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Review

## **An International Assessment of Mangrove Management: Incorporation in Integrated Coastal Zone Management**

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**Abstract:** Due to increasing recognition of the benefits provided by mangrove ecosystems, protection policies have emerged under both wetland and forestry programs. However, little consistency remains among these programs and inadequate coordination exists among sectors of government. With approximately 123 countries containing mangroves, the need for global management of these ecosystems is crucial to sustain the industries (*i.e.*, fisheries, timber, and tourism) and coastal communities that mangroves support and protect. To determine the most effective form of mangrove management, this review examines management guidelines, particularly those associated with Integrated Coastal Zone Management (ICZM). Five case studies were reviewed to further explore the fundamentals of mangrove management. The management methodologies of two developed nations as well as three developing nations were assessed to encompass comprehensive influences on mangrove management, such as socioeconomics, politics, and land-use regulations. Based on this review, successful mangrove management will require a blend of forestry, wetland, and ICZM programs in addition to the cooperation of all levels of government. Legally binding policies, particularly at the international level, will be essential to successful mangrove management, which must include the preservation of existing mangrove habitat and restoration of damaged mangroves.

**Keywords:** mangrove conservation; ecosystem management; integrated coastal zone management; land-use policy; economic valuation

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## 1. Introduction

Referred to as the “rainforests of the seas”, mangrove forests function as the backbone of coastal and offshore food webs. Not only are these forested wetlands a superb nursery habitat for marine life, they also provide shoreline protection and are accordingly beneficial for local economies in approximately 123 countries/territories [1]. Unfortunately, mangroves are diminishing as a result of shrimp farming (aquaculture), coastal development, and clear-cutting for timber production. From 1980 to 2005, nearly 35,600 square kilometers of mangroves were destroyed [1–3]. Although there is no accurate estimate of the original global mangrove cover, there is a general consensus that it was once over 200,000 square kilometers. Now it appears that more than 50,000 square kilometers, approximately one-quarter of the original mangrove area, have been lost [1–7]. These numbers exceed both coral reef and tropical rain forest losses [8]. With human populations increasing at an astonishing rate in coastal areas, it is crucial that additional and improved management practices and restoration programs are implemented throughout all mangrove-inhabited nations.

Various techniques for the conservation and management of mangrove forests have been applied around the world. Detailed guidelines have been devised by a number of international organizations to help their members develop more effective mangrove management plans. These organizations include, but are not limited to, the United Nations (UN) Food and Agriculture Organization (FAO), International Tropical Timber Organization (ITTO), the Ramsar Convention, and the International Society for Mangrove Ecosystems (ISME), [1,4]. To determine how management practices are being implemented on national, state, and local levels, the plans and policies of two developed and three developing nations will be compared. In addition, the reasons for ongoing mangrove deforestation, such as increasing coastal populations and subsequent development, will be addressed and possible solutions to this destruction will be proposed.

If improvements to mangrove management and restoration programs are not made soon, there will be great losses in commercial fisheries and local economies, as well as increased erosion and shoreline instability in countless coastal communities [1,9,10]. Through an examination of the relevant literature, the determinants of successful management and restoration of mangrove forests will be assessed on an international basis. It is proposed that this analysis will help to promote the implementation of effective mangrove protection worldwide.

## 2. Literature Review: Mangrove Management Strategies

Mangroves were once recognized as worthless wastelands. This attitude made it acceptable for people to exploit mangroves as a source of land for constructing ports, condos, hotels, aquaculture ponds, and expansive infrastructure for the tourism and fisheries industries [11]. As recognition of their benefits has increased, mangrove management and conservation policies are emerging around the world.

Considered a “commons,” coastal resources are typically open to the public and are not owned by any individual. As a result, government agencies take on the responsibility of these ecosystems. In most tropical nations, the management of mangroves falls under national or statewide coastal zone management (CZM) programs. Mangroves are included in protection programs under the category of forested wetlands and may also be grouped with other wetland habitats under CZM regulations. In addition, mangrove management may often be incorporated in fishery, forestry, and land-use regimes, making effective management all the more complicated [12–14].

Due to the complexity of mangrove ecosystems, their management requires cooperation and participation by all levels of government [12,13]. In countries containing oceanfront borders, the federal government generally maintains jurisdiction over a country’s Exclusive Economic Zone (EEZ) which includes 200 nautical miles off the shoreline [14]. Thus, the responsibility for marine activities, such as international commerce, navigation, and security, rests with most federal governments. State and regional governments are often granted authority to implement CZM programs. In most developed nations, the local governments preside over zoning and development decisions within the coastal region, which directly affects mangrove forests and nearby wetlands [12,13]. With multiple levels of government and jurisdiction involved in the protection of mangroves, the related policies and programs can become quite complicated [14]. Yet these policies and programs are the key to the sustainable management of mangroves and the adjacent coastal ecosystems [15].

### 2.1. History of Coastal Zone Management

Historical records document mankind’s management of coastal ecosystems over millennia. Many management traditions encouraged conservation tactics which were easy to achieve prior to colonialism since most human populations were relatively small. As colonization of the coastal zone progressed, control over coastal areas was transferred from communities to local and national governments. This transition to government rule led to commercial operations, overexploitation of resources, and numerous environmental impacts. Natural resource exploitation was justified by the benefits of food production, employment, and overall social and economic improvements. Such justifications led to reactive conservation and management. Protection programs were initiated (and still are) *after* a resource was already damaged. This reactive approach is one of the leading causes of mangrove deforestation [14,16].

Some of the earliest forms of mangrove management originated in South and Southeast Asia, particularly in Bangladesh and Malaysia. Both countries devised complete forest management plans for their mangroves, which are still in place to this day [4,17]. Management of the mangrove forests, or the “mangal,” in Bangladesh, locally known as “Sundarbans,” has been documented as far back as the 1890s [18]. Likewise, the Malaysian Forest Department has been actively managing the sustainable harvest of mangroves within the Matang Forest in Perak since the late 19th century. As seen in both countries, the main goal in early management of mangrove forests was the extraction and utilization of its wood for construction timber, paper, and charcoal. Over time, the management focus has shifted towards conservation and sustainable use of the mangal (Table 1) [4,15,17].

**Table 1.** Timeline of coastal zone management history and the associated programs.

Time Period	Management Trends	References
Traditional (1800s–1900s)	Small human populations: Conservation was a priority <i>Transition to...</i> Larger human populations: Government rule in the coastal zone	[4,15–17]
1960s	<ul style="list-style-type: none"> <li>• Introduction of “Sectoral Management”</li> <li>• Multiple agencies involved in management (<i>i.e.</i>, fisheries and forestry)</li> <li>• Focus: Production and utilization</li> </ul>	[17,19,20]
1970s–80s	<ul style="list-style-type: none"> <li>• 1971: Ramsar Convention ratified</li> <li>• 1972: U.S. CZM Act (<i>other countries followed with CZM programs of their own</i>)</li> <li>• 1986: Origin of the ITTO</li> <li>• Late 1980s: Introduction of community-based and multiple-use management</li> </ul>	[14,16,17,21–26]
1990s	<p><b>Introduction of <i>Integrated CZM</i></b></p> <ul style="list-style-type: none"> <li>• Collaboration between sectors</li> <li>• 1990: Origin of the ISME</li> <li>• 1992: Earth Summit</li> <li>• 1994: FAO published <i>Mangrove Forest Management Guidelines</i></li> <li>• 1997: ISME and ITTO published <i>Mangrove World Atlas</i></li> </ul>	[1,12,15,16,21,27–34]
Modern Day	<ul style="list-style-type: none"> <li>• Implementation of ICZM that incorporates: Ecosystem-based, multiple-use, and adaptive management</li> </ul>	[4,12,13,15,21,28–30]

### 2.1.1. 1960s: Sectoral Management

The exploitation of mangroves for financial gain became more prevalent in the 1960s, particularly in countries that exploited their mangroves for timber production. This time period was the beginning of single-sector management [19]. Divisions, in terms of regulatory agencies and departments, were made among fishery, forestry, coastal navigation, and many other sectors involved in coastal zone activities. The result was an overabundance of agencies and departments, each managing one component of the larger coastal ecosystem. Single-sector management led to confusing and overlapping jurisdictions within the coastal zone and disregard for protection of the coastal ecosystem as a whole [20]. Regrettably, the main goal of coastal management during the 1960s was *production and utilization* of coastal resources rather than conservation [17].

