Chapter 16
Conservation and Management of Tropical Coastal Ecosystems

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Abstract All major coastal ecosystems in the tropics are being degraded. The problems include losses of biodiversity, reduced ecosystem functions, and costs to coastal human societies. Declines in species' abundances, and habitat loss and modification are the result of the demands for aquaculture, port construction, trawling, excessive nutrient loads, overfishing and collecting, sedimentation from catchment activities, invasive species, and climate change. A global response to these changes has been conservation and management approaches that aim to reduce, reverse, and prevent unnatural changes and address their underlying causes. Successes in conservation and management are likely when actions are designed to achieve the fundamental ecological goals of ensuring resilience, maintaining ecosystem connectivity, protecting water quality, conserving species-at-risk, conserving representative samples of species and assemblages, and managing at the appropriate spatial scale. Achieving societal aspirations for coastal ecosystems requires that management approaches address the socio-economic aspects of issues and include stakeholder consultation, participation, and education. Achieving long-term success in conservation and management requires coastal nations to address fundamental issues such as lack of information for management decision-making, population growth and poverty, limited technical and management capacity, poor governance, lack of stakeholder participation, the mismatches between the issue and the geographic scale of management, lack of an ecosystem perspective, ineffective governance and management, and a lack of awareness of the effects of human activities.

Keywords Coastal zone management · Marine protected area · Socio-economics · Stakeholder participation · Sustainability

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16.1 Introduction

Great changes have occurred in many tropical countries in recent decades and these have led to problems in their coastal and marine ecosystems and their dependent human societies. For example, in the Red Sea ‘In the late 1960s, probably 98% of the total Red Sea coast was in practically virgin condition . . . ’ (Ormond 1987). The rapid development that occurred in parts of the Red Sea since the 1960s (as a direct result of the expansion of petroleum-based economies) had profound consequences for its ecosystems, with the loss of this ‘virgin’ status in many places. Coral reefs near urban and industrial centers were degraded by land-filling and dredging, port activities, sewage, and tourism. Three-quarters of the Red Sea’s mangrove stands were negatively affected by camel grazing, felling, cutting, solid wastes, sewage, burial by mobilized sand dunes, or obstruction to tidal flows. Sharks were overfished and overfishing by industrial trawlers in the Gulf of Aden depleted cuttlefish and deep-sea lobsters (Gladstone 2008).

A global response to the problems occurring in all tropical coastal ecosystems (including the Red Sea) has been the design and development of a range of conservation and management tools, approaches, and principles and these will be the focus of this chapter. I begin by justifying the need for conservation and management from the perspectives of the benefits human societies derive from them, and the ecological, social, and economic costs flowing from their degradation. I then review nine major goals for conservation and management. Each goal is described and justified, and some practical case studies of the ways each is being implemented are provided. There is a rich vocabulary in the disciplines of coastal conservation and management (Kay and Alder 1999) but I have selected ‘goals’ to illustrate the point that achieving these goals will help achieve the conservation and sustainable use of coastal ecosystems. Readers interested in additional related topics (e.g., financing, legal aspects) will find many relevant references herein. I have deliberately focused on the practical ways of addressing current issues, rather than a detailed review of the issues, and readers interested in the latter can consult several excellent recent reviews (Connell 2007, Fine and Franklin 2007, Glasby and Creese 2007). Examples of the practical actions that can be applied are described in case studies in boxes and many more are listed in Appendix 16.1 at the end of this chapter. The references cited in Appendix 16.1 provide the starting point for further exploration of a diverse and exciting literature.

16.2 The Values of Coastal Ecosystems

Coastal ecosystems in the tropics include coral reefs, mangroves, and seagrass. Coral reefs, described as ‘the largest durable bioconstruction projects on Earth’ (Knowlton and Jackson 2001), are the major centers of marine diversity. More phyla inhabit coral reefs than tropical rainforests, and coral reefs probably contain close to one million species, although only about 100,000 have been described (Harrison and Booth 2007). The presence of coral reefs influences the physical structure of the coastline and adjacent ecosystems, and they protect mangroves and seagrasses against the sea.

Seagrasses are the only marine representatives of the flowering plants and the habitats they form ('seagrass beds') contain diverse assemblages of other organisms. There are more than 70 seagrass species, with centers of diversity occurring in southwestern Australia, Southeast Asia, and Japan/Republic of Korea (Gillanders 2007). Mangrove forests are the other plant-based coastal habitat that occurs in the high intertidal areas of soft sediment shorelines. Mangroves and seagrass beds contribute to other habitats through export of detritus (see Chapter 3) and the movements of juvenile and adult organisms (see Chapters 8 and 10), and both habitats trap sediments and thereby protect coral reefs (Connolly and Lee 2007).

The conservation and management of coastal ecosystems can be justified by the need to maintain the benefits they provide to human society (Duarte 2000, Turner 2000, UNEP 2006). Ecosystem services, including provisioning, regulating, and cultural services, are the benefits humans derive from ecosystems and their supply is dependent on supporting services (Table 16.1). Provisioning services provide the products used by humans for subsistence, enjoyment, and enterprise, and include pharmaceuticals, curios, building materials, and food from fisheries and aquaculture. Regulating services include shoreline protection and stabilization from waves and storm surges (provided by coral reefs, mangroves, and seagrass), and sediment trapping and pollutant filtering (by mangroves and seagrass).

Cultural and amenity services are the non-material benefits obtained from ecosystems. These include the attributes of ecosystems that are appreciated and used for tourism, recreation, cultural, and spiritual reasons. These services also include the traditional knowledge that forms the basis of much fisheries management, tourism, alternative food sources and medicinals, education, and research (UNEP 2006). Humans use beaches, cliffs, estuaries, open coasts, and coral reefs for recreation and their aesthetic values. Coastal recreational activities such as boating, fishing, swimming, walking, beachcombing, SCUBA diving, and sunbathing produce substantial economic and social returns to coastal nations and communities. The rapid growth of coastal tourism and the associated economic and social benefits means that it is now an essential component of the economies of many small island states (Spurgeon 2006, UNEP 2006).

These ecosystem services depend on the availability of habitats and nurseries, primary productivity, and nutrient cycling. The associated benefits of habitats and nurseries include their usage by a diverse range of species and communities, support for ecologically, recreationally, and commercially significant species, and opportunities for life cycle completion (by providing pathways of connectivity between different habitats) (UNEP 2006).

16.3 Issues for Coastal Ecosystems in the Tropics

All major coastal ecosystems are experiencing degradation throughout tropical regions of the world (summarized in Table 16.2). Coral cover is a case in point. Overall, 30% of global coral reefs are already severely damaged and 60% may be

Table 16.1 The range of services provided by tropical ecosystems and examples of the benefits provided to human society from these services (X indicates the ecosystem provides a significant amount of the service) (adapted from UNEP 2006)

Ecosystem Service	Estuaries	Mangroves	Lagoons and salt ponds	Intertidal	Rock and shelf reefs	Seagrass	Coral reefs	Inner shelf
Cultural services								
Aesthetics	X		X	X			X	
Cultural and amenity	X	X	X	X	X	X	X	X
Education and research	X	X	X	X	X	X	X	X
Recreational	X	X	X	X	X		X	
Provisioning services								X
Fiber, timber, fuel	X	X	X					X
Food	X	X	X	X	X	X	X	
Medicines, other resources	X	X	X				X	
Regulating services								
Atmospheric and climate regulation	X	X	X	X	X	X	X	X
Biological regulation	X	X	X	X	X		X	
Erosion control	X	X	X			X	X	
Flood/storm protection	X	X	X	X	X	X	X	
Freshwater storage and retention	X		X					
Human disease control	X	X	X	X	X	X	X	
Hydrological balance	X		X					
Waste processing	X	X	X			X	X	
Supporting services								
Biochemical	X	X					X	
Nutrient cycling and fertility	X	X	X	X	X		X	X

Table 16.2 Synthesis of issues negatively affecting tropical coastal ecosystems

Issue	Mangroves	Seagrass	Intertidal rock and mud	Beaches and dunes	Coral reef	Soft bottoms
Alterations to natural hydrology	X	X				
Climate change	X	X	X	X	X	X
Collection for timber, fodder, fuel	X					
Destructive fishing practices		X			X	X
Disease	X				X	
Excessive nutrients, other pollutants, solid wastes	X	X	X	X	X	X
Grazing by domestic animals	X					
Habitat loss, modification, destruction	X	X	X	X	X	X
Invasive species	X	X	X	X	X	X
Lack of information (and assessment methods) for component biodiversity, distribution, natural patterns of variation	X	X	X	X	X	X
Limited technical and management capacity	X	X	X	X	X	X
Oil spills	X	X	X	X	X	
Overfishing/collecting	X		X		X	X
Poor governance and corrupt politics	X	X	X	X	X	X
Population growth, poverty	X	X	X	X	X	X
Recreation		X	X		X	
Sedimentation	X	X			X	X
Tourism	X				X	
Tropical storms	X	X		X	X	
Upstream agricultural practices	X	X			X	X

Sources: Gladstone (2006), Wilkinson (2006), UNEP (2006) lost by 2030 (Wilkinson 2006). Recovery of coral reefs will be slow or not occur at all when they experience multiple stressors (Connell 1997). There has been a region-wide decline in coral cover in the Caribbean from 50 to 10% between 1977 and 2001 (Gardner et al. 2003). This loss of Caribbean coral reefs has been greater than any time in the last 100,000 years (Precht and Aronson 2006). The Indo-Pacific region contains 75% of the world's coral reefs and has experienced substantial declines in coral cover: average coral cover was only 22.1% in 2003 and cover declined at the annual rate of 1% in the past 20 years and 2% between 1997 and 2003 (equivalent to an annual loss of 3,186 km^2) (Bruno and Selig 2007).

