Chapter 23

Island Systems

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BOXES

FIGURES

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*This appears in Appendix A at the end of this volume.

Main Messages

The coastal, marine, and inland ecosystems of islands provide valuable regulating, provisioning, and cultural services to more than 500 million people. Many small islands have a strong traditional dependence on marine and coastal biodiversity for their food, tools, industry, medicine, transport, and waste disposal. With increasing human population pressures through high migration and reproductive rates, island systems face several serious issues both in the immediate and the near future.

Islands systems, in spite of size, category, climate, and social conditions, share a commonality, identified here as the "isola effect." This represents the physical seclusion of islands as isolated pieces of land exposed to different kinds of marine and climatic disturbances and with a more limited access to space, products, and services when compared with most continental landmasses. In addition, subjective issues such as the perceptions and attitudes of islanders themselves on their conditions and their future on the island are incorporated into the "isola effect."

Coastal fisheries, a particularly important and traditional source of food, protein, and employment on many islands, are seriously depleted. Overfishing has already deprived island communities of subsistence fishing and caused conflicts in many tropical islands across Asia. Island states and their exclusive economic zones comprise 40% of the world's oceans and earn significant foreign exchange from the sale of offshore fishery licenses, but this situation cannot last forever.

Watershed modification on islands has had a negative impact on water resources in terms of water quality and quantity as well as flow regime. Despite limited coverage on some islands, forested watersheds are critical regulators of island hydrology. Without adequate freshwater resources, small islands depend on desalinated or imported water. Island water supply is often threatened by pollution, particularly from poorly treated sewage.

The natural land cover of island systems has changed drastically under the pressure of growing human populations and consequent exploitation of the landmass. On some islands, the impact has exceeded critical thresholds, particularly along the coastal fringe. Anthropogenic changes range from deforestation for cropland to urbanization and the abandonment of degraded land. All these have immediate repercussions on habitat destruction and loss of biodiversity. One conspicuous effect of natural and anthropogenic actions in the coastal zone threatening islands systems is the erosion of soft coastlines (sandy and muddy beaches).

Island systems are highly dependent on outside sources for food, fuel, and even employment, which together increase the economic fragility of many islands. At the same time, island resources are increasingly affected by globalization and trade liberalization. It is questionable whether regional or international groupings of islands, such as the small island developing states, can respond adequately to such pressures.

Energy constraints are particularly critical in island systems. The usually limited size of islands, their constrained capacity to provide ecosystem services (in spite of type or size), and often their distance from large-scale energy supply systems are key factors to explain why energy issues are an important factor in island systems. However, oceans—through currents, tides, waves, and thermal and salinity gradients—offer a source of new renewable forms of energy that remain underexplored.

Low-lying island systems are under threat from climate change and predicted sea level rise. These in turn are expected to have serious consequences on flooding, coastal erosion, water supply, food production, health, tourism, and habitat depletion. The sea level rise would be severe or devastating to millions of people living on low-lying islands and atolls. The projected changes in temperature and rainfall could disrupt terrestrial and marine ecosystems on most islands, especially small ones. Increased flooding and coastal erosion will have serious consequences for the tourism industry. The incidence of dengue fever has been correlated to the Southern Oscillation Index, and extremes in rainfall are likely to exacerbate diarrheal illnesses. Islands need to develop appropriate coastal assessments and management so as to adapt to these changes in a sustainable manner.

The coastal systems of islands, such as coastal forests, dunes, mangroves, coral reefs, and seagrass meadows, are being altered through agriculture, aquaculture, coastal urban sprawl, industrialization, and resort development. In addition, these changes produce further stresses on the island systems, such as the production of sewage, solid waste, and water pollution. These alterations exacerbate the fragility of island systems.

23.1 Introduction

This chapter presents an overview of the status of and trends in island ecosystem services. Its aim is to recognize the services that islands, as a composite of ecosystems, provide to human well-being, to discuss the drivers of change on island systems, and to offer a critical assessment of these drivers in light of the trade-offs between change and ecosystem services.

23.1.1 Overview

Islands differ in their geological and geomorphologic settings and geography, in their physical, biological, climatic, social, political, cultural, and ethnic characteristics, and in their stage of economic development. Yet they share several characteristics that not only unify them as a distinct category but underscore their overall vulnerability in the context of sustainable development (Maul 1993; Leatherman 1997).

As islands and island chains are associated with specific geophysical settings, they are strongly influenced by the surrounding ocean and atmosphere. Their geophysical conditions may result in economic strength for some, but they can pose hazards that threaten the economic viability of others. Some islands are densely populated, and islanders rely on the sea for sustenance and economic viability, but many islands do not have the material or human resources to address the issues that are central to human well-being.

Islands generally have a distinct character or uniqueness, though these component characteristics are difficult to define (Granger 1993). One prevalent idea is that many islands can be defined by their small size and isolation in relation to the mainland, thus justifying a special and differential treatment to small island countries. On the other hand, Srinivasan (1986) has presented an alternate view that "many of the alleged problems of small economies are either not peculiar to small economies or can be addressed through suitable policy measures" and that "causes of economic and social stagnation in some of these economies cannot be attributed to their smallness."

This chapter addresses the environmental issues relevant to the ecosystem services that fit the technical and legal descriptions pertaining to islands and that are unique to these island systems. This uniqueness is here called the "isola effect," which takes into account the particular physical seclusion of islands as isolated pieces of land exposed to different kinds of marine and climatic disturbances and with a more limited access to space, products, and services when compared with most continental landmasses. In addition, subjective issues such as the perceptions and attitudes of islanders themselves on their conditions and on their future on the island are incorporated into the ''isola effect.''

Some emphasis is placed on small island developing states, as they are most at risk from projected global changes. Like other small islands, SIDS share limited physical size; generally limited natural resources; high susceptibility to climatic changes and natural hazards such as tropical cyclones (hurricanes) and associated storm surges, droughts, tsunamis, and volcanic eruptions; and relatively thin fresh water supplies that are highly sensitive to sea level changes. The vulnerability of islands or island economies can be attributed not only to smallness itself but also to the disproportionate impacts of natural disasters. Smaller island systems tend to have limited fertile soils and an unreliable water supply, and natural hazards can seriously affect their economic base. Ecological constraints such as sea level rise, salinization of coastal aquifers, and changes in rainfall distribution are exacerbated in such systems and are expected to increase with climate change and its anticipated oceanic impacts.

Small island developing states, in particular, experience even more specific challenges and vulnerabilities arising from the interplay of socioeconomic and environmental factors, such as small populations and economies, weak public- and private-sector institutional capacities, remoteness from and dependence on international markets, high cost of transportation, limited diversification in production and exports, export concentration, and income volatility and vulnerability due to exogenous economic shocks, leading to greater volatility than in other countries (Nurse et al. 2001; CBD 2004).

23.1.2 Definitions and Categorization

Islands can be defined and categorized in a number of ways, each useful for some purposes, but no single definition or categorization fits all needs. Most available definitions on islands tend to incorporate the size factor (Granger 1993). Additional threshold criteria include remoteness and morphology, population size, and gross domestic product, but their validity remains questionable.

Islands are usually defined as pieces of land surrounded by water, formally smaller than Greenland, which has 2.2 million square kilometers (Gorman 1979). As such, they can include independent island states, archipelagic states, and islands associated with large countries.

Combinations of area and population have been proposed to define islands, such as 13,000–20,000 square kilometers with fewer than 1.0–1.2 million people. The UNESCO Man and the Biosphere Programme consider ''small islands'' to be 10,000 square kilometers or less in surface area and to have 500,000 or fewer residents (Hess 1990). Additional criteria, including surface area, GNP, and population size, were used to define Pacific island systems as ''small,'' ''very small,'' and ''micro'' (Lillis 1993). The Commonwealth Secretariat uses a threshold of 1.5 million people to define ''smallness,'' which is accepted by UNESCO. Of the developing countries and territories with populations below 1 million, 60 are islands and only 16 are not (UN 2002).

From a biological perspective, many islands are small biotopes, with terrestrial (nonmigratory) fauna that have been sufficiently isolated from continents that there have been little if any movements or genetic exchanges with continental populations, leading to local adaptation and endemism (Rosenzweig 1995; Vicente 1999). For migratory species, however, island landmasses are not difficult to reach, and island ecosystems can provide critical habitat for species that are not genetically unique to that island (such as breeding beaches for marine turtles and stopover sites for migrant birds).

Islands can be categorized by physical aspects such as latitude (tropical, temperate, or Arctic), underlying geology or island structure (continental islands and oceanic islands, with the latter subdivided into volcanic islands and carbonate islands), hydrology (a runoff basin area), altitude (high versus low islands) and habitat (suitable habitats for an organism that are surrounded by unsuitable areas, such as mountaintops, lakes, caves, or host plants), land area, or human population or by some political (such as former colonial affiliation) or economic index (GDP). Islands can also be grouped by sociocultural categories—either at the centre or at the periphery of a culture, an economy, or some other national or regional designation. Human colonization patterns provide another distinction. In the Caribbean, for instance, few of the original peoples remain, whereas the peoples of Pacific have been there for at least 2,000 years.

