Wetland Conservation Concerns in Southern Mexico

Tatiana Lobato de-Magalhães, Ph.D., PWS, Lucia Guadalupe Cruz, and Everardo Barba[1]

ABSTRACT

Approximately 16 percent of Southern Mexico's surface area is comprised of wetlands which harbor an abundance of plant and animal species, including endangered and endemic species. With two-thirds of the total wetlands of Mexico and one-third of Mexican Ramsar sites, the Southern Mexico region plays a critical role in wetland conservation worldwide. Despite national and international efforts, many wetland species and ecosystems are threatened in this region. This review includes information related to seven Southern Mexico states: Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, and Yucatán. From coastal areas to highlands, this region has around 2,020 mapped wetlands (64,298 km^2) and 41 Ramsar sites. Alarmingly, only 13 of the 41 Ramsar sites have management plans implemented. Regardless of the importance of inland wetlands in terms of their area and economic value, issues regarding their conservation and restoration are generally lacking or neglected. Southern Mexican wetlands are also severely threatened by changes in natural habitats, particularly those associated with excessive exploitation of natural resources, tourism, and the oil industry.

INTRODUCTION

Southern Mexico is a megadiverse, neotropical region that harbors several types of wetlands such as mangroves, riparian forests, floodplains, and cenotes (sinkholes) (Figure 1). According to the National Wetland Inventory, wetlands cover six percent of Mexico (CONAGUA 2020). In Southern Mexico, 2,020 wetlands occupy 64,298 km^2, representing two-thirds of the total wetlands in Mexico and 16% of the Southern Mexican States territory (the states of Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, and Yucatán).

Mexico is the country with the second highest number of Ramsar sites (142 sites designated as Wetlands of International Importance), behind the United Kingdom (175 sites) (Mauerhofer et al. 2015). There are 41 Ramsar sites in Southern Mexico, which represents approximately 29% of the total Mexican Ramsar sites (Ramsar 2020a; Table 1). The region's wetlands are valuable heritage places that provide several ecosystem services (Smardon 2006; Gortari-Ludlow et al. 2015), and substantially contribute to maintaining biodiversity at local and landscape levels (Mora-Olivo et al. 2013; Alcocer and Aguilar-Sierra 2019). This region has some of the highest levels of aquatic plant species richness and endemism worldwide (Murphy et al. 2019).

The National Wetland Policy highlights Tabasco State as having a vast expanse of wetlands (floodplain zones), particularly the *Pantanos de Centla* Biosphere Reserve (Figure 1a, Figure 2), with an area of 3,027 km^2, covering 12% of the total state surface. Among these, the Grijalva River and the Usumacinta River form an estuarine region which is considered one of the most important deltas in North and Mesoamerica because of the water flow and the importance for migratory birds and other species (IUCN 2020; SEMARNAT 2020).

WETLAND TYPES AND CLASSIFICATION

According to the National Wetland Inventory (CONAGUA 2020), Southern Mexican wetlands are grouped into three major classes: 1) marine and coastal wetlands, including marine and estuarine systems, 2) inland wetlands, including lacustrine, palustrine, and riverine systems, and 3) human-made wetlands (Table 1; Figure 3). Wetlands are further classified based on their hydrological regime (permanent, intermittent, and temporary wetlands), soil properties (texture and composition), and vegetation type, such as the endemic flooded low evergreen forest ecosystem in the Yucatán peninsula (Bala'an K'aax) and the islands of vigorous tree vegetation associated with springs and water holes, which constitute a critical habitat for wildlife, *Los Petenes* in the Campeche State (Figure 1b) (Lot 2004; Ramsar 2020a).

Marine and Coastal Wetlands

This wetland type represents around 15% of the total mapped wetlands. Marine wetlands (Figure 1c) are most represented by a seagrasses community or *ceibadal* (e.g., *Halodule, Syringodium,* and *Thalassia* species) (Creed et al. 2003) and mangroves (Figure 1d). Some threatened mangrove plant species are *Avicennia germinans* (black

1 El Colegio de La Frontera Sur (ECOSUR), Mexico; Corresponding author contact: ebarba@ecosur.mx

mangrove), *Conocarpus erectus* (button mangrove), *Laguncularia racemosa* (white mangrove), and *Rhizophora mangle* (red mangrove) (SEMARNAT 2010). Campeche and Quintana Roo States have a large portion of mangroves on the Atlantic Coast, and Chiapas State contains large areas of mangrove on the Pacific Coast.

