A Situational Analysis of MANGROVES in the Mesoamerican Reef System



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Rich Wilson of Seatone Consulting and Lauretta Burke and L. Jasmine Lambert of the World Resources Institute prepared this situational analysis report.

Executive Summary

Mangroves are a globally rare yet highly threatened forest ecosystem, covering approximately 152,000km^2 of the world's surface (Spalding et al., 2010). A total of 73 mangrove species and hybrids are dispersed across 123 countries and territories around the globe. Sustainable long-term management of the world's mangroves is critical to maintain healthy ecosystem function, promote local economic development and ensure the safety and security of nearby populations and associated coastal infrastructure.

A vast amount of literature exists on mangrove ecology, ecosystem service values, and most recently, quantified economic and carbon-based (blue carbon) values. Mangroves support and maintain viable fisheries, sequester carbon, provide subsistence provisions to local inhabitants, filter nutrients and sediment, enable thriving tourism and protect coastlines from waves and storms among many other values (Mukherjee et al., 2014).

Studies also demonstrate that the loss of mangroves in recent decades has been severe. Recent research suggests that 25% of the world's original mangrove cover is gone (Spalding et al., 2010). The primary and emergent human-caused drivers of mangrove destruction include:

- Coastal development (e.g. roads, ports, urban growth and tourism accommodations)
- Agriculture and aquaculture
- Pollution and environmental degradation
- Local exploitation (e.g. wood for cooking or building)
- Rising seas due to climate change

Many activities that damage coastal environments where mangroves thrive—aquaculture, dredging and poorly planned development, discharge of pollution and sewage—are driven by short-term economic gain versus consideration of the long-term impacts to people and nature. Economic valuation helps quantify the ecosystem service values that mangroves provide people. Calculating such values is increasingly recognized as an integral component of natural resources management, economic development and land-use planning (Vo Quoc et al., 2012).

Along the Mesoamerican Reef System, alteration of coastal landscapes is the leading human cause of mangrove deforestation. Climate change, rising seas and a potential increase in the frequency of extreme weather events presents an emerging and perhaps even greater long-term threat. Although each country fronting the reef has taken steps in recent years to improve protection of its coastal environment, the legal frameworks affording specific protections for mangroves generally remain out-of-date, poorly enforced or underdeveloped.

The Mesoamerican Reef Leadership Program (MAR-L) is presented with a unique and timely opportunity to increase awareness of the value of mangroves across the Mesoamerican Reef System, strengthen conservation efforts and promote sustainable long-term management of these important coastal ecosystems. Successful training of the newest cohort of MAR-L Fellows will build individual and institutional competency, foster collaboration at multiple scales, and achieve conservation impacts that extend and evolve well beyond the 2015 program cycle.

Scope and Methodology of the Situational Analysis

In February 2015, Seatone Consulting (Seatone) and the World Resources Institute (WRI) submitted and received support from Fondo Mexicano para la Conservación de Naturaleza for a joint proposal to assist the MAR-L Program in development and execution of its 2015 program cycle. Program staff requested a literature review and situational analysis that describes the status and trends of mangrove ecosystems in the region, identifies current and emerging conservation challenges and opportunities, and includes key considerations that guide MAR-L trainings and Fellow efforts to develop and lead local studies and conservation initiatives.

The literature review focused primarily on mangrove ecosystems along the coastal zone of the Mesoamerican Reef System (Mexico, Belize, Guatemala and Honduras). That said, statistics on mangrove cover and loss were generally more available at a national level for each country versus information specific to the Caribbean coast. Moreover, additional resources were reviewed in order to understand and describe mangroves along the Mesoamerican Reef System within a global context. In total, Seatone and WRI analyzed and distilled information from >100 documents that shed light on the following topics:

- General and regional specific description of mangrove ecosystems
- Documentation of ecosystem services and links with nearby ecosystems
- Economic valuation literature reviews and methods
- National and local mangrove ecosystem inventories and field studies
- Threats to mangrove ecosystems (global, regional and local)
- Hurricane and anthropogenic impacts
- Monitoring and mapping of mangrove ecosystems
- Assessment of blue carbon stocks
- Mangrove restoration programs and techniques

Four primary questions guided the research and subsequent data analysis. In addition, nearly 20 regionally based mangrove experts and conservation practitioners were consulted to help inform the research process and validate findings. Guiding questions included the following:

1. What is the historical and current status and trends of mangrove ecosystems, globally and along the coastal zone of the Mesoamerican Reef System?
2. What type of valuation studies have been conducted to date on mangrove ecosystems, globally and within the Mesoamerican Reef System?
3. What can be said about the goods, services and economic contribution of mangrove ecosystems?
4. What are the current and emergent conservation challenges and opportunities facing MAR-L Program Fellows interested in mangrove protection across the Mesoamerican Reef System?

Finally, this report acknowledges certain limitations of the methodology used to conduct the literature review and prepare the situational analysis.

- *Apparent information gaps*. The desktop nature of the study, supported by contact with local experts and conservation practitioners, revealed a much higher number of resources for Mexico and Belize versus Guatemala and Honduras. As such, a greater level of analysis is provided in these two country profiles.

- *Spanish language limitations*. Neither Seatone nor WRI consultants are fully fluent in Spanish. Colleagues in the region were consulted at times to help interpret Spanish language documents. The authors acknowledge bias based on reviewing and referencing a greater number of English language material.

Importance of Mangroves

Like a tangled net cloaking the coast along tropical and subtropical zones, mangroves are a globally rare yet highly threatened forest ecosystem. Recent estimates suggest that mangrove ecosystems cover approximately 152,000km^2 of the world's surface (Spalding et al., 2010). Often associated with the beauty and biodiversity of the tropics, mangroves provide a wide range of ecosystem services and possess significant economic value for people. Sustainable long-term management of mangroves is critical to maintain healthy ecosystem function, promote economic development and ensure the safety and security of nearby populations and associated coastal infrastructure, particularly in places like the Mesoamerican Reef System.

