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An overview of Cuban seagrasses

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ABSTRACT.—Here, we present an overview of the current knowledge of Cuban seagrasses, including distribution, status, threats, and efforts for their conservation. It has been estimated that seagrasses cover about 50% of the Cuban shelf, with six species reported and *Thalassia testudinum* K.D. Koenig being the most dominant. Seagrasses have been studied primarily in three areas in Cuba (northwest, north-central, and southwest). *Thalassia testudinum* and other seagrasses exhibit spatial and temporal variations in abundance, and updating of their status and distribution is needed. The main threat to Cuban seagrass ecosystems is low seawater transparency due to causes such as eutrophication and erosion. High salinities limit their distribution in the Sabana-Camagüey Archipelago, partly the result of freshwater dams and roads. Seagrass meadows play important ecological roles and provide many ecosystem services in Cuba, with efforts underway to preserve this ecosystem. Research and management projects are directed toward integrated coastal zone management, including a ban on trawl fisheries and the extension of marine protected areas to contain more seagrass meadows. In addition to updating species distributions, it is urgent that managers and researchers in Cuba examine the resilience of this ecosystem in the face of climate change.

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Seagrasses are the only angiosperms that have evolved for living in permanent immersion in seawater (den Hartog and Kuo 2006). They form ecosystems—seagrass meadows—that are highly productive, host a wide variety of marine organisms, and provide multiple goods and services. Costanza et al. (2014) estimated that seagrass/algae beds offer services with a value of \$28,916 ha^{-1} yr^{-1}, taking into account climate regulation, erosion control, nutrient cycling, refuge, food production, raw materials, genetic resources, recreation, and cultural services. In Cuba, Baisre (1985) recognized that seagrass ecosystems are very important for sustaining fisheries, along with coral reefs and mangroves. Based on an evaluation using 2002 carbon emission data, Cuban seagrasses sequester an estimated 33% of the carbon emitted by the country (Martínez-Daranas 2010).

Despite their importance, seagrasses have experienced decline at a global scale for decades, placing them among the most vulnerable ecosystems on the planet (Waycott et al. 2009). The causes of decline have been attributed to anthropogenic activities, such as coastal development, deterioration of water quality, invasive species, and climatic change, as well as to natural causes (Larkum et al. 2006).

Given the significance of this ecosystem to Cuban marine biodiversity and the economy, there has been an effort in the last five decades to understand the characteristics, dynamics, and status of seagrasses. These efforts have led to several conservation initiatives, including research and monitoring, establishment of marine protected areas, coastal management actions, etc. Here, we provide an overview of the current knowledge of Cuban seagrasses, the threats to this ecosystem, and future prospects for research and conservation.

Distribution and Abundance of Seagrass Species in Cuba

The earliest papers mentioning Cuban marine angiosperms focused on the taxonomy of marine plants (Howe 1918) and higher plants (Sauget 1946). The most common species of marine angiosperms along the Cuban shelf are *Thalassia testudinum* K.D. Koenig, *Syringodium filiforme* Kützing, and *Halodule wrightii* Ascherson (den Hartog, 1970, Suárez et al. 2015). *Thalassia testudinu*m is the dominant species in most seagrass meadows, where it is often monospecific. *Halophila decipiens* Ostenfeld and *Halophila engelmannii* Ascherson can be found in turbid waters, such as bordering channels between mangrove keys, or deeper waters in bays (den Hartog 1970, Buesa 1974, Martínez-Daranas et al. 2013). Both species have a discontinuous distribution along the northern coast, from the western zone to Nuevitas Bay in north-central Cuba. Along the south coast, *H. engelmannii* has been found from western Cuba to the Gulf of Ana María, and *H. decipiens* also found from western Cuba, but only as far east as Cienfuegos Bay.

Halophila ovalis (R. Brown) J. D. Hooker was found in 2016 off Santa María Key along the north-central Cuban shelf, surrounded by *Rhizophora mangle* Linneaus stands (Hernández-Albernas and Borges-Casas 2017). This species, usually reported in the Indian and Pacific oceans, was also found in a shallow lagoon on the west shore of Antigua in the Caribbean West Indies (Short et al. 2010). It is only the second report of this nonnative species in the western Atlantic Ocean.