According to Article 121 of Part VII of the International Convention on the Law of the Sea, an island is a naturally formed piece of land surrounded by water on all sides, emerging above the surface of the sea at the highest tide, capable of sustaining human habitation or economic life on its own, and with dimensions that are smaller than that of a continent.

Conceptually, the MA defines islands as lands isolated by surrounding water and with a high proportion of coast to hinterland. The degree of isolation of an island from the mainland in terms of natural and social aspects leads to the ''isola effect.''

For mapping and statistical purposes, the MA uses the ESRI ArcWorld Country Boundary dataset, which contains nearly 12,000 islands, including islands belonging to the Association of Small Island States and in the Small Island Developing States Network. In this chapter, populated islands with more than 0.15 square kilometers of surface area, up to the size of Greenland, are considered islands. In addition, islands had to be separated from the mainland by at least a distance of 2 kilometers, and only when the isolation or the perceptions of the islanders could be verified.

23.1.3 Insularity

Insularity is a distinguishing feature of islands and is influenced by their size to some extent. For example, islands cannot materially modify their macro-climate because of their size, with the exception of the largest, such as Greenland, New Guinea, Borneo, Sumatra, Hispaniola, Madagascar, and Sri Lanka (Granger 1993). Island systems have highly coupled terrestrial and marine ecosystems due to their large ratios of coastline lengths to land area. In such contexts, the impacts of natural or anthropogenic changes are much more immediately visible than for larger continental systems (Brookfield 1990). Moreover, islands with limited areas have limited capacity to buffer or trade off natural hazards or anthropogenic disturbance.

Although insularity is clearly increased by geographic, socioeconomic, and political isolation (Granger 1993), sociocultural factors are probably more important in defining the insular characteristics of islands. The more powerful the links with the outside world, the less pronounced will be insularity, no matter the size of the island.

The perception that islanders have of themselves can be explored further to refine the uniqueness and peculiarities of islands. Human sciences consider ''islands'' as places where the inhabitants see themselves as islanders. The German Brockhaus Encyclopedia's definition of islands includes not only the conventional idea of a piece of land surrounded by water on all sides, but also the idea that water, and especially the sea, permeates the whole of the island—physically and culturally—and that the island is submitted to some kind of insular marine condition leading to the ''isola effect.''

23.2 Condition and Trends in Island Ecosystem Services

Island systems provide important ecosystem services, such as biodiversity, fisheries, energy, fresh water, vegetation cover, traditional ecological knowledge, and tourism. Insularity leads to an obvious strengthening of the linkages between island ecosystem services and people. Over time, these linkages have been further affected by human pressure, which has contributed to an increase in the vulnerability of island ecosystems and to a reduction of species diversity (Baldacchino 2004).

23.2.1 Island Biodiversity

23.2.1.1 Isolation

Surrounded by water, which functions as a barrier to terrestrial animal and plant dispersion, islands provide a clear example of ecological isolation where biodiversity issues assume critical importance through endemism. (See also Chapter 4.) The size, distance, and period of isolation from large landmasses often culminate in high levels of adaptive specialization and thus high levels of endemism. Isolation, as a by-product of biogeographic insulation, is a key factor of evolutionary change, for it allows the genetic reservoir of a population to become distinct from that of other populations. Island isolation has usually led to a high level of plant and animal specializations associated with high endemism, and this is especially true for small isolated oceanic islands (Whittaker 1998; Dullo et al. 2002).

The very nature of isolation is, however, important to humans and biodiversity, for it is their isolation that has often excluded threatening processes from causing the extinction of many species. For example, the red fox in continental Australia has had a devastating impact on native mammals, yet its absence from many of Australia's offshore islands allows mammals that are endangered or extinct on the adjacent mainland to persist (Algar et al. 2002).

23.2.1.2 Dispersal, Speciation, and Extinction in Islands

The isolation of oceanic islands lends itself to another important phenomenon for nonmigratory species: low or no dispersal. Island species, particularly those on small islands, evolved in competition with a relatively low number of other species under the influence of natural selective forces peculiar to insular conditions (CBD 2004). Therefore, the flora and fauna have reduced competitive ability, small populations, and narrow distributional ranges compared with continental areas (Dullo et al. 2002). This is not necessarily true for continental islands (that is, within the influence of continents or large landmasses), which have a more complete fauna that fills the available habitats and closely resembles that of the adjacent mainland portion of the continent (Gibbons 1990). This is the case, for instance, for recently formed forests in Puerto Rico, which are composed of both native and alien species (Lugo and Helmer 2004).

The difficulties in dispersal and the isolation of populations in small isolated islands is due to the barrier that the sea presents to the dispersal of terrestrial species. The number of species on an island is therefore a consequence of area, the distance from continental landmasses, impoverishment, and in some cases competition with species that have become established earlier. The surface of a given region allows us to predict, with a high level of certainty, the number of present species based on the species-area relationship of MacArthur and Wilson (1967). Nevertheless, other authors, having analyzed the influence of constraints other than area, have found alternative variables that help to explain regional predictions of the number or richness of species for particular taxonomic groups, such as the number of vascular plants, vegetation height, or number of soil types (Case 1975; Dueser and Brown 1980).

Rapid speciation is frequent, and morphological and physiological change and adaptation are inevitable in many insular taxa. Adaptive radiation will proceed to the extent that new niches become available, particularly following disturbance events, such as land clearing. General mechanisms that promote population ''smallness'' (*sensu* Caughley 1994) include local catastrophes such as fire, anthropogenic change, direct or indirect killing, introduced predators and competitors, and introduced diseases. Each of these parameters will affect the biota that has become specialized to an insular ecosystem, increasing the probabilities of extinction. Island ecosystems are especially sensitive to disturbances and vulnerable to extinction, which can occur at rates that often exceed those of continental systems. As such, islands have been sites of concentrated extinction: of the 724 known animal extinctions in the last 400 years, about half were of island species, and at least 90% of bird species that became extinct in that period were island dwellers (CBD 2004).

23.2.1.3 Islands as Biodiversity Hotspots

Since island species tend to be concentrated in small areas, the contribution of islands to biodiversity is out of proportion to their land area, and many of them are considered biodiversity ''hot spots'' in global terms (Mittermeier et al. 1998). Although islands constitute less than 7% of the land surface of the world, one in six of Earth's known plant species occur on oceanic islands (Fisher 2004). In addition, endemism is typically high on islands. For instance, more than 80% of vascular plants of Saint Helena and the Hawaiian Islands are endemic (Rosabal 2004). High altitudinal ranges coupled with aridity (among Mediterranean islands) or tropical climes (among equatorial islands) further encourage endemism.

23.2.1.4 Island Biodiversity and Human Well-being

The health and wealth of island ecosystems and the conservation of biodiversity have important implications for the ecological, social, and economic well-being of island populations. Island systems provide habitats for plant, animal, and microbial species inhabiting both marine and terrestrial environments. Together with geological features, these habitats have particular value due to their high endemism or their absence on nearby mainland areas, making islands important refuges for many species.

Marine and coastal biodiversity still remain essential for many islanders, particularly those living in traditional societies, to meet their daily needs for food, tools, industry, medicine, transport, and waste disposal, in spite of new technologies and lifestyles. This is the case for many of the Pacific islands, including the Marshall Islands, Kiribati, and Tuvalu, which together contain some of the highest coastal biodiversity in the world (UNEP 2004c). Biodiversity is a particularly essential component of food security in small, isolated islands.

23.2.2 Fisheries

For many islands, and especially small oceanic islands and island states, fish provide an almost indispensable source of animal protein. In the Philippines, some 1,500 coastal communities (70% of the population) account for 40–60% of the national fish capture (www.oneocean.org). Traditional methods do not generally deplete the fish stocks. However, modern fishing methods, pollution, and the impacts of natural hazards have meant that the limits of sustainable fishing have been reached on many small islands or areas of larger islands. (See also Chapter 18.)

The small islands of the Pacific, Caribbean, and Indian oceans have narrow coastal shelves surrounded by deep waters. A simple fishing pressure index based on estimates of the number of people actively fishing (according to FAO) per kilometer of coastline suggests that fishing pressure is greatest in the China-Philippines area. (See Figure 23.1 in Appendix A.) Overfishing in the near shore of these islands has led artisanal fishers to venture further offshore for access to pelagic resources such as the large tunas. This has led to encounters and conflict with the already well established industrial factory ships of more industrialized countries or other island states fishing in these waters using longlines or purse seines. These conflicts over marine resources are increasingly being arbitrated through the provisions of the United Nations Convention on the Law of the Sea.

The importance of fisheries can be illustrated by reference to the Caribbean, though there are similarities with other regions. The FAO database shows that in both Central America and the Caribbean, about 500,000 people were actively fishing in the 1990s (or less than 0.1% of a total the population of 145 million), with fish protein contributing about 7% of total protein consumption. The export value of fish and fisheries products increased from $400.6 million in 1976 to $1.6 billion in 2000. Per capita annual consumption of fish in the Caribbean is approximately 15 kilograms, which is approximately three times as much as in the United States.