A total of 73 mangrove species and associated hybrids are dispersed across 123 countries and territories around the globe. Mangroves[1] are trees or large shrubs that are particularly adept at surviving harsh environmental conditions. Their evolution has forged unique survival features in the face of high salinity, anaerobic and waterlogged soils, and a challenging environment for seed dispersal and propagation. Moreover, mangroves are a haven for biodiversity and science continues to show critical interdependencies with nearby ecosystems such as seagrass beds and coral reefs (Mumby et al., 2004; Nagelkerken et al., 2008; Harm et al., 2008). The most expansive mangroves commonly occur at the mouths of rivers, such as large deltas or smaller estuaries. Mangroves can also be found in bays, lagoons and along the open coastline, especially in areas with the right combination of sediments and low wave energy (Spalding et al., 2010; UNEP, 2014).

Mangroves provide numerous ecosystem services that contribute to human wellbeing (Spalding et al., 2010; Vegh et al., 2014; UNEP, 2014). Around the globe mangroves support and maintain viable fisheries, sequester carbon, provide provisions to local inhabitants, filter nutrients and sediment, enable tourism and protect coastlines from waves and storms among many other values (Mukherjee et al., 2014). The economic values derived from these services fall into two categories: direct use value and indirect use value. Direct use value refers to consumptive activities like fishing or wood harvesting, or non-consumptive activities like kayaking or bird watching, which involve a direct interaction with the ecosystem. Indirect use value refers to the services the ecosystem provides, such as storm protection or water filtration.

Generally, direct human uses of mangroves along the Mesoamerican Reef System include fish capture for market-sale and personal consumption, timber harvesting and fuelwood collection,

[1] Unless otherwise specified as a particular species or set of species, the terms "mangroves" and "mangrove ecosystems" are used interchangeably throughout this paper.

shoreline protection, tourism and recreation, education, research, and aesthetic and cultural enjoyment. Specific human uses and values may differ across the four countries. Furthermore, services associated with any given mangrove ecosystem will vary based on location, condition of the mangroves, and specific use by government, business interests or local communities.

Status and Trends of World's Mangroves

Mangroves are well studied the world over. A vast amount of literature exists on mangrove ecology, ecosystem service values, and most recently, quantified economic and carbon-based (blue carbon) values. Studies also show that the loss of mangroves around the world in recent decades has been severe. According to the United Nations Food and Agriculture Organization (FAO), approximately 35,600km^2 (3,560 hectares) of mangroves were cleared or otherwise destroyed between 1980 and 2005. A recent comprehensive compilation of research suggests that 25% of the world's original mangrove cover is now gone (Spalding et al., 2010).

Anthropogenic (human-caused) drivers of mangrove destruction are often the result of land use activities near dense population centers along the coastal zone. Mangroves are also susceptible to degradation and impaired ecosystem function caused by extreme weather events such as hurricanes and tropical storms (Cahoon et al., 2003; Zaldivar Jiménez et al., 2004; Vanselow K.A. et al., 2007). Globally, the primary and emergent anthropogenic threats to mangroves include:

- Coastal development (e.g. roads, ports, urban growth and tourism accommodations)
- Agriculture and aquaculture
- Pollution and environmental degradation
- Local exploitation (e.g. wood for cooking or building)
- Rising seas due to climate change

The continued loss of mangroves around the world threatens countless species that depend on these ecosystems and may negatively impact up to 100 million people living in the coastal zone (UNEP, 2014). Although global losses decreased when comparing the 1980s (≈1.04% per year) to the 2000 – 2005 time period (≈0.66% per year), mangroves are still destroyed at a rate 3 – 5 times faster than any other forest type (Spalding et al., 2010). Recognizing the severity of the situation necessitates thoughtful consideration of the most effective governance approaches, resource management strategies and human behavior that will stem the tide of mangrove destruction around the globe.

The good news is that many tools and techniques now exist to quantify the value of mangroves, as well as map, monitor, and, where needed, restore these unique and valuable ecosystems. Some countries, including along the Mesoamerican Reef System, have established policies, regulations and resource management strategies that strengthen mangrove protection. This trend bodes especially well given that large swaths of mangroves are now found within protected areas and internationally recognized sites (e.g. Ramsar, UNESCO World Heritage) around the world. In the long run, protecting mangroves before they are degraded and need restoring may require less investment and thereby reap greater economic and ecosystem service benefits for people and nature (UNEP, 2014).

Mangroves in the Mesoamerican Reef System

From the northern tip of Mexico's Yucatán Peninsula, south along the eastern edge of Belize and Guatemala, to the northern portion of Honduras—an area collectively known as the Mesoamerican Reef System—mangroves are predominant along the coastal zone, up rivers and around lagoons, and scattered across the region's many offshore islands. A wide range of figures exists for mangrove cover and loss for the larger Central America region, which includes the Mesoamerican Reef System. Table 1 includes estimates of Central American mangrove cover based on publications, maps and satellite images used to prepare the *2010 World Atlas of Mangroves*. Conversely, a 2010 FAO *Global Forest Resources Assessment* estimates that mangrove cover in Central America declined from ≈4,810km^2 (481,000 hectares) to ≈4,430km^2 (443,000 hectares) between 1990 – 2010 (FAO, 2010). Each country profile below describes, among other things, recent mapping and monitoring efforts that have, particularly in Mexico and Belize, significantly improved our understanding of the status and trends of mangroves across Central America generally, and the Mesoamerican Reef System specifically.

Table 1. Estimates of mangrove cover in Central America

Country	Land area (km^2)	Total forest area (km^2)	Mangrove area (km^2)	Number of native species
Mexico	1,908,690	642,380	7,700.57	5
Belize	22,800	16,530	957.53	5
Guatemala	108,430	39,380	177.27	6
Honduras	111,890	46,480	628.00	5

Adapted from the 2010 World Atlas of Mangroves.