Halophila baillonis Ascherson has been reported in Cuba (Howe 1918, Sauget 1946), but its presence needs confirmation. Urquiola Cruz and Pérez Hernández (2009) consider that specimens identified as *H. baillonii* by Sauget (1946) are actually *H. decipiens*. Howe's (1918) original identification may also have been in error.

Ruppia maritima Linnaeus, which is typical in environments with high salinity variation (den Hartog and Kuo 2006), has been found in the Cuban keys, coastal lagoons, and bays (Guimarais Bermejo and González de Zayas 2009, Guimarais Bermejo et al. 2011). Yet the taxonomy of the genus *Ruppia* is not completely clear, and the identification of several specimens of other species in this genus as *R. maritima* is common worldwide (den Hartog and Kuo 2006). For example, one study of the genus from different sheltered bays and lagoons with marine or brackish water along the Mexican Yucatán Peninsula report specimens morphologically distinct from *R. maritima*. As a result, den Hartog et al. (2016) described a new species, *Ruppia mexicana* den Hartog and Van. The genus requires further study in Cuba.

Besides *H. wrightii*, several authors have reported *Halodule beaudettei* den Hartog for Cuba (den Hartog 1970, Buesa 1975, Alcolado 1990, Urquiola Cruz and Novo Carbo 2009). The main characteristics used for the identification of species in this

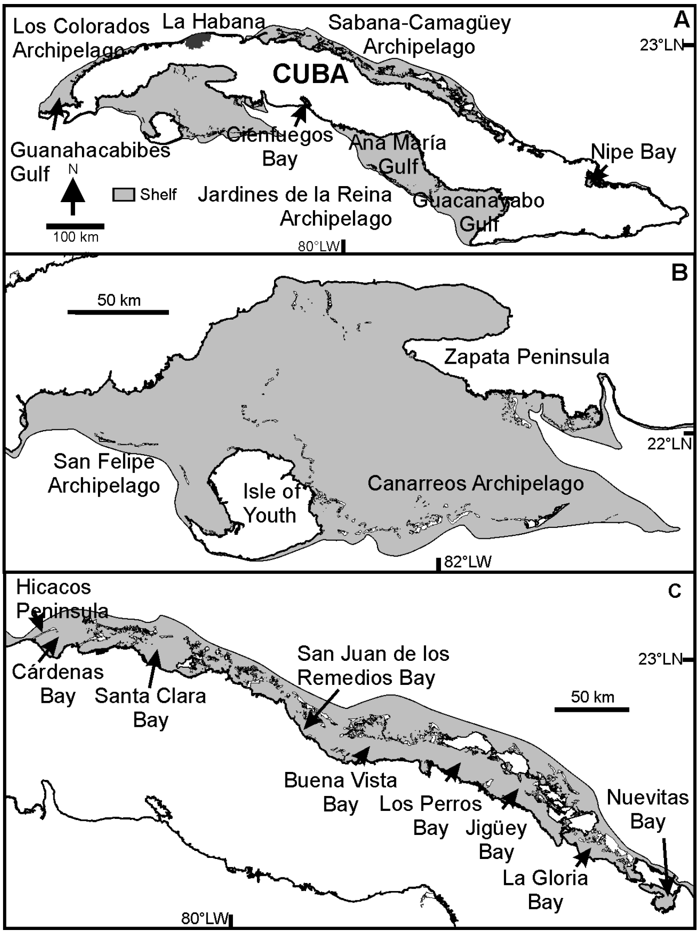

Figure 1. Study area for Cuban seagrasses: (A) Cuban marine shelf, (B) Gulf of Batabanó, (C) Sabana-Camagüey Archipelago.

genus are the shape of the leaf tip and the width of the leaves (den Hartog 1970, den Hartog and Kuo 2006, van Tussenbroek et al. 2010). However, leaf morphology has shown a certain degree of variability, and reproductive structures are not known for all species (Phillips and Meñez 1988, Martínez-Daranas 2002); therefore, it is recommended that this genus be analyzed by molecular tools for elucidating species.