Habitat loss and modification are being driven by the demands for aquaculture, port construction, trawling, road construction, and the building industry (UNEP 2006). Approximately 75% of sheltered tropical coasts worldwide were once occupied by mangroves, but this figure is nowadays probably closer to 25% (Dahdouh-Guebas 2002). The use of mangroves and seagrass as nursery habitats by many coastal species, including commercially important species, highlights the more widespread costs that are felt from loss of these habitats.

Invasive species are likely to be an increasing cause of change in coastal ecosystems (UNEP 2006). Invasive species influence fisheries, local ecological interaction, and coastal infrastructure, and their effects will be difficult to reverse. The major route of transfer of invasive species is in ship's ballast water. Ships began using water to control their draught, trim, and heel in the last nineteenth century in place of solid materials. However, it is only in recent years with the advent of larger tankers traveling at faster speeds that the chance of successful transfer of organisms around the world increased substantially. Currently, global shipping annually transfers 12 billion tonnes of ballast water around the world (Facey 2006).

Climate change will be one of the dominant causes of change in coastal ecosystems, especially mangroves, coral reefs, and beaches, through its potential influence on sea level, storm frequency, sea temperatures, and oceanographic processes such as upwellings and surface currents. Changes arising from climate change will be difficult to reverse and are likely to manifest as coral bleaching, coastal erosion, alterations in plankton delivery to coastal zones, and altered calcification processes arising from changes in ocean chemistry (Fine and Franklin 2007).

The food delivered by fisheries is one of the most important services derived from coastal ecosystems (see Chapter 15), e.g., fisheries based around coral reefs in developing countries provide food to about 1 billion people in Asia. After a period of intense growth in catch beginning in the mid-twentieth century, catches began to stagnate and decline at the end of the 1980s due to overfishing (UNEP 2006). The percentage of under-exploited stocks has declined and the percentage of stocks exploited at or beyond their maximum sustainable yield has increased. At the same time increases in per capita consumption of fish stimulated the rapid growth of aquaculture to fill the gap between production and demand, and aquaculture is the fastest growing primary industry globally. Many wild capture fisheries and aquaculture practices are leading to: physical damage to habitats and associated changes in community structure (e.g., from trawling) or complete habitat loss (e.g., due to conversion from mangroves to aquaculture), pollution, over-exploitation of species for fish meal, changes in trophic ecology manifested as reduced numbers of top predators (‘fishing down the food web’), effects on by-catch species (especially turtles, seabirds, sharks), and the spread of infectious diseases (UNEP 2006).

Major losses of seagrass have occurred in Florida and Australia and degradation is expected to accelerate in Caribbean and Southeast Asia (UNEP 2006). The major causes of seagrass loss are nutrient loading, sedimentation, dredging, and loss from algae farming. Coral reefs are highly degraded throughout the world: 20% are severely damaged and unlikely to recover, with the areas of most concern being the Caribbean and Southeast Asia (UNEP 2006). Major activities degrading coral reefs include: destructive fishing, collection for construction, overfishing, nutrient loading, bleaching, and sedimentation from catchment activities.

Underlying causes of many issues for coastal ecosystems (Table 16.2) include lack of information for management decision-making, population growth and poverty, limited technical and management capacity, poor governance and corruption, lack of institutional collaboration, a focus on solving single issues, lack of stakeholder participation, mismatch between the issue and the geographic scale of management, lack of an ecosystem perspective, ineffective governance and management, and a lack of awareness of the consequences of human activities (Duda and Sherman 2002). The remainder of this chapter considers goals for conservation and management of coastal ecosystems and the practical steps needed to address the immediate and underlying causes of issues.

16.4 Goals for Conservation and Management of Tropical Ecosystems

The protection of coastal tropical ecosystems and the maintenance of ecosystem services is a highly desirable though complex aim. Conservation and management are more likely to succeed when they are planned with reference to goals or guiding principles that are based on ecological and socio-economic understanding. The remainder of this chapter is a synthesis of nine goals for conservation and management. These goals acknowledge that successful conservation and management requires consideration of species and ecosystems and the people who use and manage them. Five goals relate to the need to conserve biodiversity and associated ecological processes at the scale of whole ecosystems and include: maintenance of resilience, connectivity, and water quality, the recovery of species at-risk of extinction, and conservation of representative samples of biodiversity. Four goals relate to the people and institutions who use and manage coastal ecosystems and include: understanding of the socio-economic context, stakeholder participation, education (which includes capacity building), and management at the appropriate spatial scale. Each goal is supported by examples of the management actions and interventions and many of these (e.g., establishment and management of marine reserves, environmental assessment) are relevant to several goals, which reinforces their general power for conservation and management. Appendix 16.1 is an overview of the practical actions that can be utilized to achieve each goal.

16.4.1 Providing for Resilience

Tropical ecosystems are affected by anthropogenic and natural disturbances such as storms, coral bleaching, crown-of-thorns starfish, invasive species, shipwrecks, pollution events, disease, and fishing. Resilience is the ability of an ecosystem to recover from a disturbance and maintain its production of goods and services (Carpenter et al. 2001). A large number of coral reefs were affected by the 1998 bleaching event and the resilience of reefs to continued bleaching events is a major concern. Resilience requires ecosystems to possess biological and functional diversity including herbivores (especially grazing parrotfish and sea urchins; Mumby et al. 2006, 2007), mobile species that move between ecosystems (such as fishes moving between mangroves, seagrass, and coral reefs), a reef framework consisting of scleractinian corals and coralline algae, predators (that maintain a high diversity of herbivores and control bioeroders), corallivores, and settlement facilitators (such as bacteria, diatoms, coralline algae) (Nyström and Folke 2001, Grimsditch and Salm 2005). An ecosystem's resilience will be facilitated by its connections with source areas that provide large numbers of recruits that maintain populations in sink areas. Resilience will be naturally greater in dense reef networks where individual reefs are highly connected but resilience is likely to be less for isolated reefs (Roberts et al. 2006). Appropriate environmental conditions for successful recruitment are required and these may relate to water quality, light availability, limited sedimentation, and availability of suitable substratum (Grimsditch and Salm 2005).

Resilience can be maintained by a range of management actions (Appendix 16.1). Key functional groups can be conserved through: fisheries management, species-specific action plans (Gladstone 2006), protection of spawning aggregation sites (Gladstone 1986, 1996), and Marine Protected Areas (MPAs). Fisheries management (e.g., banning fish traps) can maintain both functional diversity and abundant populations (Mumby et al. 2007). Population rehabilitation (e.g., via transplantation of urchins) may be necessary to return the resilience of specific sites (Jaap et al. 2006). Populations of targeted species recover in no-take MPAs (Edgar et al. 2007). The grazing intensity of parrotfish in MPAs can be double that occurring in non-reserve areas (Mumby et al. 2006) and is associated with significant increases in the density of coral recruits (Mumby et al. 2007). Coral reefs within MPAs are more resilient to a major natural disturbance and the effects of increasing human usage (see Box 16.1). Populations of a diverse range of species that are protected within MPAs act as 'source' areas by producing large numbers of genetically diverse propagules that will be available for settlement in downstream 'sink' areas. Additional protection of highly important source areas (e.g., spawning aggregation sites) is likely to be necessary because many have been decimated by targeted fishing (Sadovy 1993).

Box 16.1 Maintaining resilience through MPAs

MPAs are one of several management tools that are necessary to maintain the resilience of coral reef ecosystems. The result of unmanaged use is clearly illustrated by the change in Jamaican coral reefs. The resilience of Jamaica's coral reefs to disturbance had been compromised by the loss (through overfishing) of the predators (triggerfish) and competitors (parrotfish) of the grazing sea urchin *Diadema antillarum* (which controls growth of macroalgae and therefore facilitates coral recruitment and growth). Grazing by the sea urchin was the main control of the growth of algae and necessary to the recovery of Jamaica's coral reefs from the devastating loss of coral caused by Hurricane Allen in 1981. However, pathogen-induced mortality of *D. antillarum* in 1983–1984 led to an explosion in growth of algae and a phase shift of the entire ecosystem from being coral-dominated to an algae-dominated system. Recent surveys indicate recovery of urchin populations is occurring in some areas of the Caribbean with associated increases in coral cover. However, the change in Jamaica's reefs had a significant effect on the local economy. Two MPA experiences illustrate the alternative scenarios that may arise when reefs are managed to maintain resilience. The Bahamas' Exuma Cays Land and Sea Park (ECLSP) has been protected from fishing since 1986 and this has resulted in an increased survival of large-bodied parrotfish (despite the increased density of parrotfish predators). As a result the grazing intensity by parrotfish in the ECSLP is double that of non-reserve areas, which has led to a fourfold decrease in cover of macroalgae and a twofold increase in density of coral recruits. In contrast to the regional-wide decline in coral cover that followed the mass mortality of *D. antillarum*, the reefs of Bonaire did not experience overgrowth of macroalgae and no decline in coral cover. Spearfishing was banned on the reefs of Bonaire in 1971 and the Bonaire Marine Park was established in 1979. The lack of an effect from the loss of sea urchins in Bonaire is attributed to the abundant grazing fish that remained there.

Sources: Hughes (1994), Carpenter and Edmunds (2006), Mumby and Harborne (2006), UNEP (2006), Mumby et al. (2007)

On a larger scale, Integrated Coastal Management (ICM) that includes spatially coordinated protection of connected ecosystems (such as seagrass, mangroves, coral reefs) will sustain adult populations of important functional groups. ICM also provides for management of human activities in associated terrestrial ecosystems (such as catchments) to limit changes in water quality and thereby maintain the environmental conditions required for resilience, e.g., suitable water quality for coral settlement and survival (McCook et al. 2001).