Table 2. Mangrove species of Central America (*Mangroves found in the Mesoamerican Reef System)

Species	Mexico	Belize	Guatemala	Honduras
Acrostichum aureum		✓		✓
Avicennia bicolor			Pacific only	
*Avicennia germinans**	✓	✓	✓	✓
*Conocarpus erectus**	✓	✓	✓	✓
*Laguncularia racemosa**	✓	✓	✓	✓
*Rhizophora mangle**	✓	✓	✓	✓
Rhizophora x harrisonii	✓		✓	

Adapted from the 2010 World Atlas of Mangroves.

Mexico

Mexico has the greatest extent of mangroves of any country in the Wider Caribbean, including its Central American neighbors. In fact, Mexico is ranked fourth in total mangrove cover worldwide, following only Indonesia, Australia and Brazil. Mangroves cover ≈7,700km^2 (≈770,000 hectares) across the country, or 5.4% of the world's total coverage (Spalding et al., 2010; Valderrama et al., 2014). That said, several scientists point out that past use of different methodologies to assess total national cover makes it difficult to establish a precise figure (Ruiz-Luna et al., 2008; Valderrama et al., 2014). In the southeast, mangroves occur on all sides of the Yucatán Peninsula, many found inside the boundaries of national parks and Ramsar or UNESCO World Heritage sites. Total cover in states for this region of Mexico is ≈4,237 km^2 (≈423,000 hectares), with 22% occurring in Campeche, 16.9% in Quintana Roo and 12.9% in the Yucatán (Calderon-Alguilera et al., 2012).

Direct alteration of the landscape for human development is a primary driver of mangrove loss in Mexico. Moreover, in some areas pollution or changes in hydrology have caused such extensive degradation that restoration opportunities may now be limited (Valderrama et al., 2014; Zaldivar Jiménez et al., 2010). On the Pacific side of the country, large-scale human impacts are commonly, though not exclusively, attributable to land conversion for shrimp farms, salt production or some other form of agriculture or animal husbandry. Looking to the east side of the Yucatán Peninsula, development of tourism-related infrastructure in Cancun and further south has led to massive loss of mangroves (Spalding et al., 2010). Shrimp farming impacts are present but to a lesser degree than in Pacific states. At the same time, scientists are beginning to understand how mangroves filter pollutants and reduce negative environmental impacts generated from these farms (Zaldivar Jiménez et al., 2012).

The Yucatán Peninsula, and its extensive mangroves, is also regularly susceptible to large-scale hurricane and tropical storm impacts. Moreover, research suggests these extreme weather events may increase in scale and frequency as global temperatures continue to rise (Bender et al., 2010). Studies in the Yucatán Peninsula are distinguishing between the effects of human versus natural impacts on mangroves. Research is revealing the most important agents of disturbance and the influence hurricanes have on mangrove structure, productivity and resilience (Caulderon-Aguilera et al., 2012; Adame et al., 2012). It is also important to note that a relatively new study has quantified blue carbon values across nine sites in the Sian Ka'an Biosphere Reserve, further demonstrating the value that healthy, intact mangroves have in a warming world (Adame et al., 2013).

Mexican researchers and conservation practitioners have long recognized the ecological and socio-economic importance of mangroves. In 2005 the National Commission for the Knowledge and Use of Biodiversity (CONABIO) established a National Mangrove Committee to promote the sustainable use, conservation and restoration of mangroves across the country. CONABIO estimates a 10% loss of national mangrove cover from 1970 – 2005 (Valderrama et al., 2014; CONABIO website[2]). In the Yucatán Peninsula, mangroves were lost at an annual rate of 1.8%

[2] http://www.biodiversidad.gob.mx/ecosistemas/manglares2013/manglares.html.

from 1976 – 2000, though recent research suggests some recovery has occurred, due in part to restoration efforts (CONAFOR, 2010; Valderrama et al., 2014). Researchers calculated the national-level loss estimate by evaluating records from three distinct time periods—1970 to 1980, 2005 and 2010—and are currently working on a 2015 estimate.

One positive trend is that ≈43% of total mangrove cover across Mexico is found within 32 federally protected areas (Spalding et al., 2010). Along the eastern edge of the Yucatán Peninsula, mangroves occur in well known protected areas near Cancun and Puerto Morelos; offshore on the islands of Isla Contoy, Isla Mujeres, Cozumel and the coral atoll Banco Chinchorro; and in the Sian Ka'an World Heritage Site and Biosphere Reserve. In addition, leading mangrove researchers are now utilizing consistent monitoring and mapping techniques at a national level—the Monitoring System of Mexican Mangroves—to further refine mangrove cover and loss estimates, inform resource management and catalyze ongoing restoration work. Scientists in the Yucatán Peninsula have developed a robust methodology for mangrove restoration and efforts are underway at several sites. Restoration programs, one study notes, should focus on appropriate site identification, characterization of environmental conditions and development of clear program objectives (Zaldiver Jiménez et al., 2010).

Belize

Internationally recognized as "Mother Nature's Best Kept Secret," Belize is renowned for its lush rainforests, ancient Mayan ruins, beautiful mangroves and beaches, and close proximity to the largest coral reef system in the western hemisphere. Situated between Mexico to the north and Guatemala to the east and south, Belize is home to approximately 350,000 people and boasts a rich cultural diversity. In 1996, the barrier reef fronting Belize, including mangroves found throughout the area, was inscribed as a UNESCO World Heritage Site for its Outstanding Universal Values (UNESCO, 1996). More recently, a WRI study showed that mangroves alone contribute USD $74 – $209 million annually to the Belize economy (Cooper et al., 2008). Today, much of Belize's endowed natural and cultural wealth is set-aside in an extensive network of terrestrial and marine protected areas.