Inland Wetlands

Most of the Southern Mexico wetlands are classified as inland wetlands (82%). They include mostly freshwater palustrine wetlands described as swamps, floodplains, marshes, and forested wetlands (riparian forests, palm thickets, and inundated low lands) (Figure 1e). Riparian forests are comprised of *Salix negra*, *S. caroliniana*, and *S. chile* (willows). Lowlands floodable forests are represented by *Annona glabra* (swamp apple) (Campeche State), *Dalbergia brownei* (rosewood), and *Ficus padofolia* (*fig* tree) (Tabasco State) (Lot 2004). Lacustrine wetlands (Figure 1f) occur mostly in highlands and are less abundant than palustrine wetlands (Olmsted 1993). Rooted floating-leaved plants are numerous in lakes, lagoons, canals, and open freshwater wetlands (e.g., *Nymphaea* – waterlily, *Nuphar* – waterlily, *Nymphoides* – floatingheart, *Potamogeton* – pondweed, and *Sagittaria* – arrowhead) (Lot 2004). Fifty-eight plant species are associated with calcareous warm-water rivers of Yucatán peninsula including *Bacopa monnieri* (water hyssop), *Eleocharis geniculata* (spikesedge), *Hydrocotyle umbellata* (manyflower), *Lemna aequinoctialis* (duckweed), *Nymphaea ampla* (waterlily), *Paspalum notatum* (bahiagrass), and *Typha domingensis* (cattail) (Tapia-Grimaldo et al. 2017). Sinkholes (*cenotes*) are a unique type of inland wetland associated with a karstic geology. The cenotes are an important freshwater resource in the Yucatán peninsula region that are highly impacted by tourism (Figure 1g); they harbor several rare and threatened aquatic species (Cervantes-Martínez

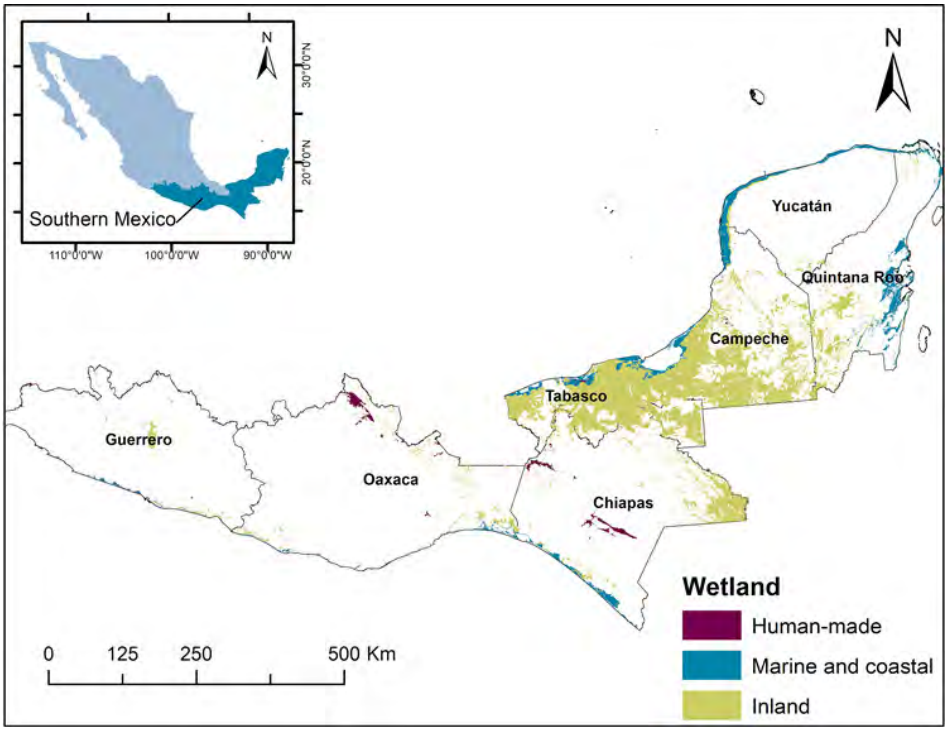
FIGURE 1. Southern Mexico wetlands: (a) palustrine wetland, *El Palmar, Pantanos de Centla* Biosphere Reserve, Tabasco State; (b) islands of tree vegetation associated with springs and water holes, *Los Petenes*, Campeche State; (c) marine wetland with seagrasses vegetation, *Laguna de Términos,* Campeche State; (d) mangrove, Tabasco State; (e) riverine rainforest, *Rio Tzendales*, Chiapas State; (f) lacustrine wetland, *Laguna Catazaja*, Chiapas, (g) sinkhole (cenote) frequented by tourists, Quintana Roo State, and (h) wetland habitats associated with waterfalls, *Parque Nacional Cañón del Sumidero*, Chiapas State.

