A Study on the Maritime Affairs

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Abstract

Biological connections throughout the Gulf of Mexico region pervade waters of the United States, Mexico, and Cuba. Identification of important high-biodiversity habitats and the species that utilize such uncommon habitats in the Gulf of Mexico provides a scientific basis for cooperative international marine conservation and policy. Combined with a compatibility analysis of existing national marine policies, an ecosystem-based marine spatial planning tool would enhance the understanding of connectivity elements and processes, map distribution of habitats with high biodiversity, minimize discontinuity among national marine policies, and maximize coordinated international protection while managing transboundary living marine resources based on biophysical characteristics of the large marine ecosystem. Existing conditions in the Gulf of Mexico region support an enterprise to design several alternatives for an international network of marine protected areas in the Gulf of Mexico for joint consideration by policy decision-makers from the United States, Mexico, and Cuba. The same model could apply to other transboundary large marine ecosystems.

**Key words:** transboundary ecosystem, marine protected area network, connectivity

1. Introduction

The Gulf of Mexico (GMx) is a semi-enclosed, international sea that comprises a large marine ecosystem bordered by three nations: the United States (U.S.), Mexico, and Cuba. As such, the GMx provides important habitat for many transboundary living marine resources, ranging from highly migratory species to sessile invertebrates. Most transboundary species represent connectivity of the existing ecological network within the GMx and into the Caribbean Sea. These species may rely on important habitat features, such as hard and soft banks, hard-substrate reefs, and even man-made structures such as oil platforms, distributed in a semicircular fashion around the GMx continental shelf. Known key habitat areas have varying vertical relief from the seabed, collectively constituting a complex seascape of submerged islands. Protection of these habitat features throughout the GMx is an integral component of international ecosystem conservation and management. Properly designed habitat protection is imperative for maintenance of ecological connectivity and biodiversity, which are the most commonly identified criteria necessary to sustain marine ecosystem health (Foley *et al*., 2010).

2. Biophysical setting

The region for the proposed international MPA network is the GMx, which encompasses waters of the U.S., Mexico, and Cuba. The GMx is a semi-enclosed oceanic basin that is connected to the Caribbean Sea via the Yucatan Channel and to the northwestern Atlantic Ocean by the Florida Straits. Terrestrial boundaries of the GMx include the U.S. to the north, Mexico to the south and west, and Cuba to the east. For the purposes of this analysis, the eastern marine boundaries of the GMx extend from Key Largo, Florida, U.S., to Punta Hicacos, Matanzas, Cuba, and from Cabo de San Antonio, Pinar del Río, Cuba, to Cabo Catoche, Quintana Roo, Mexico (Figure 1; Felder, Camp, and Tunnell, 2009).

**Figure 1.** Gulf of Mexico study area

C:\Users\hnash\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Word\GoMx map w sectors.tif

**Source** : Adapted from Felder, Camp, and Tunnell, 2009

Regardless of shelf sediment type, the vast majority of the GMx continental shelf is composed of soft substrate. However, several hard-substrate habitats, including reefs, banks, diapirs, and rocky outcrops, exist in spots along the continental shelf and exhibit various levels of biodiversity. While hard-substrate habitats comprise only a small portion of the GMx continental shelf, they have concentrated, high biodiversity when compared to biodiversity of species that inhabit the surrounding soft-substrate habitats (Parker and Curray, 1956; Rezak, Bright, and McGrail, 1985). Areas with true coral reefs include the Dry Tortugas and Florida Keys off southern Florida, the Flower Garden Banks on the outer continental shelf off Texas, the Tuxpan and Veracruz Reef Systems off the Mexican state of Veracruz, the Campeche Bank Reefs on the shelf west of the Yucatan Peninsula, and reefs off northwestern Cuba (Tunnell, 2007a). Coral reefs in the northwestern GMx are submerged while coral reefs in the southern and eastern GMx are typically emergent. The hard-bottom banks, such as Stetson and Southern Banks, exhibit a gradual transition from temperate communities nearshore to tropical communities offshore (Rezak et al. 1985). The transition for benthic communities on the GMx mid and outer shelves, as seen elsewhere as well, appears to be associated with substrate type (Rezak, Bright, and McGrail, 1985).

3. Ecological framework

Although an MPA network would likely result in numerous ecological benefits, the goal to facilitate the ecosystem’s resiliency and recovery after a disturbance is most strongly supported by two conservation targets: connectivity and biodiversity.