16.4.2 Maintain/Restore Connectivity

Connectivity is the linkage of spatially disjunct populations and systems via dispersal of eggs and larvae, the movements of juvenile and adult organisms, and the passage of water masses. Tropical ecosystems are connected at a range of spatial and temporal scales:

(1) across environments, e.g., via the flow of water and its constituents from catchments to estuaries and then to coral reefs (Torres et al. 2001; see Chapter 2),
(2) across ecosystems, e.g., seagrass, mangroves, coral reefs by the ontogenetic and diurnal migrations of fishes (Ogden and Ehrlich 1977, Mumby et al. 2004, Mumby and Harborne 2006; see Chapters 8 and 10),
(3) between examples of a single system, e.g., between coral reefs by between-reef movement of larvae or adult fishes migrating to spawning aggregation sites (see Chapter 4), and
(4) within a single habitat, e.g., return of larval fishes to their natal reef, the diurnal movements of fishes between reef habitats, or the ontogenetic movements by coral reef fishes among reef habitats (Nagelkerken et al. 2000).

The ecological processes that are supported by connectivity include population replenishment, primary productivity (Meyer and Schultz 1985, Ogden 1997), and habitat formation (Bellwood 1995). Mixing of freshwater runoff and coastal waters adjacent to rivers and estuaries creates a different environment that is occupied by distinct species assemblages (Veron 1995). The connectivity between catchments and coasts that creates these unique coastal environments thereby supports the great biological diversity of tropical coasts.

Ecosystems are resilient when they remain connected to sources of replenishment. Conversely, resilience may be diminished by population declines in source areas (Roberts et al. 2006) and loss or degradation of the habitats required by different ontogenetic stages (Mumby et al. 2004). Management actions to maintain/restore connectivity include the protection or rebuilding of viable populations in areas that are well-connected to downstream areas, the protection of corridors of connected habitats (such as mangroves, seagrass, and coral reefs), and the rehabilitation of degraded habitats (Appendix 16.1). For example, reductions in populations of the rainbow parrotfish (*Scarus guacamaia*) in the western Caribbean are related to loss of nursery habitat (mangroves) and overfishing. However, despite fishing restrictions recovery is non-existent in areas where mangroves are absent (Mumby et al. 2004). *S. guacamaia* is listed as vulnerable on the IUCN Red List. The size, location and number of MPAs needed to maintain connectivity will vary with the density of habitats, the reproductive strategy and habitat requirements of the species of concern, the degree of self-replenishment, and the risks of future loss (Roberts et al. 2006).

A negative consequence of connectivity between terrestrial and coastal ecosystems is the degradation of coastal ecosystems from unmanaged land uses. For example, substantial areas of seagrass have been lost due to declines in water quality associated with poor land use practices in catchments. The unique nearshore coral assemblages adjacent to the Great Barrier Reef have been degraded by declines in water quality arising from extensive land clearing for agriculture in catchments (Furnas 2003). Maintenance of connectivity at this landscape–seascape scale requires integrated actions that address land use in catchments and human uses of each connected habitat (Appendix 16.1).

16.4.3 Protect Water Quality

Nutrient and sediment loads to the coastal zone increase following catchment alterations for agriculture and grazing, urbanization, and industrialization. Increases in these loads can have extreme effects such as the creation of coastal 'dead zones' or zones of hypoxia (Joyce 2000). The effects of elevated nutrients and sediment loads on coastal ecosystems will depend on input levels, historical ambient loads, the natural dispersal processes, and the extent of other simultaneous stresses (Furnas 2003). There is still considerable debate about the relative importance of declining water quality or reductions in herbivores as the cause of change of many coral reef systems from coral to algae-dominated (Precht and Aronson 2006).

Of longer-term significance for coastal ecosystems may be the additional reduction in resilience to natural and anthropogenic disturbances caused by declines in water quality. The most extreme examples of the ecosystem-wide effects of eutrophication have occurred in semi-enclosed bays following point-source discharges of sewage, e.g., Kaneohe Bay, Hawaii (Grigg 1995) or urban-industrial effluent, e.g., Barbados (Tomascik 1990). Excessive nutrients released into Kaneohe Bay caused persistent plankton blooms. Corals suffered extensive mortality due to freshwater runoff and sedimentation. Proliferation of filter-feeders (which fed on the plankton) and macroalgae on the dead coral substratum inhibited coral settlement and prevented reef recovery. Reefs became more unstable for settlement due to crumbling caused by boring organisms. Major improvements in the coral reef ecosystems of Kaneohe Bay followed infrastructure developments including the redirection of sewage offshore (Appendix 16.1). Seagrass beds adjacent to developed catchments are likely to be influenced by increased sediments, nutrients, and the addition of herbicides. Particular concerns relate to the transfer of land-derived herbicides from seagrass to herbivores such as dugong (Furnas 2003), and overgrowth of corals (Miller and Sluka 1999).

Larger-scale effects may follow degradation of adjacent terrestrial systems. On the mainland adjacent to the Great Barrier Reef, land-use practices have increased the quantity of sediment and nutrients in run-off seven-fold since 1850. Although seemingly an enormous increase, it has been difficult to link directly these increases with the degradation that has been observed in some coastal and island fringing coral reefs (in part because of the lack of long-term monitoring). However, most of the disturbed reefs are located adjacent to catchments where there have been significant amounts of land clearing and fertilizer usage. In addition, given the long time periods required for degraded ecosystems to recover and the likelihood of additional anthropogenic and natural stresses compromising this recovery, a precautionary approach to management that includes changing current land-use practices is recommended (Appendix 16.1) (Furnas 2003). For example, the goal of the Reef Water Quality Protection Plan is halting and reversing the decline in water quality entering the Great Barrier Reef within 10 yrs. The two objectives to achieve this goal are to (i) reduce the load of pollutants from diffuse sources in the water entering the Reef, and (ii) rehabilitate and conserve areas of the Reef catchment that have a role in removing water borne pollutants. Some of the practical steps that are being implemented to achieve these objectives include: self management approaches, public education, economic incentives, planning for natural resource management and land use, regulatory frameworks, research and information sharing, government-private partnerships, the setting of priorities and targets, and monitoring and evaluation (The State of Queensland and Commonwealth of Australia 2003). Additional practical steps are provided in Appendix 16.1.

16.4.4 Conservation and Recovery of Species-at-Risk

Some species are especially vulnerable to over-exploitation and habitat loss due to features of their life history (such as slow growth, late maturity, low fecundity), specialized habitat requirements, restricted breeding season or their habit of aggregating in a limited number of localized areas at predictable times to reproduce (Dulvy et al. 2003, Claydon 2004; Box 16.2). The current status of some of these species is that 37% of sharks, rays, and chimaeras are threatened/near-threatened, three species of sea turtles are critically endangered and three are endangered (from a total of seven species), and shorebirds are declining globally (UNEP 2006). The IUCN's Red List of Threatened Species includes 1,530 marine species of which 80 are threatened with extinction and 31 have a high risk of extinction. A particular concern is the rate of new additions to the list of threatened marine species. Fish species that have declined recently include the giant humphead wrasse *Cheilinus undulatus* (Sadovy et al. 2003), humphead parrotfish *Bolbometopon muricatum* (Donaldson and Dulvy 2004), and the Banggai cardinalfish *Pterapogon kauderni* (Allen 2000; Fig.16.1).

Box 16.2 Conservation and recovery of species at-risk: the Banggai cardinalfish

The Banggai cardinalfish *Pterapogon kauderni* is naturally vulnerable because it is endemic to the Banggai Islands, in central-eastern Sulawesi, Indonesia, over an estimated area of 34 km^2. Like other species in the family Apogonidae males of the Banggai cardinalfish incubate the fertilized eggs within their mouth; however, it is unique in the very small number of eggs (12–40) which are large (2.5–3.0 mm) and lack a pelagic larval phase following hatching. Males incubate the eggs for 2–3 weeks and continue to brood the newly hatched juveniles within their mouth for another 6–10 days. Emergent

juveniles are independent, but mortality is high. Due to the lack of a pelagic dispersive phase there is no prospect of recovery of locally depleted populations by recruitment from outside sources. The species is highly prized in the aquarium trade because of its beautiful appearance, unique biology, and ease of capture, and large numbers (700,000–900,000) are collected annually. The population declined by 89% between 1995 and 2007 following the start of the aquarium fishery. Further problems include habitat destruction from dynamite fishing and net damage to corals. *P. kauderni* was listed on the IUCN Red List as endangered in 2007. The most promising conservation measure would appear to be replacement of the wild capture industry by captive breeding, including at the community-level; however, there has been little take up of this so far.
Sources: Allen (2000), IUCN (2007)

Fig. 16.1 The Banggai cardinalfish (*Pterapogon kauderni*), listed as endangered on the IUCN Red List in 2007 (photo: David Harasti)

Conservation measures are designed to prevent or arrest declines and facilitate recovery of depleted populations. The necessary practical steps include the development of recovery plans, critical habitat protection, captive breeding, trade restrictions, provision of alternative livelihoods for coastal communities that utilize these species, national legislation, international treaties, and community education (Appendix 16.1).