Mangroves occur in most coastal areas of Belize, including up rivers, along bays and lagoons, and strewn across numerous offshore cays and coral atolls. In 1998, Andrew Zisman, a doctoral student from the University of Edinburgh, completed a national-level mapping study and determined that mangroves covered ≈785.11km^2 (≈78,511 hectares) at that time (Zisman, 1998). In 2008, the Healthy Reefs Initiative (HRI) collaborated with the Water Center for the Humid Tropics in Latin America and the Caribbean (CATHALAC) to update the 1998 data. Subsequently, CATHALAC and the World Wildlife Fund (WWF) used satellite imagery and local fieldwork to assess coverage over a 30-year time period. This study determined that ≈15.6km^2 (1,566 hectares), only about 2% of total mangrove cover in Belize, was lost from 1980 – 2010 (Cherrington et al., 2010). The Environmental Research Institute of Belize validated the 2010 mapping effort and found that the results were 90.7% accurate overall (Cho-Ricketts and Cherrington, 2011).

Much of the Belize's mangrove cover remains intact and healthy. Significant mangrove loss—primarily the result of development or agriculture—has occurred around Belize City and its nearby cays, Corozal and the northern Belize district, and the popular tourism destination of Ambergris Caye (Belize CZMAI, 2013). In the south, shrimp farming has contributed to degradation and loss of mangroves in several coastal areas. More recently, mangroves around Placencia lagoon and several offshore islands have been cleared, sometimes illegally, to make way for local development projects (Mckee et al., 2009; Spalding et al., 2010). Like the Yucatán Peninsula, the coastal regions of Belize, especially its offshore islands, also frequently experience hurricane impacts. One study demonstrated that intact mangrove ecosystems help protect coastal areas during extreme such weather events (Granek and Ruttenberg, 2007). Another study revealed the regrowth potential of mangroves following hurricanes and tropical storms (Piou et al., 2006).

In 2009, UNESCO listed the barrier reef environment as a World Heritage Site in Danger, partly due to sale of public lands on small mangrove islands (UNESCO, 2009). The listing catalyzed conservation leaders to revise and strengthen the country's outdated mangrove legislation, however new regulations have yet to be approved and signed into law. In early 2015, the Belize government negotiated a "Desired State of Conservation" with UNESCO that, if achieved, will secure the removal of the "Site in Danger" listing. The agreement sets out indicators and methods of verification to measure progress towards the desired state. Establishment of key legal instruments—including the Integrated Coastal Zone Management Plan, the Living Aquatic Resources Bill and the new mangrove regulations—is critical for achieving the goals of the agreement (UNESCO, 2015). New management plans will also be developed for the Glover's Reef and South Water Caye Marine Reserves, the latter of which has been a hot spot for mangrove loss.

Conservation leaders recognize the economic and ecological benefits provided by Belize's mangroves. Moreover, the private sector values nature-based tourism as a primary economic driver and source of jobs. Today, resource management authorities and conservation groups monitor mangroves throughout the country, especially in protected areas and sites recently degraded by poorly planned development. Several mangrove restoration efforts have taken place in different locations although no database exists that comprehensively documents past and present projects. The Belize Coastal Zone Management Institute and Authority, in its *State of the Belize Coastal Zone 2003-2013* report, includes recommendations for strengthening the management, research and monitoring of mangroves across Belize. In addition, the Department of Forestry recently teamed up with Duke University researchers to measure blue carbon values at Turneffe atoll, the first study of its kind in Belize.

Guatemala

The Caribbean coastline of Guatemala stretches approximately 150km along the Gulf of Honduras. The coastal environment and nearby waters are home to rainforests, mangroves, sea grass beds and some limited coral reefs. The most extensive mangroves are found in Graciosa Bay and near the mouths of three major rivers—the Dulce, Temash and Sarstun. Mangroves also reach further inland near El Golfete and Lake Izabal, principally due to saltwater intrusion in these areas (Spalding et al., 2010). Guatemala first enacted mangrove protections under the 1998 Forestry Act. A few years later, a joint partnership of government and non-governmental organizations began mapping and monitoring the country's forests, including mangroves (Hernández et al., 2012).

Large areas of mangrove on both the Pacific and Caribbean coasts of Guatemala have been cleared to make way for agriculture and aquaculture, notably shrimp farms. On the Pacific side, banana plantations have caused pollution, eutrophication of lagoons, and in some cases, degradation of nearby mangroves due to changes in hydrology and sedimentation (Spalding et al., 2010). Looking towards the Caribbean, pollution from rivers draining into the Gulf of Honduras is increasingly impacting coastal marine ecosystems. Conversion of coastal land to agriculture or cattle farming has also resulted in loss of mangrove cover and contributes to sedimentation and erosion. Moreover, an increase in the use of pesticides and fertilizers has fouled many coastal waters where mangroves are found (Kramer et al., 2015).

Available statistics on mangrove cover and loss in Guatemala vary widely and may require validation to determine accuracy. A 2005 FAO study estimates that ≈11km^2 (1,100 hectares) of mangroves were lost between 1980 and 2005, representing nearly 10% of the country's total mangrove cover (FAO, 2005). A recent UNEP publication suggests both Guatemala and Honduras have lost up to 40% of their historical mangrove cover (UNEP, 2014). The most recent in-country assessment of Guatemala's mangroves, facilitated by the Ministry of Environment and Natural Resources and CATHALAC, states that mangroves still cover ≈188km^2 (18,800 hectares) of land across the country. Today, nearly 90% of mangroves on the Caribbean coastline are found within established national protected areas (Hernández et al., 2012). Moreover, the Sarstun-Temash National Park and Punta de Manabique Natural Reserve, home to extensive mangrove forests, are also internationally recognized Ramsar sites.