The development of seagrass meadows in Cuba is favored by its wide marine shelf of 53,126 km^2 (Fig. 1A). This shelf is not uniform, with four broad, shallow zones (i.e., <30 m deep, with extensive portions 5–6 m deep): (1) northwestern zone, including Los Colorados Archipelago (Fig. 1A); (2) north-central zone, with the Sabana-Camagüey Archipelago (Fig. 1A, 1C); (3) southwestern zone, with the Gulf of Batabanó and two archipelagos (Fig. 1A, B); and southeastern zone with the Ana María and Guacanayabo gulfs and Jardines de la Reina Archipelago (Fig. 1A, Claro 2007). These zones are separated by terraces with a narrow shelf and high exposure, where rocky shores and hard bottoms typically prevail, such as off northern Havana, and southern Cienfuegos (Fig. 1A). Cuba also has more than 4000 small islands and mangrove keys, most in the aforementioned archipelagos (Fig. 1A–C),

Table 1. Values (mean or range) of foliar biomass ($g\ m^{-2}$, dry weight), foliar production ($g\ m^{-2}\ d^{-1}$, dry weight) and shoot density (m^{-2}) of seagrass species in different areas of Cuban shelf. Species: *Tt*: *Thalassia testudinum*; *Sf*: *Syringodium filiforme*; *Hw*: *Halodule wrightii*; *Hd*: *Halophila decipiens*; *He*: *Halophila engelmannii*. Sources: [1] Buesa (1975), [2] Martínez-Daranas et al. (2014), [3] Martínez-Daranas et al. (2005), [4] Martínez-Daranas (2007), [5] Tussenbroek et al. (2014), [6] Arias-Schreiber et al. (2008).

	Foliar biomass					Foliar production	Shoots density			
Area	*Tt*	*Sf*	*Hw*	*Hd*	*He*	*Tt*	*Tt*	*Sf*	*Hw*	*He*
Northwestern	190.0[1]	3.5[1]		0.14[1]	0.25[1]		14–497[2]	2–425[2]	11–447[2]	0–37[2]
North Havana	73.7–193.4[3]					2.6–4.3[3]	610–1267[3]			
North-central	95.6[4]	7.4[4]	4.3[4]				732[4]			
	80.7[5]					2.0[5]	663.3[5]			
	78.3[5]					1.8[5]	656.7[5]			
Southwestern	12–102[6]						148–589[2]	5–648[2]	524–572[2]	
Southeastern							39–767[2]	1–215[2]		

yielding a coastline of 5746 km (Claro 2007). Those islands, along with shallow reefs, bays, gulfs, inlets, and channels, provide relative hydrographic stability, retaining sediments adequate for the establishment of seagrasses.

Where the shelf is wider, seagrasses cover extensive areas. The northwestern Cuban shelf has an estimated area of 2740 km^2, 75% of which is dominated by *T. testudinum* beds (Buesa 1974, 1975). The north-central area of the shelf spans 8311 km^2 with an estimated 5625 km^2 covered by seagrasses (Alcolado et al. 2007). A more precise map of marine habitats using remote sensing was generated for the southwestern zone. It indicated that of the 21,305 km^2 area, seagrass covered 13,818 km^2, representing 64% of the Gulf of Batabanó (Cerdeira-Estrada et al. 2008). In the southeastern zone, only the Gulf of Ana María has been mapped: of 9398 km^2, 24% (2255 km^2) is covered by seagrasses (Ventura Díaz and Rodríguez Cueto 2012). Collectively, these reports indicate that about 50% of the Cuban shelf is covered by seagrass meadows, consistent with Alcolado's (2007) estimation. There is little published information about seagrasses on the eastern zone of Cuba. The shelf here is rather narrow, and seagrass meadows appear only in more sheltered areas, such as bays and reef lagoons (i.e., Castellanos et al. 2004, Martínez-Daranas et al. 2005, 2014, Zayas et al. 2006, Moreira et al. 2009). The large wetlands in this area, such as Gulf of Guacanayabo and Nipe Bay, deserve further examination.