*3.1 Biological connectivity*

Biological connectivity can occur as genetic connectivity or demographic connectivity (Cowen, 2002). The former is based on temporal “stepping stones” in the context of a large spatial scale, and the latter stems from the effects of geographic “stepping stones” over a long temporal scale. Accordingly, intact demographic connectivity generally maintains genetic connectivity (McCook *et al.*, 2009). While studies of both types of connectivity are relevant to the task of designing a network of MPAs, a focus on maintaining demographic connectivity is better suited for a multi-species approach and spatial planning for a large marine ecosystem such as the GMx.

**3.1.1** Passive ecological connectivity

Pelagic early life stages of some species undergo passive transport, either solely or in concert with active movements. Passive biological connectivity stems from oceanographic currents that act as vectors to transport nutrients and early life stages, such as planktonic eggs and larvae as well as juvenile sea turtles, from one habitat feature to another. Surface currents, deep currents, convergent currents, and episodic turbulence and their variable velocities and directions play substantial roles in dispersal or retention of eggs, larvae, and nutrients. However, currents alone do not determine connectivity paths (Roberts *et al.*, 2006). Larval behavior, such as vertical migration and late-stage horizontal swimming, denotes active movement, which is an important species-specific factor that may help explain why some species have high larval retention while others have high larval dispersal from shared spawning grounds. Other factors, such as pelagic larval duration, distance to suitable recruitment habitat, life histories, larval behavior, adult spawning strategies, current patterns, water temperatures, and extreme weather events, also affect connectivity at the larval stage. Strong storms such as hurricanes likely increase larval dispersal for some species as long as turbulent conditions do not increase larval mortality. Therefore, population connectivity through larval transport varies greatly by species, location, and oceanographic conditions.

Although scientific approaches for comprehensively describing larval dispersal, even for a single species, are not yet mature (Jones *et al.*, 2009), many larval dispersal studies have yielded useful data. Larval retention and local self-recruitment drive population dynamics for some species (Cowen *et al.*, 2002; Swearer *et al.*, 2002). However, larval dispersal is also a means of ecological connectivity (Domeier, 2004; Roberts *et al.*, 2006; Christie *et al.*, 2010). Ecological connectivity likely results from a combination of larval retention and larval dispersal at population and community levels (Swearer *et al.*, 2002; Planes, Jones, and Thorrold, 2009; Butler *et al.*, 2011). For example, brooding corals at an individual reef may thrive from high levels of self-recruitment in addition to occasional long-distance supplements from other reefs up to tens of kilometers away; therefore, larval retention and larval dispersal are both important in sustaining the population (Jones *et al.*, 2009). Various connectivity patterns existed within a single community in Hawaii, which is likely the case in most geographic locations (Toonen *et al.*, 2011).