Honduras

Mangroves are found throughout the Caribbean coastline of northern Honduras, along the Moskitia coast in the east and surrounding the Gulf of Fonseca in the southwest. The Bay Islands— Guanaja, Roatan, Utila and Cayos Cochinos—also have substantial mangrove coverage, most notably on the southern shore of each island (Spalding et al., 2010). Similar to Guatemala, available statistics for national level mangrove cover and loss vary widely. According to the 2005 FAO report, from 1965 – 2001 mangrove cover in Honduras declined from ≈2,978km^2 (297,800 hectares) to ≈530km^2 (54,300 hectares). As noted above, a recent publication suggests Honduras has lost approximately 40% of its total mangrove cover (UNEP, 2014). The National Institute of Conservation and Forestry Development, Protected Areas and Wildlife (ICF) estimates that, as of 2014, 52% on the nation's remaining mangroves occur in the Gulf of Fonseca, 33% in Moskitia, 12% in Colon-Cortes and 3% in the Bay Islands (ICF, 2014).

Shrimp farming has been a leading cause of mangrove loss in Honduras. This is especially true in the Gulf of Fonseca, where shrimp farm operations expanded from ≈5.8km^2 (5,800 hectares) in 1985 to more than ≈16km^2 (16,000 hectares) by the year 2000 (Spalding et al, 2010). One study used satellite imagery to document the loss of approximately 11.9% of mangrove cover in the gulf as a result of converting land to other uses, especially shrimp farms (Chen et al., 2013). This same study suggests that ≈1.2km^2 (1,200 hectares) per year may be lost by the year 2020. Throughout the country, fuel wood collection remains a common practice near coastal communities. In popular tourism destinations like the Bay Islands, mangrove loss is often the result of land clearance for development of hotels, roads and other tourist facilities.

Like its neighbors to the north, Honduras also frequently experiences hurricanes, which, in some cases, have resulted in devastating impacts for the region's mangroves. In 1998 hurricane Mitch destroyed 97% of mangroves on the island of Guanaja in the Bay Islands (Spalding et al., 2010). Field studies in subsequent years show that loss of sediment and peat, as a result of widespread destruction, has inhibited mangrove recovery across the island (Cahoon et al., 2003; Vanselow et al., 2007). On the Pacific side, massive rainfall associated with hurricane Mitch caused widespread damage to shrimp farms and in turn led to nutrient loading and release of pollutants throughout the Gulf of Fonseca. Resulting impacts to mangroves and associated fisheries fueled social conflict between local fishermen and shrimp farmers (Spalding et al., 2010).

The largest loss of mangroves in Honduras, up to 24km^2 (24,000 hectares), has occurred in the Gulf of Fonseca (ICF, 2014). One upshot of the damage incurred by hurricane Mitch, and its effects on local people, was the creation of a vast set of protected areas surrounding the Gulf of Fonseca, much of which is also now a designated Ramsar site (Spalding et al., 2010). Along the Caribbean coast, the most recent in-country study estimates that ≈3.3km^2 (3,300 hectares) of mangroves have been lost in the region, primarily as a result of a port development project in the Alvarado Lagoon in Puerto Cortes (ICF, 2014). Many of these mangroves along the Caribbean coast and in the Bay Islands are now found in national parks and refuges, several of which are also Ramsar sites. In 2013 the entire island of Utila was formally designated as a Ramsar site, becoming the latest area of mangroves in northern Honduras to receive international recognition.

Like its northern neighbors, researchers have begun assessing blue carbon values of mangroves at select sites in Honduras. One study, awaiting publication, sampled mangroves at 24 sites across 3 coastal zones in Honduras, including the Gulf of Fonseca, Tela on Caribbean coast, and three of the bay islands. Extensive field sampling was conducted to assess composition, structure, biomass and both above and below ground carbon stock values. Additional field measurements looked at how roosting birds affect nutrient dynamics in mangrove ecosystems.[3]

Economic Valuation of Mangroves

Economic valuation is a tool that helps quantify both monetary and non-monetary benefits (ecosystem services) that mangroves provide people. Many activities that commonly damage coastal environments where mangroves thrive—aquaculture, dredging and poorly planned development, discharge of pollution and sewage—are driven by short-term economic gain

[3] Personal communication with Dr. Rupesh Bhomia, Center for International Forestry Research and Department of Fisheries and Wildlife, Oregon State University (USA).

versus consideration of the broader, long-term impacts to people and nature. Economic valuation shows increasing potential to inform land-use planning, coastal zone management and sustainable development practices (Vo Quoc et al., 2012). Applying economic valuation to mangrove ecosystems along the Mesoamerican Reef System, and sharing the results with decision-makers, resource managers and the wider public, will help:

- Improve understanding of ecosystem service and economic values mangroves provide
- Encourage investment in long-term sustainable management
- Provide decision support tools and information to guide management
- Establish appropriate fees to enter or use a protected area
- Set appropriate values for damage compensation
- Support long term socio-economic stability and biodiversity conservation

Implementing an Economic Valuation

Methodologies for conducting economic valuation range from sophisticated and complex to straightforward and relatively non-technical. Limited human resources in government departments and nongovernmental organizations (NGOs) often means that even when in-house staff possess skills to conduct economic valuation, the needed capacity to support such efforts may not be available. Furthermore, some economic valuation methodologies require complex ecological and economic modeling methods and tools, which many government departments and organizations in Mesoamerican Reef System countries do not possess. At times, hiring an outside consultant or partnering with a research institute or university may be necessary. In some cases, a non-specialist, such as a MAR-L Fellow, can learn from or manage consultants and experts, and thereby participate fully in the design and implementation of an economic valuation.

An analysis and a valuation of ecosystem services lie at the heart of any economic valuation. However, for any economic valuation to achieve policy influence it is advantageous, if not critically important, to consider the following steps early in the process:

- Identify the relevant policy question
- Consider the context
- Review previous valuation studies
- Identify and engage stakeholders
- Identify decision-makers and other target audiences
- Draft a communications strategy

The guidebook, *Coastal Capital: Ecosystem Valuation for Decision Making in the Caribbean,* provides a roadmap for how to conduct an economic valuation and influence policy decisions (Waite et al., 2014). Table 3 includes an overview of the three main phases—scoping, analysis, and outreach—with a list of key steps associated with each phase.