### 2.1.2. 1970s and 1980s: Heightened Environmental Concern

One of the first formal efforts to conserve coastal resources was the U.S. Coastal Zone Management Act of 1972. Following the example set by the U.S., a number of other countries formed CZM programs of their own. These early initiatives remained focused on individual sectors of the coast, as well as individual habitats, rather than taking a true integrated and comprehensive approach [21].

In 1971, the ratification of the Ramsar Convention brought conservation and the issue of wetland degradation to the forefront of coastal management. The Ramsar Convention was the first legally binding, global treaty on environmental conservation and natural resource sustainability [22]. In addition

to the designation of Wetlands of International Importance for the Ramsar List, the Convention also requires all contracting parties to implement the “wise use principle.” The wise use principle is a term synonymous with sustainable use: a method of natural resource utilization that does not exhaust the resource. In response to this requirement, national wetland policies and management schemes were developed for wetland protection in many of the participating countries [23].

Increasing concern over environmental issues during the 1970s and 1980s gave rise to a number of United Nations (UN) initiatives to aid countries in the sustainable use and management of their natural resources. One such initiative was the International Tropical Timber Organization (ITTO). The ITTO devoted its efforts to assisting member countries in sustainable forest management and conservation [24,25]. The ITTO has developed international policy documents to promote sustainable forestry, including mangrove forestry, and has assisted its members in implementing these policies. Decision 9 of the International Tropical Timber Council established the ITTO *Mangrove Conservation Programme* in 2000 during the organization’s 29th session. This program set the stage for ongoing mangrove research under the ITTO [26].

During the 1980s, the idea of multiple-use management became more widespread to accommodate the variety of activities conducted in the coastal zone [14,16,21]. Due to the complexity of the mangal and the activities associated with them, it has been concluded that managing the tropical forests in isolation would be unsustainable [17]. In 1998, Cicin-Sain and Knecht [21] demonstrated that the traditional single-sector management approach rarely produced successful outcomes since mangroves are intimately connected with neighboring ecosystems [17].

### 2.1.3. 1990s: Towards Integrated Coastal Zone Management (ICZM)

The 20th century brought about immense population increases and excessive utilization of coastal resources [21]. The resulting damage to mangroves, sand dunes, tidal marshes, seagrass, and other nearby habitats demonstrated the need for stricter management of *human* activities. Policy makers, environmentalists, and economists addressed this issue by moving away from sectoral management and towards a more integrated management approach [27].

In 1992, Clark [12] defined integrated coastal zone management (ICZM) as the “caretaking of common property resources,” including, but not limited to, mangrove forests, coastal waters, and coral reefs. In 2000, Olsen and Christie [28] suggested that the ultimate goals of ICZM were the sustainable quality of coastal ecosystems and of coastal communities, thus incorporating the human factor. In 2003, Olsen furthered this idea by stating ICZM is a process that helps managers achieve sustainable coastal development by providing less complicated avenues for public policy negotiation and implementation. The term “multiple-use” was brought into the definition by Ehler in 2003 [19], who addressed the responsibility of national, state, and local governments in facilitating the coordination of agencies, organizations, and economic sectors involved in ICZM. Christie [29] discussed the importance of sound policies, regulations, and education. While each definition of ICZM touched on valuable aspects of coastal management, Christie [29] provided the most concise definition that will be referred to throughout this review: ICZM is a *balance* of development and conservation that ensures multi-sectoral planning, public participation, and conflict mediation. This management regime can be considered

both “top-down” and “bottom-up” since both the government and local communities are involved in the process [16].

Mounting interest in ICZM in the 1990s can be attributed to the United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit or Rio Summit. Held in Rio de Janeiro, Brazil in 1992, the Earth Summit gave “political legitimacy to the concept of *integrated* ocean and coastal management” and led to a “fundamental shift in thinking” towards sustainable development [21]. Two of the documents compiled during the conference contain specific guidelines for the conservation of mangroves: Agenda 21 and the Statement of Forests Principles. Chapter 17 of Agenda 21 focused specifically on ocean and coastal management. A key theme of Chapter 17 was the need for new approaches to coastal management that were integrated, precautionary, and proactive. While Agenda 21 was aimed at the issues of sustainable development within the ocean and coastal zone, the *Statement of Forest Principles* addressed the fact that *all* types of forests, including mangroves, must be considered in conservation and management plans. Although it was not legally binding, the *Forest Principles* set the stage for future initiatives in sustainable mangrove forest management [21,30].

The Food and Agricultural Organization (FAO), a division of the UN, also turned their attention to the issue of unsustainable development and environmental degradation. A substantial amount of research has been conducted under the umbrella of the FAO’s Forestry Department to determine appropriate methods for mangrove management. For instance, in 1994, the FAO published a document entitled *Mangrove Forest Management Guidelines*, which provided a wealth of information to member countries on mangrove physiology, management, and restoration [31]. A more recent FAO publication, *The World’s Mangroves 1980–2005*, documented the past and contemporary coverage of mangrove forest area and served as a tool for managers and decision makers worldwide [15].

Additional recommendations for mangrove-specific management have been formulated by the non-profit, non-governmental International Society for Mangrove Ecosystems (ISME). Established in 1990, the ISME contributes to the conservation, rehabilitation, and sustainable use of mangroves [32]. With the support of the ITTO, the ISME created an invaluable resource for mangrove researchers, managers, and decision makers: the Global Mangrove Database and Information System (GLOMIS) project. First introduced in 1996, GLOMIS was created to establish an international database on mangrove ecosystems. The GLOMIS website (<http://www.glomis.com/>) is open to the public and consists of a searchable database of scientific literature relating to mangroves, research conducted on all aspects of mangroves, and projects and programs associated with mangroves [33]. The relationship between the ISME and ITTO also led to the production of the first *Mangrove World Atlas* in 1997 and the more recent *World Atlas of Mangroves* published in 2010 [1,34].

#### 2.1.4. Modern Management: Integrated, Adaptive, and Ecosystem-Based

The 20th century saw significant improvements in the field of CZM and mangrove management as a result of the programs formulated by the Ramsar Convention, ITTO, Earth Summit, FAO Forestry Department, ISME, and numerous other organizations. However, modern CZM regimes remain fragmented [12,13]. Multiple sectors (*i.e.*, fishery, maritime, forestry, *etc.*) continue to overlap one another’s jurisdiction. Olsen and Christie [28] explain that ICZM is not a replacement for sectoral management; instead, ICZM provides another tool for governing the coasts.

Creating a balance between development and conservation is not a simple task. As stated by the FAO in 2007 [15], ICZM may be one of the key solutions to conflicting land uses. The current goal of ICZM is to benefit not only the natural resources but also coastal communities, industries, businesses, and governments [4,29]. Therefore, ICZM must manage human activities as well as the state of natural resources. For these management strategies to be successful, changes in human behavior are essential. In conjunction with behavioral changes, tools and techniques that can be used to implement ICZM include zoning for multiple uses, setback lines, special area planning, acquisition, easements, development rights, coastal permits, mitigation, restoration, and protected areas [21,29].

Research and hands-on experience in the 21st century exemplified that the most effective ICZM programs have reliable sources of external funding, in addition to long-term commitment from government agencies, non-governmental organizations, and other interested parties [29]. The development of an ICZM program typically requires a decade or more, rather than a few short years; thus it is vital to have secure financial support prior to initiating new ICZM strategies [29]. Due to the long initiation process and the dynamic characteristics of the coastal zone, it is imperative to keep the program flexible [28]. This flexible approach, also referred to as “adaptive management,” is meant to be modified as new information is introduced and the management scheme is altered over time [21].

Although information and technology have become widely available to aid countries in implementing ICZM, the financial and political status of developing countries has prevented action at the national level. On the other hand, most developed countries maintain sectoral programs to assist in coastal management [30]. It has been suggested in the literature that the most successful approach to ICZM, whether in developed or developing countries, is the combination of national, regional, and local action. In most countries, tidal areas directly adjacent to the coastline are under the legal jurisdiction of the national government, while the intertidal zone (where mangroves are located) is under the jurisdiction of the local or state government [14,21]. For ICZM to be truly integrated, it is clear that all levels of government must be synchronous when it comes to regulations and policies for the coastal environment.

