INTRODUCTION

Much of the vast ocean realm that covers the planet is composed of very deep water. Thousands of meters below the surface, the bottom of the ocean lies in complete darkness and is sparsely populated. However, where the seafloor slopes up toward the continental shelf and the flanks of oceanic islands, marine life becomes more concentrated due to the greater availability of sunlight and nutrients from upwelled water and terrestrial inputs. Tropical nearshore areas are comprised of a variety of habitats which are frequently classified according to their dominant substrate, geological, and biological features. While some sandy or rocky substrates are sparsely colonized or devoid of life, others provide habitat for seagrasses and other plant and algal communities. In some hardbottom areas where conditions are right, the seafloor is colonized by a variety of tiny colonial invertebrates known generally as corals. Over millions of years, these tiny organisms have created enormous underwater structures that provide a foundation for an elaborate community of creatures that together constitute one of the most amazing and diverse ecosystems on the planet. An oasis in a vast ocean, coral reefs attract and concentrate a breathtaking assemblage of colorful and fanciful organisms that challenge the limits of the imagination (Figure 2.1). Scientists estimate that this highly complex interdependent system supports over one million species, with potentially millions more yet to be described. In addition to their importance for biodiversity, coral reef ecosystems are important for human communities as well, by performing essential ecosystem services; supporting major fishery resources; providing educational, social, recreational, cultural, and medicinal opportunities; and generating economic benefits for millions of people, especially through coastal tourism.

Figure 2.1. Coral reefs provide the structure that attracts and concentrates a colorful assortment of interesting organisms. Photo: NOAA NOS.

The vibrant underwater world of coral reefs comprises less than 1% of the surface of the planet, primarily due to the narrow physiological tolerances of hermatypic, or reef-building, corals. Nearly all coral reefs are found throughout tropical and subtropical oceans between 30ºS and 30ºN latitude, primarily in waters less than 30 m deep (Huston, 1985; Grigg and Epp, 1989). Their distribution is influenced by nutrient availability, salinity, light, substrate, sediment type, temperature, and exposure to wave action (Lalli and Parsons, 1995; Hoegh-Guldberg, 1999; Szmant, 2002; Leichter et al., 2003; Wolanski et al., 2003). Seawater temperatures in coral ecosystems generally range between 18°–29°C (Glynn, 1996; Barnes and Hughes, 1999), although some corals seem to have adapted to tolerate slightly higher temperatures for short periods of time. Many organisms living in coral reef ecosystems are photosynthetic and are restricted to shallow depths with sufficient light penetration (Veron, 1986; Barnes, 1987).

Shallow-water coral reef ecosystems under United States jurisdiction occur in the shared waters of the Caribbean Basin, Gulf of Mexico, and Atlantic Ocean near the east coast of Florida, and across the Pacific Ocean on both sides of the equator. The Freely Associated States of the Republic of Palau, the Federated States of Micronesia (FSM) and the Republic of the Marshall Islands (RMI) are located in the tropical western Pacific Ocean. Pacific reef systems tend to proliferate on oceanic islands in a number of habitats ranging from offshore banks to shallow atoll lagoons. Many Pacific islands formed as a result of volcanic activity beneath the earth's surface and/or uplift of limestone or sedimentary rock. Movement of the enormous Pacific plate across tectonic 'hot spots' resulted in the creation of several long island chains which developed complex reef systems over time. In general, as soon as lava cools and forms stable, hard substrate, corals begin to colonize the submarine margins of islands as narrow fringing reefs. As the islands age, coral reefs continue to gradually accrete while the central land area slowly erodes and subsides, until, after millions of years, the island itself may

disappear completely, leaving a necklace of low sand islets and extensive reefs surrounding a broad lagoon (Figure 2.2). Cores taken from coral reefs near Bikini and Enewetak Atolls, Marshall Islands revealed coral deposits nearly 1.4 km thick, which are believed to be 50-59 million years old (Spalding et al., 2001). Many stages of island development, from creation by active volcanoes to submergence beneath the surface, are evident in the archipelagos of the Pacific.