Table 3. Key Steps for Influential Economic Valuation

Phase	Steps
1. Scoping	1.1. Identify the policy question to be addressed by ecosystem valuation (i.e., the intended use of the study)
	1.2. Consider the context of the study area to determine if economic valuation is the right approach - Threats to coastal resource health - Economic dependence on coastal resources - Local champions - Governance
	1.3. Conduct a literature review of previous relevant coastal valuation studies
	1.4. Identify and engage stakeholders who are interested in the policy question, clarify objectives of the study, and clarify how each will be engaged - Primary stakeholders (e.g., fishers, farmers, local tourism businesses, local civil society groups) - Secondary stakeholders (e.g., national and local government officials, resource managers) - External stakeholders (e.g., NGOs, developers, tourists, external investors, universities, media)
	1.5. Identify decision makers and other target audiences (usually among the stakeholder groups identified above) and begin developing a communications strategy
2. Analysis	2.1. Develop scenarios of possible futures through a participatory process (e.g., through Driver-Pressure-State-Impact-Response [DPSIR] framework or critical uncertainty approach)
	2.2. Analyze the changes in ecosystem services under the scenarios (e.g., through modeling, expert opinion, or information transfer)
	2.3. Choose methods to value or monetize the changes in human well-being—ensuring the methods are appropriate to the policy question
	2.4. Collect and analyze biophysical and socioeconomic data (e.g., primary survey data, secondary data)
	2.5. Account for risk and uncertainty in valuation results
	2.6. Develop and apply decision support tools (e.g., cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis)
	2.7. Report valuation results clearly and transparently, in a way that is useful to stakeholders and other valuation practitioners
3. Outreach	3.1. Develop synthesis products derived from the valuation results for decision makers, using metrics and products that are relevant to the target audience
	3.2. Communicate valuation results to decision makers—ideally through an interactive and iterative process—through a variety of channels (e.g., public and private meetings, traditional and social media)
	3.3. Share the study and results with the wider coastal valuation community
	3.4. Monitor and assess the impact of the economic valuation study

Adapted from Waite, R., et al., 2014. *Coastal Capital: Ecosystem Valuation for Decision Making in the Caribbean.* Washington, DC: World Resources Institute. Available at: wri.org/coastal-capital.

Stakeholder Engagement

Conveners of economic valuation studies should consult local stakeholders in order to identify the relevant policy question and conservation challenge, and then develop appropriate study objectives. Effective stakeholder engagement capitalizes on the public's desire to influence policy and, in the case of mangroves, resource management decisions that may affect them. Involving stakeholders in both the design and implementation of a study helps foster buy-in, promotes understanding, utilizes local knowledge and reduces potential opposition to uses of valuation results. When done well, stakeholder engagement helps address challenging natural resource management issues in a way that is constructive, informed by a broad base of local knowledge, and allows managers and the public to significantly influence each other's thinking.

Benefits of Valuation

Economic valuation benefits a broad range of people, governments and institutions. At a local or national level, valuation results can directly influence public policy, resource management strategies, conservation investment and economic development planning. Economic valuation helps compare the costs and benefits of different future scenarios—scenarios that could be possible options for development, or natural resource management, such as the establishment or expansion of a terrestrial or marine protected area. Economic valuation can also help decision makers understand how to enforce regulations in a cost effective manner, how to maximize public benefits derived from a particular ecosystem, and how to mitigate the risks of ecosystem degradation. In establishing a monetary value—even a "rough" estimate—of ecosystem services, economic valuation helps facilitate rational, broadly inclusive and far-sighted decision-making (Waite et al., 2014).

Dealing with Uncertainty

Valuation of ecosystem services involves a series of assumptions because it combines an interpretation of the status and productivity of an ecosystem, estimates of human use of resources, and the financial value of ecosystem use. For example, in estimating the value of mangroves for fisheries, assumptions about the productivity of fish in the mangrove (in kilogram/hectare/year) could be combined with estimates of fishing effort (e.g. how many people fish, using what gear, achieving what kilogram/hectare/year landings), and the market price of the given species of fish. In a similar example for shoreline protection, the estimate might combine assumptions about the frequency of storm events of a given size (occurrence per year); wave reduction provided by mangroves (in feet or meters); degree of property damage resulting from flooding to a certain height (% of value); and value of the property damaged and cost of displacement and/or loss of use. There is typically some uncertainty associated with each component, and when combined, the assumptions result in a compound uncertainty.

Uncertainty can be reduced through specific measurement of characteristics within a study site (e.g. fisheries productivity), however, these kinds of measurements can be expensive and time consuming. Valuation is often implemented by "transferring" value estimates (or at least functional relationships) using the best available information about sites with similar characteristics. However, sites vary considerably from place to place, so this approach has some shortcomings. In addition, valuation estimates vary due to the fluctuating circumstances of the variables included. This may include, for example, changes in the market price of a good produced, such as fisheries. Another variable likely to change over time is the price of carbon and the ecosystem service value associated with carbon sequestration. Uncertainties always exist when conducting economic evaluation of ecosystem services and should be clearly stated in technical summaries.

Communicating Results

Economic valuation is complex, and it can be challenging to communicate results in a way that achieves the goal of influencing policy outcomes. It is important to identify and clearly communicate the key messages of the results, along with some explanation of the underlying assumptions of the valuation. It is also necessary to keep the target audience in mind—such as decision makers one wants to influence, or a wider stakeholder group—and consider the professional background, interests and level of technical understanding the recipients of information might possess. For example, products that demonstrate economic valuation results to a resource manager or protected area enforcement officer should be crafted in a way that links the results directly to topics of interest (e.g. regulatory obligations) of the recipients.