The abundance of Cuban seagrasses varies in the different areas of the shelf. As *T. testudinum* is the most common and climax species, most existing data is about this species. Other species usually have lower amounts of biomass, although shoot density could be similar or higher than *Thalassia*'s in some cases (Table 1).

In the northwestern zone, Buesa (1975) found differences in total biomass of *T. testudinum* depending on depth: *T. testudinum* was found to depths of 14 m, though it is more abundant in the first 5 m. For the other species, there we no statistical differences in biomass according to depth: *H. engelmannii* was found to 14.4 m, *H. decipiens* to 24.3 m, and *S. filiforme* to 16.5 m depth. Other studies in the Cuban shelf are limited to shallower areas.

Temporal variability in density, biomass, and production of *T. testudinum* has been assessed in several areas of the Cuban shelf. *Thalassia testudinum* growth is positively correlated with temperature and radiance. Although there are only two climatic seasons in Cuba (a rainy season from May to October, and a dry season from November to April; Planos et al. 2013), *T. testudinum*'s foliar biomass and shoot density generally increases from March to April, or the spring, and decreases from January to February in the winter (Buesa 1974, Martínez-Daranas et al. 2005, 2009a). Buesa (1974) found that temperature and light quantity and quality appear to be the major limiting factors for depth distribution of this species.

Evidence of phosphorus limitation was found in *T. testudinum* leaves (Martínez-Daranas 2010) in the southwestern zone of the Cuban shelf (Gulf of Batabanó), where the mean phosphorus concentration in leaves was lower than that recorded at other locations, such as Florida Bay and Barbados (Table 2). The mean C:P ratio (1297.3 to 1) was three times the estimated mean for marine angiosperms of the world (435:1) according to Duarte (1990). Phosphorus limitation could explain lower values of leaf biomass in this area (Table 1), as well as the absence of species with higher nutrient requirements, such as *S. filiforme* and *H. wrightii*. Phosphorus scarcity can be explained by the fine sediments that are rich in calcium carbonate (oolithic sands) found in extensive areas of Gulf of Batabanó. Carbonate sediments have a high capacity for sequestering phosphates from aquatic media, and this mechanism is negatively related with particle size (Erftemeijer and Middelburg 1993). In the tropics, nutrient limitation is likely a permanent situation that can reduce the growth, productivity, and biomass of seagrasses (Hemminga and Duarte 2000). This limitation could reduce seagrass resilience to climate change, hurricanes, and other stressors. It will be important to assess the limitation of nutrients in seagrasses and to examine if this limitation is reinforced by the increase of seawater temperature.

Biodiversity Associated with Cuban Seagrasses

Eighty species of macroalgae (15 Rhodophyta, 11 Ochrophyta, and 54 Chlorophyta) have been found in the seagrass meadows of the Gulf of Batabanó (Alcolado 1990). In the Sabana-Camagüey bays (north-central zone), seagrass meadows are occupied by 216 macroalgae species (149 Rhodophyta, 36 Ochrophyta, and 31 Chlorophyta; Martínez-Daranas et al. 2008). The most common macroalgae species in seagrass meadows are of the orders Bryopsidales, Dasycladales, Cladophorales (Chlorophyta), and Ceramiales (Rhodophyta). Well-represented genera include *Halimeda*, *Caulerpa*, *Penicillus*, *Udotea*, and *Laurencia* sensu lato (Suárez et al. 2015).

