodamalis gigas*), West Indian monk seal (*Monachus tropicalis*), and Atlantic eelgrass limpet (*Lottia alveus alveus*). We may now be witnessing the extinctions of species such as the white abalone (*Haliotis sorensi*), barndoor skate (*Raja laevis*), and Texas pipefish (*Sygnathus affinis*) (Casey and Myers 1998, Carlton et al. 1999, Roberts and Hawkins 1999). Moreover, we are seeing greater incidences of local extinctions, such as those documented in the Wadden Sea, Netherlands (Wolff 2000). These local extinctions need to be taken much more seriously, because as we find increasingly greater local genetic variation, we may realize that these local extinctions were real extinctions of species and subspecies.

Finally, we had assumed that marine species and ecosystems are eminently restorable, which is almost certainly another myth. For example, it is commonly assumed that if we stop overfishing species, fish stocks will be able to rebound. In a few cases, such as Chesapeake striped bass (*Morone saxatilis*), there have been remarkable rebounds (Richards and Rago 1999), and these cases are widely promoted. However, a broader analysis of fished species suggests that rebounds are uncommon (Hutchings 2000). It is also clear that our success at restoring ecosystems such as salt marshes is limited (Minello and Webb 1997, Zedler 2000). Given our continuing inclination to drastically threaten and alter marine species and ecosystems and our limited ability to correct these mistakes, we must plan to conserve and manage the marine environment with significantly more forethought than in the past.

An Overview of Regional Planning in Marine Environments

A growing number of marine regional plans have been developed in recent years (Table 11.1). These include plans by the World Wildlife Fund (WWF) for the Sula-Sulawesi Seas, the Meso-American Reef, and the Nova Scotian shelf (Day and Roff 2000). The Nature Conservancy (TNC) has completed plans in the central Caribbean (Sullivan Sealey and Bustamante 1999), the northern Gulf of Mexico (Beck and Odaya 2001), the Cook Inlet, Puget Sound/Georgia Straits, and the Chesapeake Bay regions. The WWF and TNC jointly completed a plan in the Bering Sea (Banks et al. 2000). The Australian government is developing regional plans across the Great Barrier Reef (http://www.gbrmpa.gov.au/corp_site/key_issues/conservation/rep_areas/index.html) and elsewhere in Australia, such as Tasmania (Department of Primary Industries Water and Environment 2001). In California, a statewide marine planning exercise is currently being conducted that approximates the scale of regional planning even though the planning area is delimited by geopolitical boundaries.

Most of the formal planning in marine environments, however, has generally been done at scales smaller than regions within politically, not ecologically, defined units. For example, it is common and often mandated to have plans for states, countries, and federally designated areas (e.g., U.S. National Marine Sanctuaries), many of which are much smaller than ecological regions and do not have ecologically defined borders (e.g., Leslie et al. 2003). Many plans are done at the scale of individual bays or estuaries

Table 11.1 *A Review of Marine Regional Plans*

Region	Aims	Lead Group(s) and Partners	Targets	Examples	Goals	Tools/Methods	Data
Central Coast, British Columbia, Canada	MPA Network	The Living Oceans Society	Ecosystem, focal species	Kelp, geoduck beds, inlets, sea otter, marbled murrelet	A priori: No	Delphi, MARXAN analysis	Digital elevation model, fisheries, ground surveys
Bering Sea, Alaska, Russia	Biodiversity conservation, sustainable fisheries	WWF, TNC	Oceanographic ecosystem, species assemblages	Bathymetry, upwelling, polynyas, eelgrass, wetlands, fish, invertebrates	A priori: No	Delphi	Ground surveys
Northern Gulf of Mexico, U.S., Mexico	Biodiversity conservation	TNC	Ecosystem, imperiled species	Seagrass, oyster reefs, Gulf sturgeon, Florida manatee	A priori:Yes Numerical: In general, 20% of targets	Sites v1.0, Delphi	Trawl data, aerial photography, satellite imagery
Central Caribbean, multiple nations from Cuba to Venezuela	Biodiversity conservation	TNC	Ecosystem, oceanographic, species assemblages	Mangroves, coastal wetlands, Caribbean current, upwelling events, fish, invertebrates	A priori: No	Delphi	Digitized nautical charts
Eastern Africa	Biodiversity conservation	WWF	Ecosystem	Mangroves, sandy shores, coastal lakes	A priori: No		
Meso American Reef, Mexico, Belize, Guatemala, Honduras	Biodiversity conservation	WWF	Ecosystem, focal species	Coral reefs, mangroves, salt-water crocodile, manatees	A priori: No		
Puget Sound, Georgia Straits, U.S.-WA, Canada-BC	Biodiversity conservation	TNC	Ecosystem, focal species	Salt marsh, kelp beds, eelgrass, forage fish spawning, grounds, rockfish	A priori:Yes Numerical: 30% of total shoreline, 30–60% of individual species	Delphi, Sites VI.0, and data intensive	Aerial surveys, fisheries, ground surveys
Chesapeake Bay Lowlands, VA, MD, DE (U.S.)	Biodiversity Conservation	TNC	Ecosystem, focal species	Tidal flats, tidal marsh, blue crab, yellow perch	A priori:Yes Numerical: In general, 20% of existing targets	Delphi and data intensive	Aerial surveys, fisheries, ground surveys
Mid-Atlantic, U.S.	Biodiversity conservation, sustainable fisheries	NRDC	Ecosystem, focal species	Sargassum mats, boreal red coral, North Atlantic right whale, loggerhead turtles	A priori: No	Delphi, GIS software	N/A
Cook Inlet, Alaska	Biodiversity conservation	TNC	Ecosystem, indicator species	Eelgrass beds, kelp beds, harbor seal, dungeness crab	A priori:Yes Numerical: In general, 20% of existing targets	Delphi	Aerial surveys, ground surveys, fisheries

(e.g., U.S. National Estuary Program), which is ecologically sensible because bays and estuaries are reasonably independent ecological units. There are, however, few if any overarching plans to identify whether these are the most appropriate bays or estuaries to meet particular aims regionally. In the United States, the National Oceanographic and Atmospheric Administration (NOAA) identified marine ecoregional boundaries to inform the development of its National Estuarine Research Reserve (NERR) system (Clark 1982). The aim was to ensure that at least one NERR was placed in each region before adding multiple NERRs to regions. Formal regional plans were not done to site the NERRs.

The ultimate aim of any planning program needs to be clear from the start, and the lack of clarity and multiple aims confound many planning efforts (see Chapter 3). This is true for any type of planning, but many marine planning efforts appear to have been particularly troubled by conflicting and/or unclear objectives. Some planning, by charter, is only intended to identify marine reserves or Marine Protected Areas (MPAs). An MPA is generally defined as any area of the intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, that has been reserved by law or other effective means to protect part or all of the enclosed environment. A marine reserve is usually identified as a more restrictive category of MPA and excludes some uses, often fishing. Most planning efforts, however, could have a wider mandate than the establishment of MPAs but are perceived either by the planners and/or stakeholders to be MPA or marine reserve plans. Marine plans by governments (e.g., British Columbia's Ministry of Sustainable Resource Management and NOAA Marine Sanctuaries) often have multiple and seemingly conflicting objectives, perhaps an unavoidable consequence of trying to satisfy multiple stakeholders.