16.4.5 Conservation of Representative Samples of Species and Assemblages

The global biodiversity crisis stresses the need for samples of the variety of species and assemblages to be conserved in perpetuity so that future generations can share the same experiences as us and to fulfill human society's moral responsibilities towards biodiversity. A further rationale is that different ecosystems have different functional values (Mumby and Harborne 2006) and therefore conservation of representative examples of each will ensure maintenance of a suite of ecological functions and processes. Properly managed MPAs are the most appropriate practical action tool to achieve this aim (Appendix 16.1) and they can vary from large multiple-use MPAs (within which areas are zoned for different levels of use with no-take reserves buffered by a zone of less restrictive usage) to networks of smaller no-take marine reserves.

Selection of candidate protected areas requires the clear delineation of a set of MPA selection criteria that fulfill a society's vision for biodiversity conservation. Selection of MPAs within Australia, for example, is guided by the criteria of comprehensiveness, adequacy, and representativeness (Australian and New Zealand Environment and Conservation Council Task Force on Marine Protected Areas 1999). When these criteria are combined with criteria for connectivity, population replenishment, and resilience, conservation planning can achieve multiple objectives for biodiversity conservation and maintenance of ecological functions (see Box 16.3). Deficiencies resulting from a history of *ad ho*c selection of MPAs (Pressey and McNeill 1996) are nowadays addressed by the use of automated and objective reserve selection software (Possingham et al. 2000). Reserve selection programs aim to achieve the selection criteria for the minimum cost and select sites that are complementary (Box 16.3). Conservation planning to represent samples of the variety of biodiversity should ideally be based on accurate spatial data, such as maps for the planning area of the distribution boundaries of species, assemblages, and habitats, as well as ecological understanding of the factors and process (e.g., depth, wave exposure, oceanography) that underlie variation in species and assemblages. However, these data are rarely available because of patchiness in sampling records, access problems, uncertain taxonomy, financial constraints, and limited research (Gladstone 2007). Surrogates are a potential solution to this issue when they can be shown to represent other unmeasured species and assemblages (Gladstone and Owen 2007), and their distribution is already mapped within the planning area or data on their distribution is more easily and cheaply obtained (Appendix 16.1). Recent advances in remote sensing and habitat mapping show great promise for economically and rapidly providing spatial data suitable for conservation planning (Mumby and Harborne 2006). The selection of MPAs must also include socio-economic considerations and these are discussed in the following section on socio-economic assessment.

Box 16.3 Approaches to conservation planning for MPAs

The Seaflower Biosphere Reserve (San Andrés Archipelago, Colombia) was declared a UNESCO international biosphere reserve in recognition of its great significance in the Caribbean for its biodiversity and endemism, and covers an area of 255 km^2. Along with other island groups in the Archipelago its biodiversity values are to be conserved by establishing a multiple-use MPA that includes no-take reserves. The process of designating the boundaries of potential reserves began with the confirmation (via extensive field surveys) that habitats classified *a priori* represented distinct assemblages of species. General criteria for designating reserve boundaries included the requirement that individual reserves should cover at least 10 km^2 to ensure population viability, be placed on every coastal shelf and include representatives of each habitat present, and have straight line boundaries to facilitate compliance enforcement in the field. Additional specific criteria included the need to include within reserves spawning aggregation sites, rare and ecologically significant habitats (e.g., mangroves, seagrass), and corridors of ecologically connected habitats (seagrass, mangroves, coral reef). Stakeholders (local fishers) were consulted about these criteria and provided their own preferences for reserve boundaries. The reserve boundaries nominated by the fishers covered 27–32% of the area, the scientist's boundaries (based on the above general and specific criteria) covered 38–41% of the area (with an average of 30% coverage of each habitat type; Friedlander et al. 2003). The Seaflower MPA was declared in 2005.

Working at a much larger spatial scale, the Great Barrier Reef Marine Park-covers 344,400 km^2 (85% of the area of California) and is a World Heritage site. Increasing pressure from a range of different uses, and a recognition that the levels of protection afforded to the Park's biodiversity in no-take areas was inadequate (only 4.5% of the Park was no-take and 80% of this was coral reefs) led to a re-zoning process called the Representative Areas program. The planning units were 70 bioregions, and decisions on candidate locations for no-take areas were guided by scientific operational principles (e.g., no-take areas should have a minimum length of 20 km to maintain population viability) and social, cultural, economic, and management feasibility operational principles. The process involved the identification of alternative sets of no-take areas that achieved the biological objectives (determined by reserve selection software) and the integration of the social, cultural, economic, and management factors (based on a high degree of stakeholder consultation). The final outcome was a re-zoning with more than 33% of the Park's area designated as no-take reserves which represented a five-fold increase in the total global area of no-take reserves (Fernandes et al. 2005).

16.4.6 Understanding the Socio-Economic Context

Twelve percent of the total global population (equivalent to 31% of the global coastal population) lives within 50 km of a coral reef (UNEP 2006). People have favored coastal locations for settlement because, among other benefits, these areas tend to contain the greatest biological productivity. Sixty-five percent of cities with populations above 2.5 million inhabitants are located along the world's coasts. One billion people depend on fish catches from shallow coastal waters dominated by coral reefs (Whittingham et al. 2003). Coastal populations in many countries are growing at double the national rate (Turner et al. 1996). Small island states typically have experienced population growth rates of around 3% per annum, although the rate of emigration is also high in some cases. Many islands are also densely populated with the capital island of the Maldives, Malé, providing an extreme example. It is home to 56,000 people despite being only 1,700 m long and 700 m wide (Pernetta 1992).

Economic valuation of ecosystem services quantifies their contribution to human welfare and provides further support for conservation and management (Costanza et al. 1997, Costanza 1999, Balmford et al. 2002). Methods of economic valuation have been reviewed (Ahmed 2004) and the estimates of economic benefits are impressive. Earth's oceans contribute about US$21 trillion per year to human societies from their provision of food, materials, and services (e.g., atmospheric gas and climate regulation, cycling of water, nutrients, and wastes; Costanza 1999). The net economic benefits of coral reefs are estimated to be US$30 billion per annum, including US$100 million annually from recreational fisheries (UNEP 2006). Fisheries on small island states in the Caribbean provide full-time and part-time direct employment for more than 200,000 people and indirect employment for an additional 100,000 (UNEP 2006). A synthesis of recent economic analyses of the value of tropical coastal ecosystems is provided in Table 16.3.

The human costs of ecosystem degradation can be measured in terms of loss of revenue, opportunities, and social costs such as reduced income and loss of a preferred lifestyle (Table 16.4). The costs of ecosystem degradation are experienced more deeply in the coastal communities of developing countries, which have a greater dependence on coastal ecosystems (Turner et al. 1996, Dahdouh-Guebas 2002). Declines in the production values of ecosystems will lead to social and economic hardships, loss of tourism potential because of declining attractiveness, and loss of option values such as the potential for pharmaceutically active compounds or future tourism ventures (Bruno and Selig 2007). The reliance of human society on coastal ecosystems means that conservation has to be balanced with sustainable use.

An understanding of the importance of cultural factors will increase the likelihood of success of conservation and management. Cultural significance can relate both to places and activities. Culturally significant places are areas that are important to a community because of some attribute of the natural environment or its association with a spiritual activity. MPAs have been used to protect culturally significant sites (Kelleher and Kenchington 1992, Gladstone 2000, Salm et al. 2000). For example, in the Farasan Islands (Red Sea) the local community organizes an annual festival to coincide with the mass spawning of the parrotfish *Hipposcarus harid* in a single bay (Fig. 16.2) (Gladstone 1996). The bay was given the highest level of protection in the zoning scheme for the multiple use Farasan Islands MPA to simultaneously protect the spawning ground and thereby ensure the sustainability

Table 16.3 Summary of economic values derived from coastal and marine tropical ecosystems (all values are in US$)

Ecosystem	Economic value	Basis of economic value	Source
Coral reef	$30 billion per year or $100,000–$600,000 per km^2	Net potential benefits in goods and services, including tourism, fisheries, and coastal protection worldwide	Cesar et al. (2003)
	$1 billion per year (1991/92)	Great Barrier Reef, Australia	Driml (1994)
	$128 million (1991/92)	Commercial fishing sales from the Great Barrier Reef	Driml (1994)
	$94 million (1991/92)	Expenditure on recreational fishing and boating on the Great Barrier Reef	Driml (1994)
	$628 million (1991/1992)	Expenditure by tourists on accommodation and commercial passenger vessels on the Great Barrier Reef	Driml (1994)
	$3.1 billion–$4.6 billion per year (2000)	Fisheries, dive tourism, and shoreline protection services of Caribbean coral reefs	Burke and Maidens (2004)
	$310 million per year (2000)	Coral reef-associated fisheries in the Caribbean region	Burke and Maidens (2004)
	$2.1 billion per year (2000)	Net benefits from dive tourism in the Caribbean region	Burke and Maidens (2004)
	$700 million–$2.2 billion per year	Shoreline protection services provided by Caribbean reefs	Burke and Maidens (2004)
	$2.4 billion per year	Value of coral-reef based fisheries in Southeast Asia	UNEP (2006)
	$1.2 billion per year	Reef-based tourism in Florida Keys, USA	UNEP (2006)
	>$1.0 billion per year	Direct revenue from 1.6 million visitors to Great Barrier Reef	UNEP (2006)
	$300,000–$35 million per year	Recreational value per reef in marine management areas in Hawaiian Islands	UNEP (2006)

Table 16.3 (continued)