**3.1.2** Connectivity in the Gulf of Mexico

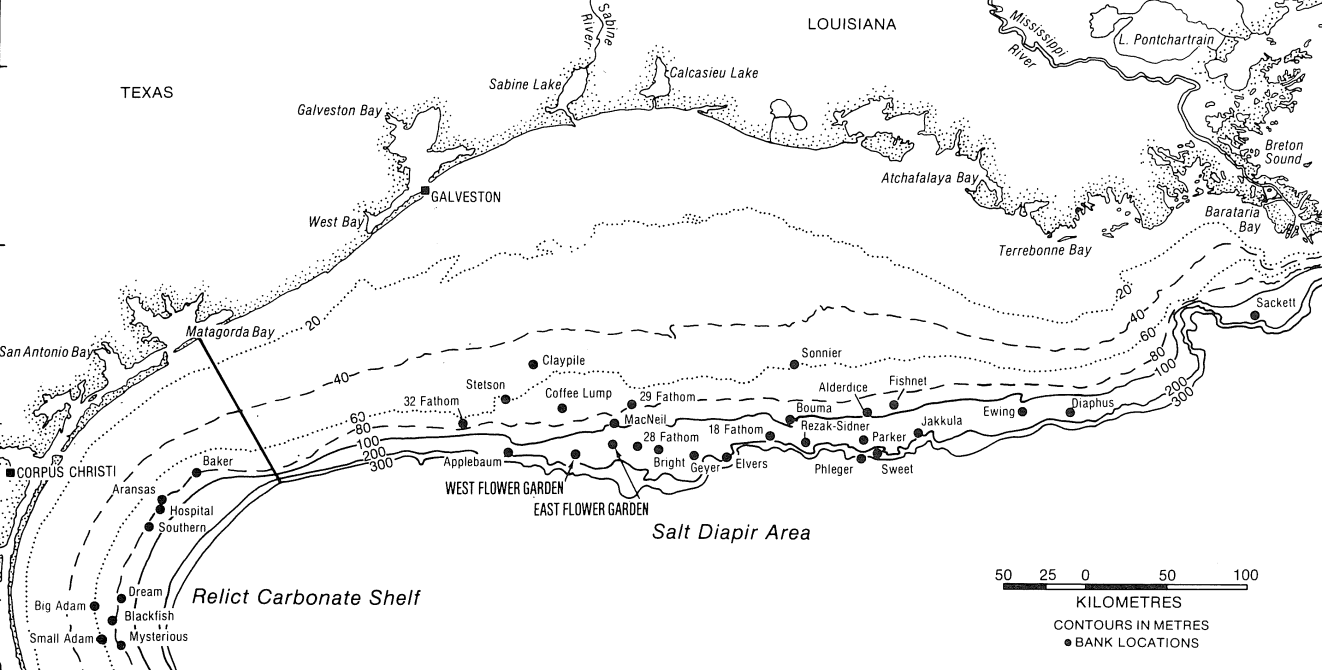
Specifically in the GMx, habitat “stepping stones” may appear topographically distinct and somewhat isolated, but they represent ecological nodes that are connected via passive and active movements throughout the GMx and Wider Caribbean region. Several studies support connectivity in the GMx based on transport via ocean currents (Lugo-Fernandez *et al.*, 2001; Phinney *et al.*, 2001; Jordan-Dahlgren, 2002; McBride and Horodosky, 2004; Vásquez-Yeomans *et al.*, 2009; Paris *et al.*, 2008). Based on drifter routes, potential larval connectivity exists for broadcast-spawning coral species, and perhaps even some brooding species, between West and East Flower Garden Banks and to other banks and platforms to the east and southwest within the GMx (Lugo-Fernandez *et al.*, 2001). Ocean currents may have had an important role in the die-off of *Diadema antillarum* most likely by dispersal of a waterborne pathogen from the western Caribbean Sea into the GMx in 1983-1984 (Phinney *et al.*, 2001). A high degree of gorgonian species similarity occurs across large distances in the southern GMx, and gorgonian distribution appears to be linked by surface currents (Jordan-Dahlgren, 2002). Ocean currents are also capable of dispersing long-lasting, planktonic ladyfish (morphs *Elops saurus* and *E.* sp.) larvae across long distances in the eastern GMx (McBride and Horodosky, 2004). Currents are likely the driving mechanism for transporting bonefish larvae (*Albula* spp.) from offshore areas of the GMx and Mexican Caribbean to coastal nursery grounds (Vásquez-Yeomans *et al.*, 2009). Some degree of connectivity is evident among populations of queen conch (*Strombus gigas*) that may support its existence as a metapopulation; although the population in Campeche Banks, Mexico, appears isolated, the Mexican Caribbean queen conch population is slightly related to the Cuban and Floridian populations as a result of some subregional larval exchange via the Loop Current (Paris *et al.*, 2008). Therefore, the queen conch demonstrates weak demographic connectivity but steadily maintained genetic connectivity.

*3.2 Biodiversity*

Biodiversity is the variety of species and the variability of their abundances throughout space and time of a defined study (Magurran, 2004). Reduction of biodiversity can adversely affect ecological stability. Functional groups of species perform specific roles, many of which are linked to ecosystem services provided to society, and removal of a functional group can destabilize an ecosystem (Folke *et al.*, 2004). Therefore, maintaining biodiversity, which includes isolated populations, is an important objective in ecosystem-based management and marine spatial planning initiatives.

Key biodiversity indicators include measures of species richness and species evenness as well as identification of occurrences of rare species, such as those listed according to Federal statutes (*i.e.* Endangered Species Act of 1973, as amended [16 U.S.C. § 1531 *et seq.*]) and the IUCN (International Union for Conservation of Nature and Natural Resources) Red List of Threatened Species (IUCN, 2010). The GMx hosts more than 15,000 species making it one of the most diverse marine ecosystems in the world (Tunnell, 2009). The GMx is a faunal transition zone, or ecotone, with high biodiversity of mesopelagic fishes (Bangma and Haedrich, 2008). GMx had the highest species richness and species abundance when comparing mesopelagic fish fauna to those of the North and South Sargasso Seas as well as the Venezuelan and Columbian Basins of the Caribbean Sea. High but variable levels of biodiversity of benthic fauna exist throughout the GMx continental shelf (Rabalais, Carney, and Escobar-Briones, 1999). However, the northern GMx generally does not have high biodiversity of deep-benthic fauna, but the Mississippi Trough has the highest deep-benthic species richness in the northern GMx (Haedrich, Devine, and Kendall, 2008). Finally, seabird diversity varies seasonally, but the southern GMx hosts close to four times as many seabird species as the northern GMx (Peake, 1999; Davis, Evans, and Wursig, 2000; Tunnell, 2007c)