In contrast to most Pacific reefs, many reef formations in the Caribbean Basin have developed in shallow-water environments near relatively stable continental land masses. Coral reef ecosystems near continents tend to be older than reef systems on many oceanic islands, and are often subject to greater terrestrial inputs, such as freshwater, sediments and nutrients. To a large extent, reefs located on broad continental shelves benefit from their close association with estuaries and mangrove forests which filter out harmful nutrients and sediments as well as nurture large juvenile fish populations important to reef ecosystems. In turn, shallow or emergent reefs protect fragile coastlines by absorbing wave action during storms and high swells.

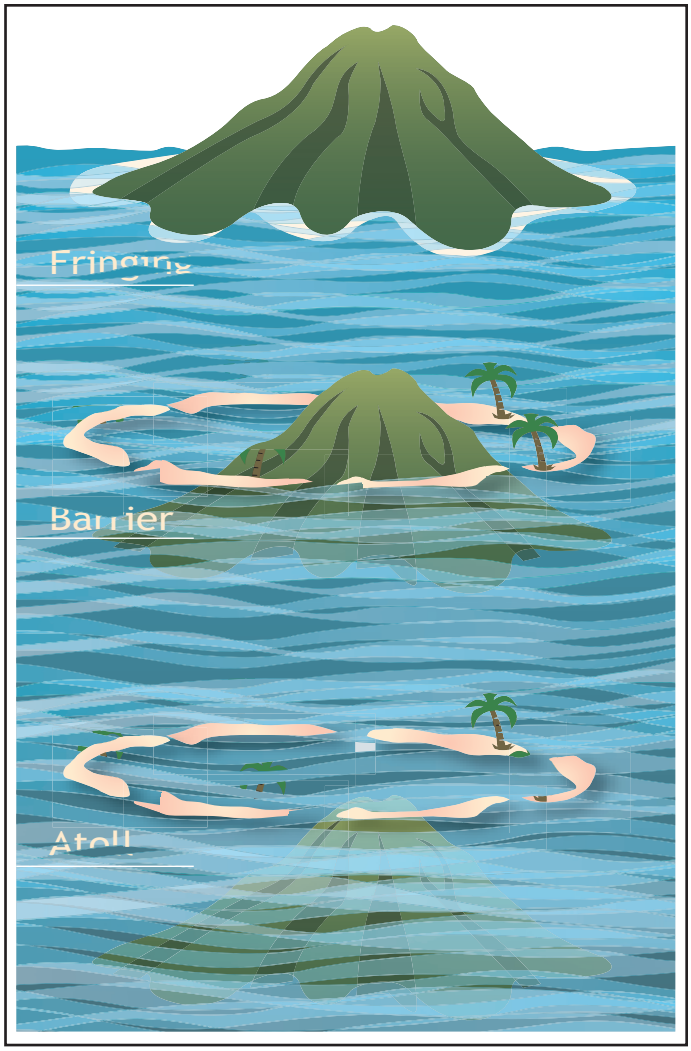

Figure 2.2. A diagram depicting the evolution of a coral ecosystem on a volcanic island. As the island ages, wind and rain erode the land while reefs along the island perimeter accrete.

Coral Reef Ecosystem Components

A coral ecosystem can be considered a mosaic of habitats defined by substrate, cover, and structural zones (Figure 2.3). Benthic habitats found in a coral ecosystem include unconsolidated sediments (e.g., sand and mud); mangroves and other emergent vegetation; submerged vegetation (e.g., seagrass and macroalgae); hermatypic coral reefs and associated colonized hardbottom habitats (e.g., spur and groove, individual and aggregated patch reefs, and gorgonian-colonized pavement and bedrock); and uncolonized hardbottom (e.g., reef rubble and uncolonized bedrock). Typical structural zones include the reef crest, forereef, reef flat, backreef and lagoon (FMRI, 1998; Kendall et al., 2001; Coyne et al., 2003; NOAA, 2003). While hermatypic coral reefs are important marine habitats, other habitats, such as bare sand or seagrass, are also important to the overall ecology and function of the ecosystem. Mangrove forests, hardbottom coral habitats, submerged vegetation habitats, and softbottom sand and mud habitats serve as important spawning and growth areas (Ogden and Ehrlich, 1977; Lindeman, 1986; Parrish, 1989; Christensen et al., 2003; Kendall et al., 2003; Mumby et al., 2004).

