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Status of seagrass ecosystem in Kauswagan, Lanao Del Norte and Laguindingan, Misamis Oriental, Southern, Philippines

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Abstract

The study was conducted to determine the present status of seagrass resources of Laguindingan, Misamis Oriental and Kauswagan, Lanao del Norte and compared this through time with secondary data. It employed the transect-quadrat methods. Perpendicular to the shoreline, three (3) 100-m transect lines at 200-m interval between each transect were laid. Seven seagrass species were recorded comprising 38.6% of the total number (19) of seagrass species found in the Philippines. The seagrass community in all sites surveyed showed that it is highly dominated by *Thalassia hemprichii* species. However, there were no significant differences in species richness and diversity based on single-factor ANOVA statistical analysis ($p>0.5$). The abundance of *T. hemprichii* could probably be due to the prominent characteristic of this species where it could grow well in different types of habitat with various environmental conditions. The condition of seagrass beds in both areas were fair and the low Shannon-Wiener Diversity Index of seagrass in Kauswagan, Lanao del Norte ($H'=0.76\pm0.22$) and in Laguindingan, Misamis Oriental respectively ($H'=0.40\pm0.35$) indicate low stability in the community, which means that the condition of the seagrass ecosystem could be under threat, both from natural and anthropogenic activities. Over time, a fluctuating trend in species composition and a notable decline in seagrass species diversity and abundance have been observed in both areas. This present status calls an immediate response from the decision makers concerned for the sustainable management and conservation of the seagrass resources.

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Introduction

As an ecotone between mangrove forests and coral reefs, seagrass habitats are home to many economically and ecologically important marine resources (Fortes, 2010). They are considered as one of the most financially valuable natural ecosystems worldwide (Baker *et al.,* 2015). Seagrasses may not have the preferential and widely recognized status as that of the iconic condition of coral reefs but they rank, however, as high or higher in terms of ecosystem services. In the Philippines, seagrass meadows support at least 172 species of fish, 46 species of invertebrates, 51 species of seaweeds, 45 species of algal epiphytes, 1 sea turtle and 1 species of dugong. Moreover, 10,000 tons of leaves produced in an acre of seagrass beds can support about 40,000 fishes and 50,000 invertebrates (Mukhida, 2007).

Aside from providing food, they serve as breeding, nursery and foraging grounds for migratory fishes from adjacent habitats like coral reefs and mangroves (Unsworth *et al.* 2008). They are also responsible in the maintenance of genetic variability, potential biochemical utility, stimulate nutrient recycling, stabilize and improve water quality, and act as sediment traps and natural breakwaters which function as natural barriers against wave action and coastal erosion (Guidetti *et al.,* 2002). Seagrasses are not only supportive to marine biota, as their occurrence is directly relevant to human populations especially in the tropical coastal waters where people along the coasts depend largely on the seagrass ecosystem for their daily subsistence in terms of food. However, like any other ecosystems in the world, these resources have been declining globally due to anthropogenic threats (Duarte, 2002).

Runoff of nutrients and sediments which affect water quality is the greatest anthropogenic threat to seagrasses, with other stressors includes aquaculture, pollution, boating, construction, dredging and landfill activities, and destructive fishing practices. Diminishing and reduced quality of seagrass beds are occurring in many locations where development and overuse are impacting the coastal zone.

Thousands of hectares of seagrass beds have been lost as a result of eutrophication, pollution, and land reclamation for housing, airports and shipping facilities (Green and Short, 2003). Thus, seagrass meadows, and the ecosystem support and services, they provide are threatened by a multitude of environmental factors that are currently and errantly changing or will continue to change

In the Philippines, much attention has been on the importance of coral reefs and mangroves while seagrasses, its social, cultural, and economical aspect, have generally been neglected (de la Torre-Castro *et al.*, 2014) or not perceived as an integral part of the process. This bias towards coral reefs and mangroves is particularly evident in the Indo-Pacific region (Unsworth and Cullen, 2010). It is only recently that they have been recognized as important social-ecological ecosystems worldwide (Cullen-Unsworth *et al.*, 2013).

In this context, the focus of the study is to determine the present status of seagrass resources and compare this through time and to recommend interventions to enhance science-based policy measures towards sustainable management and conservation of seagrass resources.