(Photos a, b, c, e, f courtesy of Everardo Barba; d courtesy of Alejandro Betancourth; g and h courtesy of Paula Montoya)

FIGURE 2. Panoramic view of *Pantanos de Centla* Biosphere Reserve, Tabasco State.

(Photo courtesy of the Mexico Mangrove Monitoring System developed by CONABIO/ SEMARNAT. Photo taken by Joanna Acosta)

FIGURE 3. Wetlands in Southern Mexico States. (Adapted from National Wetland Inventory; CONAGUA 2020)



(Map elaborate by Tatiana Lobato de Magalhães Ph.D., PWS)

et al. 2018; Mondragón-Mejía et al. 2019). Highland wetlands are extremely important for the provision of water to Southern Mexico cities like San Cristóbal de las Casas. The dominant aquatic plants in highland wetlands are *Typha* (cattail), *Phragmites* (common reed or *carrizal*), *Cyperus* (umbrella sedges), *Eleocharis* (spike-rushes), and *Schoenoplectus* (bulrushes) (Lot 2004; Chediack et al. 2018).

Human-made Wetlands

Human actions have created wetlands in places, especially through dam construction. They represent about three percent of Southern Mexico wetlands.

ECOSYSTEM FUNCTIONS AND THREATS

Southern Mexican wetlands provide several ecosystem services and are also impacted by human uses such as livestock, aquaculture, excessive exploitation of natural resources, and industrial expansion (Tables 2 and 3). For example, *Ría Lagartos* (Yucatán State) is an important estuarine wetland for flamingo nesting as well for economic activities such as fishing, agriculture, salt production, and livestock. Another activity that has a strong impact on wetlands is the selective extraction of native palms such as *Pseudophoenix sargentii* (buccaneer palm or *kuka'*), *Thrinax radiata* (thatch palm or *chit*), and *Coccothrinax readii* (Mexican silver palm or *nacax*), which are used for decoration along avenues and hotels in cities like Cancun. In *Laguna de Terminos* (Figure 1b) (Campeche State), the exploitation of natural resources has been crucial for the local economy during the last three centuries, through the extraction of dye sticks, precious woods, and chewing gum. This wetland is known for the sustainable use and management of *Crocodylus moreletti* (Mexican crocodile) populations for commercial purposes based on its skin (SEMARNAT 2020).

Regarding economic valuation of wetland ecosystem services, inland wetlands are rated higher than estuarine ones in Tabasco State: palustrine ($9,689 USD/ha/year), lacustrine ($6,366), mangrove ($2,653), and coastal lagoon ($1,926) (Camacho-Valdez et al. 2020). Overall, inland wetlands are threatened by the land-use changes and by the oil industry, especially the swamps, floodplains, and marshes in Tabasco State. The extraction of hydrocarbon has led to major wetland impacts (Domínguez-Domínguez et al. 2019; Camacho-Valdez et al. 2020). Furthermore, in the last two decades the *Pantanos de Centla* (Tabasco State) has experienced a notable land-use change – the conversion of natural floodplain vegetation to livestock and agricultural areas (De la Rosa-Velázquez et al. 2017). Lowland floodable forests have been drastically reduced by agricultural activity (conversion to pasture and farmland) and overexploitation of the *Haematoxylum campechianum* (campeachy tree or logwood), which was used for a long time as a natural source of textiles dye, applied in histology for staining, and for medicinal uses (Lot 2004).