Many planning efforts are flawed from the beginning by evaluating only one threat (usually overfishing) and developing only one strategy (MPAs). This myopic scope limits considerations of many potential targets (e.g., noncommercial species), threats (e.g., water pollution), and strategies (e.g., habitat restoration, pollution reduction). In addition, these MPA-focused plans tend to vilify powerful stakeholder groups (e.g., recreational and commercial fishing groups). A broader and more balanced view should be taken, and this is happening more often. Fishing is one important threat, and MPAs are one important strategy in the marine environment.

To the extent possible, regional planners should focus first on identifying the conservation areas that best and fully represent the biodiversity of

that region. Only after these areas are identified should strategies for their conservation be addressed. The approaches for the conservation of these areas can vary. Effective coastal and marine conservation will often require approaches that address the many threats to the marine environment that arise in watersheds. For example, the conservation of some marine areas will require improvements in water clarity and quality through strategies from pollution abatement to best management practices for abating excess runoff of soils and nutrients from farms. Other conservation efforts will be directed in the coastal zone to address the increased hardening of shorelines (e.g., jetties and seawalls) and loss of coastal habitats through strategies such as restoration, better management practices, and the acquisition of coastal and submerged lands. Still other area-based approaches will be necessary to abate threats from excessive recreational use, such as from boat anchors and cruise liners. Finally, marine reserves will also be of use in some areas.

The ultimate objective of the planning process outlined in this book is to identify a set of conservation areas that represent the full array of biodiversity within a region and that are likely to persist over the long term (see Chapter 7). The remainder of this chapter makes recommendations for carrying out the major steps in the conservation planning process, as developed in previous chapters, for coastal marine environments.

Identifying Targets: Ecosystems, Species, and Aggregation Sites

The first step in regional planning is to identify conservation targets (Table 11.2). In marine environments, the most effective planning approach is to focus on marine ecosystems and the ecological processes that sustain them. This approach presumes that conserving a representation of all the ecosystems will also conserve a representation of the diversity of species found in these ecosystems, an assumption that deserves more rigorous testing. Typical marine ecosystems include seagrasses, coral reefs, kelp beds, mangroves, salt marshes, tidal freshwater marshes, and sponge gardens.

Identifying ecosystems has always been a fuzzy concept, a point reinforced by the lack of clear definitions for ecosystem, community, habitat, and similar terms (e.g., Whittaker 1975). Among marine ecologists, it has been common vernacular to use the terms *ecosystem* and *habitat* interchangeably. The term *habitat*, in particular, has been used in multiple senses to describe the area used by an individual species (e.g., the habitat of the

Table 11.2 *Conservation Targets for The Nature Conservancy's Northern Gulf of Mexico Ecoregion Plan*

Ecosystems (and Subcategories)	Some Characteristic Species
Primary Ecosystem Targets	
Seagrass	*Thalassia testudinum, Syringodium filiforme, Halodule wrightii*
Tidal freshwater grasses	*Vallisneria americana, Potamogeton* sp., *Ruppia maritima*
Oyster reefs	*Crassostrea virginica*
Salt marsh	*Spartina* sp., *Juncus roemerianus, Distichlis spicata*
Polyhaline saltmarsh	*Spartina alterniflora, Juncus roemerianus, Distichlis spicata*
Mesohaline saltmarsh	*S. alterniflora, D. spicata, S. patens, Scirpus americanus*
Oligohaline saltmarsh	*Paspalum vaginatum, S. patens, Eleocharis* sp., *Sagittaria lancifolia*
Sponges and soft corals	Loggerhead sponges, vase sponges, sea fans, small hard corals
Tidal flats	Algae, polychaetes, bivalves
Tidal fresh marsh	*Scirpus* sp., *Typha* sp., *Cladium* sp.
Intertidal scrub/forest	*Avicennia germinans,* Iva sp., *Baccharis* sp.
Secondary Ecosystem Targets	
Muddy-bottom habitats	Polychaetes, amphipods, isopods
Coquina beach rock	*Donax* sp.
Beaches and bars	Shorebirds, mole crabs, amphipods and isopods
Serpulid worm reefs	Family Serpulidae
Imperiled Species	
Fringed pipefish	*Anarchopterus criniger*
Gulf sturgeon	*Acipenser oxyrinchus desotoi*
Diamondback terrapin	*Malaclemys terrapin* (ssp. *macrospilota, pileata, littoralis*)
Dwarf seahorse	*Hippocampus zosterae*
Opossum pipefish	*Microphis brachyurus lineatus*
Texas pipefish	*Syngnathus affinis*
Florida manatee	*Trichechus manatus latirostris*
Kemp's ridley turtle	*Lepidochelys kempii*

From Beck and Odaya 2001.

redfish) and for large areas of similar composition used by many species (e.g., seagrass habitat). Throughout this chapter, the term *ecosystem* is used to identify characteristic assemblages of plants and animals and their associated physical environment (e.g., marshes or oyster reefs). The term *habitat* is used in reference to the area(s) used by individual species. Modifiers are added to identify the particular habitats used by an animal. For example, the blue crab (*Callinectes sapidus*) has a seagrass habitat and a marsh habitat, and these refer to particular portions of seagrass and marsh ecosystems, respectively, used by the crab (e.g., Beck et al. 2001).

Once definitions are clear, it helps to have a consistent and reliable classification scheme to identify the different types of ecosystems. Although there is a growing number of classification schemes for marine ecosystems, they are less well developed than their counterparts for terrestrial environments. Most schemes are at coarse spatial scales (Cowardin et al. 1979, Davies and Moss 1999, Allee et al. 2000), but some schemes have been developed at finer resolutions for use within regions (e.g., Dethier 1992, Wieland 1993) or to focus within particular marine ecosystems, such as coral reefs or mangroves (e.g., Holthus and Maragos 1995, Twilley 1998, Mumby and Harbone 1999).

Ideally, classification schemes should be based on biological data; when this is not possible, surrogate data are used. In deeper water environments, typically beyond the depth range of 20–30 m for aerial imagery, classification schemes must usually use the more readily available abiotic data (see Chapter 4), such as sediment type, depth, slope, and temperature (e.g., Zacharias et al. 1998, Day and Roff 2000, Roff and Taylor 2000). These schemes rely on the assumption that certain physical factors control or are at least significantly correlated with repeating and characteristic assemblages of plants and animals. Such assumptions may not always be correct and are rarely tested. Consequently, in identifying ecosystem targets, planners should always place an emphasis on using biological data whenever they are available. As noted in previous chapters, a combination of abiotic and biotic-based targets will likely be most effective in conserving the full array of biodiversity in any given planning region.

Chapter 4 pointed out that not all biodiversity can be conserved through a focus at the ecosystem level. Those elements of biodiversity that are least likely to be represented by such a focus are endangered and imperiled species. Many of these species require individual attention because managing their habitats alone is necessary but insufficient for their conservation needs. In other words, they are declining faster than their habitats (e.g., Florida manatee, *Trichechus manatus latirostris,* and Kemp's ridley turtle, *Lepidochelys kempii*). It is also important to identify target species that are vital to the structure and function of ecosystems, because they are, for example, keystone species (Power et al. 1996) or ecosystem engineers that are crucial for creating or structuring ecosystems, such as oysters (Lawton 1994, Lenihan 1999). For all of these species, it is necessary to consider their role within ecosystems in each region; we cannot assume, for example, that a species is a keystone species in one region just because it is classified as such in another region. The role that species play in ecosystems varies geographically (Menge et al. 1994, Power et al. 1996).