Materials and methods

Study sites

Laguindingan, Misamis Oriental, located at 8°35'71" N, 124°67'2" E (Fig. 1), is among the 24 municipalities of Misamis Oriental in Northern Mindanao. The 165 ha seagrass beds and extensive mangroves of Laguindingan provide habitat for a wide diversity of flora and fauna, providing an excellent field laboratory for many schools in the region. A 22-ha fish sanctuary or marine protected area (MPA) was established in 2001 covering three contiguous ecosystems: coral reef, seagrass beds and mangrove area.

Kauswagan, Lanao del Norte lies on the mid-central portion of the Northwestern Mindanao coastline situated at 8° 9' 35" N, 124° 8' 51" E (Fig. 1) and is located along the coast of Iligan Bay. The coastline of Kauswagan is sandy with a wide stretch of mud flats and majority of the residents are situated at the coastal lowlands. Most of the coastal areas in Kauswagan is densely populated by local residents and is rich in seagrass cover. Thus, fishing, shellfish and echinoderm gleaning are present and are main sources of their livelihood.

Fig. 1. Map showing the study areas in 1) Laguindingan, Misamis Oriental and 2) Kauswagan, Lanao del Norte, respectively. *Source: Google Earth.*

Seagrass assessment

Seagrass assessment was done using the transect-quadrat method. Perpendicular to the shoreline, three (3) 100-m transect lines at 200-m interval between each transect were laid. In each transect, quadrats of 50 x 50cm (subdivided into grids with 25 sectors) at regular intervals of 10 meters were laid and seagrasses within the 0.25 m x 0.25m quadrat were identified and recorded to determine the species composition and percent cover (abundance) of each species. Exact location of the transect lines were recorded using a hand-held Geographic Positioning System (GPS). All data in the field were written in a slate board and later on transcribed for data analysis.

The condition of the seagrass beds was determined using the criteria set by Fortes, 1989 as stated below:

Condition	Criteria
Excellent	76-100% coverage
Good	51-75% coverage
Fair	26-50% coverage
Poor	0-25% coverage

Data Analysis

Seagrass Species Abundance (Expressed in Percent Cover)

The percent cover of seagrasses found in each quadrat was estimated by recording the dominance of each species in each of the 25 sectors using defined classes after Saito and Atobe (1970). The process was repeated for each species in the quadrat. Table 1 was used as reference to record the percentage cover. Calculation was done using Microsoft Excel™.

Table 1. Determining percentage cover in seagrasses.

Index	Amount of substratum covered	% Substratum covered	Midpoint % (M)
5	½ to all	50-100	75
4	¼ to 1/2	25-50	37.50
3	1/8 to 1/4	12.5 - 25	18.75
2	1/16 to 1/8	6.25 – 12.5	9.38
1	Less than 1/16	< 6.25	3.13
0	absent	0	0

The cover (C) of each species in each 0.5 x 0.5 m quadrat was calculated as follows (English *et al.*, 1997):

$$C = \frac{\sum(Mi \times fi)}{\sum f}$$

where: *Mi* = mid-point percentage of Class i *f* = frequency (number of sectors with the same class of dominance (i)

Species Diversity Index

Paleontological Statistics (PAST) Computer Software was used in analyzing and calculating the Shannon-Wiener Diversity Index for species diversity of seagrass in each sampling site.

$$H = -\sum_{i=1}^{s}(Pi \times Ln\ Pi)$$

Where: *S* = the total number of species in each transect,

Pi = the density/cover of species *i* divided by the total density/cover per transect.

Statistical Analyses

Single-factor Analysis of Variance (ANOVA) and t-test were done to determine significant differences in seagrass diversity indices within and between sampling sites. The significance level with P values lower than 0.05 ($p<0.05$) were considered significant. Microsoft Excel was used in initial data processing.

Results and discussion

Species Composition and Diversity

Eight seagrass species were found in all sites surveyed. The dugong grass, *Thalassia hemprichii* was the dominant species followed by the *Cymodocea rotundata* (round-tip seagrass). Other species found in the area were *Enhalus acoroides* (tropical eel seagrass), *Cymodocea serrulata* (toothed seagrass), *Halodule uninervis* (fiber-strand grass), *Halophila ovalis* (spoon grass) and *Halodule pinifolia* (fiber-strand grass).