Consumption in several SIDS in the Caribbean is higher than local production and has to be satisfied by imports. These are very high in the insular states and account for the majority of the fish supplied for human consumption—such as in Haiti (70%), Jamaica (78%), and Martinique (80%). The composition of imports in the small island states is dominated by dried, salted, and smoked fish but fresh, chilled, and frozen products are also imported, mainly by countries with a tourism industry. The FAO database shows that exports of fish from the Caribbean (mostly for the U.S. market) have also been growing steadily and in 2000 were valued at approximately $1.2 billion. Export products are dominated by high-value commodities such as shrimp *Penaeus* sp., spiny lobster (*Panulirus* sp.), tunas (*Thunnus* sp.), snappers (Lutjanidae), and queen conch (*Strombus gigas*), which command premium prices on the international market.

Perhaps one of the most important roles of fisheries is the employment opportunities they offer for thousands of people in a region where the high levels of unemployment continue to be a major concern. The fisheries sector provides stable full-time and part-time direct employment for more than 200,000 people and indirect employment for another approximately 100,000 in the secondary sector (processing and marketing), boat building, net making, and other support industries. In addition, it is estimated that each person in the fisheries industry has five dependents, making the total number of people who depend on fisheries for their livelihood approximately 1.5 million. Those engaged in fishing often have low levels of formal education, limited access to capital, and limited occupational and geographical mobility.

Further information on fisheries can be found in Chapter 18.

23.2.3 Fresh Water

The issue of freshwater resources on islands involves many of the same problems facing developing countries in general, including inadequate human and financial resources. However, islands also have unique physical, demographic, and economic features, including relatively limited surface areas and natural resource bases (arable land, fresh water, mineral resources, conventional energy sources), greater sensitivity to natural disasters (typhoons, hurricanes, cyclones, earthquakes, volcanoes), and an isolation from mainland systems—all of which contribute to the vulnerability of their water resources. These all lead to the impact of the surrounding sea being more pronounced for small islands than for large islands and mainland areas.

23.2.3.1 Physical Conditions

Fresh water is scarce in many small islands, which mainly rely on rainfall harvesting, surface reservoirs and flows, or groundwater lens floating on top of the salt water for the majority of their resources. Severe water shortages are often experienced on atolls and raised limestone islands where there are no rivers. The amount of fresh water available on islands is dependant on rainfall, and this varies according to the geographic location of the island and its climate conditions. Natural events, such as El Niño, can result in a shift of expected rainfall patterns so that islands that normally have abundant rain, such as some of the central Pacific islands, may also experience periods of drought.

Vanuatu, for instance, experienced major droughts in 1978 and 1983; Samoa had the same experience in 1971 and 1989; and Fiji in 1987, 1992, and 1997. The 1987 Fiji drought was one of the worst in a century, beginning in the 1986 dry season and extending through the 1986/87 wet season.

The El Niño event in 1997/98 brought some of the worst droughts on record to the Northern Mariana Islands, Guam, the Marshall Islands, Nauru, Papua New Guinea, Fiji, Tonga, Samoa, and American Samoa. The Marshall Islands received slightly over two inches of rain from January to March 1998, just 8% of the norm. After more than four months of the El Niño–caused drought, the Marshall Islands government declared the country a disaster area. Desalination plants were sent to Majuro and Ebeye, the two main urban centers, while smaller water makers were installed on ships to provide fresh water to the outer islands. From August 1997 to March 1998, the highlands of PNG experienced one of the worst droughts on record, creating a national crisis and the need for an airlift of emergency food and water supplies (Lean 2004).

One of the main natural sources of fresh water on islands and in coastal areas is groundwater reservoirs. Water balance is not easy to determine, and average groundwater recharge normally requires in the region of 20–25% of rainfall, which is not easily retained on islands. Although there are several technologies available, islands cannot expect to develop their groundwater resources easily. Overpumping of groundwater through bore holes can lead to salination problems, which can have serious consequences for food production and human well-being. Also, salination may be enhanced by natural hazards, such as sea level rise, that cause higher penetration of sea water into the freshwater aquifers.

In several SIDS, freshwater shortage is amplified by the lack of effective water delivery systems and waste treatment, coupled with increasing human populations and expanding tourism, both of which may result in the overabstraction of water, contamination through poor sanitation and leaching from solid waste, and the use of pesticides and fertilizers (Bridgewater 2004).

23.2.3.2 Desalination

Desalination of the surrounding seawater to provide a source of fresh water is an option that has been explored by a number of islands, but expensive existing technologies mean this it is still a very costly way of supplementing the freshwater supply. Technology to implement reverse osmosis that leads to seawater desalination is proving a useful alternative to improving freshwater supply (Veza 2001). Ocean thermal energy conversion plants are also being proposed for island states not only to generate energy from thermal gradients but to help with the desalination process. (See Chapter 7 of MA *Policy Responses* for more on desalination).

23.2.3.3 Water Quality

Lack of safe drinking water and sanitation is one of the major causes of disease and death worldwide (WHO 2001). On islands, particularly small islands with rugged interiors (such as islands off the east coast of Peninsular Malaysia), people tend to be concentrated on the more gently sloping lands along a coastline. The resulting high population densities can cause problems for the safety of water supplies, which can easily become polluted by poor sanitation facilities or by facilities that are sited too close to the source. Also, the increased use of pesticides and fertilizers and leaching from solid waste disposal sites pose additional pollution hazards to ground and surface water on many islands. (See also Chapter 15.)

23.2.4 Forestry and Vegetation Cover

The extent of forest cover varies greatly among islands (Dulloo et al. 2002; CBD 2004). The forest cover of SIDS represents less than 1% of the forest area of the world. Insular Africa has 0.006%, insular Asia 4%, insular Caribbean 0.15%, and insular Oceania 0.9% of the total forest surface of the world (FAO 2001). In spite of the relatively small area of forest cover in global terms, some tropical and sub-tropical islands have significant forest cover and are characterized by comparatively short distances between upland and coastal forest areas.

Forest is estimated to cover a total of 75 million hectares, or about 63% of the combined land area of 41 SIDS, compared with the world average of 29.6% (CBD 2004). Under such conditions, island forests are critical regulators of freshwater supply for consumption, irrigation, and industrial uses. Forests also contribute directly to food security through the provision of food and animal products. Also on many tropical islands, mangroves are an important source of fuelwood and household products, provide a nursery for many marine fish and invertebrate species, and protect the coast from erosion.

For many of the larger islands, such as Borneo, forests also contribute significantly to the national economy and to the international trade in wood and non-timber forest products (Wilkie et al. 2002). In addition, forest cover buffers against natural hazards and anthropogenic disturbance. The prevention of erosion by forest cover has a direct impact on the health of coastal and marine systems by reducing the sediment load. Forests also play a buffering role, particularly in small tropical islands, against the impacts of tropical storms, hurricanes, and cyclones combined with high rainfall levels (Wilkie et al. 2002). On Hainan Island, where rubber plantations have replaced the local forests, it has been found that the plantations can still have an important hydrological ecoservice function (Jiang and Wang 2003).

Although the overall rate of island deforestation appears to have slowed down in the last decade, annual deforestation on islands is almost three times the world average rate (0.8% compared with 0.3%) (FAO 1999). The main causes of deforestation include conversion for agricultural use and for infrastructure development such as roads, ports, housing, and tourism development (CBD 2004).

Regarding global biodiversity, loss of forests in island systems often has more serious impacts than forest loss in continents due to intensified interactions of various activities within a limited geographic space and to the loss of endemic species and rare ecosystems (FAO 1999).

23.2.5 Cultural Services

23.2.5.1 Traditional Ecological Knowledge

The term traditional ecological knowledge commonly refers to the knowledge that indigenous peoples have about their environment, which is used to sustain themselves and to maintain their cultural identity. TEK covers a wide range of subjects, from agriculture, fishing, plants, and forests to general aspects of culture. (See Box 23.1 and Chapter 17.) Local cultivators, fishers, and other resource users often have a profound knowledge of the highly varied environments that could be better tapped in assessing the potential use of locally available resources and the sustainable development opportunities of their environments.

TEK is an integral part of the dynamics of island systems and the islanders who live there. For example, Indonesia has strong traditional medicine and many varieties are practiced, the oldest being the *Jamu* system of herbal medicine (Erdelen et al. 1999). Some 10% of Indonesia's total flora is estimated to have a medical value, and some 40 million Indonesians depend directly on biodiversity (Erdelen et al. 1999).

In addition, many stories and beliefs of islanders show the role of traditional villages and communities in improving the marine environment. For example, the Balinese believe in the harmony between God, communities, and nature for coastal management, and the traditional village has many roles, including protecting the coastal region from destruction by outsiders, promoting availability of knowledge to communities, assessing problems caused by populations, and maintaining healthy natural resources for the next generation (sustainable development) (Sudji 2003).

The greatest use of TEK on islands relates to sustainable use and management within customary inshore fishing grounds, for example in Fiji (Veitayaki 2004), in the customary prohibition on the use of resources (*ra'ui*) in Rarotonga in the Cook Islands, and in the village reserves in Samoa in the Pacific (MacKay 2001). Traditional ecological knowledge and customary sea tenure are also integrated into the conservation management of bumphead parrotfish (*Bolbometopon muricatum*) in Roviana Lagoon in the Solomon Islands (Aswani and Hamilton 2004).