Aggregation sites, which are usually associated with the physical convergence of water and land or of different water masses, are a third major type of target in marine systems. It is common in the marine environment to see large aggregations of species consistently occurring at particular places in space and time. These aggregations are often found in areas of high biological productivity or where different water masses meet (or both). Examples are the spawning aggregations of reef fish, and breeding congregations of seals and sea lions on haulout sites. Many spawning aggregations of reef fish occur at outer reef promontories where the inshore reefs meet oceanic currents (W. Heyman, TNC, personal communication). These currents presumably carry the spawned larvae to many new habitats for the settlement of juveniles. Upwellings, where cold, nutrient-rich water masses come up from depth to the surface, are another area known for abundant aggregations of species and are often areas with high productivity. Enhanced productivity and aggregations often occur in retention zones where water masses converge or are retained, such as near the mouth of bays (e.g., Chesapeake Bay) or in passages between islands. These areas of retention and convergence may be particularly important for larval transport, because larvae congregate actively and passively at these fronts (e.g., Pineda 1999).

In many marine plans, it is common to include fished species as targets, but this may not always be appropriate. Fished species are often included because there the substantial data on these species, although the quality, not just the quantity, of these data must be evaluated. Moreover, there is often concern about the potential threats from overfishing. For plans that are developed to identify representative areas of marine biodiversity, fished species should be included as targets only if they are truly imperiled (which is uncommon because most will go to economic extinction before they are truly imperiled) or have declined to such a degree that they affect overall ecosystem integrity. Some species can be truly imperiled by fishing, such as right whales (*Eubalaena glacialis*), white abalone (*Haliotis sorensi*), and stellar sea cows (*Hydrodamalis gigas*). Some fished species, such as oysters (e.g., *Crassostrea virginica*), green turtles (*Chelonia mydas mydas*), and sea otters (*Enhydra lutris*), have declined to such a degree that their low abundances may critically affect ecosystem integrity, (e.g., Jackson et al. 2001). Fished species should not be included as targets solely because of threats posed by fishing; this misses the point of identifying targets. Threats to biodiversity are addressed in the development of strategies for the conservation areas that are selected in the planning process (see Chapter 13).

Setting Conservation Goals

A conservation goal is characterized by the amount and quality of the target that should be represented in conservation areas across the planning region (see Chapter 6). There are many theoretical studies, and a growing number of empirical studies, examining how to set marine conservation goals, but as in terrestrial environments, much work remains to be done. Most of the recent work on species and ecosystem goals has been spurred by interest in identifying how large marine reserves need to be to conserve populations and ecosystems (for review, see Roberts and Hawkins 2000, National Research Council 2001). Much of this discussion revolves around two different objectives for setting goals in marine environments: fisheries management and biodiversity conservation. Goals associated with fisheries management aims are intended to identify the size of reserves that are necessary to conserve and possibly enhance the stocks of exploited species. Goals associated with biodiversity conservation objectives are intended to identify the minimum areas necessary to represent and conserve marine diversity in a region. The most important distinction between these objectives is that the areas (e.g., reserves) required to meet fisheries management goals will generally be much larger than the areas required to meet biodiversity goals. Stated another way, we can represent and protect biodiversity in smaller areas than will be required to reduce the risk of fisheries overexploitation and to increase fisheries yields (e.g., Hastings and Botsford 1999). The focus in this chapter is on the representation of biodiversity in conservation areas.

Numerous studies suggest that reserves may need to cover 10–40% of a region to be effective as a tool for biodiversity conservation (see reviews in National Research Council 1999, Roberts and Hawkins 2000). Turpie et al. (2000) suggested that a system of reserves that encompassed nearly 30% of the South African coast would be required to represent the known fish species on the coast. Ward et al. (1999) indicated that most of the marine taxa within Jervis Bay, Australia, would be accounted for only after 40% of the bay was contained within conservation areas. Most species-area curves suggest that the greatest losses of species richness will occur as remaining habitats decline below 20% (see Chapter 6,principle 3). Models show that the potential connectivity among marine reserves increases greatly as the amount of conserved areas approaches 30% (Roberts and Hawkins 2000). Similar to the terrestrial history of goal setting described in Chapter 6, some discussions about goals for marine conservation have been as politically motivated as they have been ecological. In 1998, for example, 1600 scientists and conservationists signed a statement indicating that we should aim to conserve 20% of the oceans by 2020.

Ecological knowledge and intuition is paramount in selecting goals, but a sensitivity analysis can also be informative. It may help to systematically vary the conservation goals for the targets and determine how this affects the size of the priority areas required to meet the goals (Figure 11.2). Curvilinearity in this relationship has important implications. Depending on the form of this relationship, the area required to meet goals can change dramatically. In some cases, small changes in goals (say from 20–30% in Figure 11.2) may require substantially larger areas (e.g., dashed line in Figure 11.2) or have little impact on the area required (e.g., dotted line). Sensitivity analyses should never be the final arbiter in identifying goals. Ecologically appropriate goals need to be set to determine the necessary areas/actions regardless of cost. However, careful consideration must be given to the higher costs that accompany certain goals, especially in the face of considerable uncertainty in identifying ecological goals.

Ideally, conservation goals should be based on historical or preexploitation estimates of the abundance and distribution of the targets. Unfortunately, goals often have to be based on current distributions (e.g., Beck and Odaya 2001). Many ecosystems and species have declined greatly in recent history. Setting goals on these diminished abundances ensures further degradation on a shifting baseline. The fact that every new generation of scientists and citizens sets ever lower goals for the "natural" state by referring only to recent personal memories of diversity and abundance is a real problem. Historical data can be difficult to find, but recent papers indicate that developing reasonable historical estimates of abundance in the marine environment is possible (Jackson 2001, Jackson et al. 2001, Wing and Wing 2001). (For a detailed discussion of the issue of historical context, see Chapter 6, principle 8.)

Most of the present exploration of goals focuses only on current conditions. Analysts have not given much consideration to what additional areas

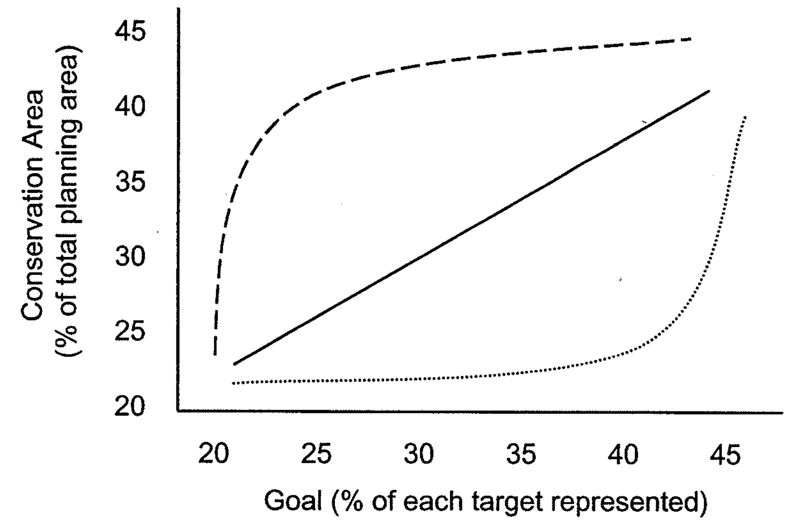


Figure 11.2 Hypothetical sensitivity analyses. The solid line indicates a 1:1 relationship in the goals set and the area required to meet those goals. The two curves represent different scenarios for how changes in goals can have vastly different effects on the area required to meet those goals. The dotted line suggests that small changes in goals may have little effect on the size of conservation areas required, while the dashed line suggests just the opposite.

may be necessary to buffer against natural and anthropogenic catastrophes. Alison and colleagues (2003) have examined the incidence of hurricanes in the Gulf of Mexico and oil spills on the west coast of North America to determine how much larger goals may need to be in order for diversity to be preserved in the face of future catastrophes. Their analysis suggests that considerations of potential catastrophes will likely increase goals by a factor of 1.1–1.25. In other words, if the intended goals are to include 20% of an ecosystem target without considering the impact of potential catastrophes, then actual goals should be adjusted to 22–25%.