## *2.2. Guidelines for Mangrove Management*

Although the primary causes of mangrove destruction have been thoroughly documented and identified, decision makers and managers rarely have access to the necessary tools and data to prevent these damages [35]. The historical evolution of ICZM depicts several planning strategies that have been created to aid decision makers and managers in the conservation of mangrove forests. The most recognized guidelines for successful mangrove management are those published by the FAO Forestry Department, Ramsar Convention, ITTO, and ISME, with assistance from the World Bank, Centre for Tropical Ecosystems Research (cenTER Aarhus), Wetlands International, and a plethora of other donors and contributors (Table 2) [21].

The management guidelines presented by these four international entities demonstrate the growing consistency in coastal ecosystem management and conservation. While the FAO Forestry Department and ITTO are focused on forestry management, the Ramsar Convention is dedicated to wetland conservation [25,31,36]. The ISME remains the sole organization devoted to mangrove-specific management [32]. Even though each entity may have different principal goals, they come to a consensus on the key elements of mangrove management (Table 3).



**Table 2.** Primary management guideline documents for mangrove ecosystems.

FAO	ITTO	Ramsar Convention	ISME
<ul style="list-style-type: none"> <li>Mangrove forest management guidelines (1994) [31]</li> </ul>	<ul style="list-style-type: none"> <li>ITTO Guidelines for the Sustainable Management of Natural Tropical Forests (1992) [37]</li> <li>Mangrove Workplan (2002) [25]</li> <li>ITTO guidelines for the management and restoration of tropical forests (2002) [38]</li> <li>ITTO Action Plan 2008–2011[26]</li> <li>ITTO Action Plan 2013–2018 [39]</li> </ul>	<ul style="list-style-type: none"> <li>Guidelines for management planning for Ramsar sites and other wetlands (1993) [36]</li> <li>Guidelines for developing and implementing National Wetland Policies (1999) [36]</li> <li>New Guidelines for management planning for Ramsar sites and other wetlands (2002) [36]</li> </ul>	<ul style="list-style-type: none"> <li>Charter for Mangroves (1991) [40]</li> <li>ISME Mangrove Action Plan (2004) [32]</li> <li>Principles for a Code of Conduct for the Management and Sustainable use of Mangrove Ecosystems (2004) [41]</li> </ul>

**Table 3.** Key elements of mangrove management as presented by the FAO Forestry Department, ITTO, Ramsar Convention, and the ISME in the corresponding management guideline documents.

Management Element	Description	References
Integration of Mangrove Protection in CZM Plans	Incorporating all facets of the coastal zone into one program.	[25,31,32,36]
Multiple-Use Management	Managing an area for numerous purposes/activities (e.g., recreation, research, fishing). Mangrove uses can be controlled with zoning laws.	[14,25,31,36,41]
Precautionary Approach	Resource managers cannot dismiss an environmental issue simply because there is a lack of scientific certainty.	[32,33,37]
Adaptive Management	Management plans must be flexible and have the ability to change as new information becomes available.	[25,31,36,41]
Public Involvement	The local people must be empowered with management responsibility to increase their will to support conservation. The wellbeing and livelihoods of the indigenous people must be addressed in the management plan.	[25,31–33,37]
Quantifiable and Realistic Objectives	Prior to implementing the management plan, goals must be determined so future assessments can be analyzed effectively.	[25,31,36,41]
Frequent Monitoring and Assessments	Managed mangrove forests must be evaluated at predetermined time intervals to assess the success of the management scheme.	[25,31,36,41]
Restoration	All damaged and removed mangroves should be restored. Funding should come from the responsible party (“polluter pays” rule).	[25,31,32]
Environmental Impact Assessments (EIAs)	EIAs will help prevent negative impacts from new construction projects near a protected mangrove habitat.	[25,31,36,41]
National Mangrove Program and Policy	National frameworks should exist in all 123 mangrove-inhabited nations to help coordinate management activities.	[13,36,39,41]

The FAO, ITTO, Ramsar Convention, and ISME documents all promote the integration of multiple-use management within ICZM programs or similar national environmental efforts. Establishing quantifiable and realistic objectives that can be easily monitored and evaluated is shown to be a vital first step in management plan preparation. Incorporating environmental impact assessments (EIAs) for mangrove habitat alterations is also strongly advised. It is recommended that managers follow these general guidelines but also maintain flexibility in order to adapt to changing environmental, political, and economic conditions [25,31,36,41].

The importance of incorporating the local community in management decisions is emphasized in all of the guidelines. Without public support and consideration for socioeconomic conditions, environmental management plans are likely to fail. Public education programs can also promote the precautionary approach, particularly with specialized training for planners, managers, and scientists [32,33,37].

A lack of research and information dissemination is highlighted throughout the guideline documents, particularly in the ISME's *Principles for a Code of Conduct for the Management and Sustainable Use of Mangrove Ecosystems* [41]. The ISME has played a substantial role in promoting research collaboration and information sharing, especially with the creation of the *World Mangrove Atlas* in 1997. Funded by the ITTO, the 1997 *Atlas* was published in collaboration with the World Conservation Monitoring Centre (WCMC), part of the UN's Environment Programme (UNEP) [34]. A second edition, now titled the *World Atlas of Mangroves*, was released in 2010. The Mangrove Action Project (MAP) is an excellent role model for information dissemination via public forums, bulletins, action alerts, and a multitude of other resources provided online (<http://mangroveactionproject.org/>) [1].

Furthermore, the GLOMIS website (<http://www.glomis.com/>) contains a directory of references and publications on mangroves that is available to the public. Sources such as MAP and GLOMIS serve as the initial steps in developing mangrove information databases in every country. Once nationwide databases are established, the status of mangrove biological diversity can be monitored more frequently and efficiently, and provide convenient access to useful management information [41].

The ITTO, Ramsar Convention, and ISME suggest that mangrove-inhabited countries develop a national mangrove policy to be coordinated by a national committee [36,39,41]. Oversight of this caliber will provide consistency and standardization within a country's mangrove management plans.

Finally, it is recommended that all existing mangrove habitats be identified and categorized into areas for preservation, conservation, or sustainable use. The ISME stresses the need for immediate rehabilitation of all mangrove forests that have been damaged by human activities [32]. These guidelines provide exceptional advice for managers and policy makers but they remain relatively vague. Therefore, an overview of five individual case studies will be discussed to determine how mangrove management is accomplished on a smaller scale.

### 2.3. Case Studies

An examination of mangrove protection policies on an international scale requires the comparison of countries from both the eastern and western hemispheres. Drastic differences in governance strategies for tropical nations can have serious implications on the success of ICZM programs [16]. Thus, the five case studies presented here include two developed countries, the U.S. and Australia, and three developing countries, Belize, Bangladesh, and Kenya. An assessment of the local, state, and federal

policies/programs associated with mangrove protection and ICZM in each of the five countries was conducted to determine where legal infrastructure is lacking (Table 4).

**Table 4.** Overview of the five case study countries and their management programs related to mangrove conservation.

Country	Mangrove Protection Policies	Implementation of ICZM	International Involvement
<b>United States</b>	National Environmental Policy Act (NEPA) Clean Water Act (CWA) <ul style="list-style-type: none"> <li>National Pollution Discharge Elimination System (NPDES)</li> <li>Section 404 (wetlands)</li> <li>National Estuary Program (NEP)</li> </ul>	CZM Act of 1972 <ul style="list-style-type: none"> <li>Special Area Management Plans</li> <li>Coastal Zone Enhancement Program</li> <li>National Estuarine Research Reserve System (NERRS)</li> </ul>	Contracting Party to the Ramsar Convention ITTO Member
<b>Australia</b>	Environmental Protection & Biodiversity Conservation Act of 1999 (EPBC Act) Commonwealth Reserves <ul style="list-style-type: none"> <li>Marine Protected Areas (MPAs)</li> </ul>	<i>No national ICZM program at this time (states are responsible for coastal resource management)</i> Oceans Policy (1998) <ul style="list-style-type: none"> <li>Marine Bioregional Planning &amp; MPAs</li> </ul>	Contracting Party to the Ramsar Convention ITTO Member
<b>Belize</b>	Belize Forests Act <ul style="list-style-type: none"> <li>Forest Reserves</li> </ul> Marine Protected Areas (MPAs)	CZM Act of 1998 <ul style="list-style-type: none"> <li>Coastal Zone Management Authority and Institute (CZMAI)</li> <li>MPAs</li> </ul> ICZM Plan of 2013 <ul style="list-style-type: none"> <li>Coastal Planning Regions</li> </ul>	Contracting Party to the Ramsar Convention
<b>Bangladesh</b>	Sundarbans Wildlife Refuge Afforestation Proceedings (Bangladesh Government) Forest Policy of 1994	<i>No national ICZM program at this time</i> ICZM Plan Project (2002–2005) Coastal Zone Policy (2005)	Contracting Party to the Ramsar Convention
<b>Kenya</b>	Environmental Management and Coordination Act (EMCA) (1999) <ul style="list-style-type: none"> <li>Coastal, Marine, and Freshwater Sub-Department of the EMCA</li> <li>Marine Protected Areas (MPAs)</li> </ul>	<i>No national ICZM program at this time</i> Draft ICZM Policy (2007) ICZM Action Plan for Kenya 2010–2014	Contracting Party to the Ramsar Convention