At times, practitioners may need to simplify valuation results to make them accessible to a broader, non-technical audience, while still ensuring that important nuances of the analysis are not lost. In addition, enabling stakeholders to jointly examine the results at an early stage can help inform development of final recommendations that are broadly acceptable to a wide range of groups. Similarly, involving decision makers in the production and interpretation of valuation results can be a particularly effective way of encouraging the use of those results in decision-making. Ultimately, results produced in collaboration with partners, stakeholders and local "champions" within decision-making bodies, tend to achieve the greatest influence and most lasting outcomes.

Avenues for communicating and disseminating results and recommendations may include:

- Traditional media
- Social media (e.g., Facebook, Twitter)
- Launch events, stakeholder workshops or other public meetings
- Partner networks
- Targeted private meetings
- Relevant conferences and events
- Information campaigns—advertisements / social marketing
- Tourist education (e.g., the importance of mangroves)

When communicating results, practitioners should also keep in mind:

- Desired actions the audience can take
- Methods for maintaining credibility and communicating quality research
- Benefits of working with partners, influential stakeholders, and local "champions" whenever possible

Economic Contribution of Mangroves

There is a growing body of literature on the ecosystem service values derived from mangroves. Studies with this type of focus increased around 2000 then declined slightly in subsequent years. Most recent studies have occurred in Asia, perhaps due to the drastic loss of mangroves in that part of the world. Although the Americas (including Central America) are home to 30% of the world's mangroves, a recent literature review found that only 19% of mangrove valuation studies have been completed in this region (Vegh et al., 2014). Mangroves provide several important ecosystem service and economic values along the entire Mesoamerican Reef System, including, but not limited to, the following:

Coastal Protection

Mangroves help protect coastal communities and associated infrastructure against damage associated with storm events, such as routine waves, storm waves, and hurricane or tropical storm surges. Mangroves mitigate wave energy (and associated wave height), thereby reducing both erosion and flooding. Wave height reduction associated with mangroves varies depending on the biophysical characteristics of an area. Elements such as mangrove forest width and density, water depth, and ocean floor configuration influence the extent to which mangrove roots are able to exert drag force on incoming waves and thereby decrease wave height. Various specific benefits have been documented in different areas of the world:

- In Vietnam mangrove forests reduce wave heights 5 – 7.25 times more than on beach surface lacking such vegetation (Quartel et al., 2007).
- In the Gulf Coast of South Florida, wave height is reduced at a rate of 40 – 50 cm per 1 km of mangrove forest along the shoreline and 20cm per 1 km on islands dispersed throughout open waters (Zhang, 2012).
- Generally, mangroves reduce the height of wind and swell waves over relatively short distances: wave height can be reduced by between 13% and 66% over 100 meters of mangroves (Spalding et al., 2014).

In calculating the coastal protection values of mangroves, practitioners of economic valuation should consider both routine waves and severe impacts associated with hurricanes and tropical storms. Of note, the value of a mangrove forest associated with storm protection will vary depending on the type of infrastructure and economic activities taking place in nearby areas.

Fisheries

Mangroves are critically important fishery habitat, and generally yield high quantities of fish, crabs, shrimp and mollusks. Mangroves increase fish production rates and numerous species rely on mangrove habitat for part of their life cycle (Mumby et al., 2004; Faunce and Serafy, 2006; Crona and Ronnback, 2007). In Belize mangroves contribute an estimated USD $3 – 4 million per year by supporting healthy fisheries (Cooper et al., 2009). However, the fact that many fish caught near mangroves are kept for local consumption, versus sold on an open market, makes it difficult to determine precise values of many mangrove fisheries. In such instances, obtaining information directly from local populations is critical for producing relatively precise results. Direct use value is the most widely used method to account for the economic value of fisheries as an ecosystem service (Vo Quoc et al., 2013; Waite et al., 2014; Huxham et al., 2015).

Tourism

Recreational activities in and around mangroves are considered services provided by these coastal ecosystems. Ecotourism is an important economic driver in many places of the world, including along the Mesoamerican Reef System, and mangroves are often seen as the link between the terrestrial and marine ecosystems that attract environmentally conscious tourists (UNEP, 2011). Methods for accessing the recreation-related value of mangroves can be achieved through several means. Most often direct use value and opportunity costs of visitors for a given tourist location is used to estimate this value. Contingent valuation is alternative when data is unavailable or otherwise hard to come by.

A recent direct use value study in Belize—estimating gross revenues and taxes from marine recreation, as well as revenues from accommodation and other tourist spending on days spent using mangrove ecosystems—determined that USD $60 – 78 million in tourism revenue is directly linked to the presence of healthy mangroves (WRI, 2008). Another study utilized values from previously published sources to determine that mangroves in Kenya have a mean value of USD $41/hectare/per year (Huxham et al., 2015).

Soil Accretion

The complex root systems of mangrove forests help to slow water flow, which allows sediment to settle and accrete rather than erode (McIvor et al., 2013). This enables increasing soil volume as mangroves capture riverine or coastal sediments that pass through, as well as add organic matter via roots, leaves and woody material (Spalding et al., 2014). Mangrove root growth also pushes the soil upward, creating higher soil levels. Studies demonstrate mangrove soils growing up to 10 millimeters per year in sites from Australia to Belize. This may indicate that mangroves could help coastal communities “keep up” with sea level rise caused by global climate change (Krauss et al., 2013; Spalding et al., 2014).

Provisions

Many communities along the Mesoamerican Reef System depend on mangroves to support their livelihoods in the form of either timber harvesting or fuelwood collection. For such direct provisioning services, monetary values can be estimated by multiplying the volume per year extracted by the relevant market price, taken as sale (for traders) or purchase (for consumers) and subtracting harvest/production costs where possible (Huxam et al., 2015). This type of data is best gathered through surveys and directly speaking with members of the community that are reliant on mangrove wood.

Nutrient and Sediment Filtering

Mangroves filter sediment and pollutants from coastal runoff, generating clean water that is favored by nearby coral reefs. However, these regulating ecosystem services have yet to make it into the economic valuation literature (see the fisheries section above for more information on the economic value of fisheries supported by these filtering services).