Humans in Coral Reef Ecosystems

For thousands of years, humans have lived in coastal areas adjacent to coral reef ecosystems. Coastal and island communities regularly harvested marine resources for food, and in some areas, marine resources provided the primary, if not only, source of protein. In addition to providing basic sustenance to island and coastal communities, reefs have inspired art and legends and provided humans with natural products, jewelry, pharmaceuticals, building materials, transportation pathways, and recreational opportunities. Many cultures cite strong cultural ties to reef ecosystems and resources, and have gone to great lengths to protect the resources from overexploitation, as evidenced by the elaborate systems of reef tenure and conservation practices devised by some Pacific island communities to regulate the use of marine resources.

Figure 2.3. Examples of some of the types of benthic habitats found in the shallow-water coral ecosystems of the United States. Left to right and top to bottom, these are:
1. Mangrove, Salt River, St. Croix, USVI
2. Bare Sand, Midway Atoll, NWHI
3. Macroalgae and sand, Puerto Rico
4. Hardbottom with macroalgae, Kure Atoll, NWHI
5. *Thalassia* seagrass, St. Croix, USVI
6. Linear reef with live coral, Midway Atoll, NWHI
7. Hardbottom with crustose coraline algae, Lisianski, NWHI
8. Spur and groove, Mona Island, Puerto Rico
9. Uncolonized pavement with sand channels, Mona Island, Puerto Rico

Photos: CCMA-BT.

Reef ecosystems also provide intangible benefits that have inspired a long romance with the coast and draw millions of people each year to visit or live near coastal areas of the tropics. On the U.S. mainland alone, 10.5 million people live in areas adjacent to coral reef ecosystems, and island populations continue to increase through population growth and immigration. In fact, population growth and associated development has been identified as a key threat in American Samoa and several other small island states. Tourism and recreational activities also temporarily increase the number of people inhabiting coastal areas. A recent report by the U.S. Commission on Ocean Policy (2004) provides evidence of the increasing importance of tourism and recreation to the economies of coastal communities. Staggering numbers of people visit coastal areas every year to fish, dive, surf and recreate. As a result, the economic benefits from coastal and ocean resources have experienced a fundamental shift from a products-based to services-based system, with tourism and recreation generating more income than mineral and living resource extraction, transportation, and shipbuilding (U.S. Commission on Ocean Policy, 2004).

Coral reef ecosystems found in the U.S. support millions of dollars worth of goods and services (e.g., commercial and recreational fisheries, tourism, etc.). Recent estimates indicate that activities associated with Hawaii's coastal ecosystems produce about $364 million for the state's economy every year (Davidson et al., 2003). Activities associated with Florida's coastal ecosystems contribute an estimated $2.7 billion annually to its economy (Johns et al., 2001). The intangible values of U.S. coral reef ecosystems–such as aesthetic, ecological, and cultural values–are difficult to quantify and are excluded from these economic value estimates.

All of this attention and interest in coastal areas in general, and coral reef ecosystems in particular, are not without consequence. Against a background of natural disturbances, increased disturbance from human activities reduces the resilience of coral reef ecosystems and can contribute to alarming declines in their overall health. Key anthropogenic stressors include climate change and bleaching; disease; urban and tourism-related coastal development; sedimentation; toxic chemical pollution; overfishing; physical damage from ships, boats, and anchors; invasions of exotic species; and marine debris (Davidson, 2002; Wilkinson, 2002; Gardner et al., 2003; NCRAS, 2002).