Ecosystem	Economic value	Basis of economic value	Source
Mangrove	\$9,990 per ha per year	Disturbance regulation, waste treatment, habitat, food production, raw materials, recreation	Costanza et al. (1997)
	\$1,500 per km^2	Potential net benefit for medicinal plants	Ruitenbeek (1994)
	\$30,000 per km^2 per year (totaling \$10 million per year)	Forestry products (timber and charcoal) of the Matang mangroves in Malaysia	Talbot and Wilkinson (2001)
	\$750–\$16,750 per ha	Seafood supported by mangroves	UNEP (2006)
	\$600 per ha	Fisheries yields adjacent to mangroves	UNEP (2006)
	\$15 and \$61 per ha	Medicinal plants and medicinal values, respectively	UNEP (2006)
	\$6,200 per km^2 in the United States to \$60,000 per km^2 in Indonesia per year	Annual commercial fish harvests from mangroves	UNEP-WCMC (2006)
	\$2.7 million–\$3.5 million per km^2	Mangroves in Thailand	UNEP-WCMC (2006)
Seagrass	\$19,004 per ha per year	Nutrient cycling raw materials	Costanza et al. (1997)

Table 16.4 Economic losses from issues negatively affecting tropical coastal ecosystems (all values are in US$)

Issue	Economic loss	Source
Coral degradation and death could lead to loss of shoreline protection services in the Caribbean region	Totaling $140–$420 million annually (within the next 50 years)	Burke and Maidens (2004)
Cost of replacing the coastal protection provided by now degraded reefs Sri Lanka	$246,000–836,000 per km	Berg et al. (1998)
Decrease in tourism-generated income, employment, fish productivity, and shoreline protection in Indian Ocean resulting from declines in coral reef quality from 1998 bleaching event	$608 million–$8 billion (over 20 years)	UNEP (2006)
Degradation of Caribbean coral reefs could reduce net annual revenues from coral reef-associated fisheries	Estimated $95–$140 million per year by 2015	Burke and Maidens (2004)
Degraded Great Barrier Reef in Australia as the result of the predicted effects of global warming	$2.5 billion–US$6 billion over 19 years	Hoegh-Guldberg and Hoegh-Guldberg (2004)
Economic loss associated with coral bleaching over a 50 years time horizon with a 3% discount rate	$28.4 billion in Australia and $38.3 billion in Southeast Asia	Cesar et al. (2003)
Increased sea-surface temperatures, sea level rise, and loss of species due to climate change in the Caribbean	$109.9 million	Cesar et al. (2003)
Net loss after 20 years of blast fishing of coral reefs in Indonesia	$300,000 per km^2 in areas with a high potential value of tourism and coastal protection, and $33,900 per km^2 where there is low potential value	Pet-Soede et al. (1999)
Predicted net economic loss from blast fishing, overfishing, and sedimentation	$2.6 billion for Indonesia and $2.5 billion for the Philippines over a 20 years period	Burke et al. (2002)
Reef degradation that is projected to occur in the Caribbean by 2015 may reduce fisheries production by 30–45% resulting in revenue reduction from $310 million to only $140 million	$170 million in the year 2015	Burke and Maidens (2004)
Restoring a 250 meter-long beach following erosion as a result of offshore coral mining in Indonesia	$125,000 annually (over 7 years)	UNEP (2006)

Fig. 16.2 The festival of the harid parrotfish is a culturally significant event in the Farasan Islands, Saudi Arabian Red Sea, which has been incorporated into a management plan for the Farasan Islands Marine Protected Area. (**a**) Locals capturing spawning harid parrotfish, (**b**) Lower guards of the local *emir* maintain orderly conduct during the collection of the parrotfish (photos: William Gladstone)

of the cultural festival (Gladstone 2000). As a culturally significant activity, fishing fulfils many needs in fishers that are unrelated to economic returns. This can make it difficult to implement alternative livelihood schemes, even when catches are declining (Pollnac et al. 2001, Momtaz and Gladstone 2008). Understanding the personal significance of an activity such as fishing will increase the likelihood of more acceptable alternatives being developed.

Coastal communities are not homogeneous entities, consisting of groups of individuals who differ in the ways they perceive and use their environment. Perceptions and uses, in turn, depend upon a host of social, cultural, and economic factors such as age, occupation, income, ethnicity, gender, level of education, and migration status (Cinner and Pollnac 2004). Changing people's behaviors, as the fundamental means of addressing conservation and management problems, is therefore a complex undertaking. A socio-economic assessment provides the framework for comprehending the socio-economic context in which management and conservation have to operate and demonstrates the underlying causes (e.g., poverty, lack of education) of many issues for coastal ecosystems. Management can then be directed at addressing both the underlying causes of issues (which is likely to be a long-term undertaking) and the immediate effects. A socio-economic assessment covers the social, cultural, economic, and political conditions of stakeholders (Bunce et al. 2000, Browman and Stergiou 2005). Specific areas that may be assessed include stakeholder characteristics, resource use patterns, gender issues, stakeholder perceptions of problems and management, organization and resource governance, traditional knowledge, community services and facilities, the local business environment, the incomes of stakeholders, and the economic values of resources (Bunce et al. 2000). Appendix 16.1 provides specific examples for each step of the socio-economic assessment and Box 16.4 provides three case studies that illustrate the ways in which socio-economic understanding has been used to develop conservation and management actions.

Box 16.4 Case studies in the assessment of the socio-economic context for management

Case study 1: Great Barrier Reef Marine Park Representative Areas Program (GBRMPRAP)

The aim of the GBRMPRAP was to comprehensively conserve examples of the Marine Park's biodiversity, which was likely to lead to a substantial increase in the number and total area of no-take areas. There was a high risk of conflict with the Park's existing users: tourism, commercial fishing, and cultural and recreational activities employ 44,000 people and contribute A$3.7 billion annually to the economy of the Park and its catchment (Access Economics 2007). Managers of the GBRMPRAP established a social, economic, cultural steering committee (comprised of representatives of management and stakeholder groups) that developed social, cultural, economic, and management feasibility operational principles that would guide decision-making about the location of no-take areas in partnership with bio-physical operational principles. A key operational principle was to 'maximize complementarity of no-take areas with human values, activities and opportunities' by placing no-take areas where conflicts with indigenous users' aspirations, non-commercial and commercial extractive users, and all non-extractive users, would be minimized. Federal government financial support for displaced fishers enhanced the community's acceptance, and reduced the economic costs, of the greatly expanded network of no-take areas (Fernandes et al. 2005).

Case study 2: The economics of blast fishing

Declines in fish catches, ease of use, and demands of creditors, forced many fishers into blast fishing in Indonesia. Blast fishing targets schooling reef fishes but also kills other fishes and invertebrates that are not collected and damages reef habitat. The latter has opportunity costs such as the foregone benefits of tourism. A lack of political will (arising from lack of awareness of the economic costs of blast fishing) is the main reason for the lack of enforcement of this illegal activity. Pet-Soede et al. (1999) quantified the economic costs of blast fishing in Spermonde Archipelago, Southwest Sulawesi, Indonesia, from observations at sea (numbers of bombs, fish catch biomass), interviews with fishers and middlemen (for data on number of trips, costs, and profits), and from the logbook records of fishers of their daily catches. The authors estimated the blast impacts on corals from surveys done while diving. The projected cost of 20 years of blast fishing in areas of high value coral reef was a net loss of US$306,800 per km^2 through loss of coastal protection and foregone benefits of tourism and non-destructive fisheries, which are four times greater than the net private benefits. Management options suggested by this socio-economic assessment include an awareness program (to inform blast fishers of the links between blast fishing and their own livelihood and the general status of Indonesian coral reefs, the latter to counter the blast fishers' perceptions that catches can be improved by traveling to other reefs), provision of alternative livelihoods (e.g., pelagic fisheries, mariculture, tourism), greater enforcement, and a locally managed credit system (Pet-Soede et al. 1999).

Case study 3: Using understanding of the influence of socio-economics on the perceptions of coastal resource issues to address underlying causes

The coastal resources adjacent to the small fishing village of Mahahaul (Mexico) support fishing and tourism and are therefore socially and economically significant to residents. A socio-economic assessment and interviews revealed that most residents believed the reef and fishery were in poor condition. The migration status, wealth, and education of residents influenced their perception of the causes of the issues with wealth being the most influential: poorer residents only attributed declines in fisheries to fishing whereas wealthier residents understood the issue to be the result of a host of inter-related factors (e.g., fishing, increasing tourism, land-based activities). Wealthier residents are therefore more likely to support ecosystem-based management approaches. Developing an understanding of the need for holistic management throughout the coastal community (and thereby improving its chances of success) requires management approaches that include increasing the wealth of poorer residents, e.g., by providing alternative livelihoods or supporting other income generating activities (Cinner and Pollnac 2004).

16.4.7 Stakeholder Participation

Stakeholders are the 'people, groups, communities and organizations who use and depend on the reef, whose activities affect the reef or who have an interest in these activities . . . ' (Bunce et al. 2000). Stakeholders include government agencies mandated with responsibilities for conservation and management, local and indigenous communities, international and local non-government organizations (NGOs), the international donor and lending organizations, the private sector, educators, and researchers. The number of stakeholder groups participating in a conservation and management issue will vary with the issue (e.g., MPA planning vs. fisheries regulations), its scale (e.g., planning for a local MPA vs. an international network of MPAs), the development status of the planning area, and any mandated requirements. Management actions are usually led by governments, but not always. The development of the Ecoregion Plan for the

Sulu-Sulawesi Marine Ecoregion has been led and sustained by an NGO (see Box 16.7).

The participation of stakeholders in management is an acknowledgement of stakeholders' material and personal interests in the outcomes of conservation and management and the practical benefits of this participation. The active inclusion of stakeholders can overcome the limitations of management that arise from insufficient funding, e.g., the participation of stakeholders in monitoring. Communities may also have a strong motivation to initiate and participate in management because an issue directly affects them, e.g., declining fish catches (Pollnac et al. 2001). Stakeholders' desires to participate also reflect a broader need by individuals to make a personal contribution to the sustainability of the marine environment.