The total species composition recorded in all sites surveyed comprised 42% of the total (19) seagrass in the country. The number of species recorded in each area however, contradicted to previous published reports. A 2009 study on the seagrass resources in Macajalar Bay where Laguindingan, Misamis Oriental was one of the assessed study areas had recorded a total of 9 seagrass species. In another study, a total of 8 species of seagrass inside a 0.25m² quadrat frame was recorded in Laguindingan, Misamis Oriental by Fortes & Nadaoka *et al.* (2015).

The present study only recorded a total of 8 species. In Kauswagan, Lanao del Norte, higher number of species was found in the present study compared to the previous published report of Redondo *et al.* (2017), where only 6 species were recorded. However, the 8 species recorded in this study were present in the study of Uy *et al.* (2006) in his assessment of the seagrass meadows in the coastal barangays of Northeastern Mt. Malindang where he observed a total of 11 species of seagrass.

Seagrass species composition has an average range of 2 to 3 spp/0.25m2 and ANOVA showed significant differences between sites (P<0.05, Table 3). Notable species, namely *H. ovalis* was only observed in Kauswagan, Lanao del Norte with a mean seagrass cover of 1.90% (Fig. 2). *H. ovalis* grows on coarse coral rubble to soft mud, and in sand where it is occasionally almost completely buried (Meñez *et al.* 1983). They can be found in pure strands or mixed with *Thalassia hemprichii, Halodule uninervis*, *Halodule pinifolia, Cymodocea rotundata,* and *Enhalus acoroides* (Meñez *et al.*, 1983). The rarity of *H. ovalis* compared to other seagrasses could indicate the species' habitat preference to a particular type of sediment composition present in the area. Laguindingan has a muddy-sand substrate while Kauswagan has a sandy substrate which could favor the growth of *H. ovalis* species. It also suggests that it is less tolerant of the prevailing hydrographic parameters occurring within the region (Abubakar *et al.*, 2018).

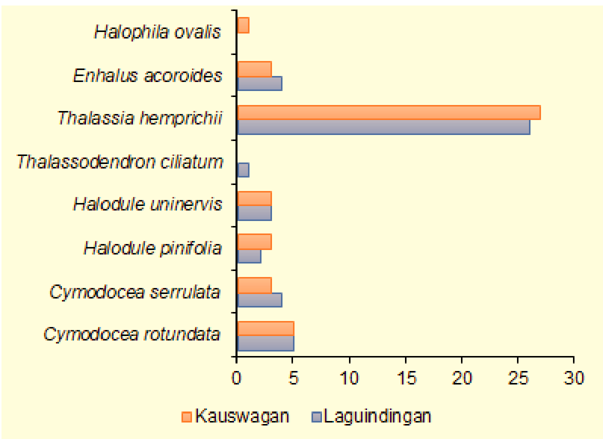

Fig. 2. Seagrass species composition in Laguindingan, Misamis Oriental and Kauswagan, Lanao del Norte.

Species composition is influenced by a number of factors. A study of Espinosa (2018) showed that physical characteristics of the substrate (muddy-sand, sandy, rocky-sand, or sandy-loam), the reef structure, fish grazers, daylength and water quality condition interacting independently or in combination in each geographic area play an important role in the overall composition of seagrass species.

The seagrass community in both sites surveyed showed that it is highly dominated by *T. hemprichii* species with a dominance value of 0.85±0.15 and 0.76±0.04 in Laguindingan and Kauswagan respectively (Table 2), a result that is the same with previous reports (Fortes & Nadaoka, 2015; Redondo *et al.*, 2017). *T. hemprichii* is a firmly anchored seagrass that is common in the tropical region of the Indian Ocean and western part of the Pacific and found mostly on mud-coral-sand or coarse coral-sand substrates, in sheltered habitats in the Philippines that has been observed growing from the base and through fingers of corals at 6 m deep which can form large seagrass beds (Meñez *et al.*, 1983).

Table 2. Diversity indices of seagrasses in all sites surveyed.