TEK has also been of direct benefit in the protection of reefs from adverse impacts from commercial and recreational fisheries, scuba diving, snorkeling, aquarium fish collection, and onshore development (Calamia 1996). It has helped ensure sustainable development of the intertidal zone, with a focus on shellfish gathering and marine tenure in the atoll communities of western Kiribati, Micronesia, which are under pressure from population growth, urbanization, extractive technologies, and expanding market opportunities (Thomas 2001). While it is possible to integrate local and scientific knowledge in fisheries (Mackinson 2001), policy-makers and managers find TEK generally unsystematic and its generally unstructured nature makes its difficult to use in regional and national decision-making.

Traditional ecological knowledge has also served as a foundation for the conservation of trees outside forests in small island states of the Pacific Ocean (Thaman 2002). In addition, the knowledge of traditional agroforestry systems and associated traditional knowledge can serve as basis for addressing deforestation, forest degradation, agro-deforestation, and loss of diversity. In Pagbilao, Philippines, ecological knowledge has been shown to

BOX 23.1

Traditional Knowledge That Is Important to Environmental Management (Unit B5 1998)

Agriculture
- The many different varieties of crop plants and their utilization
- The best places, conditions, and times for planting, caring for, and harvesting crops
- Food storage techniques
- Control of crop sicknesses, insects, and other pests
- Management of agricultural land, both seasonally and from year to year; planting sequences or rotations; periods of fallow to allow the land to recover; techniques for soil improvement
- Control of erosion and wind damage
- Identification or classification of soils
- Water management and irrigation, including complex systems of aqueducts and irrigated terraces
- Controls on land use and access to land

Fishing
- Fishing methods and materials
- Knowledge of fish species and their behavior, migration, and reproduction
- Best fishing locations, times, and techniques for each species
- Controls on fishing: limited access to fishing areas, taboo areas or seasons, catch restrictions
- Changes in fishing resources, effects of overfishing, "how things used to be"

Animals and Hunting
- Behavior of species and hunting or trapping methods
- Controls or limitations on hunting: taboo areas, special times for hunting and restrictions to special occasions or special ranks

Plants and the Forest
- Useful trees and the qualities and uses of their woods
- Techniques for cutting and hauling trees from the forest
- Edible plants and plant parts (nuts, leaves, bark, roots, and so on)
- Medicinal plants and their uses
- Genetic resources, varieties, or special features of plants; loss of varieties
- Changes in the forest, loss of forest cover (where the forest used to be)

General
- Traditional names for and classifications of species and communities
- Calendars related to the weather, to celestial bodies (solar and lunar cycles, appearance or movement of stars), or to association with natural events such as the flowering or fruiting of trees or the migration of birds
- Weather patterns and prediction, cycles of rain and drought, changes in climate
- Natural catastrophes, cyclones, tsunamis, floods; signs and warnings; effects and areas affected
- Changes in the environment, past extent of the forest and agricultural areas, former locations and populations of villages
- Environmental knowledge: who possessed it, how it was used and transmitted

improve economic assessment of the mangroves (Ronnback and Primavera 2000), and in the Marshall Islands and atolls, traditional knowledge of medicinal plants serves as an inexpensive way to maintain human health (Nandwani and Dasilva 2003).

TEK has provided new biological and ecological insights, is useful in resource management and environmental assessment, has been used for protected areas and conservation education, and benefits development agencies by providing a more realistic evaluation of the environment in development planning (Berkes 1993; Calamia 1996).

UNESCO's work on the TEK of islands has emphasized that recording and applying traditional ecological knowledge provides one approach to making more effective use of global biological wealth, particularly as a starting point for strategies of integrated conservation and sustainable development. It also recognized that there may be considerable scope for information on techniques and practices refined over generations in one part of a particular geographical ecological region, to be tested and adapted to other localities.

On some tourist islands, the commercial value of traditional knowledge and cultural property is already well recognized through its contribution to income from tourism, arts, and crafts. However, many islanders are justly concerned about the unauthorized and uncompensated use of their heritage, including the appropriation of indigenous arts and cultural expression, similar to the ongoing appropriation of indigenous biodiversity material or knowledge by industrial-world companies and researchers (so-called biopiracy). They are also concerned about the introduction of "modern" agricultural, fishing, and medicinal practices that threaten to replace traditional ways. Biopiracy has been recorded in areas used for ecotourism, and the Maldives and Pacific Island states have been particularly vulnerable to such thefts (GRAIN and Kalpavriksh 2002). UNESCO has recognized that much of the TEK and cultural knowledge is unrecorded and unexploited, and every year part of this knowledge is lost through the loss of natural habitats and transformation of local cultures. (See also Chapter 17.)

Much of the traditional island cultures and environmental knowledge has already been lost in recent decades. For instance, in Pohnpei information on components of Micronesian life—such as planting taro, the use of plants to stun and capture fish, fermentation methods for breadfruits, and construction of outrigger canoes—has been lost as older generations have died (Lee et al. 2001). Traditional knowledge on canoe making and turtle catching are under the greatest risk of loss (Balick 2003).

23.2.5.2 Tourism

Globally, tourist arrivals increased from 25 million in 1950 to 700 million in 2003 and are expected to double by 2020 (Christ et al. 2003). Despite multiple international crises (economic recession, SARS, terrorist attacks, and the war on terrorism), international tourism has grown 4–5% in the past decade (WTO 2001). Tourism is an important contributor to or dominates the economies of many small island states. (See Table 23.1.) The Caribbean is the most tourism-dependent region in the world and accounts for about 50% of world cruise tourism berths, while the Maldives is the most tourism-dependent country.

Tourism based on the natural environment is a fast-growing component of the tourism industry. In the last decade, nature (or eco-) tourism, which can be defined as travel to unspoiled places to enjoy nature, has emerged as the fastest growing segment of the industry, with an estimated growth rate of 10–30% annually

Table 23.1. Tourist Arrivals and Tourism Expenditures as Share of GNP, 2001 (Scott 2003; WTO 2003)

Country	Tourists	Tourism Expenditure
	(thousand)	*(percent)*
Anguilla	47.9	65.1[a]
Antigua and Barbuda	93.1	43.8
Aruba	691.4	42.7[a]
Bahamas	1,428.2	40.0[b]
Bahrain	2420	8.3[a]
Barbados	507.0	28.8[b]
Bermuda	274.9	23.0[a]
British Virgin Islands	296.0	41.3[c]
Cape Verde	115	4.0[a]
Cayman Islands	334	71.7[c]
Comoros	24[b]	7.0[b]
Cyprus	2697	20.2[b]
Dominica	67.9	20.2[b]
Dominican Republic	2,868.9	14.2
Fiji	348.0	12.3
French Polynesia	228.0	10.1[a]
Grenada	123.3	17.1
Guam	1,124.1	71.5
Haiti	142	1.4
Iceland	303.0[b]	4.1
Indonesia	5,153.6	2.4
Ireland	6,749.0	3.1
Jamaica	1,276.5	17.0
Japan	4,771.6	0.1
Kiribati	4.6	4.2
Madagascar	160	2.8
Maldives	461	57.3
Malta	1180	17.3[b]
Marshall Islands	5.4	3.5[b]
Mauritius	660	13.6
Montserrat	10[b]	32.4[a]
New Caledonia	100.5	0.3[b]
New Zealand	1,909.4	4.7
Papua New Guinea	54.2	3.3
Philippines	1,796.8	1.5
Puerto Rico	3551	6.5[d]
St Kitts and Nevis	74.2	22.0
St Lucia	250.1	36.9
St Vincent and Grenadines	70.6	25.6
Samoa	88.3	15.0
San Tome and Principe	7.6	18.7
Seychelles	129	20.1[b]
Singapore	7,518.6	6.1[b]
Solomon Islands	3.4	2.0a
Sri Lanka	336.8	12.5
Taiwan	2,562.5	1.2[a]
Tonga	32.4	4.5
Trinidad and Tobago	383	2.8
United Kingdom	22,833	1.1
Vanuatu	53.2	21.7

[a]1999 [b]2000 [c]1998 [d]1997

(Conservation International 2002). Of the various forms of nature tourism, coastal/marine tourism, including islands, is the largest component. Biodiversity plays a key role in the nature tourism development of many islands and is the major tourism attraction for islands such as Madagascar and Borneo (Christ et al. 2003). Ecotourism extends as far as the subantarctic islands, where special voyages give tourists the experience of a variety of marine and pelagic fauna, using the islands as a base.

There is a great potential in many SIDS for the further development of ecotourism, which is often a small but rapidly growing share of their market economy. Ecotourism can provide employment and generate income while helping to protect and conserve natural resources and contributing to the implementation of national biodiversity action plans (ECOSOC 2004).

Tourism has a great potential for biodiversity conservation and the promotion of the sustainable use of natural resources. In the Seychelles, for instance, tourism has been a major force and source of funding for biodiversity management and conservation, as well as ecosystem rehabilitation. In many cases, tourism is the only means by which a management infrastructure can be put in place on isolated islands to enable conservation activities. Indeed, well-informed tourists are increasingly the driving force behind the tourism industry's involvement in biodiversity management (Chafe 2004).