Assessing Existing Conservation Areas

Defining protection and finding well-protected areas in the marine environment are difficult tasks (Jamieson and Levings 2001). While many large areas exist as marine sanctuaries, parks, and reserves, little direct management action is aimed at conservation of marine resources in these areas. In many of these seemingly protected areas, few activities are excluded (Jamieson and Levings 2001). Many NOAA Marine Sanctuary managers have noted that the public assumes that these sanctuaries are highly protected, when in fact little harmful activity is prohibited. A similar situation has been observed for Canadian marine sanctuaries (Jamieson and Levings 2001). History has shown that from a social and political standpoint, it can be very difficult to change usage patterns in protected areas after the rules or zones are in place.

In most regions, identifying existing marine conservation areas is a complex endeavor. NOAA was recently mandated with identifying all the marine protected areas in the United States (Executive Order 13158), a job that turned out to be far more complicated than expected. In addition to the problems identified above, there are multiple agencies with jurisdiction and protected area designations in the coastal and marine environment. Whereas this multiplicity of agencies is not different in terrestrial environments, the agencies have had a longer time to develop more consistent approaches to their work and definitions. The fact that water masses and species move more regularly between artificial jurisdictions in the marine environment only adds to the complexity of the problem. In a few regions, marine zonation, even though complex, has been clearly identified. For example, in many regions of the Great Barrier Reef, Australia, several different use zones (e.g., areas for fishing, anchoring, diving, or research) have been clearly identified on widely available navigation charts.

In the developing world, paper parks are as serious an issue in the marine as in the terrestrial environment, possibly even more so. The fact that an area is declared a park or MPA "on paper" does not mean it is being well managed from a conservation point of view. While an area may be declared an MPA, it can be very difficult to limit access to marine areas and enforce rules. On the whole, all existing marine conservation areas need to be carefully scrutinized to ensure that the biodiversity within them is being adequately safeguarded.

Assessing Population Viability and Ecological Integrity

As planners gather data on the distribution of the targets and note their locations, they should try to include only populations of species and examples of ecosystems that are likely to persist into the future. Doing so will ensure a selection of conservation areas with targets that are intact currently and will remain viable into the future. In the ideal world, population viability analyses (PVAs) would be available for each

species. Formal analyses of viability are rare for marine species, and similar analyses of integrity are virtually nonexistent for marine ecosystems. One of the classic PVA models was for loggerhead turtles, *Caretta caretta*; this study indicated that one of the critical factors for this species was the number of males reaching adulthood (Crouse et al. 1987). Another recent analysis noted that the number of adult females was critical to the viability of the endangered North Atlantic right whale, *Eubalaena glacialis* (Fujiwara and Caswell 2001). Even the life of one adult female right whale matters.

Although PVAs for species and analyses of ecological integrity for ecosystems may not be available, there are often factors that can be used to "screen" or filter out areas that are not likely to have the best or most viable examples of species and ecosystems. Recall from Chapter 7 that these factors can be used individually or collectively in "suitability indices." Examples of such factors in marine systems are water quality; shoreline hardening (seawalls, jetties); indicators of high-use areas (docks, moorings, marinas); shipping lanes; and oil rigs. A typical use of these variables is effectively steering the selection of conservation areas away from places with low water quality, high use, or other possible types of degradation.

Selecting Conservation Areas

A number of different procedures have been used to identify conservation areas in marine regional plans. These range from stakeholder input to expert opinion to area selection algorithms. Most plans employ multiple methods.

The planning process in the Florida Keys National Marine Sanctuary for the Tortugas ecological reserves, while not a regional planning process per se, was an example of a plan that was largely driven by discussions among scientists and stakeholders in workshops. Stakeholders were eventually asked to draw and compare lines on maps (i.e., potential conservation areas) in the workshops (Haskell et al. 2000). There was remarkable consensus among the stakeholders for identifying and designating areas in the Tortugas, particularly given the previous high level of acrimony for identifying areas in the rest of the Florida Keys. Numerous senior NOAA managers have wanted to replicate this process.

The important lesson to be learned from the Tortugas designation was not the selection process itself, but the fact that the Tortugas was an ideal place for a marine reserve (i.e., a comparatively low-cost conservation area). The potential for consensus was greater because stakeholders were not as strongly invested in the area. The Tortugas are comparatively difficult and expensive to reach by fishermen and tourists, there was little coastal development, and portions of the lands and waters were already protected. While these ideal conditions may not exist in other regions, some of them can be found in areas in most regions. Much more consideration needs to be given to identifying the areas of low cost for conservation (i.e., "low-hanging fruit"). There seems to be an unfortunate tendency for managers and conservationists to focus first on the most difficult areas for conservation (i.e., "the battle zones").

Some plans use Delphi workshops, which involve gathering scientific experts who are asked to draw lines on maps to outline the most important areas for conservation of particular taxa. In the mid-Atlantic seaboard of the United States, the Natural Resources Defense Council led a Delphi workshop to identify potential priority areas (Natural Resources Defense Council 2001). The Bering Sea regional plan of TNC and the WWF (Banks et al. 2000) and the central Caribbean plan of TNC (Sullivan Sealey and Bustamante 1999) included systematic considerations of conservation targets and were data driven whenever possible. They were also strongly influenced by expert opinion in Delphi analyses. In California, the statewide process to identify marine reserves, directed by the Marine Life Protection Act, started first as a Delphi plan developed by scientists. This plan was discarded, and the state has started over with a purely stakeholder-driven planning process.

Area selection algorithms are being used increasingly to help planners identify conservation areas (see Chapter 8). Most marine planners are using algorithms developed by Australian ecologists Ian Ball and Hugh Possingham. The earlier and more terrestrially oriented version of their software is known as SPEXAN. (Working with scientists at the University of California, Santa Barbara, TNC changed the name to Sites.) This software has been further adapted for use in the marine environment as MARXAN (Ball and Possingham 2000).

Both Sites and MARXAN have been used in several different marine planning efforts at regional and smaller scales. In the northern Gulf of Mexico, TNC used Sites to help identify potential conservation areas (Beck and Odaya 2001). The results from using this algorithm were then presented at a scientific workshop where participants were asked to critique the selected areas and identify gaps and problems. The final portfolio of conservation areas integrated results from the area selection algorithm and expert opinion (see Figure 11.3, in color insert). This is a good example of using these algorithms as they were intended—a tool to aid planners and biologists, not a stand-alone approach to selecting conservation areas.

In the Puget Sound/Georgia Straits region in the United States and Canadian Pacific Northwest, TNC and partners are also using Sites to help select marine conservation areas (Ferdaña 2002). In this regional plan, a stepwise analysis was done with Sites to account for differences among the targets in their ecological importance and data quality. Targets that were known to be ecologically important and met high data-quality standards (i.e., the data were comprehensive throughout the region, spatially precise, and recently updated) were run first through the model, and the priority areas that were chosen were then locked in for subsequent runs of the model. This procedure was repeated four times (see Figure 11.4a, in color insert). The final model results were then evaluated by external scientists, and a number of large (or seascape-scale) areas were identified (see Figure 11.4b, in color insert).