Diversity Indices	Laguindingan	Kauswagan
Shannon diversity (H')	0.40±0.35	0.76±0.22
Evenness (J')	0.35±0.17	0.36±0.08
Dominance (D)	0.85±0.15	0.76±0.04

The dominance of *T. hemprichii* is due to its high abundance throughout the study areas. This seagrass species usually dominates over the other species when present in mixed seagrass meadows (Short *et al.*, 2010). Even under algal blooms, *T. hemprichii* can grow and develop optimally thus it can successfully colonize seagrass beds than other species – its root system and its adaptability to the low concentrations of light during algal blooms are believed to be the factor for its resilience (Han *et al.,* 2014).

Analysis of species diversity showed no significant differences in species diversity (P > 0.05 Table 3) in all sites surveyed. However, species diversity (H' = 0.76±0.22) in this study is low compared to a 2017 study of seagrass in Kauswagan, Lanao del Norte with an average H' = 1.43 (Redondo *et al.*, 2017) but is higher than that of the seagrass conducted in Hagonoy, Davao del Norte with an average species diversity of H' = 0.31 (Jumawan *et al.*, 2015). In Laguindingan, Misamis Oriental, lower species diversity (H' = 0.40±0.35) was observed in the present study compared to a previous study by Roa-Quiaoit *et al.,* 2009 with H' = 0.59. In 2009, Laguindingan ranked 2nd in low species diversity among 14 municipalities assessed within Macajalar Bay, Misamis Oriental (Roa-Quiaoit *et al.* 2009). Consequently, the high dominance values exhibited within the community resulted in a low evenness score (0.35±0.17 and 0.36±0.08, Table 2) of the seagrass species in the area, indicating low value of uniformity.

Table 3. Results of statistical tests on species composition and diversity of seagrass in all sites surveyed.

Diversity	Comparison	Stat Model	P-value
Species compositio(S')	Between sites	One-way ANOVA	0.12^{ns}
Species diversity (H')	Between sites	One-way ANOVA	0.62^{ns}
Evenness (J')	Between sites	One-way ANOVA	0.92^{ns}

Legend: ns, *not significant; +, significant at p < 0.05*

A study by Hemminga and Duarte (2000) showed that seagrasses which had extensive distribution had a high adaptability so that it could grow well in different types of habitat with various environmental conditions but the high value of the dominant species could also mean that the community is less diverse. Seagrass diversity could be influenced by a number of factors such as topography, physical condition, activity of coastal communities around the seagrass beds, seagrass adaptation, predation and associated biota (Heck *et al.,* 2006), substrate conditions, seasons, tides, wave energy strength, the content of organic matter in the sediment and other environmental factors (Short *et al.,* 2003).

High species diversity leads to high structural complexity, high fish production, high water clarity, high sediment stability and high resilience to environmental stressors (Duffy, 2006).

Furthermore, diverse assemblages are predicted to be more productive, on average, than species-poor assemblages, because their larger range of traits allows exploitation of a greater fraction of available resources (niche complementarity), and because diverse assemblages are more likely, by chance alone, to contain species that grow well under the local conditions (the sampling effect) (Duffy, 2006). With high species diversity, stability of aggregate ecosystem properties (e.g. total plant biomass) under changing environmental conditions are enhanced (Naeem 1998, Yachi & Loreau, 1999), because functionally redundant species can provide insurance when any one species is lost and because variation among species in response to environmental change (response diversity) can even-out temporal fluctuations in community biomass (Elmqvist *et al.,* 2003).

The seagrasses *C. serrulata, H. uninervis, H. ovalis, H. pinifolia, T. ciliatum* and *S. isoetifolium* were found to have few number of individuals, in turn low density values. This is because these species have the inability to adapt to different environmental conditions and cannot grow dominant. Seagrass adaptability to environmental conditions are very different from one species to another (Wahab *et al.,* 2017).

Overall, the low Shannon Wiener of seagrass in Kauswagan, Lanao del Norte (H'=0.76±0.22) and in Laguindingan, Misamis Oriental respectively (H'=0.40±0.35) indicate low stability in the community, which means that the condition of the seagrass ecosystem could be under threat, both from natural and anthropogenic activities (Unsworth *et al.,* 2019).

Seagrass percent cover

T. hemprichii has the highest percent cover (27.53% and 26.05%) in Kauswagan, Lanao del Norte and Laguindingan, Misamis Oriental respectively, followed by *C. rotundata* (4.98%) in Kauswagan, and *E. acoroides* (4.77%) in Laguindingan. All other species have percent cover of less than 10% (Fig. 3).