Frequent threats to the highland wetlands are urbanization, pollution, mining, and agricultural activities. Several monocotyledons aquatic species historically recorded above 2,000 m a.s.l. (Chiapas State) were not detected in a recent floristic study; the authors consider that it could indicate a process of local extinction (Chediack et al. 2018).

BIODIVERSITY, ENDEMISM, AND THREATENED SPECIES

Southern Mexico wetlands harbor several endemic species such as *Lithobates brownorum* (leopard frog), *Bolitoglossa yucatana* (Yucatan mushroomtongue salamander), *Cyprinodon macularius* (desert pupfish), *Caretta caretta* (loggerhead sea turtle), *Chelonia mydas* (green sea turtle), *Eretmochelys imbricada* (hawksbill sea turtle), and *Sanopus splendidus* (splendid toadfish). The following states harbor a rich number of aquatic plant species and are considered priority states for the conservation of strictly aquatic plant species in Mexico: Chiapas (225 species), Campeche (220), Oaxaca (210), and Tabasco (186) (Mora-Olivo et al. 2013). The *Pantanos de Centla* (Tabasco State) alone harbors around 569 plant species (76 used by people and 13 rare or threatened) and a fauna with more than 523 vertebrate species (IUCN 2020; SEMARNAT 2020). The *Anillo de Cenotes* are home to endemic species of reptiles (e.g., *Terrapene carolina yucatana* – Yucatan box turtle), amphibians (e.g., *Bolitoglossa yucatana)*, and birds (e.g., *Stelgidopteryx ridgwayi* – Yucatan rough-winged swallow, *Cyanocorax yucatanicus* – Yucatan jay, and *Melanoptila glabirostris* – black catbird). These cenotes are also home to a number of endangered or threatened species (Cervantes-Martínez et al. 2018; IUCN 2020; Ramsar 2020a). The highland wetland *Humedales de Montaña La Kisst* (Chiapas, 2,120 m a.s.l.) supports great populations of fish and amphibians, with at

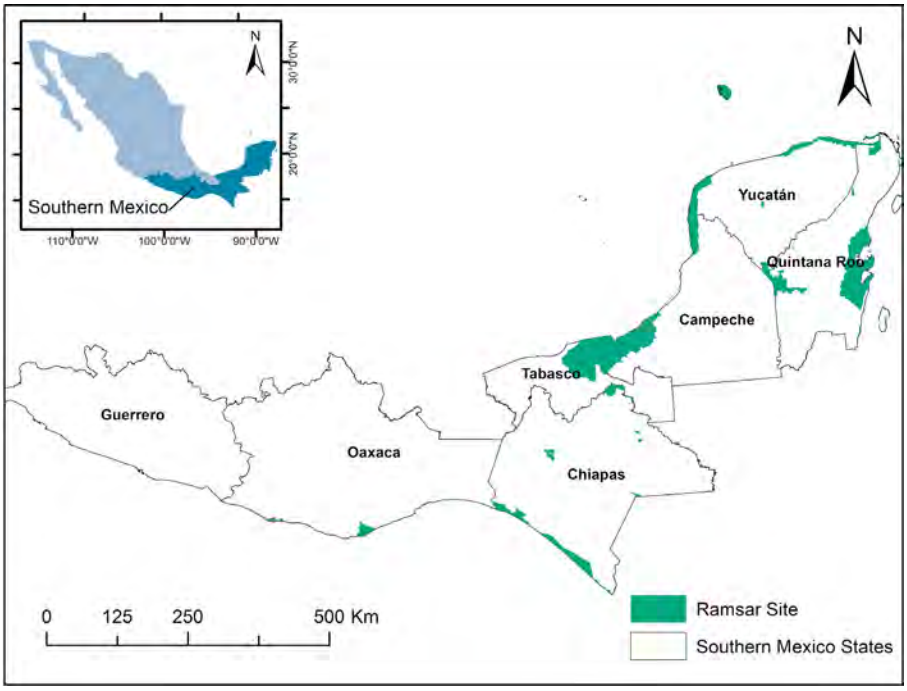
TABLE 1. Extent of wetlands in Southern Mexico based on National Wetland Inventory (NWI) and Ramsar sites.