There is never just one "optimal" solution (i.e., set of conservation areas) in regional planning, but it is possible to do irreplaceability analyses to identify those areas that must be part of a plan (see Chapter 8). Such analyses have been conducted with data from the Florida Keys (Leslie et al. 2003). Results indicated that a number of areas were irreplaceable in a biodiversity plan; that is, some areas would be necessary in any potential plan to represent the marine diversity in the nearshore areas of the Florida Keys. However, once these core areas were included, there were many options for choosing the remaining conservation areas needed to fulfill the conservation goals. Thus, it would be possible to attempt to choose configurations that could meet biodiversity goals with the greatest benefit and least impact on stakeholder groups. Irreplaceability analyses were also used in California by the scientific advisory panel for the Channel Islands National Marine Sanctuary to identify potential marine protected areas (Airame et al. 2003) and by TNC in the Puget Sound/Georgia Straits region to combine analytic and Delphi results for selecting conservation areas.

One of the key decisions in selecting potential conservation areas is determining their minimum effective size (see below for a discussion of networking multiple areas). Previously, the general advice would have been that marine conservation areas needed to be much larger on average than terrestrial areas, to account for the open and dynamic nature of marine ecosystems and the mobility of marine species. Indeed, it was not even clear that area-based approaches (e.g., marine reserves) would be useful for the conservation of marine diversity. Theoretical analyses suggested that individual conservation areas must exceed the dispersal distance of target species or cover very large sections of the coast (Hastings and Botsford 1999, Botsford et al. 2001). For many targets, these theoretical results would require very large conservation areas, larger than most of the marine reserves in place at present.

Nonetheless, recent compilations of the empirical evidence from a growing number of marine reserves shows that the present area-based efforts can be surprisingly effective for the conservation of biodiversity (Cote et al. 2001, Halpern 2003). After marine reserves are put in place there are increases in density, biomass, organism size, and diversity (Figure 11.5), and these effects can occur surprisingly quickly (Halpern 2003, Halpern and Warner 2002). Moreover, even the smallest marine reserves

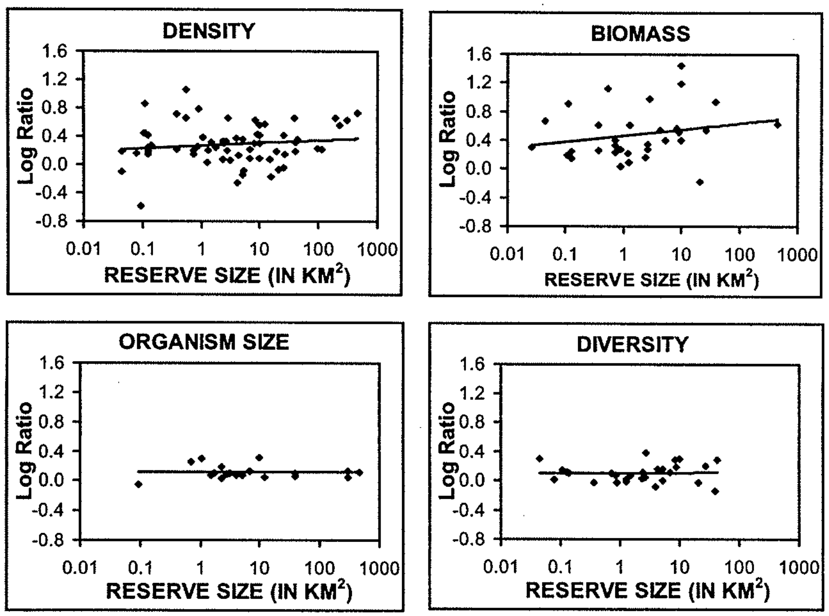


Figure 11.5 The effects of size of marine reserve size on the density, biomass, size, and diversity of invertebrates. Each point represents a paired comparison of the effect of a reserve compared to a control (either the same places before and after reserve designation, or a reserve versus a nearby control site). The difference ratio (*d*) is used for each pair of sites for the biological measure of interest. Data are plotted as the log of the ratio (*d*) versus the log of reserve size. When $d = 0$, the reserves had no effect on the biological measure. When $d > 0$, the reserves had a positive effect on the biological measures. Note that almost all of points are > 0, indicating that reserves had higher density, biomass, size, and diversity of animals than control sites. In all cases except invertebrate biomass, *d* values were significantly different from zero. The slopes of all regression lines are not significantly different from zero, indicating that reserve size did not have a significant proportional impact on the differences between reserves and control sites. (From Halpern 2003. Reprinted by permission of the Ecological Society of America.)

seem highly effective in protecting and enhancing the density, biomass, size, and diversity of marine species (Figure 11.6) (Halpern 2003).

Few scientists would have predicted that some of these smallest reserves would have worked to conserve diversity. Whether or not these reserves can withstand disturbance and ensure viability and integrity is an open question. It seems unlikely, in the absence of other protection for sites in the region (i.e., a network), that these small reserves can be effective in the long term. Part of the effectiveness certainly lies in the fact that even if areas outside marine conservation areas are degraded, they still harbor many of the species and ecosystems of concern. This situation is unlike most terrestrial cases where many historical habitats and ecosystems are now completely lost or uninhabitable.

Designing a Network of Priority Conservation Areas

Single conservation areas are not likely to be effective. Considerations of connectivity are probably more important in marine environments than terrestrial environments because of the mobility of many species (through

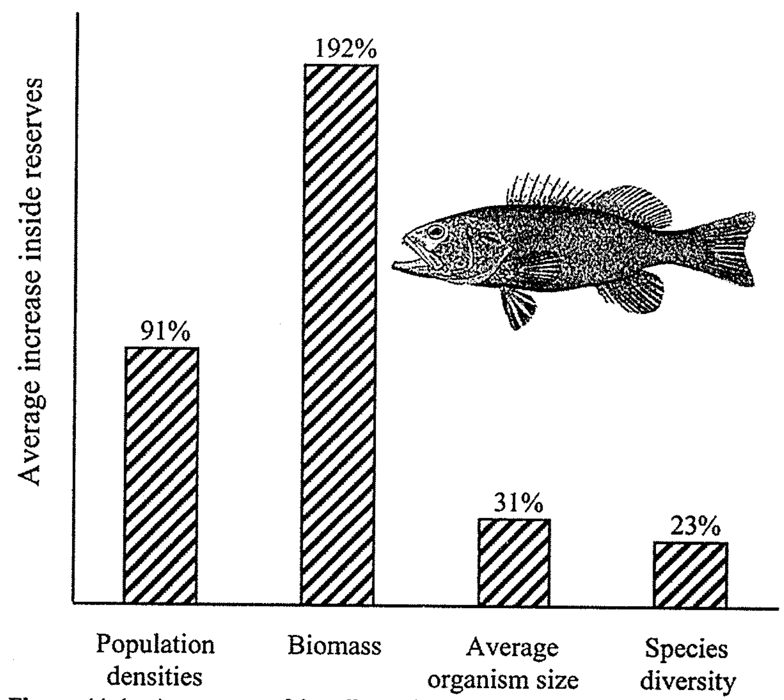


Figure 11.6 A summary of the effects of marine reserves for all taxa of fish and invertebrates.

movement and larval dispersal) and the potential quick spread of marine threats over large areas (e.g., water pollution and invasive species).