Stakeholder participation leads to improved compliance with management regulations and so is more likely to provide successful management outcomes (Bunce et al. 2000). For example, a comparison of MPAs that had been established and managed by central governments with little/no community participation with MPAs that had been established, planned, and managed with a high level of community involvement found that although there were few differences between the two groups in the bio-physical benefits, stakeholder conflicts were more successfully resolved in the community-based MPAs (Alcala et al. 2006). The likely outcome of this difference is a greater chance of long-term sustainability for the community-based MPAs. Limited involvement by stakeholders has been a significant factor in the failure of MPA management in the Caribbean (Mascia 1999) and elsewhere (Beger et al. 2004).

Additional benefits of stakeholder participation include development of more acceptable management practices (Gladstone 2000, Friedlander et al. 2003, Fernandes et al. 2005), improved relationships between management agencies and stakeholders (Bunce et al. 1999, Fernandes et al. 2005), and reduced stakeholder conflicts due to ease of communication and closer links between stakeholders and community management teams (Mefalopulos and Grenna 2004, Alcala et al. 2006). Agencies benefit from the increased awareness by stakeholders of the management process and the support this engenders for an organization and its aims. The increased awareness of coastal issues amongst participating stakeholders is likely to produce positive flow-on effects to other aspects of people's interaction with the environment.

The opportunities for stakeholder participation include participation in the planning process (e.g., by representing the interests of stakeholder groups), the use of local knowledge in the planning process, the incorporation of traditional management practices in management plans, stakeholder-led planning and management (see Box 16.7), assistance with management implementation (e.g., as volunteer community rangers), public review of draft management plans and environmental assessments, and opportunities for volunteerism (Figs. 16.3, 16.4, Box 16.5). Specific examples of these different opportunities for participation are given in Appendix 16.1.

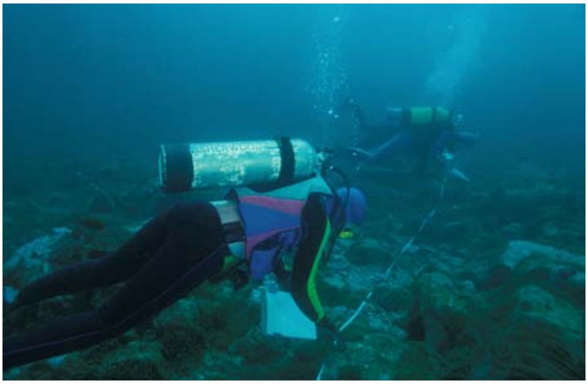

Fig. 16.3 Recreational SCUBA divers from the Solitary Islands Underwater Research group assisting with volunteer coral reef monitoring in the Solitary Islands Marine Park, Australia (photo: Ian Shaw©)

Fig. 16.4 Reef HQ volunteers are a valuable source of information for the general community about the Reef HQ Aquarium and the Great Barrier Reef Marine Park (photo: Great Barrier Reef Marine Park Authority)

Box 16.5 Community volunteers working for coral reef conservation

The Reef HQ Volunteers Association grew out of community enthusiasm for active involvement with the work of the Reef HQ Aquarium (Townsville, Australia). The goal of the Reef HQ Aquarium is to 'Inspire all to care for the Great Barrier Reef'. The Volunteers Association involves the community in achieving this goal through the ongoing education of the general public about the Great Barrier Reef and the Marine Park. Volunteers are engaged in nearly all facets of the Reef HQ Aquarium's operations, including interpretation, education, curatorial, exhibits, administration, promotions, and marketing. Interpretive volunteers assist with visitor information, conduct talks/tours and visitor surveys, craft activities, and provide one-to-one interpretation about the Reef. Education volunteers assist with school groups during the day and sleepovers at night. Administrative volunteers assist with databases, mail-outs, and photocopying. Exhibits volunteers help with displays. Curatorial volunteers help maintain tanks, prepare feeds, water changes, and other duties. Marketing and promotions volunteers conduct sales calls to hotels/motels and other tourism outlets and promote the Reef HQ Aquarium at special community events. Since its inception in 1987, the Volunteers Association has trained over 975 volunteers, who have collectively contributed over 290,000 hrs of voluntary service, which is valued in excess of A$4 million dollars. New volunteers undergo an initial 18-h basic training course over a seven-week period, followed by an additional 8 hrs of specialized team training over a four-week period. This induction is designed to equip volunteers with information, skills, and confidence needed to provide visitors with an informative and enjoyable experience. The training course covers diverse topics including: operating structure of the Reef HQ Aquarium and an orientation of the facility, marine biology, coral reef ecology, and communication skills and presentation techniques.

Source: staff and volunteers at the Reef HQ Aquarium

Ensuring the success and sustainability of stakeholder participation is challenging but essential, given most issues usually require long-term solutions. Many stakeholders volunteer in their spare time and often with little support and so avoiding volunteer and stakeholder 'burnout' is a major concern, especially when conservation activities come to depend almost entirely on volunteer workers. Practical steps to ensure success and sustainability include: maintaining the mechanisms for ongoing stakeholder input, demonstrating the links between participation and positive conservation and material outcomes for participants, combining community development plans with conservation, providing information, education, and community activities, mandating continued stakeholder participation in legislation, public recognition of successful partnerships, and partnerships with local rather than central governments (Appendix 16.1).

16.4.8 Education

It is essential to develop people's understanding of the relationship between their actions and the environmental problems these may create. It is also essential for people to appreciate the costs arising from not properly managing human uses of ecosystems. Both are needed as a step in getting people to accept the need to change their behavior. A central means of achieving this understanding is communication, education, and public awareness: 'Without communication, education and public awareness, biodiversity experts, policy makers and managers risk continuing conflicts over biodiversity management, ongoing degradation and loss of ecosystems, their functions and services. Communication, education and public awareness provide the link from science and ecology to people's social and economic reality' (Van Boven and Hesselink 2002). This section reviews the recognition given to the importance of education, the range of potential benefits, and specific examples of successful education approaches (summarized in Appendix 16.1).

The central role of education in conservation and management is recognized in international conventions such as the United Nation's Agenda 21 (1992) and Johannesburg Plan of Implementation (2002). It is also incorporated into regional conventions such as the Protocol Concerning Specially Protected Areas and Wildlife that is part of the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region. Education is a key management action also in issues-based programs (e.g., Great Barrier Reef Water Quality Protection Plan). In recognition of the significance of education the United Nations declared 2005–2014 the Decade of Education for Sustainable Development.

Education is a powerful tool to develop and increase political will for the need for management (Pet-Soede et al. 1999) and to demonstrate to stakeholders the consequences of their activities, e.g., overfishing (Bunce et al. 1999). Education can support the development of new management actions by explaining the need for management to stakeholders (Fernandes et al. 2005) and demonstrating the potential benefits from examples of similar management (Rodriguez-Martinez and Ortiz 1999, Alcala et al. 2006). Demonstrations of the positive benefits of establishing community-based MPAs have been effective at stimulating fishing communities in the Philippines to create new MPAs (Alcala et al. 2006). Enhancing users' experiences (e.g., by providing information to tourists) will increase the support amongst the broader community for management. Education is as effective as enforcement at ensuring users' compliance with MPA regulations (Alder 1996). Stakeholders' personal ecological effects can be significantly reduced by brief educational interventions that provide information and skills instruction, and education to reduce the impacts of divers on corals has been particularly effective (Medio et al. 1997, Rouphael and Inglis 2001, Hawkins et al. 2005).

On the other hand, lack of awareness (e.g., MPA boundaries) will constrain management success (Alcock 1991, Kelleher and Kenchington 1992, Bunce et al. 1999). Inadequate education is one of the main causes of unsuccessful MPAs (Browning et al. 2006). However, not all stakeholders and groups respond positively to education and so education has to be seen as one part of a mix of management activities. Although education programs can be more expensive than other forms of management, e.g., compliance enforcement (Alder 1996), the potential for flow-on effects to other individuals (e.g., friends, family) and the lifelong changes in behavior (Browning et al. 2006) greatly amplifies the benefits of education.

Each conservation and management issue that requires education has a specific communication issue. For example, conventional environmental education may not be sufficient to convey the complexity of the connections among coastal ecosystems. Connectivity presents issues in technical understanding, complex concepts, and large-scale thinking. Research in the field of environmental education has shown that it is not sufficient to provide information (e.g., about the state of the coast, value of biodiversity) because there is no cause-and-effect from providing information to changes in attitude and behavior. A more effective approach is to create relevance in the lives of individuals (Denisov and Christoffersen 2000, NSW National Parks and Wildlife Service 2002, Gladstone et al. 2006). Major contributors to developing a commitment to conservation include childhood contact with nature (Box 16.6) and the influence of a significant adult, rather than formal education (Palmer 1995). Approaches to successful environmental education have been reviewed recently (Rickinson 2001, Browning et al. 2006). Examples of specific education activities are provided in Appendix 16.1.

Box 16.6 Educating children about marine conservation: SeaWeek on Lord Howe Island

Today's children play a vital role in the future conservation of the marine environment. It is their actions both now and in adult life that will directly affect coral reef communities. Educating children about marine environments can result in positive attitudes and behaviors that can also influence family and friends. Effective education will make children responsible managers of the world's vulnerable coral reefs. One community that takes marine education seriously is World Heritage listed Lord Howe Island. Residents actively support SeaWeek (the annual national public awareness campaign organized by the Marine Education Society of Australasia—MESA) through planned activities and events for the Central School and local community. SeaWeek on Lord Howe is timed to coincide with coral spawning. Night dives and guided snorkeling enable both children and adults to witness this spectacular phenomenon and to learn about the reproductive cycle of corals. Ecological reef walks are guided by a resident naturalist who educates island visitors about coral reefs and their unique organisms and habitats. School activities include snorkel trips conducted by one of the local tour operators and presentations by the Marine Park Manager and other guests such as visiting scientists and marine educators (Fig. 16.5).
Source: Christine Preston, Faculty of Education and Social Work, University of Sydney

The stakeholder groups providing education will vary with the context of the education program and the intended audience. Education can be the responsibility of government agencies responsible for coastal management, NGOs, universities, secondary and primary schools, the private sector (e.g., tourist resorts, private aquaria), and informal education providers (e.g., marine discovery centers, visitor centers) (Fig. 16.5).