### 2.3.1. United States (U.S.)

The coastal ecosystems of the U.S. are protected under a variety of national programs and agencies which delegate oversight to state and local governments. Three primary pieces of legislation aid in mangrove conservation in the U.S.: National Environmental Policy Act (NEPA), Clean Water Act (CWA), and Coastal Zone Management Act (CZMA). Although there are numerous policies and programs watching over the nation's coastal resources, the U.S. is lacking a national, unified policy that coordinates these coastal conservation actions [14]. There is, however, a movement in this direction with the Executive Order for a National Ocean Policy set forth in 2010 [42,43].

Enacted in 1970, the National Environmental Policy Act (NEPA) was one of the first environmental laws ratified in the U.S. Overseen by the Council on Environmental Quality (CEQ), the NEPA requires

that all federal actions be assessed for their effect on the natural environment [14]. These environmental assessments (EAs) are mandatory for all federal agency actions to help prevent irreversible damage on the environment. The preparation of an EA helps determine alternative means to achieving the proposed work and whether an environmental impact statement (EIS), similar to an EIA, is necessary. An EIS is required only if the proposed federal action is found to significantly impact the “quality of the human environment” [44]. All EISes are reviewed by the Environmental Protection Agency (EPA) to insure quality and compliance with the NEPA. Although the NEPA does not maintain regulatory authority like the CWA, this policy has led to the documentation of coastal development impacts on mangroves and other coastal habitats and has encouraged more sustainable permitting decisions [44].

Several programs have been established under the Clean Water Act (CWA) that directly affect management in the coastal zone. These programs include point source and non-point source pollution control, stormwater management, and dredging/filling restrictions in wetlands. Section 404 of the CWA restricts the discharge of dredge and/or fill material into any waters of the U.S. or special aquatic sites which include wetland habitats. Permits for these actions can be obtained from the U.S. Army Corps of Engineers (USACE) and often require mitigation to compensate for unavoidable impacts to wetlands. The regulatory authority of the USACE associated with section 404 is overseen by the EPA. By addressing some of the key issues associated with overdevelopment (pollution and wetland destruction), the CWA provides strict regulatory tools to protect the coastal zone from urban sprawl [14].

Amendments to the CWA in 1987 resulted in the establishment of the National Estuary Program (NEP). This facet of the CWA addresses mangroves more directly since they are prominent features in brackish estuaries in the southern states, particularly Florida. The NEP “aims to identify, restore, and protect nationally significant estuaries” [14]. A voluntary program, the NEP is administered by the EPA and provides funds to federal and state entities for estuary projects. A single NEP study area can encompass a large coastal region and contain multiple projects such as shoreline stabilization, exotic vegetation removal, and mangrove restoration [14,45].

#### 2.3.1.1. Implementation of Integrated Coastal Zone Management (ICZM) in the U.S.

In 1972, the U.S. Congress declared that the existing environmental management programs were inadequate to protect the nation’s coastal resources which contain a wealth of national value. Accordingly, the Coastal Zone Management Act (CZMA) was passed to encourage states to properly manage their coastal resources. Administered by the National Oceanic and Atmospheric Administration’s (NOAA) Office of Ocean and Coastal Resource Management (OCRM), the CZMA is implemented on a completely voluntary basis at state level [14]. All 35 U.S. coastal states (with the exception of Alaska) have developed their own coastal management plans based on the premise of the CZMA [46,47]. Every coastal state’s plans must be approved by OCRM for consistency with the specific elements outlined in section 306 of the CZMA. Under the CZMA, coastal states receive technical assistance and cost-sharing grants to help implement successful and consistent management practices. With CZM plans adapted to each state’s needs, the CZMA attempts to find a balance between conservation and development [14].

### 2.3.1.2. Florida, USA

In the U.S., the largest area of mangrove forest is located in Florida, estimated at 550,000 acres. Therefore, the primary mangrove management strategies in the U.S. are found in this east coast state. Large expanses of mangroves exist within Florida's array of protected areas, particularly in Everglades National Park and the Florida Keys National Marine Sanctuary. It has been projected that approximately 48 protected regions in Florida contain mangrove habitats. As early as 1987, the Everglades National Park was declared a Wetland of International Importance under the Ramsar Convention [1,34].

Approved in 1981 by NOAA, the Florida Coastal Management Program (FCMP) functions as the state's CZM authority. Due to the legal context of the state program and Florida's geography, the entire state is included in the coastal zone. The FCMP is enforced across the state by 24 statutes (enforceable policies) under five water management districts and eight state agencies. Collaborative effort among these agencies and districts guides the regulatory activities throughout Florida's wetlands and waters, including the vast expanse of mangroves [48].

Florida mangroves are directly protected under the Mangrove Protection Rule and the Mangrove Trimming and Preservation Act. In response to a significant decline in mangrove forests, the Florida legislature enacted the Mangrove Protection Rule in 1985. The rule defines the extent of how and when homeowners can conduct mechanical alternations of mangroves (*i.e.*, selective pruning) [49]. In 1996, the Mangrove Trimming and Preservation Act was established in sections 403.9321–403.9334 of the Florida Statutes to regulate mangrove alteration [50–54]. Although the U.S. does have an extensive system of coastal management policies and programs, these multiple components often diverge from the central goal of coastal resource conservation and frequently contradict one another. Consistency between state plans and local municipalities is lacking and the good intentions of the state CZM plans are frequently misinterpreted [14].

### 2.3.2. Australia

With approximately 40 mangrove species bordering its coastlines, Australia contains one of the highest levels of mangrove diversity in the world [1]. Australia's mangrove ecosystems are federally protected under the Department of Sustainability, Environment, Water, Population, and Communities. Wetland regulations overseen by this department encompass mangrove forests and other vital coastal habitats. The most fundamental regulatory tool, the *Environmental Protection and Biodiversity Conservation Act of 1999* (EPBC Act) is the central piece of environmental legislation in Australia [55].

Commonwealth Reserves established under the EPBC Act play an integral role in conserving mangrove ecosystems in Australia. These government regulated reserves include national parks, marine protected areas (MPAs), and various forms of national monuments and conservation sites. MPAs in particular provide the vast majority of mangal protection throughout coastal Australia. The national government oversees the management of MPAs within Commonwealth Waters, while some MPAs are established at the state level and encompass coastal territory [55]. Management of Australian MPAs on the national level falls under the authority of the Director of National Parks, with some responsibility delegated to the Marine Division of the Department of the Environment and Water Resources. The

Minister for the Department of the Environment and Water Resources approves all final management plans for MPAs, as well as all Commonwealth reserves [55].

As a member of the World Conservation Union (IUCN), the Australian government is obligated to follow the *IUCN's Guidelines for Protected Area Management Categories* as established in 1994. Seven categories of MPAs have been identified by the IUCN: (1) Strict Nature Reserve, (2) Wilderness Area, (3) National Park, (4) Natural Monument, (5) Habitat/Species Management Area, (6) Protected Landscape/Seascape, and (7) Managed Resource Protected Area. These seven categories form the basis for Australian MPA management principles. In conjunction with the IUCN guidelines, schedule 8 of the EPBC Act requires that each management plan explain what is allowed in the reserve, how management will be implemented, and how the plan will be sustained over time [56,57].