Rapid and uncontrolled tourism growth can be a major cause of ecosystem degradation and destruction, however, and can lead to the loss of cultural diversity. Often, such destructive development paths start with tourists discovering a destination that rapidly develops beyond its carrying capacity and eventually fails to meet tourism demands and expectations. Such developments have been spontaneous or frequently without adequate enforcement of planning laws and guidelines. Alternatively, tourism can be developed in a more careful, planned manner, with government input and a more responsible approach by developers. Smaller resorts, such as the island resorts in the Maldives (Domroes 2001) and other small tourist enterprises on many islands, have been developed successfully. Large integrated developments, such as Nusa Dua in Bali and Bintan Beach International Resort on Bintan, both in Indonesia, require large investments, depend on large tourist flows, and are more difficult to implement.

Tourism development without proper planning and management standards and guidelines poses a threat to biodiversity (Christ et al. 2003). This is compounded by the fact that environmental impacts are often not clearly visible until their cumulative effects have destroyed or severely degraded the natural resources that attract tourists in the first place, and some destinations have only recognized the costs of environmental damage after significant and often irreversible damage has been done. As a consequence, many SIDS have embarked on initiatives aimed at building a wider, more sustainable support base for the tourism industry among the local population, promoting participatory action and a sense of ownership in order to ensure the success of the industry (ECOSOC 2004). Key measures suggested include ensuring that integrated planning policies and implementation plans provide for environmental impact assessments for all tourism projects and cultural impact assessments for all large tourism operations (ECOSOC 2004).

Within the Caribbean region, fisheries are important not only as a source of food and employment for commercial and subsistence fishers but also for a growing population of recreational fishers—those fishing for pleasure and relaxation rather than for commercial gain or subsistence. Dozens of international, regional, and national fishing tournaments are held each year throughout the region. In most Caribbean countries sport fishing is promoted by tourism interests and is neither monitored nor regulated by the national fisheries administrations. In addition, watching coral reef fishes and other marine life has always been an important leisure activity of thousands of locals and tourists, and skin divers and scuba divers in the Caribbean. Over the past two decades, several countries have established marine parks and aquaria to use these resources and to promote education and conservation of their marine resource systems.

23.3 Drivers of Change in Island Systems

The stresses imposed on island systems are the result of the interplay of environmental and sociocultural factors that together have the potential to increase the impact and reduce the resilience or ability of the islands to cope with changes relative to mainland ecosystems. Like continental populations, people on islands must be able to survive the stochastic variations in their environment. However, natural hazards and anthropogenic disturbance, such as deforestation, unsustainable agricultural practices, mariculture, habitat loss, and biodiversity loss, may assume a disproportionate importance in island systems for several reasons, often depending on the latitude.

For example, some equatorial islands (such as those in the Caribbean) can have rapid rates of vegetation regeneration, as evidenced after cyclones, whereas many arid islands (such as those in the Mediterranean) do not. These differences in responses to change reflect rainfall patterns and the degree of isolation. Contrary to what happens on continents, where species immigration generally occurs rapidly, leading to recolonization, catastrophic events on some islands can have long-term effects because extinction rates are higher and rates of recolonization are much lower (Vitousek et al. 1997; Courchamp et al. 2003). Small populations are also far more prone to random nonadaptive changes in their genetic pool and consequently to chance extinction. The main drivers of island ecosystems are both natural and anthropogenically induced, and both are addressed in this section.

23.3.1 Population Issues

It is estimated that by 2025, 75% of the world's population will live within 60 kilometers of the sea, which can be considered "the global coastal zone," where more than 70% of the world's metropolises are located (UN 2002). A high proportion of this occupancy will be on islands of developing countries. (See also Chapter 19.)

Population growth in cities contributes to urbanization, and this is a serious and growing problem for some islands, particularly among those in Asia, such as Java and Luzon. Many cities on these highly populated islands cannot currently provide the basic resources for the well-being of the inhabitants. Among the Pacific islands, populations are small, but growth and rapid urbanization are also putting pressure on limited resources (Zann et al. 2000)

For many islands in the tropics, the traditional activities of the coastal population have been subsistence production, such as fishing and agriculture. With rising numbers of people moving to coastal areas and islands, conflicts over coastal resources and human values and expectations will increase in the years to come. These are further accelerated by the sociopolitical, cultural, and economic differences between the traditional inhabitants and the newly arrived populations. These differences are more evident among developing countries (where most of the tropical islands occur), which may be subject to huge and rapid internal migrations.

23.3.1.1 Outmigration

Outmigration has been a familiar process for many islands and affects the population balance beyond those related to natural birth and death rates. Outmigration may be due to the impact of outside forces or internal drivers, as when an island's economy is based on a single specialized crop that fails due to disease or market changes. For example, the Asian economic crisis of 1997–98 influenced the extent and nature of population movement between Java and the Outer Islands of Indonesia (Hugo 2000). It may in part be a response to environmental constraints at home and perceived opportunities elsewhere. For instance, migrations from many of the small island states of the South Pacific and the Caribbean have been to metropolitan countries (Connell and Conway 2000).

On many small islands dependent on fisheries, the combination of overfishing and environmental stress has led to outmigration, mainly of young adults. This can alter the size of an island's population, leading to a shift in age groups toward an older society (Hamilton et al. 2004).

However, the benefits of out-migration have also been recorded. One study on the Samoan Islands in the Pacific suggests that out-migration from rural regions generally tends to preserve the local natural environment, leading not only to a more satisfactory use of agricultural and grazing land but also to a greater retention of native species diversity (Baker and Hanna 1986). Yet people who migrate from developing rural societies to urban societies generally suffer a decline in many physical and psychological aspects of health, even though life expectancy may rise.

23.3.1.2 Role of Gender

Gender issues have not been clearly identified as affecting island societies, but this does not mean that islands have no problems related to gender inequality. Indeed, they exist and seem to be related to the same kind of issues that promote gender inequalities in continental societies. Nevertheless, the "isola effect" could increase the problems. For example, in some islands matriarchal societies appear to be driven by isolation together with other factors (such as out-migration by males). Gender inequalities are most clearly related to socioeconomic underdevelopment, a common condition of many island populations (Browne 2001; Lewis 1998).

23.3.2 Energy Issues

Although ecosystem services provide low amounts of energy nowadays (wood, biomass, and so on), energy issues are critical for islands, as unanimously recognized at the SIDS conference in Mauritius in January 2005. The availability, constraints, or scarcity of energy sources are important drivers of changes for island ecosystems and human well-being, particularly enhanced under the "isola effect." Some islands have developed around the fossil fuel industry, but in many islands the import bill for fuel alone exceeds earnings from exports (Roper 2005), lowering the capacity of improving human well-being and, consequently, increasing the pressure over natural ecosystems. Also, the potential hazard to islands linked with the operation of power plants not based on renewable sources (fossil fuels and nuclear power), where size is a factor, could outweigh the benefits of these sources to the island's people and ecosystems.

With imported petroleum being the main source of primary commercial energy (ECOSOC 2004), developing further renewable and unconventional energy sources for islands is a key issue. Islands are usually well suited to use combinations of modern renewable energy technologies and energy efficiency due to the availability of renewable energy resources and current energy consumption patterns (Roper 2005). New technologies have been developed (Cavanagh et al. 1993) that harness the energy of the sun, the wind, the earth, and the ocean, and these can be specifically targeted for usage among island systems.

The world's oceans, where islands are interspersed, represent an enormous and virtually untapped source of clean, non-polluting renewable energy (see Table 23.2). Among the facilities that the ocean offers to islanders, renewable sources of energy can be listed at the top, including the capacity of ocean tides, waves, and currents to generate energy and the extraction of power from the thermal gradient of sea water (Penny and Bharatan 1987; Sanders 1991). Technological breakthroughs, standardized plant designs, increased fossil fuel prices, market instabilities, and increased world concern over environmental issues such as climate change will increase the pace at which ocean biomass, wave, tides, the current, and ocean thermal energy conversion systems are tapped.

In a number of SIDS, small-scale solar photovoltaic power systems have been used to provide electricity in rural areas on a pilot scale, but more work on financing and institutional arrangements is needed to realize their full potential. Moreover, there is a need for technology transfer and national and regional capacity building in renewable energy and energy efficiency (ECOSOC 2004).

23.3.3 Invasive Alien Species

A major threat to oceanic island biota today is the increasing breakdown of the insularization of their habitats (Whittaker 1998). Invasive alien species are one of the primary threats to biodiversity on most islands and have caused serious ecological and economic damage and high social costs (e.g., Courchamp et al. 2003; Veitch and Clout 2002). Invasive plant and animal species often outcompete native insular species directly or indirectly for common resources and can alter the ecosystem processes of an island.