Most tropical ecosystems occur in developing countries (Fig. 16.6) where management and technical capacity or experience can be constrained by the limited opportunities for formal education and personal experience with successful management interventions. A further constraint on the capacity of many countries to

Fig. 16.5 Children testing model fish they made to demonstrate how fish swim through the water during a SeaWeek lesson (photo: John Johnstone)

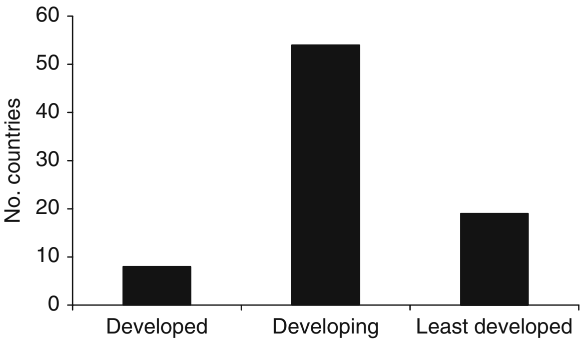

Fig. 16.6 Development status (in 2007) of countries with coral reefs. Sources: GCRMN (Global Coral Reef Monitoring Network) (2004) Status of coral reefs of the world; 2004. vol 1. Australian Institute of Marine Sciences, Townsville

conserve and manage coastal ecosystems is the migration of talented individuals to countries with greater opportunities, further weakening national capacity (Gladstone 2008). In these situations, the continuing education of conservation professionals (i.e., capacity building) (Appendix 16.1) and the development of effective and sustainable conservation and management institutions (i.e., institutional strengthening) must precede or go hand-in-hand with the implementation of more visible forms of management such as MPAs.

16.4.9 Manage at the Most Appropriate Spatial Scale

Planning by agencies and nations for sustainable use and conservation of individual ecosystems, species, catchment-coast linkages, and bioregions may be sufficient in situations where there are few external influences (e.g., isolated oceanic atolls) or no overlapping boundaries with other nations. However, there are compelling reasons for managing at much greater spatial scales. Ecosystem boundaries can be very large when they include the boundaries of relevant catchments and the extent of seaward influence of coastally-derived water masses. The semi-enclosed nature of many seas (e.g., the Caribbean Sea, Red Sea) and the large-scale, trans-boundary nature of some issues (e.g., pollution, climate change, invasive species, coral diseases) means that countries may be affected by issues occurring in neighboring countries. Pathways of connectivity resulting from the trans-boundary movements of pelagic larvae and eggs from spawning sites can cross national boundaries (Domeier 2004). Migratory species such as whale sharks, pelagic fishes, turtles, and cetaceans move between feeding and mating grounds in different countries (Eckert and Stewart 2001). Many countries also share biogeographic regions and catchments. Effective and sustainable solutions to problems are therefore more likely to follow from cooperative approaches rather than single-country actions.

In addition to these bio-physical planning considerations, variations in the development status of countries within a region may mean that the required financial, technical and management expertise for conservation and sustainable use is beyond the capacity of some countries. In these situations support from neighboring countries is required to achieve regional conservation goals (Gladstone et al. 2003). Looking even further afield, the benefits that developed countries gain from the ecosystem goods and services of developing countries places some responsibility on these developed countries to assist, where necessary, with conservation and sustainable use in these developing countries.

The practical options for large-scale management include legally binding global treaties (e.g., United Nations Convention on Law of the Sea), sectoral agreements (e.g., International Convention for the Prevention of Pollution from Ships, International Convention for the Regulation of Whaling), and species-based agreements (e.g., Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia) (Agardy 2005, UNEP 2006). In the remainder of this section I will focus on the use of spatial management to achieve large-scale conservation and sustainable use.

The Regional Seas Programme was established by the United Nations Environment Programme (UNEP) in 1974 to assist and engage countries sharing a common body of water in cooperative conservation and management activities to address regional issues. The Programme covers 18 regions (and more than 140 countries): the Antarctic, Arctic, Baltic, Black Sea, Caspian, Eastern Africa, East Asian Seas, Mediterranean, North-East Atlantic, North-East Pacific, North-West Pacific, Pacific, Red Sea and the Gulf of Aden, ROPME Sea Area, South Asian Seas, South-East Pacific, Western Africa, and the Wider Caribbean. Countries within each region commit to addressing these issues through their development of a regional plan of action and their ratification of a legally binding convention and associated issue-specific protocols.

The Wider Caribbean Region includes 28 island and continental countries with coasts on the Caribbean Sea and Gulf of Mexico and the adjacent waters of the Atlantic Ocean. Governments of these countries identified the main issues as: land-based sources of wastes and run-off, over-exploitation of marine resources, increasing urbanization and coastal development, unsustainable agricultural and forestry practices, and a lack of government and institutional capacity to address environmental problems. The Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region (the Cartagena Convention) requires countries to 'protect, develop, and manage their common coastal and marine resources individually and jointly'. The Convention has three associated protocols dealing with oil spills, specially protected areas and wildlife, and pollution from land-based sources and activities. The Protocol on Specially Protected Areas and Wildlife, which became international law in 2000, contains a list of protected species and guidelines for the establishment of protected areas, national and regionally cooperative measures for species' protection, environmental impact assessment, research, and education. Regionally cooperative measures include common measures to protect listed protected species, and common guidelines and criteria for the identification, selection, establishment, and management of protected areas (Appendix 16.1).

Large Marine Ecosystems (LMEs) are regions that cover more than 200,000 km^2 of ocean and extend from the landward boundary of catchments and include estuaries and the coastal zones out to the seaward boundaries of continental shelves or a major current system and also possess a distinct bathymetry, hydrography, and productivity. There are 64 recognized LMEs and many occur within the boundaries of UNEP's Regional Seas. The Global Environment Facility has developed an approach for nations sharing an LME to address jointly their coastal and marine issues (Duda and Sherman 2002). A trans-boundary diagnostic analysis provides a synthesis of trans-boundary concerns and their root causes. Based on this, a strategic action program (SAP) plots the reforms needed regionally and nationally. Box 16.7 illustrates the specific steps undertaken to develop a SAP.

Box 16.7 Case studies in regional approaches to conservation and sustainable use

Case study 1: Strategic Action Programme (SAP) for the Red Sea and Gulf of Aden

The Red Sea and Gulf of Aden SAP's global objective was to safeguard the coastal and marine environments and ensure sustainable use of its resources. The SAP's activities involved: institutional strengthening, reducing navigation risks and maritime pollution, sustainable fisheries, habitat and biodiversity conservation, development of a regional network of marine protected areas, support for integrated coastal zone management, enhancement of public awareness and participation, and monitoring and evaluation of the SAP's outcomes. Implementing regionally-agreed objectives at the national-level has been a major challenge. In the Red Sea and Gulf of Aden regional status assessments were used to develop regional action plans for the conservation of turtles and breeding seabirds. National action plans were developed to facilitate national implementation of the regional needs. Given the discrepancy in capacity among countries, the action plans were adapted to suit each particular country. National implementation is occurring through integrated networks of national and local working groups, government departments, agencies and personnel, non-governmental organizations, and other stakeholders (Gladstone et al. 1999, Gladstone 2006).

Case Study 2: Sulu-Sulawesi Sea Marine Ecoregion

The Sulu-Sulawesi Sea Marine Ecoregion (SSME) (shared among Indonesia, Malaysia, the Philippines) was listed by World Wide Fund for Nature (WWF) as one of its Global 200 ecoregions because of its global significance for coral and fish diversity (see Fig. 16.7), rare and endangered species (including the coelacanth), habitat richness, productive coastal ecosystems, and the large coastal population (35 million people) dependent on its resources. Degradation resulted from unsustainable levels of resource use, poverty, and increasing populations. The SSME Conservation Program involved regional conservation planning combined with specific actions for sites and species. Implementing the Program required a Biodiversity Vision (based on inputs of 70 stakeholders) that guided development of an Ecoregion Conservation Plan (requiring 12 stakeholder workshops across the three nations). The Plan identified 10 objectives with associated actions to be implemented nationally or regionally over 10 years and was formally adopted as national policy by the three nations in a memorandum of understanding in 2004. National actions included enforcement at key sites, an integrated conservation and development plan for key sites, local community education, and a GIS data base. Actions to be implemented collaboratively across the ecoregion include protection of sea turtles, improved fisheries management, and a network of MPAs (Miclat et al. 2006).