Setting

The U.S. is responsible for managing and conserving extensive shallow-water coral reef ecosystems within its maritime boundaries in cooperation with local governments of various types. U.S. States with coral reef ecosystems include Florida and Hawaii. U.S. Territories include the U.S. Virgin Islands (USVI), American Samoa, and Guam. The Commonwealths of Puerto Rico and the Northern Marianas Islands also have coral reef ecosystems. Navassa Island is an unincorporated U.S. Territory near Haiti. The Flower Garden Banks lie in Federal waters off the coast of Texas, and some of the banks are managed by the National Oceanic and Atmospheric Administration's (NOAA) National Marine Sanctuary Program in cooperation with the U.S. Department of the Interior's Minerals Management Service. The Northwestern Hawaiian Islands (NWHI) are jointly managed by the U.S. Fish and Wildlife Service (USFWS), the State of Hawaii, and the NWHI Coral Reef Ecosystem Reserve, but the islands have been proposed as the nation's 13th national marine sanctuary, and sanctuary designation seems likely in the near future. The Pacific Remote Island Areas (PRIAs) of the Line and Phoenix Islands and Johnston Atoll are primarily managed by the USFWS as national wildlife refuges, and jurisdiction over Wake and Johnston Atolls is currently in the process of being transferred from the U.S. Department of Defense to the USFWS. The Freely Associated States (FAS) of the RMI, FSM, and the Republic of Palau are sovereign nations that maintain a close economic association with the U.S. and claim similar maritime boundaries. Coral ecosystems of the U.S. and FAS cover a vast area and are distributed across large portions of the earth's surface (Figures 2.4 and 2.5).

Using depth curves depicted on nautical charts as a surrogate for the potential distribution and extent of shallow-water coral ecosystems, Rohmann et al. (in press) estimated that 36,816 km^2 of coral ecosystems may potentially be found in U.S. waters less than 10 fathoms (approximately 18 m) deep, and an estimated 143,058 km^2 in waters less than 100 fathoms (approximately 183 m) deep (Table 2.1).