In addition to the principles established by the EPBC Act, the management of Australia's mangroves is strongly based on the guidelines set forth by the Ramsar Convention. Schedule 6 of the EPBC Regulations of 2000 outlines the general management principles for Wetlands of International Importance (Ramsar Sites), many of which include mangrove forests [57]. As the first nation to sign the Ramsar Convention, Australia ensured that no activities will be allowed to impact the biodiversity or intrinsic values of its protected wetlands [55]. This promise guarantees the wise use and conservation of all critical wetland habitats in Australia. Currently, Australia has listed 65 Wetlands of International Importance under the Ramsar Convention. These protected habitats comprise approximately 7.5 million hectares [58]. Working with the Natural Resource Management Ministerial Council (NRMMC), the Australian government strives to meet the requirements of the Ramsar Convention and implements the measures outlined in the EPBC Act [59].

#### 2.3.2.1. Implementation of ICZM in Australia

Australia's Commonwealth (federal) government dictates jurisdiction over the nation's marine habitat. The coastal zone is grouped with inshore regions which typically reside under the jurisdiction of state and territory governments. The Commonwealth government does participate in coastal management as shown in the 1998 *Australia's Oceans Policy*, which was enacted to improve the management of all marine habitats including coastal wetlands and estuaries [60]. *Australia's Ocean Policy* is carried out by the Oceans Board of Management and the National Oceans Advisory Board. The Oceans Board of Management is comprised of government officials with marine interests, whereas the National Oceans Advisory Board consists of nongovernment personnel. These two perspectives provide an all-inclusive approach to policy implementation in Australia [61].

The primary goal of *Australia's Oceans Policy's* integrated multiple-use management is implemented via Regional Marine Plans. It is anticipated that regional marine planning will improve coordination and consistency between the state/territory government and the Commonwealth government [61]. Each of the five bioregional planning areas in Australia identifies a set of management provisions to help achieve ecologically sustainable development [60]. In 2005, the concept of regional marine planning was incorporated into the EPBC Act under section 176. The primary goal of the five bioregions was to provide a planning tool for the Commonwealth government in order to promote ecosystem-based management [60]. Thus, *Australia's Oceans Policy* sets the stage for integrated management of all Australia's marine ecosystems, including coastal resources [61].

In order to balance conservation and development within the fragile coastal regions, the Australian Department of Sustainability, Environment, Water, Population, and Communities developed a *Framework for a National Cooperative Approach to Integrated Coastal Zone Management*. Formally endorsed in 2003 by the NRMCC, the framework established parameters for national cooperation and sustainable development within the coastal zone. The NRMCC proposes the 2003 framework as a way to coordinate multiple jurisdictions in the coastal zone that dictate different, and often contradicting, legislative and administrative agendas. The next step for Australia's government will be to implement the tools presented by the 2003 framework and officially set forth an ICZM program for the entire country [62].

#### 2.3.2.2. Queensland, Australia

Aside from the federal wetland programs in Australia, local governments and state agencies also maintain wetland management authority. For example, the Queensland government established their own "Coastal Plan" in addition to four regional management plans which include policies related to the development, conservation, and rehabilitation of coastal habitats. Queensland's Department of Environment and Resource Management (DERM) has the primary regulatory role in implementing and overseeing these plans. Marine plants, including mangroves, are managed by the Department of Primary Industries and Fisheries (DPI&F) in Queensland. The Integrated Planning Act 1997 oversees any and all proposed disturbances to mangroves. In addition to state agencies, the Commonwealth government maintains some jurisdiction over Queensland mangroves. The Department of Sustainability, Environment, Water, Population, and Communities is a key stakeholder in Ramsar Sites, and the Great Barrier Reef World Heritage Area extends to the high watermark and thus includes mangroves under its jurisdiction. These national guidelines are essential for effective management of mangroves, but the overlap that occurs can become confusing and lead to less successful implementation and enforcement [59].

#### 2.3.3. Belize

With the western hemisphere's largest barrier reef, Belize attracts an abundance of international visitors who directly contribute to this Caribbean nation's annual income [63]. In conjunction with Belize's barrier reefs, mangrove-lined coasts and cayes entice tourists to participate in the marine activities offered by Belize's natural resources, such as snorkeling, diving, and fishing [64]. By the 1980s, the Belizeans began to recognize the important role mangrove ecosystems play in their tourism industry. Coral reefs have historically been protected through a series of MPAs, but as tourism and coastal development rapidly increased, it became apparent that an integrated management system was necessary to protect all of Belize's natural resources [63].

Although coral reefs receive the majority of the Belizean government's attention, mangroves have been protected under the Belize Forests Act since the 20th century. A permitting system for removing mangroves was established under the Forests Act and only allows the removal of mangroves after environmental assessments have been conducted (similar to the U.S. system of EIAs). Forest reserves have also been created under the Act's authority. Having been in existence since 1927, the Forests Act has been revised multiple times and received its most recent revision in 2008. In Belize, these revisions typically increase fines and sanctions associated with mangrove destruction, and improve compliance with the regulations. In addition to being protected on both private and national land by the Forests Act,

mangroves are also safeguarded by the Belize Forestry Department. Any alterations to a mangrove may require evaluation and potentially a permit from the forestry department, similar to the U.S. Mangrove Trimming and Preservation Act. Other activities, such as fishing, coastal development, and complete mangrove clearance, are regulated by the proper government agencies within the Ministries of Natural Resources, Tourism, Agriculture, and Fisheries [63,65].

### Implementation of ICZM in Belize

The first ICZM process began in Belize at a Fisheries Department workshop in 1989. One year later, a CZM Unit was developed within the Fisheries Department. Funds and technical assistance from the UN Development Programme (UNDP) and the Global Environment Fund (GEF) allowed for the development of a full CZM Project in Belize from 1993–1998. A primary piece of legislation, the CZM Act of 1998, led to the creation of the Coastal Zone Management Authority and Institute (CZMAI) [63].

Initially, the local fishermen were opposed to the CZMAI, believing that it ignored fishing interests and prohibited their standard fishing activities. Not long after the CZMAI was established, research, education, and monitoring programs were implemented. A reference and research library was also created to encourage the spread of knowledge throughout Belize. Through a series of consultations and community education programs, the unrest was eventually resolved with the fishermen [63].

The CZMAI remains one of the leading research organizations in Belize. Comprised of multiple government ministries, the national CZM Authority is in charge of creating the ICZM Plan for Belize [63]. The official Belize ICZM Plan was adopted in 2013 and includes policy recommendations for nine coastal planning regions around the nation as well as a national strategy document [66]. The combined input of the CZM Authority and the associated government ministries allowed for the creation of a Coastal Planning Program as part of the ICZM Plan. The program placed the coastal regions of Belize into nine zones based on the dominant practices within those regions. Although the program was originally established for only a few reserves, coastal planning has now been incorporated throughout the cayes and along the mainland of Belize. The ICZM Plan for Belize was actually an afterthought for improving the MPAs of coral reefs. However, it has become an effective piece of national legislation which incorporates MPAs as tools for achieving more integrated CZM [63,66].

### 2.3.4. Bangladesh

Over 41% of the world's mangroves occur in South and Southeast Asia, including the Sundarbans of Bangladesh [67]. Covering approximately one million hectares (ha), the Sundarbans are the largest coastal wetland in the world. Divided between India (~40%) and Bangladesh (~60%), the Sundarban mangrove ecosystem supports endangered species such as the Royal Bengal tiger. Due to the extensive biodiversity sustained by the mangroves in Bangladesh, several reserves, afforestation initiatives, and forest policies have been employed [67].

The Bangladesh Sundarbans have been designated as a wildlife refuge in which protection is provided to the “hot spots” of wildlife [67]. The Bangladesh government has also been directly involved in mangrove restoration, having planted over 120,000 hectares of mangrove trees. These afforestation proceedings were initiated in the 1960s to maintain the mangal as a greenbelt in order to protect properties and communities along the coastal zone from the storm surge of giant cyclones [12,13]. An



area prone to natural disasters, Bangladesh directly relies on mangrove forests to maintain the stability of its coastal communities [68].