Overgrazing by introduced stock, for example, has had an adverse impact on Mediterranean islands because of the aridness of the land. The introduction of the brush-tail possum (*Trichosurus vulpecula*) to New Zealand and its offshore islands has had devastating impacts on forest systems (Atkinson 1992). Sub-Antarctic Macquarie Island, 1,500 kilometers south of Australia, has seen a host of exotic species (particularly cats, rats, rabbits, and mice) introduced either directly or indirectly by sealers (Cumpston 1968), and the impacts of these species on endemic birds and flora has been significant (Taylor 1979; Copson and Whinam 1998). Another example of the impact of invasive species is the introduction of the brown snake (*Bioga irregularis*) into the formerly snake-free island of Guam in the 1940s. This led to the loss of 10–13 species of native forest birds and several lizard species, and power outages occur frequently as the snakes contact electrical lines and generation facilities. The cost to the island's economy from the establishment of this single invasive alien species is estimated at $5 million a year (Fritts 2002).

Table 23.2. Potential Energy Outcomes from Ocean Sources (POEMS 2004)

Resource	Power (terawatts)	Energy Density[a] (meters)
Ocean currents	0.05	0.05
Ocean waves	2.7	1.5
Tides	.03	10
Thermal gradient	2.0	210
Salinity gradient	2.6	240

[a] Expressed as proportional to the length of the water column.

The invasion of exotic species onto islands is a worldwide phenomenon, but it is uncertain whether islands are more susceptible to invasion than mainland sites (e.g. Sol 2000). The level of invasion depends on how and to what degree the native biotic community is disrupted and on the resilience of an island's ecosystems. In theory, the ecological impacts of invasive alien species on islands can occur in the same manner as on mainland ecosystems. However, these impacts are usually more rapid and more pronounced on islands due to their vulnerabilities (CBD 2004). Approximately 80% of documented introductions (planned or unplanned) of birds and mammals have been to islands (Ebenhard 1988). The effects of such introductions have often been so devastating on the native flora and fauna that it is claimed that invasive alien species are among the main environmental hazards to island systems (Vitousek et al. 1997) and have an ability to create an ecological homogenization of the island's ecosystem in addition to influencing other agents of global change (Mack et al. 2000).

Diseases and their impact on native flora and fauna have often been associated with recent island invasions, yet they remain understudied in insular environments. Avian malaria, introduced into Hawaii in exotic birds by settlers, spread through the endemic bird populations following the introduction of the southern house mosquito (*Culex quinquefasciatus*), which acted as vectors for the waterborne parasite (Van Riper et al. 1986). Similarly, the invasion of black rats (*Rattus rattus*) onto Christmas Island is believed to be responsible for the extinction of the bulldog rat *R. nativitatis* (Day 1981). The speed of introduction and spread is increasing. On the Galapagos Islands, the number of introduced plants has doubled since 1990 from 240 species to 483, now representing 45% of the total flora. In Hawaii, naturalized species account for about 47% of the flowering plant flora (CBD 2004).

There is a realization that invasions of alien species can sometimes be managed with adequate human intervention through good planning, adequate techniques, and sustained effort (Clout and Veitch 2002). However, the feasibility of eradications of invasive aliens on islands will depend on the size of the island, available resources, the public will to undertake control programs and ensure effective quarantine, and the secondary effects of the eradication action on non-target species and other benign alien species on the island. For example, ecological release may allow one alien species to become invasive following the removal of another invasive species, with no net benefit to native populations (Zavaleta 2002).

Three main issues have been identified that can help assess whether islands are subject to a higher risk of invasion than mainland areas: the opportunities for exotic species to reach islands, whether exotic species are more likely to establish on islands, and whether exotic species have a greater impact on island systems (D'Antonio and Dudley 1995). An analysis of those criteria suggests that some island systems are more likely to be invaded by alien species than similar mainland systems because there are fewer resources to deal with risk management (D'Antonio and Dudley 1995). However, it has also been argued that not all islands show evidence of higher invasion than mainland sites (Sol 2000).

Response measures needed to prevent and minimize the impacts of invasive alien species are generally known, though many island nations and territories lack material or human resources to prevent the introduction of or to control or eradicate alien species that threaten ecosystems, habitats, or other species (Veitch and

Clout 2002). The key to quarantine of invasive species is to use early detection mechanisms together with rapid-response mechanisms that can be managed with sufficient funds and powers to see eradication campaigns through to completion (Simberloff 2000).

23.3.4 Habitat Loss, Pollution, and Land Degradation

Island biodiversity has unique biological characteristics, since isolated islands provide ideal conditions for the development of new species with specialized traits. Habitat loss, through pollution, land clearing, and natural hazards, is clearly associated with biodiversity loss, expressed either as population declines or species extinctions.

Chemicals imported for agriculture, industry, transportation, health services, and households are a growing source of pollution among populated islands. Poorly treated sewage emptying into coastal areas is the major chronic pollutant and contributes to coastal nitrogen and phosphorus eutrophication and harmful algal blooms. On islands, the cumulative impact of household runoff from baths and sinks that eventually drains into the sea is also a major contributor to ecosystem decline but is frequently overlooked. This condition occurs because most people living within the coastal zone and the majority of the hinterland population in most island developing states are not connected to centralized sewage treatment facilities. A complementary problem is widespread bacteriological contamination of groundwater from soak-a-way septic systems. Added to this severe nutrient and bacterial pollutant load in coastal areas and groundwater is the addition of fertilizers and pesticides from industrial and agricultural activities.

Due to the short-term nature of the numerous pollution studies carried out on islands, it is difficult to assess the overall pollution condition or trend. However, a proxy indicator may be used, such as a simple sewage pollution index based on the number of people without access to safe sanitation per kilometer of coastline (equivalent to the density of a population living within 100 kilometers of the coast without access to safe sanitation divided by the length of coast).

Because of the complexity of initial attempts to use topography to define the extent of the coastal zone, this study assessed the level of direct human modification of the coastal zone by examining the population within 100 kilometers of the coast. The estimate was derived for the World Resources Institute using a spatially explicit database reflecting global human population (CIESIN et al. 2000). Figure 23.2 (in Appendix A) suggests that coastal sewage pollution is a ubiquitous problem around the world except for industrial countries in North America, Australia, and Europe. Regionally, the Philippines, Latin American, Caribbean, and African and Asian islands stand out as having significant problems.

Although the deleterious effects of pollution are generally recognized, the focus of attention is usually on the immediate aesthetic affects of very visible pollutants, such as garbage and oil spills, or on the human health effects of bathing in contaminated marine waters rather than the long-term deleterious effects of the decline in the ability of an ecosystem to sustainably provide services such as fish or coastal protection. Yet in the long term it is the chronic rather than episodic pollution that has the greatest impact on the limited ecosystem services of islands (Mohammed 2002; Burke et al. 2001).

Increased amounts of hazardous waste are often associated with limited facilities for waste disposal in island systems. As such, many inhabited and uninhabited islands face increasing problems of coastal pollution of land origin, as well as external pollution threats, which may include hydrocarbon pollution originating from local and international shipping and offshore activities and the fast-growing threat of disposal of the toxic wastes of industrial nations in the exclusive economic zones of developing islands and at land sites from which coastal waters can become contaminated. Incidents of dangerous and illegal pollutants being discharged into streams and oceans have increased on islands, with growing urbanization and establishment of manufacturing industries, as a result of, among other factors, inappropriately sited and poorly managed garbage dumps, poorly planned development, inadequate disposal methods, and destruction of and encroachment onto coastal habitats (UNEP 2004a, 2004c). Moreover, the use of agrochemicals has become standard practice in the agricultural production systems in SIDS to respond to export requirements (CBD 2004). The fertilizers, pesticides, and herbicides required to maintain high crop yields contaminate aquifers and affect the biology of sensitive riverine and coastal ecosystems (UNEP 2004b).

Islands are also facing increased problems of coastal and beach erosion due to inappropriate forms of coastline engineering and tourism development that often use coral and beach sand as building material. The degradation of critical ecosystems like coral reefs, mangrove forests, and seagrass meadows reduces the natural defenses of the coast, increasing the potential of erosion from hurricanes and storms. Coastal problems are aggravated by the vulnerability to environmental change of many coastal habitats, such as coral reefs, seagrass beds, and mangroves. Deterioration in coral reefs, for example, is caused by sewage discharge, often aggravated by tourism, and by land runoff in the form of erosion products and chemical fertilizers and pesticides. (See Chapter 19.)

23.3.5 Economic Changes

The issues and priorities relating to economic development differ from one island group to another and reflect the nature of the island systems and the extent of use of island resources. For many small island states, constraints to economic development include a small population size, with limitations in terms of trained and skilled personnel; limited exploitable land; an often weak infrastructure (transport, energy, communications and the basic service sectors, and health and education); distance from foreign markets; a restricted and undiversified natural resource base; heavy dependence on international trade; and often amorphous exclusive economic zones with little or no protection from poaching by foreign fishing or from mineral exploration interests.

23.3.5.1 Land Ownership

Land ownership can be an important driver of island ecosystem change. For example, customary land tenure in island countries such as Samoa, Papua New Guinea, or the Solomon Islands makes it difficult to lease land for tourism, forestry, mining, or extensive farming. Within the Pacific, land is a particularly sensitive issue, especially in the tourism sector (Samoa 2003).

23.3.5.2 Access and Transportation

The geographical isolation of an island has a number of implications for its economy. The sourcing of raw materials and inputs from overseas markets can be costly when minimum volumes are required for orders. Due to this isolation from major markets, downstream processing of local products—such as agricultural produce and the drying, salting, and smoking of fish—is necessary. Increased isolation for many islands has meant more reliance on the local environment and resources.