**Figure 2.** Selected high-biodiversity sites in the northwestern GMx



**Source** : Adapted from Rezak, Bright, and McGrail, 1985.

**Table 1.** Hard banks and reefs on GMx continental shelf in Federal waters

|  |  |  |
| --- | --- | --- |
| Geographic group | Number of known sites | Location |
| Northwestern reefs & banks | 34 | Off Texas & Louisiana | |
| Northeastern reefs & banks | 9 | Off Mississippi, Alabama, & northern and mid Florida | |
| Southwestern Florida shelf | 3 | Off southern Florida | |
| Northwestern Cuban reefs | 4 | Between Punta Hicacos & Cabo de San Antonio (Cuba) | |
| Campeche Bank reefs | 15 | Off western Yucatan | |
| Veracruz reef system | 25 | Off City of Veracruz | |
| Tuxpan reef system | 6 | Off City of Tuxpan and Cabo Rojo | |
| South Texas banks | 20+ | Off Texas south of Matagorda Bay | |

**Sources** : Rezak , Bright, and McGrail, 1985; Tunnell, 2007b

4. Network design

From a spatial-planning perspective, the existing hard-substrate banks and reefs of the GMx large marine ecosystem would translate well into an international network of MPAs. Additional habitat sites, such as slope sites and artificial habitats, may supplement the connectivity provided by the hard banks and reefs. Some of the many intermediate delivery cold seeps on the continental slope have developed diverse communities that may offer connectivity to some of the hard-bottom habitats as well. Evidence exists of biological connectivity between hard banks and reefs and oil and gas platforms (Lugo-Fernandez *et al.*, 2001; Fenner and Banks, 2004). While including platforms with relatively short lifespans in an MPA network may not be warranted, decommissioned platforms that are toppled to the bottom in the Rigs-to-Reefs program or decommissioned platforms that are left in place without toppling might be appropriate for inclusion in an MPA network (Hoffman, 2011). Regardless, network management design should include features to incorporate flexibility to modify existing features and add future components and adaptability to accommodate temporal and spatial ecological shifts resulting from long-term dynamics, such as climate change, as well as episodic events, such as natural or anthropogenic disasters. An MPA network would facilitate ecological recovery following such destabilizing events. For example, if a hurricane destroys one habitat area and its subpopulation of a fish species, another habitat area might serve as a stepping stone in the restoration process as it supplies or receives larvae transported by currents.

5. Marine policy and law in the Gulf of Mexico

Most waters in the GMx belong to one of the three bordering nations. However, there are two small areas, the Western Gap and the Eastern Gap, that are located beyond the Exclusive Economic Zone (EEZ) of the U.S., Mexico, or Cuba and, therefore, subject only to international law. For practical and geographical purposes, the scope of this analysis is limited to Federal waters in the GMx, thus excluding the Western and Eastern Gaps as well as the state waters along the U.S. Gulf coast. Mexico and Cuba do not have designated state waters; thus, the analysis extends to the coast in Mexican and Cuban waters while the U.S. analysis is focused offshore beyond state waters. Coincidentally, geology and ecology in the GMx region favor such a demarcated analysis as well.

*5.1 Existing marine protected areas in the Gulf of Mexico*

The U.S., Mexico, and Cuba each have MPAs in their Gulf waters. However, the three nations do not use a consistent definition of MPA. Much confusion exists regarding the term “marine protected area.” Some people confuse MPA with a no-take area or marine reserve. As a result, new terms, such as “marine managed area,” are being used to avoid the misconception that an MPA is not a multi-use designation. The IUCN uses six categorical definitions, which helps alleviate the confusion to some extent by focusing on conservation criteria instead of nomenclature. In the U.S. and elsewhere, MPA examples include Federal parks, sanctuaries, monuments, critical habitats, essential fish habitats, wildlife refuges, and National Estuarine Research Reserves (NERRs); tribal refuges; State and local NERRs (Federal/State joint protection), parks, reserves, and conservation areas; non-governmental set-asides by organizations or other private property owners; and *de facto* MPAs designated for other purposes such as exclusion areas, oil and gas lease blocks, or shipping lanes.