Wetland	Number of Wetlands	Total Area (km^2)	Reference
Total NWI	2,020	64,298	CONAGUA 2020
Marine and Coastal	392	9,602	
Inland	1,558	52,610	
Artificial	70	2,085	
Ramsar sites	41	34,232	Ramsar 2020a
Marine and Coastal	26	29,451	
Inland	15	4,782	

TABLE 2. Ecosystem services provided by wetlands in Southern Mexico. (Adapted from Smardon 2006; Camacho-Valdez et al. 2020; Ramsar 2020a.)

Ecosystem Services Provided by Wetlands
• Recreation and tourism
• Scientific and educational uses
• Heritage places
• Drinkable water storage
• Hydrological flow regulation
• Biological production (wetland food and non-food products)
• Biogeochemical cycle regulation (erosion protection, pollution control and detoxification, nutrient cycling, and soil formation)
• Wildlife habitat and biodiversity conservation (genetics, endemism, and rare and threatened species)

FIGURE 4. Ramsar sites in Southern Mexico States. (Adapted from Ramsar 2020a)



(Map elaborate by Tatiana Lobato de Magalhães Ph.D., PWS.)

least 10 species being endemic or under a protection category (e.g., the endemic fish *Profundulus hildebrandi* - Chiapas killifish, and the endemic plant *Wolffia columbiana* – Columbian water-meal) (Chediack et al. 2018; Ramsar 2020a).

Several wetland species are critically endangered due to habitat loss. The International Union for Conservation of Nature's Red List of Threatened Species lists one species of Fungi, 46 plants, and 375 animal species associated with Southern Mexican coastal and inland wetlands (IUCN 2020). Concerning the threatened categories of IUCN, seven species are *critically endangered*, 17 species *endangered*, 27 species *vulnerable*, 15 species *near threatened*, 276 species *least concern*, and 80 species *data deficient* (Table 4). In regard to aquatic animal species, there are four species of mollusks, 125 species of arthropods (Insecta and Malacostraca), 145

TABLE 3. Activities that threaten Southern Mexico wetlands. (Adapted from Gortari-Ludlow et al. 2015; Domínguez-Domínguez et al. 2019; Camacho-Valdez et al. 2020; Ramsar 2020a.)

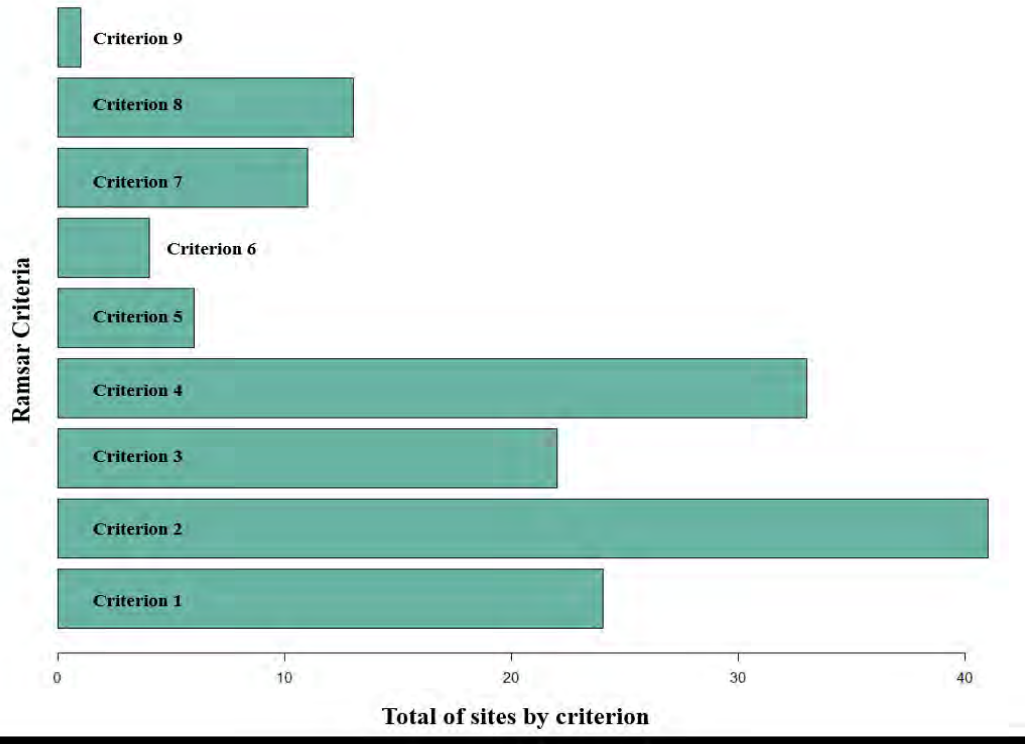
Wetland Threats
• Change in natural habitats (agriculture, livestock, aquaculture, and human settlements)
• Excessive exploitation of natural resources (fishing and harvesting aquatic resources, logging and wood harvesting, hunting and collecting terrestrial animals, marine and freshwater aquaculture, and gathering plants)
• Changes in flow regime (drainage and canals construction)
• Wastewater (rural, urban, and industrial)
• Drought (high temperature and high evaporation)
• Infrastructure projects (road construction)
• Oil industry (hydrocarbon extraction and processing)
• Unsustainable use (tourism and navigation)