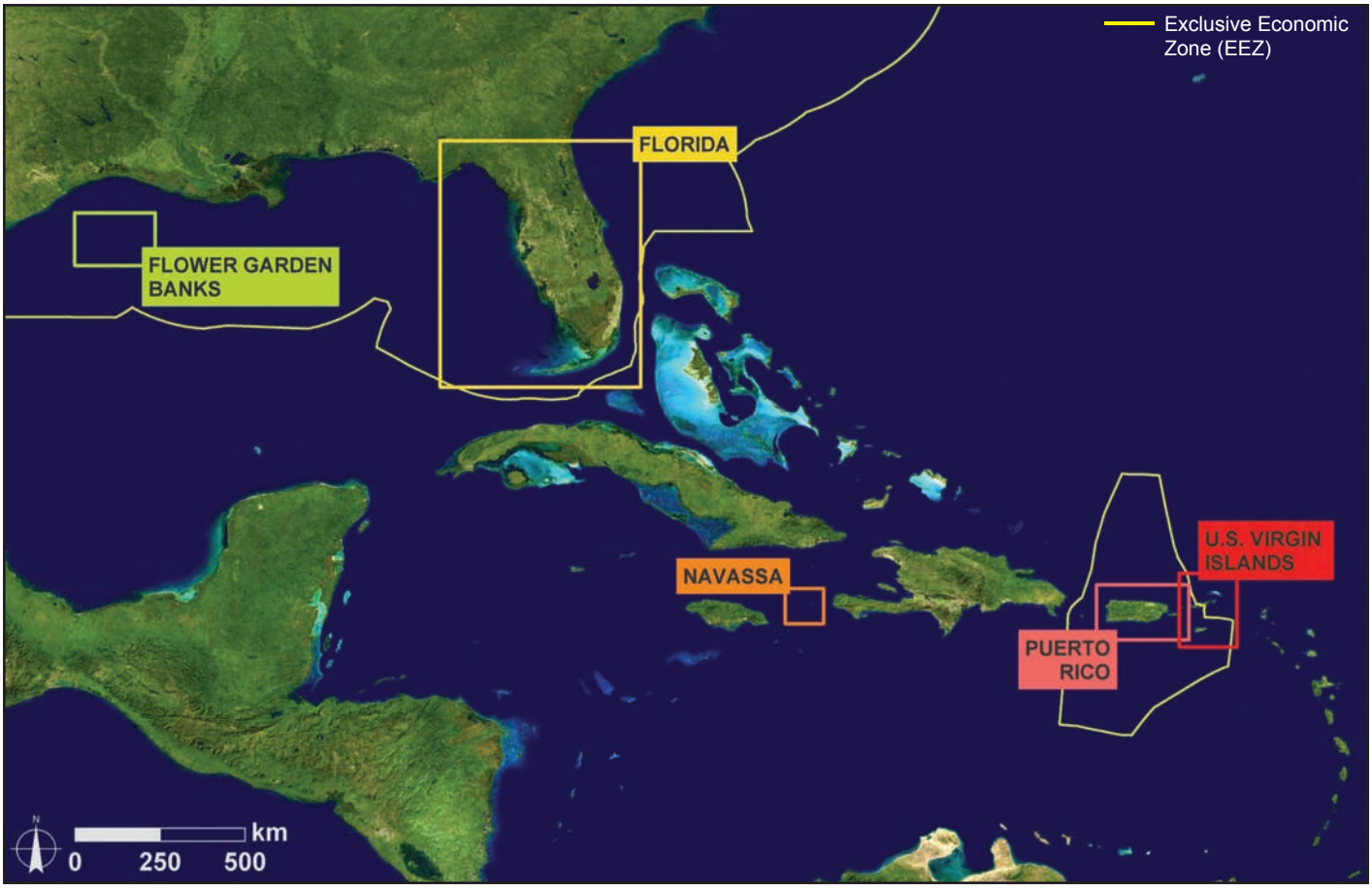

Figure 2.4. A map depicting the location of U.S. coral reef ecosystems in the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea.