Over ten million people in Bangladesh depend on the resources produced by mangrove forests for commercial and subsistence activities [69]. Thus, forest management has been a critical factor in the development of Bangladesh's economic productivity. Consequently, the initial Bangladesh forest policies (1894 and 1955) were more "exploitative in nature" than conservative [18]. Under the sovereign Bangladesh government, a third forest policy was developed in 1979. The current forest policy was established in 1994 and focuses on ecosystem preservation as well as the improvement of socioeconomic conditions. As of 2008, the policies developed in 1994 had not been fully implemented even though financial aid and technical assistance had been received from the Asian Development Bank (ADB) [18].

The policies surrounding forestry and environmental management are under the authority of the state (national government) in Bangladesh [18]. Comprised of several government agencies, coastal management at the national level in Bangladesh is institutionally and socially fragmented. The most politically powerful and wealthy control the outcome of government regimes as well as the most productive coastal businesses (*i.e.*, aquaculture corporations). These affluent individuals are able to seize coastal land from the indigenous due to their "political protection," power, and wealth [68]. As a result, economic returns are low, and coastal habitats have received extensive damage. These conditions remain persistent throughout the Bangladesh Sundarbans [68].

#### Implementation of ICZM in Bangladesh

Under the Bangladesh Ministry of Water Resources (MoWR), a Coastal Zone Policy was created in 2005. Management plans under this policy involve the protection and sustainable use of the coastal resources in Bangladesh, including mangrove forests. However, support for ICZM was not acknowledged in Bangladesh until 1999. The national Coastal Zone Policy that was finally adopted in 2005 aims to integrate coastal zone activities into a national process as well as aid in sustainable livelihood options and reduce poverty. In addition to socioeconomic concerns, the Coastal Zone Policy incorporates the preservation and rehabilitation of coastal ecosystems. Although the Coastal Zone Policy appears promising, an official, nationwide, ICZM program has yet to be established in Bangladesh [18,68].

#### 2.3.5. Kenya

Compared to other mangrove inhabited regions, East Africa's mangrove losses have been less drastic. However, the sparse distribution and stunted growth of East Africa's mangal is evidence of overexploitation, particularly in Kenya. Timber production and export, as well as local use of mangrove wood for fuel and fish smoking, are the chief culprits responsible for mangrove declines in Kenya. Clearance of mangrove forests for aquaculture, saltpans, and urbanization has also significantly contributed to mangrove degradation [1].

Since 1932, Kenya's mangroves have been classified as "government reserved forests". Early forestry protection measures were implemented via harvest permits, but proved to be ineffective. Excessive exportation of mangrove products in the 1940s and 1950s led to one of the first mangrove management efforts along the Lamu Archipelago, where the most extensive mangrove habitat in Kenya is located.

Additional mangrove protection was pursued through an official ban on the export of mangrove products in 1978 and again in 1982 [1,70].

At the state (national) level, Kenya's environmental regulations fall under the authority of the Ministry of Environment, Water, and Natural Resources. Under the Ministry, Kenya's key environmental policy, the Environmental Management and Coordination Act (EMCA), was established in 1999. The National Environment Management Authority (NEMA) was instated as the sole regulatory authority responsible for carrying out the mandates of the EMCA. Not only did the EMCA harmonize over seventy sectoral statutes, the act also requires the use of environmental impact assessments (EIAs) for any activities associated with wetlands, mangroves, and other sensitive coastal habitats. Furthermore, sections 42 and 55 of the EMCA provide a directive to the Coastal, Marine, and Freshwater Sub-Department to ensure focus on coastal regulations, with particular emphasis on development-related issues [71,72].

Mangrove protection is also employed by the Kenya Forestry Service, thus making a consistent approach to management more difficult with the multiple government entities involved. The Kenya Forestry Service is a state (national) corporation established in 2007 under the Forest Act of 2005. In line with the mandates of the Forest Act, the Kenya Forest Service has initiated the preparation of a national mangrove forest management plan. The Forest Service's goal is to sustainably manage and conserve Kenya's forest resources while alleviating poverty and reducing mangrove degradation [73,74].

Extensive MPAs have been established throughout Kenya to further safeguard the country's coastal resources, including mangroves. Two of Kenya's MPAs are even declared "UNESCO biosphere reserves" [1]. In addition, multiple mangrove restoration efforts have been performed, specifically in Gazi Bay along the southern coast of Kenya. As of 2008, it is estimated that approximately 100 hectares of damaged mangal were reforested in Gazi Bay. Ecotourism features, including a boardwalk and fishponds, were created within the restored mangrove forest. With nearly sixty percent of the population in Gazi depending on fishing for their primary income, the incorporation of fishponds for milkfish farming within the restored site provided alternative livelihoods for the local community. The involvement of multiple governmental stakeholders as well as the local community in the Gazi Bay restoration project is an excellent example of creating a self-sustaining mangrove preserve [75].

### Implementation of ICZM in Kenya

The concept of ICZM was originally introduced in Kenya in 1984 by the United Nations Environment Program (UNEP) and was first applied in the 1990s during a pilot project in the Nyali–Bamburi–Shanzu area [76]. In 1999, under the auspices of the EMCA, Kenya's state (national) government assigned the Coastal, Marine, and Freshwater Sub-Department the task of developing and implementing an ICZM Plan as well as a National Wetlands Policy [71,72]. A Draft ICZM Policy, prepared by the NEMA in 2007, calls for a community-based approach to restore and protect Kenya's fragile coastal resources including mangroves, seagrass beds, and coral reefs. In regards to specific mangrove protection measures, the policy recommends the expansion of existing MPAs and the creation of additional MPAs. The plan also specifies a more cohesive and precautionary approach and suggests movement away from the sectoral approach as seen in Kenya's natural resource management history [76].

Kenya's Draft ICZM Policy focuses heavily on the lack of livelihood alternatives and high poverty rates, thus insinuating the need to address socioeconomic concerns in conjunction with coastal habitat

conservation. As in many East African countries, the literacy rate is extremely low in Kenya. Therefore information dissemination and education will be critical for a successful ICZM program. Despite the fact that Kenya's environmental protection is carried out at a national level, the local communities are given close attention and provided opportunities for involvement as demonstrated in the Gazi Bay restoration project [75,76].

To assist in moving forward with a national ICZM program, the *ICZM Action Plan for Kenya 2010–2014* was published by the Coastal, Marine, and Freshwater Sub-Department. The plan provides an agenda to help guide stakeholders in the management planning process. In order to create a balance between development and environmental conservation, the ICZM Action Plan recommends a participatory and inclusive approach as outlined in the document's guiding principles. Although no legally binding ICZM plan has been established at this time, Kenya is in the process of developing an institutional framework for the country's ICZM program [76].

### 3. Results and Discussion

The rate of loss of mangrove forests remains substantially higher than that of other terrestrial forests, even as management and conservation programs have become widespread [15,20]. Humans are greedy for coastal land and the profits that coincide with its development. Increasing population pressure in the coastal zone and growing demand for development appear to be the key drivers of mangrove forest destruction. Where legislation and management are absent, the problem of mangrove overuse becomes more prominent [32]. Mangrove health, as well as that of all marine and terrestrial ecosystems, is directly influenced by the effectiveness of their management and conservation [15]. Based on the results of the five case studies, three aspects of ICZM have been chosen to represent the potential solutions to mangrove destruction: (1) modification of coastal development trends through land-use reforms, (2) increased restoration initiatives and establishment of MPAs to provide safe havens for the remaining mangrove forests, and (3) placement of monetary values on goods and services supplied by mangroves to make them economically appealing to decision makers.

#### 3.1. Case Study Findings

The five case studies demonstrate the vast differences in mangrove management styles. In the U.S. and Australia, mangroves are protected under *wetland* regulations whereas Belize and Bangladesh protect their mangroves under *forestry* programs. Kenya utilizes a combination of forestry regulations as well as wetland regulations to manage the sustainable use and preservation of their mangrove habitats. While both wetland and forestry regulations are suitable mangrove management methodologies, wetland regulations tend to be more conservative in nature whereas forestry regulations are often initiated by timber production and remain focused on monetary gains rather than environmental safeguarding [25,31,36,39,41,70,72,74].