The best advice at present in the marine (and terrestrial) environment is for planners to ensure that multiple conservation areas are spread throughout a region, thereby fully representing diversity and guaranteeing that some areas will persist and survive potential catastrophes (e.g., oil spills and hurricanes). Very little is known about spatial variation in diversity in the marine environment; this fact is particularly true for genetic diversity, and it is also relevant at other levels of biological diversity. Classification systems are poorly developed in the marine environment, in part because of the lack of information about consistency and variability in assemblages of plants and animals within broad ecosystem types (e.g., seagrasses).

It is often possible to address variability in diversity in a network design by dividing the region into ecologically relevant subregions and setting conservation goals for each subregion. For instance, the northern Gulf of Mexico ecoregion was divided into three separate subregions delineated largely by the flow from the Mississippi River. The central subregion (Galveston Bay, Texas, to Mobile Bay, Alabama) is dominated by substantial freshwater input and high sediment loads. The waters are turbid and sediments are muddy; salt marshes are the dominant nearshore ecosystem. The western and eastern subregions have much less freshwater input and consequently have clearer water, sandier sediments, and seagrasses dominating the nearshore ecosystem. The strong differences in predominant physical regimes are likely to have strong influences on diversity from genes to ecosystems across the Gulf of Mexico. Therefore, planners set goals for all the targets in each subregion.

There is a rapidly developing literature on how to factor dispersal (connectivity) into the design of a network of marine conservation areas. However, at present there are few clear answers (e.g., Roberts 1997, 1998, Swearer et al. 1999, Cowen et al. 2000, Botsford et al. 2001). In the most basic formulation, the concept is to consider how dominant patterns in ocean currents might influence the sources and settling areas for larvae. The general advice would be to spread priority sites at places along these currents and not bunch them at one end or another. Upstream areas will probably be the main sources for larval recruits that will mainly settle in downstream areas. The principal problems are that this concept assumes larvae are passive drifters and that oceanic currents are the primary flows determining larval movements. It is becoming much clearer that larvae have complex behaviors that afford significant control over how and what currents carry them (e.g., Cowen et al. 2000). Moreover, increasing evidence indicates that larvae are entrained in areas possibly by nearshore currents. These nearshore currents are complex and not well studied by oceanographers. Larvae with long larval stages (weeks to months) that could migrate hundreds to thousands of kilometers in some cases may migrate only tens of kilometers (e.g., Swearer et al. 1999). New techniques in tagging (e.g., otolith microchemistry) are helping reveal patterns in the sources and dispersal of larvae.

Some studies look at the dispersal requirements of one or a few species to assess possible designs for networks of marine reserves. The problem—just as for terrestrial environments—is that a design based on the requirements of one or a small assemblage of species will probably be irrelevant for a wide range of species. Sources for recruits of one species may be a sink for recruits of another species. It is not appropriate to design a regional network for biodiversity conservation with the requirements of just a few species in mind.

A more thorough understanding of dispersal distances of many species on a coastline will help planners make better estimates for balancing minimum size of conservation areas and maximum distance between them. For example, an examination of the dispersal distances for many species on the California coast showed different dispersal distance "peaks" or modes for suites of species (Kinlan and Gaines 2003). These patterns in the data can help lead to fairly robust advice directions for the design of a network of conservation areas. A suite of species, for instance, has very short dispersal distances (a few meters to a few kilometers), and individual conservation areas should be large enough to encompass the dispersal distances of these species. Another group of species has moderate dispersal distances (tens to hundreds of kilometers); the maximum distance between conservation areas should not exceed the median dispersal distances of these species. These estimates provide useful parameters to consider in planning, but they must be combined with knowledge about the locations of appropriate habitats, as well as other features of the marine environment that affect settlement and movement, to avoid having appropriately spaced but poorly placed conservation areas (e.g., Valles 2001).

In a network of areas, planners should not just consider representing current diversity, but also consider whether they can identify areas that are likely to be resilient or resistant to future disturbance. An example of how to begin to design conservation areas with future threats in mind comes in response to the widespread threat of coral bleaching (Salm et al. 2001). Coral bleaching occurs when corals are stressed and the symbiotic zooxanthalea, which provide most of the coral's color, are expelled from the tissues of the coral.

The coral frequently dies. In recent years, the number and extent of coral bleaching events have increased dramatically (Hoegh-Guldberg 1999, Goreau et al. 2000, Glynn et al. 2001). Some large areas have lost more than 90% of their living coral cover. The predominant stress underlying the increase in bleaching events is elevated water temperatures usually associated with El Niño events, which have been increasing in frequency and intensity. Even in massive bleaching events, some reefs remain unbleached and/or recover quickly. It may be possible to predict these patterns in coral resilience and resistance. For example, reefs that are near strong upwelling currents (i.e., cooler water), or that are partially shaded by cliffs, are more likely to survive when sea temperatures are elevated in nearby environments. If areas are particularly resilient or resistant, they can provide potential sources of new recruits to replenish impacted areas in the future.

While planners should weigh all of these potential considerations for designing a network, they should first base their designs on the representation and conservation of the known patterns and distribution of diversity (see Chapter 8). Only after they are certain a set of areas can conserve present patterns of diversity should planners address these issues of connected networks and future threats. Issues of connectivity are a hot topic in marine research, so more rigorous guidance will probably be available in the future.

Connecting Terrestrial, Freshwater, and Marine Priority Areas

Planning in coastal regions should be closely coordinated among terrestrial, freshwater, and marine environments. In coastal regions, it is not ecologically sensible to overlook information from any of the three environments or to conduct wholly separate plans in each one. Obviously, planners cannot focus on only one environment and consider certain ecosystems, such as salt marshes and mangroves, to be wholly terrestrial or marine; likewise, they cannot include targets such as salmon and sturgeon and consider only the relatively short freshwater phase of their life history (Kareiva et al. 2000). There are important connections between these environments in targets (e.g., seabirds), in threats (e.g., nutrients, oil spills, urban sprawl), and in the strategies to address them. Nonetheless, shortsightedness in planning separately in each environment is common, making it difficult to set priorities and coordinate efforts across environments. The coastal zone environment has often been divided separately by academic, governmental, and environmental organizations. Government has often had to devise whole new programs, with the difficult task of linking agencies with separate mandates for environments in Integrated Coastal Zone Management Programs.

Many areas with high estuarine and nearshore marine diversity and productivity occur in areas where uplands are intact and diverse. This correlation appears to occur because many stresses in coastal waters arise upstream. Even if there are not strong direct connections, many places appear to contain correlations between terrestrial and marine hotspots in biodiversity (Roberts et al. 2002). Planners should consider whether efforts can be colocated across environments. This efficiency should make economic sense (e.g., having one office instead of two) and enhance the potential for effective partnerships between groups and agencies with overlapping mandates and priorities in the coastal zone.

Given that few integrated regional plans exist, there is little methodology for how best to incorporate connectivity in coastal planning. The Nature Conservancy has been developing an integrated plan across all three environments in the Puget Sound/Georgia Straits region in the United States and Canada (see Figure 11.7, in color insert). Although it may seem elegant, it is not effective to simply lay a grid-based information system across all the terrestrial, freshwater, and marine environments of a region and run an area selection algorithm. The first problem encountered was that the data were quite different in structure and form in the three different environments (Ferdaña 2002), which resulted in a high degree of error in data transformation and significant information loss. In addition, the areas selected by the algorithm were biased toward places on the coastline because these areas included targets from all three environments. An answer may lie in a watershed-based selection algorithm. Planners can first examine the three environments separately to develop potential conservation areas, then determine if any areas can be moved to be aligned within the same watersheds. Extra weight should be added if there are known connections among environments (e.g., anadromous species targets).