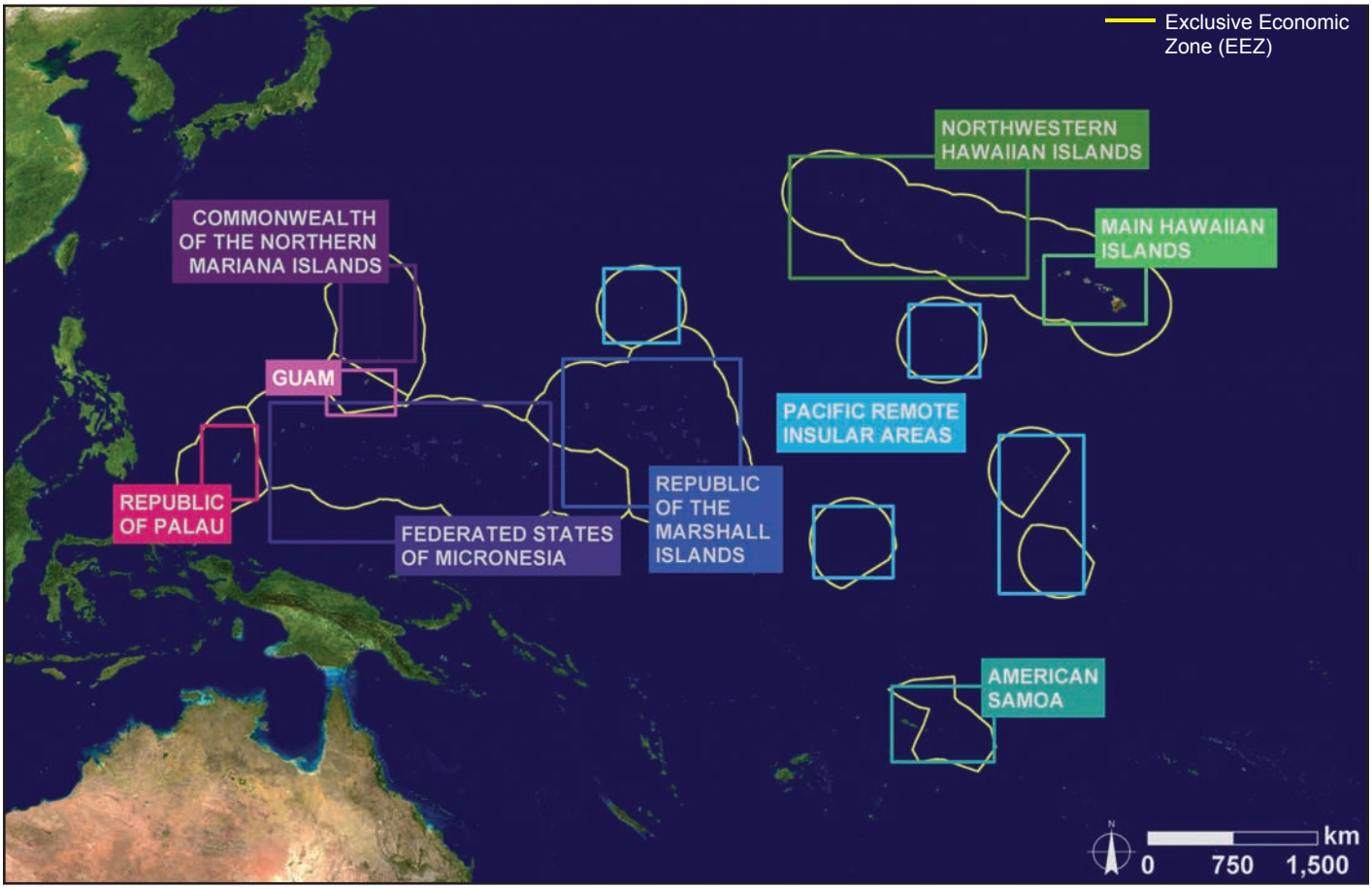

Figure 2.5. A map depicting the location of U.S. coral reef ecosystems in the Pacific Ocean. Maps: A. Shapiro.

Table 2.1. The potential area of coral ecosystems within the United States territorial sea and exclusive economic zone.[a] The area inside the 10-fathom (18 m) or 100-fathom (183 m) depth curves was derived from NOAA nautical charts.[b] Estimates for the RMI, FSM, and Republic of Palau were derived from Landsat satellite imagery. Source: Rohmann et al., in press.

LOCATION	ESTIMATED AREA INSIDE 10-FATHOM (18 M) DEPTH CURVE (km^2)	ESTIMATED AREA INSIDE 100-FATHOM (183 M) DEPTH CURVE (km^2)	AREA OF SHALLOW WATER (<15 M) ESTIMATED FROM LANDSAT IMAGERY (km^2)
USVI[3]	344	2,126	
Puerto Rico[4]	2,302	5,501	
Navassa	3	14	
Southern Florida[5]	30,801	113,092	
Flower Gardens NMS[6]	0	164	
Main Hawaiian Islands[7]	1,231	6,666	
Northwestern Hawaiian Islands[8]	1,595	13,771	
American Samoa[9]	55	464	
Pacific Remote Island Areas[11]	252	436	
Marshall Islands[12]			13,456
Federated States of Micronesia[12]			14,517
Northern Mariana Islands[10]	124	476	
Guam	108	276	
Palau[12]			2,529