It appears that the baseline programs for mangrove management have been established in most mangrove-inhabited nations. In more affluent, developed countries, regulations are focused primarily on coastal development and the associated conservation requirements. On the other hand, the developing world tends to gear their regulations towards production needs such as harvesting of mangroves and their accompanying resources. Although this does not hold true for all developing nations, particularly Belize,

these countries tend to neglect the need for national oversight. The U.S. and Australia do have substantial national policies in place to protect their natural resources. Yet overarching federal laws and regulations supported by voluntary state and local programs that encompass these wetland policies often overlap and cause managers and regulators to lose site of the overall goal [25,31,36,39,41].

The movement towards ICZM is evident in all case studies, with the U.S. paving the way. In developing nations, ICZM is commonly in the early stages of development, whereas developed nations are more likely to have established ICZM programs [28]. It can be implied that several of the guidelines established by the FAO and ISME have been implemented, whether or not this was any of these countries' intention. All five of the case studies present countries which are contracting parties to the Ramsar Convention [58], yet only the U.S. and Australia hold memberships with the ITTO [77]. The ITTO guidelines for forest management are not legally binding; however, it would be advantageous, particularly for Belize, Bangladesh, and Kenya, to participate in this forestry-based organization to help improve their management strategies [37–39].

### *3.2. Solutions to Diminish Mangrove Destruction*

#### *3.2.1. Coastal Land-Use Reforms*

Due to limited space in the coastal zone, the impacts of increasing populations are magnified [78]. With additional people comes more infrastructure and development. Most of this development occurred long before coastal geology and physiology was understood and has, therefore, created countless cases of human-induced beach erosion and habitat destruction [79]. Coastal development and environmental protection must incorporate one another; they cannot be viewed as independent activities. Therefore, environmental concerns in the coastal zone must be included in land-use decisions and policies [21].

Modern land-use patterns of low density, scattered developments dependent on cars, has been given the term “sprawl” [14]. Coastal sprawl has led to an excessive amount of impervious surfaces (e.g., pavements, sidewalks, parking lots, building foundations). These surfaces do not allow rain water to seep into the soil or flow through vegetation where excess nutrients and pollutants are diluted [78]. In order to change these trends, land-use reforms will need to be implemented. Unlike habitat protection programs, land-use planning, and therefore most coastal development, falls under the authority of local governments. For example, in the U.S., cities and towns define how and where community development should be located (and where development should not occur) in their comprehensive land-use plans [80].

To prevent additional coastal habitat damage, development patterns will need to be modified. Two tools are identified in the literature as guides to coastal development: zoning regulations and setback lines [81]. Zoning is used in a community to classify specific uses of the land and can be used directly with multiple-use management strategies. It also sets development criteria for each zone [80]. For instance, zones are used to determine where condominiums, shops, houses, ports, warehouses, and other infrastructure can be built. Each building category is subject to different regulatory requirements. Regulatory zoning is quite common for urban land-use management, yet it is not customary in CZM. Since an abundance of activities in the coastal zone compete for the same resources, it would be advantageous to incorporate zoning into CZM plans to prevent the overexploitation of coastal resources and land [13].

While zoning policies are often used to manage beachfront and coastal construction, another effective method is used to retain development behind a safety point. Often called a setback line, this jurisdictional line is located inland at a safe distance from the beach and coastal waters. Setback provisions act as buffer zones to prevent development in hazardous or sensitive habitats on or near the shore. The location of a setback line is usually determined by local erosion rates to plan for future storms and sea level rise [13]. Typically, once the setback line is in place, no structures are allowed seaward of the line. However, as seen from examples in Florida, many exceptions and “grandfathering” stipulations allow for continued development beyond these lines [82]. Potentially helpful regulatory tools like Florida’s Coastal Construction Control Line (CCCL) and setback line are often fruitless due to underlying political issues in coastal development [21,83]. If setback provisions were included in every coastal state’s CZM plan and strongly enforced on a local level, overdevelopment along the shoreline could be halted [21].

Watershed management must also become a primary focus of land use and regional planning in the coastal zone. It was suggested by Cicin-Sain [84] that a watershed-based boundary may be the most appropriate means for controlling the impact of land use on coastal habitats. The Pew Oceans Commission (a charitable trust organization dedicated to improving public policy in the U.S.) has estimated that when more than ten percent of a watershed’s acreage is covered by impervious surfaces, the water bodies within the watershed become severely degraded [78]. These impairments are carried to the coastal regions, resulting in pollution, excess nutrients, increased sedimentation, and restriction of freshwater flow to fragile coastal habitats. Similar to land-use planning, watershed planning is often left to the state and local governments, with superseding authority on the local level. However, natural watershed boundaries rarely coincide with political purview and may include multiple municipalities [14]. Therefore, watersheds must be managed on a regional level to incorporate the entire drainage basin, which includes the coastal zone. The boundaries of a watershed can also be easily demarcated, making their protection somewhat simpler. By utilizing the Pew Oceans Commission’s “ten percent threshold” theory, watershed managers can establish an empirical system to measure ecosystem function and health. Coastal managers must be aware of all activities that could impact the coastal zone, and not ignore inland watershed matters [13,78].

As demonstrated by the five case studies, where policies do exist to manage mangrove use, they are dispersed among multiple institutions (e.g., forestry, wetlands, and fisheries) [32]. The same trend is seen in development policies regarding land-use planning. Stricter regulations have been known to deter some environmental damage, but better coordination and enforcement of these regulations will be the key to success. For instance, coastal managers and environmental regulators must put a stop to “grandfathering” practices that allow construction to continue in dangerous and vulnerable coastal habitats. Such complications associated with coastal development often arise from the origin of policies and regulations: congressional legislation. Environmental policies more often than not reflect policy makers’ interests. These interests can be easily swayed by the distraction of reelection campaigns and persuasive public interest groups, particularly in the U.S. Since interest groups communicate a substantial amount of information to Congress, the bureaucracy, and voters, their preferred policies are heard above all others [85]. Their impact on policy outcomes is further enhanced by the fact that interest groups maintain instrumental political resources and are considerably more focused and aware of policy changes than the general public [83].

The influence of interest groups, economic constraints, and limitations within the political system prevent decision makers from having full discretion over policy outcomes [85]. Therefore, the ability to promote sustainable development may be politically infeasible [86]. Even when environmental regulations appear to be constructive, bureaucratic discretion alters the original intent of such regulations since the agency in charge has the right to interpret the legislation as it sees fit [87]. Furthermore, policies that may appear to protect the coastal environment are often riddled with unrealistic objectives. Unclear decisions based on complex and impractical policies often prevent the success of regulatory programs. The lack of consistent policy implementation and enforcement creates loopholes which can be exploited by land developers and other resource–user interest groups [83].

It appears that a key issue is the lack of coordination between coastal programs and agencies. Each agency has a different role and objective, but when it comes to CZM, these responsibilities must be unified [88]. National departments rarely audit state or regional CZM programs and states are unlikely to correspond with local authorities on minor land disputes [32]. To make the process more efficient, inconsistencies between the different levels of government must be eliminated through increased coordination. If all the interrelated coastal programs and agencies were legally bound to a single ICZM strategy, with similar end goals, it is more likely that their management strategies would work together rather than against one another.

### 3.2.2. Towards Sustainable Coastal Development: Smart Growth

Policy reforms and coordination of coastal programs will only be successful if they are accompanied by a change in human behavior. To achieve both conservation and development goals, communities may be required to modify existing development patterns [13]. A novel idea for environmentally friendly development has come forward in recent years thanks to initiatives in the U.S. Upon discovering that over 1,500 single-family homes were being constructed in coastal communities every day, the U.S. government created a framework for Smart Growth [89].

The Smart Growth Network was formed in 1996 and has since dedicated its efforts to reversing the trend in urban sprawl [90]. Through extensive research, the Smart Growth Network has created a set of ten principles that outline specific actions required to curb urban sprawl. The theme of this framework is movement towards compact developments that encourage walkable communities, preservation of open spaces, and revised zoning codes to allow for more housing opportunities. By building in areas where infrastructure already exists and refurbishing old structures, the need for additional land, roads, and development is reduced. By placing schools, stores, homes, and offices closer together, residents will be able to walk to their destinations rather than drive. These mixed land uses will require restructuring of zoning policies and building codes but can be integrated in state, regional, and local comprehensive land-use plans. With additional conservation easements and stricter setback provisions, there will be a reduction in polluted runoff and flooding, thus leading to a healthier watershed [88].