Carbon Sequestration

Blue carbon is a term used to describe the carbon sequestering capacity of ocean-based ecosystems such as seabed grasses, salt marshes and mangrove forests. Mangroves sequester a disproportionately large amount of carbon when compared to other forest types. Mangroves sequester carbon in three ways: 1) above ground, by new growth of branches and trunks; 2) below-ground, through the growth of new roots; and 3) in and on the sediment, through roots, primary production and trapping of sediments and organic material from outside the forest (Huxham et al., 2015). Studies in Belize document mangroves with carbon rich deposits more than 10 meters thick and over 6,000 years old (Mckee et al., 2007; Mcleod et al., 2011). It is likely that equally rich carbon deposits exist in other coastal locations across the Mesoamerican Reef System.

One recent study estimated avoided annual emissions based on rates of carbon loss of 4.85 tons of carbon per hectate^{-1} year^{-1} from sediment following mangrove forest removal (Lang'at et al., 2014; Huxham et al., 2015). The study then applied a rate of USD $10 per 1 ton of carbon to the study sites, based on the current market value from the voluntary carbon market. While variations exist between sites, the study showed an average of USD $251 per hectare of mangrove forest in avoided emissions. Because above ground carbon is not necessarily released when mangrove trees are cut down, it was not calculated into the cost estimate of avoided emissions in this particular case study. Unless wood is burned on site, limiting the avoided emissions cost to the amount of carbon stored in the roots and below ground is considered best practice for such mangrove evaluation (Huxham, et al., 2015).

Conservation Challenges & Opportunities Facing the MAR-L Program

Alteration of coastal landscapes remains the leading human cause of mangrove deforestation and degradation across the Mesoamerican Reef System. Climate change—with associated impacts like rising seas, changes in coastal dynamics and sedimentation, and a potential increase in the frequency of extreme weather events—presents an emerging and perhaps even greater long-term threat. Although each country in the region has to varying degrees taken steps in recent years to improve protection of its coastal environment, the legal frameworks affording specific protections for mangroves generally remain out-of-date, poorly enforced or underdeveloped. Even the region's numerous protected areas—perhaps the best hope for the survival of large swaths of intact, functioning mangrove ecosystems—are struggling to secure adequate financing, meet management goals and gain widespread trust and support of both policy makers and surrounding communities.

In the face of these challenges, the MAR-L program is presented with a unique and timely opportunity to increase awareness of the value of mangroves, strengthen conservation efforts and promote sustainable long-term management of these important coastal ecosystems. The following key considerations are expected to inform the program's training series and help selected Fellows design and implement projects that achieve far-reaching public policy and conservation outcomes.

- **Ensure Fellow projects are designed within the context of existing mangrove research and conservation efforts.** As Fellows begin designing locally led projects, it is critically important to consider existing research and conservation efforts already focused on mangroves or, more generally, coastal ecosystems. An early assessment of relevant agencies, organizations and initiatives will provide insight on how a project fits into the current conservation landscape. Fellows may also identify supporting partners, available resources, and ways to build on the achievements of others doing similar work.

- **Identify and secure mangrove experts as guest lecturers.** Related to the above, each workshop in the training series will integrate guest lecturers who possess expert knowledge and experience related to mangroves. Local experts provide useful information that improves understanding of key issues, informs development of project concepts, and ensures project goals and associated actions are realistic, achievable and warranted. Moreover, local experts often share lessons learned that will help Fellows avoid common pitfalls that tend to limit short and long-term project success.

- **Provide training on economic valuation and introduce Fellows to a range of progressive conservation strategies and tools.** WRI's guidebook, *Coastal Capital: Ecosystem Valuation for Decision-Making in the Caribbean*, will be utilized to train Fellows on the scoping, analysis and outreach phases of an economic valuation effort. Some may then lead valuation studies and use results to influence policy, resource management and conservation investment decisions. Fellows will also receive introductory training in the Open Standards for the Practice of Conservation, and progressive conservation concepts such as Blue Carbon, Payment for Ecosystem Services and Climate Change Adaptation.

- **Provide training on facilitative leadership, stakeholder engagement and methods for building collaborative conservation capacity.** Fellow work is grounded in community. As such, Fellows must possess knowledge and skills in stakeholder engagement. The benefits of stakeholder engagement are well founded: increased transparency and accountability, better decision-making, enhanced social equity and justice, improved public/private sector relationships and creation of durable solutions to complex environmental challenges. It is important that Fellows carefully assess, understand and adapt to the social and political landscape within which their projects are designed and embedded.

- **Explore and improve understanding of the legal frameworks that support mangrove protection and conservation in the region.** In addition to receiving training on various conservation strategies and tools, and methods of stakeholder engagement, it is equally important that Fellows possess insightful understanding of the governance frameworks and institutional arrangements within which they live and work. Fellows may gain insight on governance from local experts, lectures during the MAR-L training series, or self-led research in their municipality, state or country of origin.

- **Build Fellow knowledge, skills and abilities through mentoring opportunities.** Mentoring, or what is sometimes referred to as professional coaching, has long been recognized as an effective means to improve individual and organizational performance. In mentoring programs, mentors demonstrate, explain and model while protégés observe, question, explore and apply new skills. Fellow project design and implementation may benefit from mentoring agreements established with MAR-L program consultants, staff or even other Fellows.

The MAR-L program is renowned for recruiting, training and catalyzing talented young leaders to become conservation change agents. The most recent cohort of Fellows—which includes scientists, resource managers, community leaders and tourism specialists among others—is well positioned to build on the many existing efforts to map, monitor and enhance mangrove protection throughout the Mesoamerican Reef System. Near term success will reveal the most effective ways that Fellow projects may contribute to mangrove conservation and valuation across the region. Over the long-term the network of MAR-L Fellows, both past and present, will generate individual and institutional competency, foster collaboration at multiple scales, and achieve conservation impacts that extend and evolve well beyond the 2015 program cycle.

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