Benthic fauna that live on seagrasses have also been studied in several areas of the Cuban shelf. Alcolado (1990) reported a rich seagrass-associated benthic fauna with 40 species of Porifera, 10 Anthozoa, 118 Mollusca, 79 Decapoda (Crustacea), and 50 Echinodermata species (6 Holothuroidea, 4 Asteroidea, 7 Echinoidea, and 33 Ophiuroidea) in the Gulf of Batabanó. In Sabana-Camagüey soft bottoms, which have extensive seagrasses, Alcolado et al. (1998) found 66 Porifera, 6 Anthozoa, 140 Mollusca, 100 Decapoda (Crustacea), 90 Polychaeta, 19 Tunicata, and 53 Echinodermata species. Species richness of macroalgae, large benthic invertebrates, and fishes is higher in areas with seagrasses than in soft bottoms without marine vegetation along the Sabana-Camagüey Archipelago (Alcolado et al. 1999, Martínez-Daranas 2007) and in the Gulf of Batabanó (Arias-Schreiber et al. 2008).

Many organisms that live on seagrasses depend on detritus, while others are direct grazers (Valentine and Duffy 2006). Two endangered species that feed on seagrasses in Cuba are the Antillean manatee, *Trichechus manatus* Linnaeus, 1758 (Navarro

Table 2. Reported values [mean, standard deviaion (SD), and/or range (r) when available] of carbon, nitrogen, and phosphorus content, and nutrients relations of *Thalassia testudinum* leaves collected in several areas, and for several seagrass species. * Note that Duarte (1990) consisted of 27 species.

Source	C (%)	N (%)	P (%)	C:P	C:N	N:P	Zone
Patriquin (1972)		2.2 (r: 1.69–3.05)	0.15 (r: 0.093–0.229)				Barbados
Fourqurean and Zieman (2002)	36.9 (SD 2.5, r: 29.4–43.3)	1.82 (SD 0.40, r: 0.88–3.96)	0.113 (SD 0.037, r: 0.048–0.243)	937.4 (SD 311.5, r: 373.4–1901.3)	24.6 (SD 5.2, r: 11.1–47.1)	40.2 (SD 17.8, r: 15.4–107.1)	Florida Bay
Terrados et al. (2008)		r: 1.91–2.25	r: 0.03–0.13				Gulf of Mexico
Martínez-Daranas et al. (unpubl data)	33.4 (SD 3.1, r: 26.3–38.0)	1.9 (SD 0.4, r: 1.0–2.6)	0.074 (SD 0.03, r: 0.047–0.123)	1,271.9 (SD 357.5, r: 614.5–1873.2)	21.0 (SD 4.2, r: 13.8–30.0)	61.7 (SD 18.3, r: 33.8–94.9)	Gulf of Batabanó, Cuba
Duarte (1990)*	33.6 (SD 0.31)	1.92 (SD 0.05)	0.23 (SD 0.011)	474	24	20	30 locations worldwide

Table 3. Minimum, maximum, and critical values of several environmental variables obtained along 104 sites in Sabana-Camagüey archipelago between 2001 and 2003 (Fernández-Vila and Chirino 1993; Martínez-Daranas, 2007). [1]Value considered limiting for seagrasses development in general; [2]Value considered limiting for a determined species of marine angiosperm.

Variable	Minimum	Maximum	Critical	Species
Visibility (Secchi disc extended horizontally, m)	0.00	17.00	1.00[1]	Multiple
			1.70[2]	*Thalassia testudinum*
			1.50[2]	*Halodule wrightii*
Current speed (cm s^{-1})	2.50	40.00	40.00[1]	Multiple
			15.00[2]	*Halodule wrightii*
Salinity	25.00	57.50	43.30[1]	Multiple
Salinity variation	1.00	22.50	9.50[1]	Multiple
			7.00[2]	*S. filiforme*
Chemical oxygen demand in seawater (mg O_2 L^{-1})	0.40	29.30	5.62[1]	Multiple
			5.08[2]	*Thalassia testudinum*
Total nitrogen in seawater (µM)	2.41	310.45	172.73[1]	Multiple
Total carbon in superficial sediments (µM g^{-1})	0.60	4,503.00	2,997.60[2]	*Syringodium filiforme*
			3,690.20[2]	*Halodule wrightii*

et al. 2014), and the green turtle, *Chelonia mydas* (Linnaeus, 1758) (Azanza Ricardo et al. 2013). Several species of economic importance in Cuba feed in seagrasses, or inhabit them as part of their lifecycle, such as the spiny lobster, *Panulirus argus* (Latreille, 1804) (Puga et al. 2013), the gastropod *Lobatus gigas* (Linnaeus, 1758) (Suárez et al. 1990), and many commercial fishes (Sierra et al. 2001).