TABLE 4. Threatened species in Southern Mexico wetlands. (Adapted from IUCN 2020.)

Taxonomic Group	Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern	Data Deficient	Total
Fungi	1	-	-	-	-	-	1
Plants	-	2	-	1	43	-	46
Mollusks	-	-	-	-	3	1	4
Arthropoda	1	7	8	1	72	36	125
Fishes	2	7	12	6	76	42	145
Amphibians	2	-	-	-	3	-	5
Reptiles	1	-	5	1	22	1	30
Aves	-	-	1	6	57	-	64
Mammals	-	1	1	-	-	-	2
Total	7	17	27	15	276	80	422

fishes, five amphibians, 30 reptiles, 64 species of waterfowl birds, two mammals *Rheomys mexicanus* (Mexican water mouse) and *Trichechus manatus* (American manatee). Among the arthropods there are 152 species of insects that depend on the aquatic systems for critical stages in their life cycles, including dragonflies and damselflies. Coastal ecosystems and mangroves are crucial for the threatened crocodiles and caimans (i.e., *Crocodylus moreletti* - Mexican crocodile and *Caiman crocodilus* - spectacled caiman). Southern Mexico also shelters a vast number of waterfowl, and migratory aquatic birds that come to its wetlands in the winter, and several of these species are threatened (Platt et al. 2010; Domínguez-Domínguez et al. 2019; IUCN 2020). The aquatic turtle *Dermatemys mawii* (white turtle) is the only critically endangered reptile in the region. Other threatened freshwater aquatic turtles are *Kinosternon creaseri* (creaser's mud turtle), *K. integrum* (Mexican mud turtle), *K. oaxacae* (Oaxaca mud turtle), *Trachemys ornata* (ornate slider), and *T. scripta* (pond slider).

FIGURE 5. Number of Ramsar sites that satisfy each Ramsar criterion for Southern Mexico. Wetland type (criterion 1), biological diversity (criteria 2, 3, and 4), waterbirds (criteria 5 and 6), fishes (criteria 7 and 8), and other taxa (criterion 9). (Adapted from Ramsar 2020a, b)



(Map elaborate by Tatiana Lobato de Magalhães Ph.D., PWS)

RAMSAR SITES

Southern Mexico has 41 Ramsar sites covering 34,232 km^2 (2% of the total country surface). It represents almost a third of the 142 total Mexican Ramsar sites. Around 85% (35 wetlands) of Southern Mexico sites occur in low elevations (< 300 m a.s.l.), while the highest elevation Ramsar sites are attributed to *Humedales de Montaña La Kisst* and *Humedales de Montaña María Eugenia*, both in Chiapas State (2,120 m a.s.l.). The majority of Ramsar sites are classified as coastal and marine (64%), followed by inland wetlands (36%) (Table 1). Among inland wetlands, 13 sites have a permanent water regime and two sites are considered seasonal or intermittent. Mexican Ramsar sites have a mean size of 835 km^2. The largest site (7,050 km^2) is Área *de Protección de Flora y Fauna Laguna de Términos* (Campeche State), while the smallest site (0.2 km^2) is *Playa Barra de la Cruz* (Oaxaca State) (Ramsar 2020a).