For the sake of consistency in designing an international network of MPAs, this discussion uses the definition asserted in the U.S. President’s Executive Order (13158) issued in 2000: “any area of the marine environment that has been preserved by Federal, State, territorial, tribal, or local laws or regulations to provide lasting protection for part of all of the natural and cultural resources therein.” Therefore, non-governmental and *de facto* MPAs are excluded. Also, recall that the scope of this discussion is limited to Federal waters in the GMx, which eliminates inclusion of State and local MPAs in the U.S. considering the jurisdictional boundaries within U.S. waters.

**5.1.1** United States

Including many small State and local MPAs, there are 295 MPAs in the U.S. waters of the GMx, covering about 40 percent of the region (NOAA, 2011). Most areal coverage is protected to some extent by the National Marine Fisheries Service (mostly related to fisheries management). Only one percent of the U.S. MPAs in the GMx has a no-take restriction; therefore, almost all GMx MPAs in U.S. waters are designated as multi-use (NOAA, 2011). Of all the GMx MPAs in the U.S., 95% by area are in Federal waters (NOAA, 2011); therefore, associating an MPA network with offshore waters of the U.S. Gulf is justified. Additionally, the Rookery Bay National Estuarine Research Reserve is coordinating development of a communication framework for existing coastal MPAs (including State and local MPAs) to coordinate and cooperate as a network in the northern Gulf region (Young, 2011). Although such a northern coastal network is beyond the scope of an international network, merging the coastal and offshore networks could be a future goal once they are both well established.

Legal authorities and managing agencies vary greatly for the U.S. MPAs. However, despite the legislative fragmentation, the National Marine Sanctuary Program (NMSP) is the Federal agency that is most likely to coordinate an international network of MPAs from the U.S. perspective given that the NMSP’s statutory authority stems from the National Marine Sanctuaries Act of 1972, as amended (16 U.S.C. § 1431 *et seq*.), which is focused solely on MPAs. NMSP manages two GMx MPAs: Florida Keys National Marine Sanctuary located off southwestern Florida and Flower Garden Banks National Marine Sanctuary located about 100 mi off the Texas and Louisiana coasts. For the Flower Gardens site, NMSP issued a Draft Management Plan in October 2010 that includes a proposed expansion to modify existing boundaries and to add six banks with 500-m buffers in the northwestern GMx to the sanctuary (NOAA, 2010). The site selections were based primarily on topography and presence of coral assemblages. If approved, the expanded sanctuary could provide a good starting point for developing a Gulf-wide network of MPAs.

**5.1.2** Mexico

Unlike the U.S., Mexico has a national system of protected areas, which encompasses both terrestrial and aquatic environments. Such a consolidated system minimizes regulatory confusion and redundancy because one Federal agency, *Comisión Nacional de Áreas Naturales Protegidas* (CONANP), manages and regulates the protected areas for the entire nation. The Mexican Gulf hosts several MPAs—two national parks, two protected areas of flora and fauna, and one sanctuary (CONANP, 2011). In the western portion of the southern GMx, CONANP protects the Tuxpan and Veracruz reef systems, and in the eastern portion of the southern GMx, the agency protects the Alacrán reef and a couple of lagoon and beach areas. Mexico protects additional coastal areas, such as sea turtle beaches, that afford protection to the marine environment, but the protected area borders do not extend into the GMx. Coral reefs in the southern GMx (Figure 3), whether existing or prospective Mexican MPAs, are likely candidates for inclusion in an international network.

*5.2 Toward an integrated international governance in the Gulf of Mexico*

Transboundary species utilize habitats with disregard to political boundaries. Therefore, disconnected national marine policies and various anthropogenic pressures throughout the GMx region affect these species directly. Adverse and beneficial effects on transboundary resources caused by one nation’s policies are felt by other nations that value the same resource. Therefore, objectives of effective trinational governance of living marine resources in the GMx are: (1) to understand the key elements that maintain biological connectivity and biodiversity as mentioned in sections 3.1 and 3.2, respectively; and, (2) to agree on international policies and governance mechanisms to seamlessly protect and conserve the large marine ecosystem and to sustainably manage its transboundary living marine resources.