Conservation of Cuban Seagrasses

Given their wide distribution and susceptibility to changing environmental conditions, seagrasses are often used as biological indicators of water quality (Larkum et al. 2006). The assessment of Cuban seagrass ecosystems in relation to environmental variables has been performed in a few cases. A 2-yr study of 104 sites in the Sabana-Camagüey Archipelago found that the development of seagrasses is limited when underwater visibility is <1 m, salinity is >43, chemical oxygen demand >5.6 mg O_2 L^{-1}, and the total dissolved nitrogen is >173 µM (Table 3). Different species show different ranges of environmental tolerance; *T. testudinum* is more sensitive to light reduction than *H. wrightii*, *H. wrightii* is more vulnerable to stronger currents, and *S. filiforme* can tolerate lower salinity (Table 3; Martínez-Daranas 2007). Seawater can be turbid from suspended sediments in bays (Betanzos Vega et al. 2013) or from eutrophication as a result of runoff from the main island (Alcolado et al. 2007). Some shallow bays located in the east of the Sabana-Camagüey Archipelago, such as Los Perros, Jigüey, and La Gloria Bays (Fig. 1C), are hyperhaline in drought periods. Seawater salinity can be higher than 60, and temperature higher than 30 °C during summer (Fernández-Vila and Chirino 1993). Those conditions can limit the presence of seagrass meadows and other marine organisms (Alcolado et al. 1999, Martínez-Daranas 2007). This natural condition has been aggravated by the construction of river dams that reduce freshwater flow to bays and near coastal roads that connect the main island to tourism areas, limiting the interchange of seawater between the bays and the ocean.

Cuba had two sites included in the Caribbean Coastal Marine Productivity (CARICOMP) monitoring network that were sampled from 1994 to 2002, both located in Cayo Coco, in the north-central zone of the Cuban shelf (Table 1). Productivity and biomass of *T. testudinum* declined with decreasing water clarity, mainly because of increasing sedimentation (van Tussenbroek et al. 2014).

Cerdeira-Estrada et al. (2008) estimated that between 1985 and 2005 about 26% of the seagrass cover of the Gulf of Batabanó, about 5580 km^2, disappeared, mainly near the coast of the main island. This decline was potentially due to coastal erosion caused by human activities, such as deforestation of red mangrove, *Rhizophora mangle* Linnaeus (Hernández-Zanuy 2010). Erosion can increase turbidity, affecting submerged aquatic vegetation.

The role of seagrasses as a sediment stabilizer after hurricanes has been assessed. Moreira et al. (2009) found that *H. wrightii* was more resistant than macroalgae in Cienfuegos Bay (Fig. 1A) after Hurricane Dennis in 2005, despite a low salinity of 5. Guimarais et al. (2013) assessed Hurricane Paloma's effects on seagrasses along the Jardines de la Reina Archipelago in 2008 and found that seagrass meadows were only partially affected by sediment siltation and the uprooting of rhizomes.

Thalassia testudinum meadows have been found in areas of Guanahacabibes Gulf (Torres Conde and Martínez-Daranas 2017) and in Jardines de la Reina Archipelago (Guimarais et al. 2013), both with low coastal anthropogenic development and clear waters. Although these areas have great interest for conservation and fisheries, no extensive assessment of the state of their seagrasses has been conducted (Martínez-Daranas et al. 2009b).

In the absence of long time-series data, making forecasts about the impacts of climate change on seagrasses is challenging. Nevertheless, some negative effects are expected based on the analysis of identified threats and the state of seagrasses in the Gulf of Batabanó and the Sabana-Camagüey Archipelago (Martínez-Daranas 2010).