Fig. 16.7 The Sulu-Sulawesi Marine Ecoregion is one of the World Wide Fund for Nature's Global 200 ecoregions because of its significance for marine life (photo: David Harasti)

Coordinated networks of MPAs have the potential to achieve local, national and regional conservation goals simultaneously. Regional networks of MPAs have been designed to represent in a complementary manner examples of major regional ecosystems (Gladstone et al. 2003, Agardy 2005), source areas highly connected to areas outside a network, and areas important for species of special concern (Miclat et al. 2006; Box 16.7). To be effective, the functioning of a regional network of MPAs requires a legally binding protocol ratified by all countries within the region, a mechanism for regional coordination of the network, and active on-ground management within each of the participating MPAs. The objective of the regional coordination role should be to support individual MPAs in achieving their management objectives so that regional objectives for sustainable use and conservation are being met. The regional support role can include: development of regionally-agreed guidelines for the selection, establishment and management of MPAs, support for revenue generation, capacity building (e.g., through training in management), and monitoring (Gladstone et al. 2003). The impediments to regional approaches include lack of political will for cooperation with neighboring countries, varying capacity among participating countries, the diversity of stakeholders with varying and conflicting priorities (Agardy 2005), varying opportunities for participation by stakeholders in different countries, and incomplete ratification of legally binding agreements.

16.5 Conclusion

Addressing the issues confronting tropical coastal ecosystems requires management approaches that restore and conserve the natural patterns and functions of ecosystems. The recent advances in our understanding of the dynamics of marine and coastal ecosystems, the scales at which they operate, and the development of new technologies (reviewed in Part 3 of this book) have supported simultaneous advances in conservation and management. These advances include the selection and design of MPAs, habitat rehabilitation, environmental assessment, and the developing field of seascape approaches to management. Achieving society's aspirations for coastal ecosystems requires, on the one hand, changes to people's behaviors and greater awareness about the effects of their actions. This cannot be successful without deep understanding of human coastal societies and economies and their interaction with local coastal ecosystems. The greatest challenges to conservation and management will continue to come from larger factors such as global climate change, poverty, population growth and coastal migration, and low development status.

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Appendix

Appendix 16.1 Examples of management tools, actions, and interventions to implement the conservation and management goals reviewed in this chapter

Goal	Tools, actions, interventions
Resilience	Education about ecosystems and functional groups
	Establish MPAs to manage/minimize usage
	Fisheries management to maintain functional diversity (e.g., banning fish traps) and abundant populations
	Global action to address causes of coral bleaching
	Identify and protect source reefs (e.g., via MPAs)
	Identify and protect spawning aggregation sites and other sources of replenishment
	Integrated coastal zone management to protect water quality (e.g., catchment management to maintain water quality)
	Minimize disturbance (e.g., oil spills) to currents connecting source reefs with sink reefs
	Protect connected habitats used by all life history stages of key functional groups (Mumby et al. 2004)
	Rehabilitate habitat and species to increase populations and return keystone species (Jaap et al. 2006)
	Status assessments of key functional groups followed by development of action plans for their conservation (Gladstone 2006)
	Trade restrictions on key functional groups and species
Connectivity	Establish MPAs at well-connected reefs to maintain replenishment of downstream reefs (Roberts et al. 2006)
	Integrated coastal zone management (Furnas 2003) to manage external influences on connected habitats, e.g., land use management, development controls, habitat protection plans, environmental assessment
	Protect connected habitats used by all life history stages of key functional groups (Mumby et al. 2004), threatened species, fisheries species in MPA networks
	Rehabilitate connected habitats (Keller and Causey 2005)
Conservation of representative samples of the variety of species and assemblages	Develop maps of spatial distribution of biodiversity or suitable surrogates such as indicator groups (Gladstone 2002), habitats (Friedlander et al. 2003), environmental gradients
	Reserve selection algorithms to identify cost-effective options for MPA networks (Possingham et al. 2000)
	Selection and design guidelines for MPAs (Salm et al. 2000, Fernandes et al. 2005)
Conservation and recovery of species-at-risk	Codes of conduct for industries (e.g., eco-tourism) that interact with these species
	Community education and participation (e.g., in monitoring)
	Conservation and recovery plans
	Identification, protection and management of critical habitats, e.g., nesting sites (Gladstone 2000), spawning aggregations

Appendix 16.1 (continued)

Goal	Tools, actions, interventions
	International treaties National conservation and environmental assessment legislation Provide alternative livelihoods to communities dependent on threatened species Status assessment Substitute captive breeding for wild harvest (IUCN 2007) Trade restrictions on threatened species, e.g., syngnathids, *Cheilinus undulatus*
Protect water quality	Comprehensive monitoring of water quality, algae, and other ecosystem components Economic incentives (e.g., to encourage landholders to implement sustainable management practices and property level planning) Environmental assessment for new developments (UNEP 2006) Establish targets and priorities (e.g., identify catchments in good condition for protection) Planning for natural resource and land management (e.g., habitat rehabilitation, reduce soil and nutrient loss, minimal use of herbicides and pesticides, protect wetlands, riparian zones, and native vegetation important to maintain and improve water quality) (Furnas 2003, The State of Queensland and Commonwealth of Australia 2003) Public education and awareness (e.g., increasing stakeholders' awareness of the value for water quality of wetlands and riparian habitat) (The State of Queensland and Commonwealth of Australia 2003) Reduce and control point-source inputs via licensing (UNEP 2006), infrastructure improvements Regulatory frameworks (e.g., legislation, guidelines, compliance) Research and information sharing (e.g., distribute research findings to stakeholder groups) Self-management by stakeholders (e.g., industry-led development of best management practice for land, natural resources, and chemical use) (The State of Queensland and Commonwealth of Australia 2003) Stakeholder partnerships (e.g., industry, all levels of government, research)
Assessing the socio-economic context for management	Assess effects of management on stakeholders (Elliott et al. 2001) including the need for provision of alternative livelihoods (Pet-Soede et al. 1999, Elliott et al. 2001), or structural adjustments for displaced stakeholders (Fernandes et al. 2005) Community services and facilities (Hariri 2006) Explore alternative management options with stakeholders (Friedlander et al. 2003, Fernandes et al. 2005) Gender issues (Bunce et al. 2000) Identification of stakeholders (Bunce et al. 1999) Identify and quantify values (market, non-market, non-use) (Ahmed 2004) including costs of current uses (Pet-Soede et al. 1999)

Appendix 16.1 (continued)

Goal	Tools, actions, interventions
	Market attributes (Pet-Soede et al. 1999)
	Organization and resource governance (Elliott et al. 2001)
	Patterns of stakeholders' resource use (Bunce et al. 1999, Gladstone 2000, Cinner and Pollnac 2004)
	Stakeholder characteristics (Gladstone 2000)
	Stakeholder perceptions of the resources and issues (Bunce et al. 1999, Gladstone 2000, Cinner and Pollnac 2004)
	Traditional knowledge (Bunce et al. 2000)
Stakeholder participation	Assistance with management implementation, e.g., installation of mooring buoys (Bunce et al. 1999)
	Combine community development plans with conservation (Pollnac et al. 2001, UNEP 2006)
	Community-based management of MPAs (Pollnac et al. 2001, Beger et al. 2004)
	Demonstrated links between participation and positive conservation and material outcomes for participants, e.g., improvements in fish stocks, living standards (Alcala et al. 2006)
	Incorporation of traditional management practices (Gladstone 2000, Johannes 2002)
	Maintenance of a mechanism that provides for ongoing stakeholder input, e.g., consultative committees (Pollnac et al. 2001)
	Participation in MPA planning by representing the interests of stakeholder groups (Gladstone 2000, Friedlander et al. 2003, Fernandes et al. 2005), providing local knowledge, e.g., spawning aggregations, important species, status of fish stocks, resource-use conflicts (Gladstone 2000, Johannes 2002)
	Partnerships with local rather than central governments (Alcala et al. 2006)
	Provision of information, education, community activities (Pollnac et al. 2001, Alcala et al. 2006)
	Public review and commentary on draft management plans (Fernandes et al. 2005) and environmental assessments
	Stakeholder participation mandated in legislation (Alcala et al. 2006)
	Volunteerism, e.g., community rangers (Alcala et al. 2006), clean-up events (Bunce et al. 1999), education, habitat restoration (Jaap et al. 2006), monitoring (Hodgson 2000), animal rescue
Education	Capacity building and institutional strengthening
	Community outreach (Rodríguez-Martrínez and Ortiz 1999, Browning et al. 2006)
	Diver briefings (Medio et al. 1997)
	Eco-tourism interpretation (Andersen and Miller 2006)
	Education facilities, e.g., aquaria, marine discovery centers, visitor centers, displays, interpretative signage, nature trails (Evans 1997, Browning et al. 2006)
	Educational materials, e.g., posters, stickers, brochures, CDs, DVDs
	Mass media, e.g., radio, newspaper, TV
	Modules in school curricula (Browning et al. 2006)
	On-the-job training and workplace exchanges (Crawford et al. 1993)
	Partnerships with international donors/developed countries (Gladstone et al. 2003)
	Regional training centers (Gladstone 2006)
	Stakeholder education

Appendix 16.1 (continued)

Goal	Tools, actions, interventions
	Tertiary education (Smith 2000)
	Training workshops and short courses (Smith 2002)
	Virtual education, e.g., internet discussion forums, list servers, e-mail exchanges, International Coral Reef Information Network's–Coral Reef Education Library
Manage at the appropriate spatial scale	Analysis of regional issues and root causes (Gladstone et al. 1999)
	Formal adoption by national governments of regional/national actions (Miclat et al. 2006)
	Identification and participation of national and international stakeholders (Gladstone et al. 2003, Miclat et al. 2006)
	Legally binding regional conventions and issue-specific protocols (e.g., protected areas, pollution, biodiversity conservation) (Gladstone 2006, Miclat et al. 2006)
	Programs of complementary regional and national actions to address issues, e.g., MPA networks (Gladstone et al. 2003, Miclat et al. 2006), education, pollution reduction, capacity building, monitoring, regional database and GIS (Gladstone 2006)
	Regional coordinating mechanism (e.g., secretariat), advisory body of representatives of participating governments (Gladstone et al. 1999)

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