International policy agreement must be flexible enough to apply within the various legal systems that govern management and use of marine resources in the GMx. The U.S., Mexico, and Cuba governments each have different legal systems. The U.S. government operates under the common law system, Mexico is governed by the civil law system, and Cuba has a legal system that is an evolving hybrid of common and civil laws that is based on communism. Despite the lack of similar legislative frameworks in the GMx region, the three nations each have governance mechanisms in place that could support an MPA network as discussed in section 5.1.

6. Connectivity in other transboundary large marine ecosystems

Identifying important high-biodiversity habitats and biological connectivity coupled with a compatibility analysis of existing national marine policies could serve as the foundation for valuable ecosystem-based marine spatial planning tools in other transboundary large marine ecosystems (LMEs). Creating MPAs in semi-enclosed seas and LMEs that are experiencing intense natural and anthropogenic stresses is an important method of supporting and advancing the long-term sustainable use and conservation of these valuable ocean areas. Moreover, the growing body of scientific literature suggests that transboundary MPAs can serve as a catalyst to broader political reconciliation beyond the environmental sphere (Sandwith *et al.*, 2001; Ali, 2007).

7. Conclusions and policy implications

Based on identifiable physical and biological features and phenomena, the GMx would be an ideal location for a large-scale network of MPAs. As a result of past and ongoing trinational efforts, scientists and policy makers from the U.S., Mexico, and Cuba have identified strategies and continue to work together to ensure success of international management of shared living marine resources. An ecology-based spatial planning tool would enhance the understanding of connectivity elements and processes, identify specific sites with high biodiversity, minimize political discontinuity, and maximize coordinated protection while managing transboundary living marine resources based on biological requirements. A geographic information system (GIS) would be an optimal platform for conducting a gap analysis stemming from the composite of several layers of physical and biological data describing the GMx’s ecological network. Optimization analyses could produce alternative designs for consideration of a network of MPAs linking existing and potential new sites based on the connectivity strength of biological parameters, including species diversity. Connectivity strengths, biodiversity conservation needs, and national policies and priorities would drive the design of several scenarios for international management of an MPA network in the GMx. Also, a network design would include features to incorporate flexibility to add future components and adaptability to accommodate temporal and spatial ecological shifts resulting from episodic events, such as natural or anthropogenic disasters, as well as long-term dynamics, such as climate change. An MPA network would facilitate ecological recovery following such destabilizing events. Proposed and alternative network designs, along with metrics for measuring success, would be presented to the trinational group as the first step in the international policy decision-making process to protect and conserve transboundary living marine resources in the GMx. Successive steps should include socioeconomic analyses and stakeholder participation opportunities.

Although the GBR rezoning success is a superb example, many regions in the world, including the GMx region, may not fit the GBR model scenario closely enough to duplicate the process for reasons stated in section 4. Much planning and international collaboration in the GMx could provide a second global example for creation of a large-scale MPA network, which, in this case, would also have a prominent international marine policy component. Simplification of such a decision support tool could be considered to apply the modeling concept to other international water bodies with similar characteristics.

Given the focusing event of the Deepwater Horizon oil spill in April 2010, implementation of an international MPA network in the GMx is timely. In 2010, the U.S. President issued an Executive Order (13547), which focused on issues including, but not limited to, marine biodiversity protection, improving resilience of marine ecosystems, development of coastal and marine spatial plans, and international cooperation. In response to the disaster and to the Executive Order, the U.S. Federal government created task forces, planning bodies, funding vehicles, and goals to enable clean-up and recovery efforts to succeed in the GMx. With the heightened incentive for collaboration among the three GMx-bordering nations, effective and efficient conservation and management of transboundary living marine resources could become a reality. The existing ecologically connected habitat sites throughout the continental shelf and slope of U.S., Mexican, and Cuban waters provide an opportunity for innovative international marine policy at a regional scale. Although a toolbox full of sectoral management options exists, an international MPA network would unify regional management strategies for sustainable transboundary living marine resources in the GMx large marine ecosystem.

The ecological principles discussed here provide a solid foundation for designing an international network of MPAs in the GMx or in other transboundary large marine ecosystems. Next steps in this research include spatial designs and policy analyses for creation of an MPA network. Successful implementation, however, would require socioeconomic research to address the region’s human ecology, including valuation of ecosystem services and strong stakeholder support. The trifecta of ecology-based spatial design, trinational governance, and socioeconomic incentives would present the U.S., Mexico, and Cuba with the opportunity to form an international MPA network that facilitates sustainable, ecosystem-based management of transboundary living marine resources in the GMx.

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