For some remote islands, the provision of transport service by ferries and other forms of communication is expected to play a crucial role in influencing island population levels, economy, and quality of life (Cross and Nutley 1999).

23.3.5.3 Economic Diversification

Many island states have attempted to diversify their economies. One approach adopted has been the development of island ecotourism, which currently has a small share of the global tourism market but is growing rapidly, as noted earlier. The development of offshore financial services sectors as a means to diversify island economies has also occurred in a number of islands. This is not an easy measure, however, as experienced by the Seychelles, where substantial and complex levels of legislation and reporting mechanisms have to be in place before an offshore center is deemed internationally acceptable (Seychelles 2003).

Despite their geographical isolation, some islanders have migrated to other islands or countries. Contrary to early conceptions, research has shown remittances and associated spending by returning islanders are not unproductive expenditure but can be a significant form of private transfer of capital. Returning migrants represent people endowed with capital and new skills, which can enrich the economic, social, and cultural capital stocks of island communities, offering better prospects for development than those offered solely by domestic economic opportunities (Connell and Conway 2000). Compared with purely foreign investors, capital from return migrants can be channeled into projects that rehabilitate the island systems, such as capacity building, reforestation, integrated coastal management, policies and programs to address beach erosion, sand mining, and coral reef conservation and protection.

23.3.5.4 Globalization and International Trade

Globalization presents both difficulties and opportunities and has direct and indirect impacts on the biodiversity of islands. Various forms or types of globalization have distinct consequences for island systems (Read 2004).

With increasing globalization, many SIDS are concerned with their growing vulnerability as a whole. This is the result of their size and persistent economic structural weaknesses, as small islands face enormous difficulties integrating into the global economy. Trade liberalization accompanied by the progressive removal of trade preferences (tariffs) has severe impacts. SIDS can be marginalized in a world economy, as they are unable to compete due to high costs arising from their small size and geographical isolation.

For some islands with natural and primary resources, globalization presents an opportunity to gain access to new markets, facilitate the transfer of new technologies, and increase productivity. Their development is therefore dependent on the country's capacity to participate in a world economy, especially in agriculture and tourism. For economic development in many small islands, the choice is to be part of the global economy (Prasad 2001). Their governments encourage investments through transnational firms and policies, but these are sometimes influenced by international agencies such as the International Monetary Fund and the World Bank (Prasad 2001).

Globalization has had negative impacts on many island resources, however, particularly fisheries and agriculture. For example, longline fishery operations opened to foreign investors have negative impacts on migratory species, such as tuna. Increasing fishing efforts and new technology have depleted many local fisheries (Hunt 2003). This is compounded by often-illegal access to and overexploitation of the marine resources in the exclusive economic zones of many island states.

The global agro-food complex has increasingly embraced the most isolated and peripheral small island nations in the Pacific since the 1980s. This has had a negative impact on the environment. In Tonga, for instance, foreign investment has boosted the commercial production of squash pumpkin for Japan, with dire environmental consequences through the excess use of pesticides. And on Niue, taro production for the New Zealand market has destroyed biodiversity, disturbed animal habitats, and depleted soil nutrients, while fertilizers and insecticides have had an enormous impact on the water resource of the atolls (Murray 2001).

Globalization has implications for both individual and groups of island nations. Both have to restructure their economies to tackle mounting globalization, and one way is through the creation of regional markets or partnerships (Read 2004). CARICOM is one example of a successful association of small states.

23.3.6 Short-term Disturbances and Natural Events

Natural hazards, as extreme events such as earthquakes, droughts, floods, volcanic eruptions, hurricanes, and their follow-on effects such as storm surges or tsunamis, have a major impact on natural environments and human well-being at a global scale. The consequences of those same hazards are enhanced by the "isola effect," and they can have an even more critical impact on an island's systems and the well-being of its inhabitants.

Those islands located barely above sea level, such as the Maldives, are among the most vulnerable to the effects of extreme weather conditions and other natural hazards. The limited area of islands and their isolation due to the surrounding sea further increases their vulnerability to natural hazards. The changes in temperature and rainfall projected by the IPCC, for instance, could disrupt terrestrial and marine ecosystems of most islands, especially small ones (Lal et al. 2002).

The low coastal elevations also make the populations vulnerable to vector-borne diseases associated with waterlogged conditions, such as dengue and malaria. For instance, positive correlations between the El Niño/Southern Oscillation Index and dengue fever have been reported in 10 island countries of the South Pacific (Hales et al. 1999). In addition, global changes resulting in extremes of rainfall seem likely to have exacerbated diarrhea illness in many Pacific islands (Singh et al. 2001).

The impacts of cyclones on native wildlife include, among other things, high mortality due to the cyclone itself, starvation as a result of the disappearance of food and feed for long periods after the cyclone, predation of grounded wildlife by domestic animals, hunting by humans, failure to breed, and degraded health of habitats and ecosystems (UNEP 2004a).

Many islands situated near geological subduction zones, such as the islands of Indonesia and the Philippines, are prone to disasters associated with earthquakes and volcanic eruptions. Others, such as islands in the Pacific and Caribbean, are in regions that are subject to tsunamis. Low-lying islands are especially vulnerable to climate-induced hazards from sea level rise and tropical storm surge because of their high coastal-zone-to-land ratio, thereby reducing environmental security.

In general, nature and society are adapted to local climatic conditions. While climate is often considered in terms of averages, the extremes are at least as important in determining a region's climate. For instance, it is becoming clear that a warmer atmosphere will result in a greater number of extreme heat waves. In addition, a warmer atmosphere can hold more moisture, so changes in the hydrological cycle could alter flood and drought patterns at all scales, including islands of any size.

It is already known that tropical cyclones are the major cause of storm surges that affect small islands in the Atlantic, Pacific, and Indian Oceans. The devastating effects of recent hurricanes have received extensive coverage by the media. As mean sea level rises, present extreme levels will be attained more frequently, and new higher levels will result in significant increases in the area threatened with flooding. This will be especially true in areas where the height between sea surge and populated areas is low—in other words, there is a small surge envelope, which is typical for most small islands. Under such circumstances, even incrementally small elevations in sea level would have severely negative effects on atolls and low islands (Forbes and Solomon 1997; Nicholls et al. 1999).

23.3.7 Climate Change and Sea Level Rise

Many islands are likely to be among the communities most adversely affected by climate change as a result of their small size, their economic dependence on a limited number of natural resource–based sectors (particularly agriculture, tourism, and extractive industries), and their limited human and financial capacities (IPCC 2001). Although the full impact of climate change on islands is far from certain, adverse consequences are predicted under probable scenarios for several systems (IPCC 2001). One of the most significant impacts of current climate change is sea level rise. This is predicted to lead to inundation of coastal areas and islands; shoreline erosion and the destruction of important island ecosystems such as coral reefs, wetlands, and mangroves; soil salinization; and the intrusion of saltwater into groundwater aquifers.

The IPCC Third Assessment Report indicated a sea level rise of as little as 1 millimeter a year during the twentieth century (IPCC 2001). During the last hundred years, the sea level has risen 100–150 millimeters, and a further rise in global sea level in the range of 350–1,100 millimeters between 1990 and 2100 is predicted, although local rates may vary from negative to positive values, depending on other localized effects (IPCC 2001). The "best estimate" in this range results in a 660-millimeter rise by 2100. This is mainly attributed to thermal expansion of the upper ocean layers and to melting of glaciers and small ice caps. There are, however, many uncertainties in identifying and assessing the causes of sea level trends. (See Figure 23.3.)

As most islands belong to developing countries, they are especially vulnerable to sea level rise due to their limited financial resources to respond to this and other natural hazards. Several small islands, such as the Maldives in the Indian Ocean and the Marshall Islands and Tuvalu in the Pacific, could face total inundation within this century if rates of sea level rise accelerate. This impact is also predicted for archipelagos such as the Philippines and Indonesia, where millions of inhabitants face displacement from their homes from sea level rise. Most of their populations live very close to the sea, and a rise of as little as a meter could prove devastating. Before their lands are lost underwater, some will face loss of their freshwater supply due to saltwater intrusion, contributing to an increasing shortage of the water supply. Sea level rise will also cause increased pressure on forest reserves due to loss of coastal agricultural land by salination and will lead to migration or loss of wildlife species.