The first Mexican Ramsar site was designated in 1986 and is located in Southern Mexico at Yucatán State, *Reserva de la Biosfera Ría Lagartos*. The most recent, *Humedales de Montaña María Eugenia*, was added in 2012 and is located in Chiapas state (Ramsar, 2020a). A total of six sites were also designated as UNESCO Biosphere Reserves. With regard to geographical distribution, all seven Southern Mexican states have at least one Ramsar site (Ramsar 2020a) (Figure 4). Quintana Roo state has the largest number of sites (13), followed by Chiapas (12), Yucatán (7), Oaxaca (4), and Campeche (3), while Guerrero and Tabasco have only one Ramsar site each. Additionally, two Southern Mexico Ramsar sites wetlands extend into the territory of other countries. *Parque Nacional Lagunas de Montebello* lies on the Southern border, extending into Guatemala and *Parque Nacional Arrecifes de Xcalak* into Belize border.

The Ramsar Convention considers nine criteria to designate wetlands as of international interest for conservation (Ramsar 2020a): wetland type (criterion 1), biological diversity (criteria 2, 3, and 4), waterbirds (criteria 5 and 6), fishes (criteria 7 and 8), and other taxa (criterion 9) (Ramsar 2020b). Criteria based on wetland type and bio-

diversity are more frequently reported on than ones related to specific taxa (Figure 5). Among the 41 Southern Mexico Ramsar sites none satisfy all criteria and one fills only one criterion. The latter site is the *Parque Nacional Cañón del Sumidero* (criterion 1) that contains a unique example of a natural wetland type (humid habitats associated with waterways and waterfalls) (Figure 1h) and harbors threatened species such as *Crax rubra* (great curassow), *Ateles geoffroyi* (black-handed spider monkey), *Crocodylus acutus* (American crocodile), *Leopardus wiedii* (margay), and *Rinodina chrysomelaena* (bright yellow crustose lichen) (IUCN 2020).

CONSERVATION PERSPECTIVE AND CONCLUSIONS

Several actions have been launched since 1986 when Mexico became a signatory country of the Ramsar Convention, particularly the creation of the National Wetland Policy and a National Wetlands Committee, the designation of 142 Ramsar sites, and development of the National Wetland Inventory (CONAGUA 2020; SEMARNAT 2020). Additionally, since 1936, Mexico has been party to an agreement with the United States for the protection of migratory birds, which has contributed to the implementation of bi-national initiatives that have improved wetland conservation in Mexico. Despite the international importance of the region's Ramsar wetlands, only 71% of the Southern Mexico Ramsar sites have management plans (25 sites with concluded management plans, four sites with plans in preparation). Of these sites, however, only 13 have plans that have already been implemented. Surprisingly, the latter number represents 50% of the total Ramsar implemented management plans in Mexico. These findings denote a low level of concern with practical actions to conserve wetlands in the country (Ramsar 2020a). Further, even the implementation of management plans does not necessarily promote concrete conservation actions to protect wetlands (Gortari-Ludlow et al. 2015).

Overall, inland wetlands are being overlooked and not getting the attention they need for conservation and restoration, not only in Mexico but around the world (Reis et al. 2017). Environmental policies in Mexico have been more focused on mangroves and coastal wetlands than on inland wetlands. In 2003, the government approved a federal law regulating the wise-use, conservation, and restoration of coastal wetlands and mangroves (Norma Oficial Mexicana 022/2003; SEMARNAT 2003), and in 2005, established a National Mangrove Committee (CONABIO 2020). Unsurprisingly, estimates suggest that inland wetland losses are larger and faster than losses in coastal wetlands (Davidson 2014). Despite freshwater ecosystems recording around 90% of the aquatic plant species richness of Mexico (Mora-Olivo et al. 2013) and having higher economic values than estuarine wetlands (Camacho-Valdez et al. 2020), Mexican conservation actions focused on inland wetlands are lacking, particularly for highland wetlands (Alcocer and Aguilar-Sierra 2019).

Strong synergies among stakeholders that engage the population, private and governmental sectors, decision-makers, non-governmental organizations, and the academy are crucial to improving wetland conservation in Mexico. Projects that integrate science and practice are also essential for wetland restoration and conservation at local and regional levels. Through improved efforts to increase wetland protection awareness and acquisition of more detailed data on the degradation and change of wetland areas, including risk assessment analysis (Camacho-Valdez et al. 2020), Southern Mexican wetlands could achieve a positive future scenario. ■

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