The Smart Growth Network provides an excellent set of guidelines to encourage sustainable development, yet these principles alone will not solve the problem of coastal sprawl. A similar program should be established on an international basis, to promote sustainable development around the world. The Smart Growth strategy as well as the guidelines created by the ISME should be made legally binding to ensure they are applied in all mangrove-inhabited countries.

### 3.2.3. The Need for Restoration and Marine Protected Areas (MPAs): Reversing Mangrove Losses

In addition to land-use reforms and sustainable development initiatives, restoration projects and MPAs must be given priority in mangrove management programs. As of 2010, an estimated 25 percent of existing mangrove habitat had been incorporated into protected areas. Although over 1,200 protected areas include mangroves, the majority of mangrove forests (approximately 75 percent) remain unprotected and overexploited [1]. Based on recommendations of the ITTO's 2002 *Mangrove Workplan*, every country containing mangrove forests should mandate the establishment of protected mangrove areas and the rehabilitation of degraded mangroves [25].

Over time, the motivation behind mangrove restoration has evolved from pure profit (timber and aquaculture industries) to the recognition of mangroves as valuable coastal habitat. National governments are beginning to address the need for mangroves as an important fishery habitat and, as a result, incorporate restoration into coastal development and management schemes [91,92]. In countries subjected to hurricanes, typhoons, and tsunamis, mangrove restoration is also used to supplement shoreline stabilization [93].

Conservation and protection of coastal areas are the chief reasons for afforestation, yet the production of natural resources is also a key instigator. Throughout Southeast Asia, nearly 500 million people depend on coastal resource exploitation as a primary source of income [87]. Mangrove restoration paired with timber or fisheries production can provide employment opportunities [93] and promotes less destructive and alternative livelihood options [94,95].

Restoration efforts are commonly seen coupled with protected sites or reserves [96]. Reserves and MPAs allow for undisturbed mangroves to flourish and facilitate the rehabilitation of degraded forests. Marine reserves and/or protected areas have been established in all five of the management case studies. In the U.S., mangroves are incorporated in the Florida Keys National Marine Sanctuary. The sanctuary and the Florida Department of Environmental Protection share the guardianship role over mangrove resources in Florida [97,98]. Australia's Commonwealth marine reserves and series of MPAs protect the country's diverse expanse of mangrove habitats [55]. A Coastal Planning program has been integrated throughout the Belize cays and along the mainland to include all their marine resources in MPAs [63]. Kenya contains an extensive network of MPAs, two of which are classified as UNESCO biosphere reserves [1]. The most renowned mangrove reserves can be found in Bangladesh where the Sundarban reserve comprises the largest contiguous mangrove habitat in the world [69].

A prime example of successful mangrove restoration can be found in Malaysia in the Matang Mangrove Forest Reserve. Located in the state of Perak, the Matang Reserve has been sustained since 1908. Since that time, less than three percent of the original area has been lost. The regeneration method used in the Matang Reserve combines the harvest of wood along with the reforestation of the mangal, similar to the mangrove plantations in the Philippines. The main objective for this reserve, aside from preserving the forest, is to obtain the maximum production for both the export of goods and local consumption [99]. Examples such as the Matang Reserve in Malaysia and the Sundarban Reserve in Bangladesh should be used as models for those countries lacking successful restoration programs.

### 3.2.4. Economic Valuation

Economic concerns dominate most government decisions; these decisions control the fate of wetlands, fisheries, and coastline stability worldwide [20]. Even with stricter regulations, better enforcement, more coordination between programs, and additional MPAs, mangrove management will still depend on the people's willingness to comply. Until a simple valuation system for mangroves is devised, decision makers will continue to overlook the invaluable goods and services supplied by these forested wetlands. The FAO [31] pinpoints this issue: "The importance of resource supply is not determined by its physical or biological characteristics but by the priority that society places on its use." In other words, people's needs must be met above all else. Policies are conceptualized by economists and political scientists in terms of their costs and benefits [83]. Thus, if the economic attractiveness of mangrove conservation is heightened, there will be more incentive for compliance with environmental regulations and management programs [26].

There is no consensus on a reliable approach to ecosystem valuation [3]. However, some have attempted to place a dollar value on mangroves. Costanza *et al.* [100] and Tuan Vo *et al.* [101] agree that the value of mangroves and tidal marshes worldwide could be estimated at US\$10,000 per hectare per year [3]. Spalding *et al.* [1] and Wells *et al.* [102] prefer the range of US\$2000–\$9000 per hectare per year as an estimate for extensive mangrove forests that are already utilized by humans. If Spalding *et al.* [1] are correct that 15,000,000 hectares of mangroves are still in existence, then the approximate annual value of these mangroves would range from US\$30 billion to US\$150 billion [1,3,100–102].

Still, others proclaim that too many subjective values are involved in CZM and the inherent value of a natural resource is too ambiguous to be expressed monetarily [103]. Either way, managers must address the fact that decision making is facilitated by economic analysis [104]. By assigning monetary values to ecosystem goods and services, decision makers will have a guide to help choose between management alternatives as well as compare conservation *versus* development [3,83]. Furthermore, the general public can easily identify with monetary values and may be able to comprehend the magnitude of losing even one hectare of mangrove forest if it does in fact have a value of US\$10,000. The cost of rehabilitating the same hectare will be much greater in terms money and manpower [12].

A value system would also improve data collection and monitoring of the mangrove ecosystem by providing a quantitative tool [103]. Quantitative analysis is a simple and tangible way to determine the worth of a mangrove forest over the construction of a new hotel, port, or aquaculture farm. As predicted by Clark [13], "well-planned, conservation-oriented development will add to the general economic and social prosperity of a coastal community, while bad development will sooner or later have a negative effect" on all coastal inhabitants.

## 4. Conclusions

Increasing populations and developments within the coastal zone have caused rapid degradation to mangroves [94]. Due to the fact that most governments considered mangrove forests to be insignificant swamps until recently, policies mandating their protection and guiding their management have been far overdue in the majority of tropical countries [105]. A wide variety of policies, programs, and natural reserves have been established around the globe to help protect the remaining mangal; still there remains



room for improvement. Failure to establish a connection between the goods and services provided by mangroves with the resource itself has prohibited successful implementation of management strategies [106].

After reviewing the literature, it appears that successful mangrove management will require a combination of strategies and incorporation of all levels of government [107]. As a result of the efforts of the FAO, Ramsar Convention, ITTO, and ISME, required information to execute *integrated* CZM and restoration plans for mangrove forests can be obtained by coastal communities, managers, and decision makers. However, continuous improvements will be needed to ensure the conservation of remaining mangrove ecosystems. Land-use policies, including zoning, building codes, and setback lines, will require amendments to restrict unsustainable development in the coastal zone. These land-use reforms, along with watershed management, must be incorporated into ICZM programs to strive for Smart Growth. By implementing stricter regulations and enhancing enforcement, perhaps overdevelopment in the coastal zone can be put to an end [14,78,79].

Above all, behavioral changes must occur in coastal communities. Education campaigns will be necessary to encourage public awareness, community involvement, and compliance with mangrove management programs. Severe penalties for violators as well as rewards for whistleblowers and cooperative communities will help improve compliance. To promote these changes, a legally binding international law should be in place to ensure all tropical countries containing mangroves implement an effective ICZM framework for mangrove conservation [13]. At this time, ICZM remains an idealized model, which has yet to be fully or truly implemented in any nation [84].

In addition to an international ICZM policy, the restoration of all damaged mangrove habitats and preservation of any remaining mangroves should be mandatory. To achieve this, existing mangal should be identified and categorized into areas for preservation, conservation, or sustainable use. By performing global mangrove restoration and rehabilitation, perhaps the remaining 152,000 square kilometers of mangal can be maintained [32]. The sustainable management of mangrove ecosystems will ultimately rely on the cooperation of numerous governmental bodies as well as local stakeholders striving for a common goal: the protection and restoration of all remaining mangrove habitat [106]. With the assistance of international organizations and support from local communities, a unified approach to managing the world's mangrove forests may be accomplished in the near future.

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Haille N. Carter conceptualized the content of this review, collected literature, and prepared the final manuscript. Steffen W. Schmidt and Amy C. Hirons contributed substantially to the drafting of the manuscript through revisions and comments as well as providing additional material and suggestions.

### **Conflicts of Interest**

The authors declare no conflict of interest.

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