Increases in seawater temperature and the alteration of precipitation regimes (drought or heavy rains) are likely to have a strong effect on shallow bays with low interchange of water, such as the eastern sector of the Sabana-Camagüey Archipelago. Sea level rise will produce erosion in coastal areas, diminishing the amount of light that reaches the bottom or provoking siltation. Such effects are likely to be most acute where erosion already exists, such as the north coast of Gulf of Batabanó. The increasing intensity of tropical storms can uproot plants, and siltation or erosion is likely to affect Cuban seagrass meadows. In the Gulf of Batabanó, which has a wide shallow shelf with few geographic obstacles, seagrasses are likely to be affected by the hydrodynamic energy associated with severe storms.

Many previous studies have recognized that the status of seagrasses is threatened by anthropogenic impacts (Claro 2007, Martínez-Daranas et al. 2009a, Martínez-Daranas 2010, González-Díaz 2015). Several projects and programs for the integrated management of coastal areas are taking place in the country to achieve sustainable development and conservation of natural resources. Those projects include environmental education, reducing waste water discharges from industry, development of wastewater treatment plants in areas with new tourist facilities, replanting red mangroves in areas where the coastline is deteriorated, and banning fish trawling throughout the Cuban shelf since 2012 (Alcolado et al. 2007, Areces and

Martínez-Iglesias 2008, Hernández-Zanuy 2010, González-Díaz 2015, Menéndez Carrera et al. 2015). Studies focusing on adaptation to climate change include analysis of the vulnerability of the Cuban coastal zone, taking into account the state of coral reef crests, seagrass meadows, and mangrove forests as protection against the increases of sea level and the impact of hurricanes (Iturralde-Vinent and Serrano Méndez 2015). The Cuban National Center for Protected Areas has been monitoring coastal-marine ecosystems, gathering information to drive the establishment of marine protected areas of Cuba (Cobián et al. 2013, Hernández-Fernández et al. 2013, Suárez et al. 2013). As a result of the combined efforts, the area of protected seagrass meadows has increased (Hernández Avila 2014).

The International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Endangered Species includes marine angiosperm species in different categories of conservation. *Halophila engelmannii* is categorized as "Near Threatened," and the rest of the species found in Cuba are considered of "Least Concern" (IUCN 2017). The Red List for Cuban Flora (González Torres et al. 2016) classifies *H. decipiens* and *H. engelmannii* as "Threatened," and the rest of Cuban seagrass species as of "Least Concern." The category "Threatened" is preliminary, and it is used when the opinion of experts indicates that the species confronts a high extinction risk in the wild and could be assigned to one of the categories of threat established by the IUCN. The analysis is not supported by data following the standards of the IUCN (González Torres et al. 2016).

Future Prospects

The importance of seagrass ecosystems for Cuban marine biodiversity and ecosystem services highlights the importance of new research. This ecosystem certainly deserves more attention from scientists and the public. We propose the following future research needs:

- Understanding of the distribution and abundance of Cuban seagrass meadows is neither complete nor new; new maps informed by remote sensing are needed. The sustained use of a dedicated geographic information system would lead to more efficient monitoring of changes in subtidal habitats and better coastal zone management.
- The physiology, reproduction, and genetic variability of Cuban seagrass populations should be studied to better understand the connectivity and resilience of this ecosystem in the face of climate change and other threats.
- In the context of climate change, the capacity of seagrasses as carbon sink should be carefully assessed.
- To achieve effective management for seagrass preservation, research should address the factors (natural or anthropogenic) that cause deterioration of this ecosystem, monitoring the most vulnerable areas. Existing environmental legislation should be used to protect these systems.
- Environmental education should be used to increase stakeholder and public awareness of the importance of seagrasses, their threats and their protection.

Lastly, the medicinal properties of secondary metabolites obtained from marine angiosperms have been recently explored. The extracts of *T. testudinum* and

S. filiforme are rich in polyphenols, which have antioxidant, anti-inflammatory, and analgesic properties (Regalado et al. 2012, Menéndez et al. 2014). These plants could become an important source of natural antioxidants, with potential applications in pharmaceutical, cosmetic, and food industries. The understanding of the physiology and reproduction of marine angiosperms will be crucial for their sustainable use.

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