Key Points for Marine Regional Planning

1. Identify conservation targets quickly, focus on ecosystems, and only use species as necessary. Give consideration to aggregation sites and convergences (upwelling, retention zones) as targets in the marine environment.

2. A marine regional plan is not necessarily just a Marine Protected Areas (MPA) plan. A marine regional plan should first identify areas critical for conservation. Appropriate strategies for conservation should then be identified. MPAs are one of the possible strategies.
3. Be clear about the objectives of your plan from the beginning. Two common objectives in marine regional plans are biodiversity representation and conservation, and fisheries sustainability. These objectives will require sometimes substantial differences in the selection of targets, goals, and conservation areas.
4. If the intended use of a plan is to represent and conserve biodiversity, then fished species should be included as targets only if they are imperiled or have declined to such a degree that ecosystem integrity is compromised.
5. Identifying goals is one of the most difficult tasks in regional planning. Current estimates for goals for biodiversity conservation usually vary from 10–40% of the planning area or the present distribution of the targets. Unfortunately, few plans at present have explicit goals. When goals are explicitly identified in plans, they usually vary from 20–30% of the current distribution of the targets. Find as much historical data as possible on conservation targets to help set goals.
6. Involve partners early in marine regional planning efforts. They can provide critical input, and their involvement in planning is important if they are expected to play a role in the conservation of any priority areas.
7. In selecting priority marine conservation areas, give more attention to finding areas of low conservation cost ("low-hanging fruit"). The most well known and contentious areas ("the battle zones") are not necessarily the best areas for biodiversity conservation.
8. Make sure to represent biodiversity based on current distributions first. Then consider other factors that might affect the future distribution of targets (e.g., climate change).
9. Consider connectivity and networking among conservation areas to the extent possible. If dispersal distances for some targets are known, consider whether individual conservation areas are large enough to encompass these dispersal distances or the areas are not too far apart such that they exceed these dispersal distances. Consider the linkages among terrestrial, freshwater, and marine environments in targets and threats, and combine priority areas across environments whenever possible.

CHAPTER TWELVE

Adapting Ecoregional Plans to Anticipate the Impact of Climate Change

EARL C. SAXON

Economically we are living on our capital; biologically we are changing radically the complexion of our share in the carbon cycle.

A.J. LOTKA (1956)

This chapter examines how the practice of conservation planning at regional scales (Groves et al. 2002a) can guide the allocation of conservation funding and management resources to shelter biodiversity from the effects of climate change. Even in the face of dire scenarios, conservation choices informed by sound science (Orians 1993b, Hannah et al. 2002, Peterson et al. 2002) may anticipate the inevitable, thereby shortening the duration and attenuating the severity of the impact of climate change on biodiversity.

Considerable uncertainly exists as to both the pace and the severity of change indicated by current climate change models for any given locality. It is tempting to ignore warnings that are both dire and vague, but conservation biologists cope with similarly pervasive threats to biodiversity, such as habitat loss and invasive species. In fact, global circulation models diverge more because of their explicit social and economic assumptions than because of different treatments of climate parameters. Where opinions differ, conservation biologists might want to consider less rosy scenarios than those leading global policy makers presently prefer.

Figure 11.3. Priority marine conservation areas from TNC's northern Gulf of Mexico regional plan.

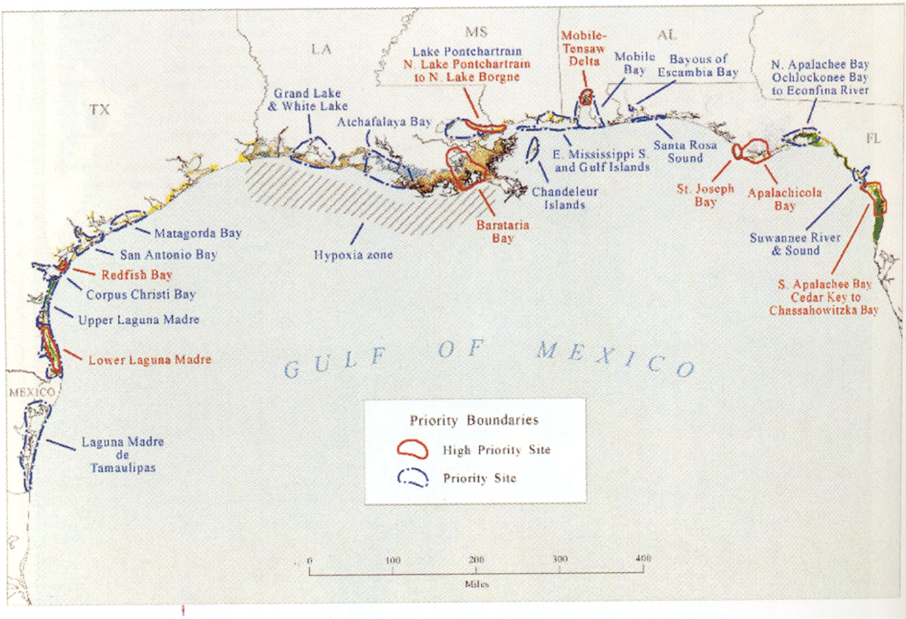
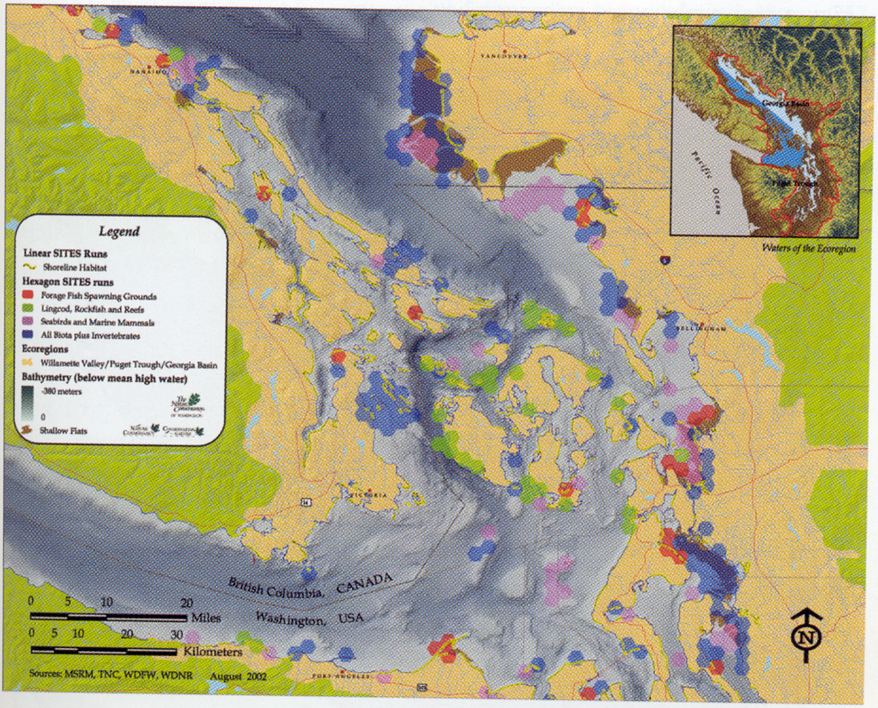