Projected global temperature increases are not expected to have widespread adverse consequences on the terrestrial ecosystems in tropical SIDS (IPCC 2001). Some changes are likely to occur, however, especially alteration of species ranges, an increase

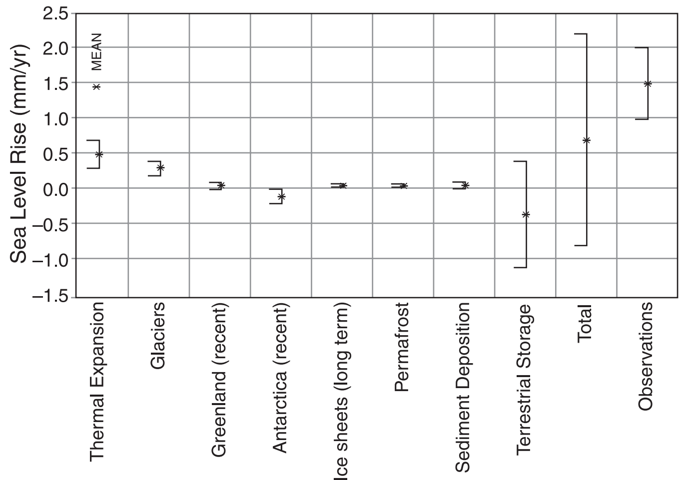

Figure 23.3. Ranges of Uncertainty for the Average Rate of Sea Level Rise and Estimated Contributions from Different Processes, 1910–90 (IPPC 2001)

in forest pest and diseases, reduction of food and water available for wildlife, and an increase in forest fire frequency, especially where precipitation remains the same or is reduced. The quantity and quality of available water supplies can affect agricultural production and human health. Similarly, changes in sea surface temperature, ocean circulation, and upwellings could affect coastal organisms such as corals, mangroves, seagrasses, and fish stocks. Tourism could also be affected through beach erosion, loss of land, and degraded reef ecosystems, as well as changes in seasonal patterns of rainfall (Nurse et al. 2001).

The SIDS account for less than 1% of global greenhouse gas emissions but are among the most vulnerable of all areas to the potential adverse effects of climate change and sea level rise (Jones 1998; Nurse et al. 1998).

Among many relevant examples, Pacific islands provide a clear case study on the issue of climate change and sea level rise. Despite having persistent trade winds and convergence zones, the climate of the Pacific Islands region continues to be dominated by interannual variability associated with El Niño/Southern Oscillation events and by extreme events such as tropical cyclones, floods, and drought. Due to the enhanced greenhouse effect, the region will likely warm by 0.6–3.5° Celsius and the climate may become a more El Niño–type, with the central and eastern equatorial Pacific warming more than the western Pacific and with a corresponding mean eastward shift of precipitation.

Future ENSO events are likely to result in anomalously wet areas becoming even wetter and unusually dry areas becoming even drier (Hay et al. 2003). Also a general increase in tropical cyclone intensity is likely with an eastward extension of their area of formation. With climate change, the Pacific will also experience a rising sea level. However, interannual variations in sea level associated with ENSO and storm surges associated with tropical storms are likely to be of greater significance than a longer-term sea level rise over decades. (See also Chapter 19.)

23.4 Human Well-being in Island Systems

Islands are not being treated here as one global ecosystem. Islands are recognized as systems each with a variety of ecosystems, and thus of ecosystem services. Combining islands of similar geographic latitudes allows for recognition of similarities in ecosystems on islands. But as there is no global "island ecosystem," common conditions as well as common trends cannot be presented at a global scale.

Another issue faced in the assessment of conditions and trends in this chapter is that only a few examples have been selected from particular islands and island groups. It was impossible to include all global islands in this assessment. However, an assessment of certain groups of islands—such as small islands off California, Mexico, and Australia as well as Pacific tropical islands (the Philippines and Indonesia) or subantarctic islands—does allow for general conclusions to be drawn. As people are a major presence in the coastal zones of islands, see also the information on coastal communities and human well-being in Chapter 19.

23.4.1 Vulnerability and Adaptation

The small size of many islands makes the people living there generally more vulnerable environmentally, economically, and socially. Their vulnerability arises from islands' limited resources, export concentration, high dependence on strategic imports, remoteness and high transportation costs, external shocks beyond their control, structural handicaps, and susceptibility to natural disasters exacerbated by climate change and sea level rise.

23.4.1.1 Adaptation to Sea Level Rise

Owing to their high vulnerability and low adaptive capacity to climate change, island communities have legitimate concerns about their future on the basis of the past and present climate model projections. Economic development, quality of life, and alleviation of poverty presently constitute the most pressing concerns of many small island states. Thus, with limited resources and low adaptive capacity, these islands face the considerable challenge of charting development paths that are sustainable and that control greenhouse gas emissions, without jeopardizing prospects for economic development and improvements in human welfare (Munasinghe 2000; Toth 2000). At the same time, islands are forced to find resources to implement strategies to adapt to increasing threats resulting from climate change, a process to which they contribute very little (Hay and Sem 1999; Sachs 2000). Consequently, the already meager resources of these island states will be placed under further pressure.

One of the most serious considerations for some small islands is whether they will have adequate potential to adapt to sea level rise within their own national boundaries (Nurse 1992; IPCC 1998). For islands where physical space is already very scarce, adaptation measures such as retreat to higher ground or a set distance separating structures from the shore would appear to have little practical utility. In extreme circumstances, sea level rise and its associated consequences could trigger abandonment and significant out-migration at great economic and social costs (Leatherman 1997; Nicholls and Mimura 1998).

23.4.1.2 Island Vulnerability

Many studies have tried to assess the ecological and economic vulnerability of island systems along different spatial scales (e.g. Sax 2001; Courchamp et al. 2003). The results of such exercises are somewhat contradictory. Many authors have suggested that the main issues are not isolation and smallness themselves, but development problems, which may be proportionately larger for island systems. According to Farrell (1991), essential problems of small island states have little to do with their smallness and may be more a matter of degree, although he admits that smallness may exacerbate the problem and its effects. An alternative view on the viability-size issue was presented by Dommen (1980), who compared a sample of small island countries with a similar set of continental countries with respect to a number of social and natural characteristics and concluded that size was an important factor.

While all developing countries face challenges in addition to the general problems of development, such as political interference, requirements for environmental friendliness, and sustainability, island nations experience specific problems arising from their limited area of land and thus have a higher exposure to interactions and exchanges of materials and energy flows than continental nations do. This vulnerability is presumed to be negatively correlated with size but is also affected by a suite of other factors: remoteness, geographical dispersion, proneness to natural disasters, the vulnerability of ecosystems to disturbance and human effects, constraints on transport and communication, isolation from markets, exposure to exogenous economic and financial shocks, a highly limited internal market, lack of land natural resources, limited freshwater supplies, heavy dependence on imports and limited commodities, depletion of nonrenewable resources, migration (particularly of skilled personnel), and a limited ability to diversify and to reap the benefits of economies of scale.

Recently, economic hegemony and new communications technology are seriously challenging these concepts of insularity. In economic terms, island-based societies like Aruba, Iceland, Bermuda, and French Polynesia are counted among the world's richest people, while those of São Tomé and Principe, Vanuatu, and the Maldives are counted amongst the poorest (Baldacchino 2004). In short, some islands with a large area but sparse human population and a limited economy that may be classified as small, while others, small in area, have gross disposable products as large as or larger than some continental economies.

There are exceptions to the typical pattern of island vulnerability as defined in terms of size, population, or GDP. For example, Singapore and Barbados have demonstrated that being physically small and lacking significant natural resources are not necessarily limitations to economic growth and prosperity. Also, some of the richest islands are heavily dependent on one or two exports such as tourism and financial services to generate considerable growth. However, all remain vulnerable to external shocks (Clayton 2004; Crowards 2004).

There have been efforts to develop a vulnerability index for small islands for a number of years, as a relatively high GNP per capita gives the impression of economic strength when in reality island economies depend on and are determined by external forces (Briguglio 1995; UWICED 2002). All SIDS have favored the development of appropriate vulnerability sub-indices as measures of the new index. Currently, the vulnerability index has yet to be accepted as an alternative to the dominant GDP per capita measure (Seychelles 2004).

Among some islands, exposure to natural hazards reflects the degree of their vulnerability to change; on others, however, this relationship is not applicable because vulnerability can be reduced through appropriate planning and preparation—as illustrated by reduced casualties from hurricanes in Cuba, which has a high level of planning and state-led provision for cyclones (Clayton 2004).

Some island states have argued for a more positive approach to the concept of vulnerability of island systems through advocating the concept of resilience—that is, increased resilience means decreased vulnerability, and vice versa (Barnett 2001). By recognizing their vulnerability, communities can build their resilience through appropriate actions and programs. Many instances of successful resilience could be emulated; they arise from a combination of factors from good governance, sound macroeconomic framework, market reform, labor productivity, social cohesion, and protection and sustainable management of the environment, including increased energy efficiency, promotion of waste management, improvement of freshwater resources management, and promotion of sustainable use of biodiversity and natural resources (Report 2004).

23.4.2 Integrated Island Systems Management

For island States, the island systems management approach, as a multidisciplinary, integrated mechanism, offers an adaptive management strategy that both addresses the issue of resource-use conflict and provides the necessary policy orientation to control the impacts of human intervention on the physical environment of islands. It was developed by the Organization of the Eastern Caribbean States and adopted by the First Ministerial Meeting on the Implementation of the Barbados Programme of Action (held in Barbados in November 1997). However, its effectiveness depends on an institutional and legal framework that coordinates the initiatives of all sectors, both public and private, to ensure the achievement of common goals through a unified approach.

The long-term development objectives of islands also need to be considered. Despite physical and natural resource limitations, important consideration will need to be given to integrated planning, social cohesion, increased attention to managing biodiversity (in particular, invasive species), and a strengthening of territorial planning if islands are to become economically, socially, and ecologically resilient and self-sufficient.

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