1 The U.S. territorial sea (and contiguous zone) extends 12 nautical miles from the baseline of each territory or coastal State. The U.S. exclusive economic zone extends 200 nautical miles from a line coterminous with the seaward boundary (baseline) of each territory or coastal State.
2 Area estimates from Rohmann et al., in press.
3 The U.S. Virgin Islands includes the islands of St Thomas, St John, and St Croix.
4 Puerto Rico includes the islands of Puerto Rico, Desecheo, Culebra, Vieques, and Mona.
5 Southern Florida extends along the Atlantic Ocean coast of Florida to Jupiter Inlet, Florida and along the Gulf of Mexico coast of Florida to Tarpon Springs, Florida.
6 The NOAA nautical chart depicts only the 100 fathom depth curve for this location.
7 The Main Hawaiian Islands includes the islands of Hawaii, Maui, Molokai, Lanai, Kahoolawe, Oahu, Kauai, and Niihau.
8 The Northwestern Hawaiian Islands includes the islands and atolls of Nihoa, Necker, French Frigate Shoals, Gardner Pinnacles, Maro Reef, Laysan, Lisianski, Pearl and Hermes, Midway, and Kure. Numerous shallow-water seamounts, such as St. Rogatein Bank or Raita Bank, also are located in the NWHI.
9 American Samoa includes the islands of Tutuila, Ofu, Olosega, Tau, Swains, and Rose Atoll.
10 The CNMI includes the islands of Rota, Aguijan, Tinian, Saipan, Farallon de Medinilla, Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Farallon de Pajaros.
11 The U.S. Flag Islands include Howland, Baker, and Jarvis Islands, Palmyra, Johnston, and Wake Atolls, and Kingman Reef.
12 Unpublished estimates of potential coral ecosystem area visible in Landsat satellite imagery. Area estimates generally include seafloor features visible in water 18–27 m (10–15 fathoms) deep. NOAA does not produce nautical charts of these locations.

At this time, nautical charts depicting either depth or extent of shallow-water coral ecosystems for the FAS are unavailable. However, an analysis of seafloor features visible in Landsat satellite imagery suggests that coral ecosystems in the FAS may comprise about 30,501 km^2 (Table 2.1).

The spatial extent of shallow water coral ecosystems is just one of several variables that differentiate coral reef ecosystems among U.S. jurisdictions. Perhaps an even more important metric is habitat quality. This metric can be characterized in a number of ways, but high habitat quality conveys the presence of a rugose and varied assemblage of healthy benthic organisms that provide structure for a robust and diverse assemblage of organisms within an environment characterized by excellent water quality with low turbidity, limited nutrients, and few contaminants. Such healthy reef ecosystems tend to support more biomass and a greater number of

species than degraded areas.

Biodiversity, or the number and abundance of species that exist within a region, is another important variable. Global marine biodiversity is believed to be highest in the western Pacific Ocean, near eastern Indonesia, and the total number of species tends to decline with distance from this biological hot spot. As a result, among U.S. and FAS jurisdictions, the Republic of Palau and other western Pacific locations (i.e., Guam, CNMI, FSM and the Marshall Islands) naturally contain a higher number of species than do locations in the eastern Pacific, Caribbean, Atlantic or Gulf of Mexico.

The degree of endemism, or the number of species that are found only within a particular location or region, is another important factor that distinguishes the jurisdictions. Scientists studying remote areas, such as the NWHI, which have a relatively low overall number of species, have recorded a large number of endemic species. Endemic species contribute greatly to the overall diversity of life on the planet and thus constitute an important conservation priority.

Among other important distinguishing characteristics among the jurisdictions is the actual composition of the coral and fish communities. Highly disturbed ecosystems often are dominated by species of coral and macroalgae that are opportunistic and tolerant of negative natural and anthropogenic impacts. Heavily fished ecosystems often are dominated by small, undesirable food fish not targeted by fishers. For corals, the prevalence of long-lived versus opportunistic species may provide some indication of the level of disturbance experienced in a region and thereby the health of the system as a whole.

The prevalence of threats and stressors to coral reef ecosystems also varies among and within jurisdictions. The NCRAS identified thirteen major threats and stressors to coral reef ecosystems that are introduced in the following chapter (NCRAS, 2002). Chapter 4 begins a series of fourteen jurisdiction chapters, in which each jurisdictional writing team provides a condition report according to a standardized structure. Each chapter begins with a few paragraphs of contextual information and a discussion of how each of the thirteen primary threats currently affects their jurisdiction. That information is followed by a summary of current monitoring activities, and project results which are grouped into the three categories of water quality, benthic habitats, and associated biological communities. They then discuss current conservation management activities pertinent to their jurisdiction before providing overall conclusions and recommendations for further action. The final chapter serves as a national-level summary of the preceding information, in addition to providing information about selected national-level developments that are pertinent to all the jurisdictions.

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