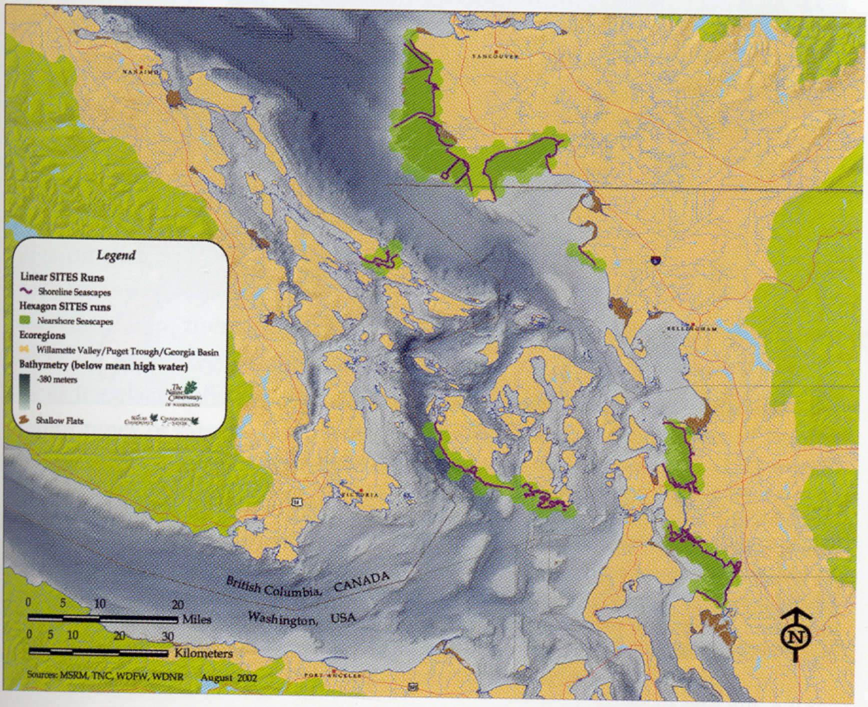
Figure 11.4 (opposite page).
Development of a Puget Sound/Georgia Straits regional plan. (a) A stepwise analysis was done in Sites (an area selection algorithm) to identify potential conservation areas. Data on the forage fish targets (e.g., herring and sand lance) were run through Sites first, and areas that met the goals for these species were then locked into the model (red hexagons) for subsequent runs. Data for lingcod, rockfish, and the rocky reef ecosystems were placed into the model next, and further areas were locked in (green hexagons). This procedure was repeated for seabirds and marine mammals (purple hexagons), and then for the rest of the fine-filter targets (blue hexagons). These results were then combined with separate Sites analyses on the linear shoreline ecosystem data (yellow segments). (b) These Sites results were evaluated and developed into large ecologically meaningful sites or seascapes.

a)



Legend
Linear SITES Runs
Shoreline Habitat
Hexagon SITES runs
Forage Fish Spawning Grounds
Lingcod, Rockfish and Reefs
Seabirds and Marine Mammals
All Biota plus Invertebrates
Ecoregions
Willamette Valley/Puget Trough/Georgia Basin
Bathymetry (below mean high water)
-380 meters
0
Shallow Flats
Waters of the Ecoregion
Georgia Basin
Pacific Ocean
Puget Trough
NANAIMO
VANCOUVER
BELLINGHAM
VICTORIA
PORT ANGELES
British Columbia, CANADA
Washington, USA
0 5 10 20
Miles
0 5 10 20 30
Kilometers
N
Sources: MSRM, TNC, WDFW, WDNR August 2002

b)



Legend
Linear SITES Runs
Shoreline Seascapes
Hexagon SITES runs
Nearshore Seascapes
Ecoregions
Willamette Valley/Puget Trough/Georgia Basin
Bathymetry (below mean high water)
-380 meters
0
Shallow Flats
NANAIMO
VANCOUVER
BELLINGHAM
VICTORIA
PORT ANGELES
British Columbia, CANADA
Washington, USA
0 5 10 20
Miles
0 5 10 20 30
Kilometers
N
Sources: MSRM, TNC, WDFW, WDNR August 2002

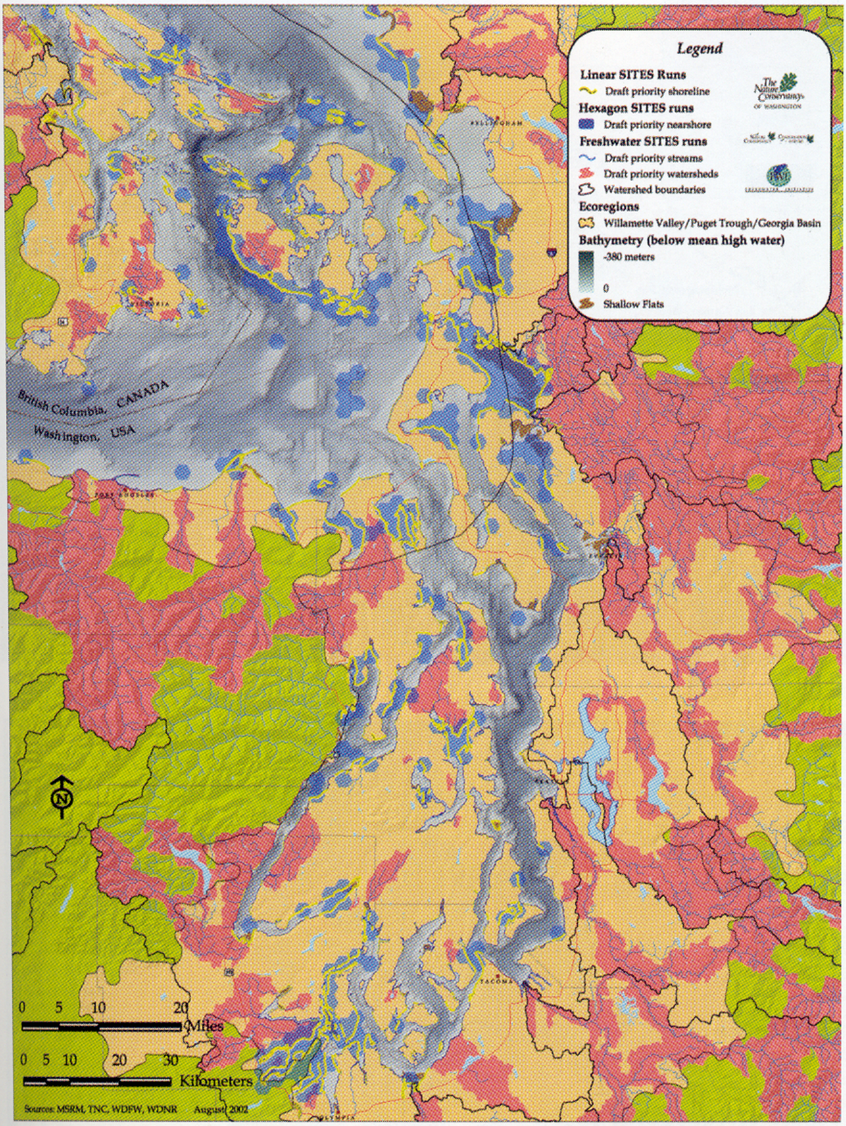


Figure 11.7. Integrating priority areas across the Puget Sound/Georgia Straits region. To aid in the development of an integrated set of priority areas, the draft marine priority areas (represented as yellow lines and blue hexagons, see Figure 11.4) were compared to draft freshwater priority areas (pink watersheds and blue stream reaches) on a watershed-by-watershed basis. Areas where there is greatest overlap among freshwater and marine areas (and terrestrial areas, not shown here) are given extra weight as priority areas. In addition, when the same conservation goals could be met by multiple priority area configurations, preference was given to configurations that best aligned freshwater and marine areas.