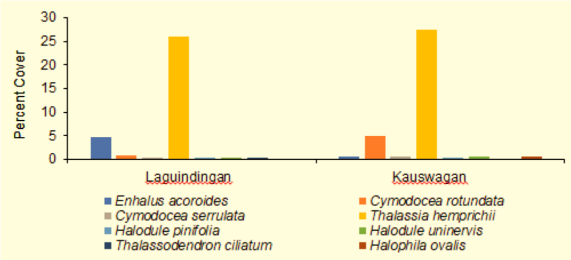

Fig. 3. Seagrass percent cover in Laguindingan, Misamis Oriental and Kauswagan, Lanao del Norte.

The high percent cover of *T. hemprichii* was found to be consistent with the results obtained in a previous study (Redondo *et al.,* 2017) where *T. hemprichii* was found to have the highest relative cover of 52% followed by *E. acoroides* with 18% and *C. rotundata* with 16%. Previous findings from a 2009 study conducted by Roa-Quiaoit *et al.*, on the ecological and fisheries profile of Macajalar Bay also showed that *T. hemprichii* ranked highest in relative cover with 26% followed by *C. rotundata* with a relative cover of 25%.

The abundance of *T. hemprichii* could be due to the prominent characteristic of this species where it could grow well in different types of habitat with various environmental conditions. The various chemical factors such as salinity, oxygen concentration, nutrient availability, pH level, turbidity, light availability, tidal exposure and waves, and various biotic factors such as epiphytes and epifauna might have favored the growth, development and reproduction of this particular species in these areas (Al-Bader *et al.,* 2014). It is considered as a climax species in the Indo-Pacific region (Short *et al.,* 2010) and usually dominates over the other seagrass species when present in mixed seagrass meadows (Meñez *et al.,* 1983).

Seagrass Condition

Average percent cover of seagrass beds in Laguindingan, Misamis Oriental was recorded at 31.93% (Table 4). This cover is considered fair based on the criteria set for habitat assessment by Fortes (1990).

Table 4. Seagrass cover and condition per transect for Laguindingan, Misamis Oriental.

Station	% Cover	Condition (Fortes)
Transect 1	31.27	Fair
Transect 2	38.98	Fair
Transect 3	25.53	Fair
Average	31.93	Fair

The area has a muddy-sandy substrate and the beds along this area support many aquatic habitats. They provide livelihood and income to the fisherfolk of the municipality. Being a marine protected area, the habitat degradation, destruction, and collection of endemic species is highly prohibited. However, ongoing developments in Laguindinan being declared as an eco-tourism park and industrial zone pose tremendous environmental threats to the overall health and existence of the seagrass ecosystem. The establishment of beach resorts and other structures is expected to contribute to pollution that may lead to habitat destruction. Recent reconnaissance of the area have documented one beach resort having no proper drainage of its swimming pools.

Another threat that the seagrass beds in Laguindingan now facing is the visible encroachment of mangroves in the seagrass ecosystem. While there is quantitative evidence to suggest that mangrove encroachment may enhance carbon storage, increase nutrient storage, and improve storm protection (Turner *et al.,* 2006), the encroachment may as well causes substantial shifts in ecosystem structure resulting in the destruction of seagrass beds ecosystem, decline in its habitat availability for seagrass-associated micro and macrobenthic fauna, recreational and aesthetic services, and change in fisheries productivity (Kelleway *et al.,* 2017).

In Kauswagan, Lanao del Norte, average percent cover was recorded at 35.24% (Table 5). This cover is also considered fair based on the criteria set for habitat assessment by Fortes (1990). Like Laguindingan, the seagrass beds along this area provides subsistence fisheries to fisherfolk within the community. However, several environmental threats ranging from power coal plant operation, fish cage belt area, docking area for fishing boats, and drainage area for some nearby residents continues to threaten the sustainable existence of the seagrass ecosystem in this area.

Table 5. Seagrass cover and condition per transect for Kauswagan, Lanao del Norte.

Station	% Cover	Condition (Fortes)
Transect 1	27.12	Fair
Transect 2	32.32	Fair
Transect 3	46.29	Fair
Average	35.24	Fair

Status of seagrass through time

Based on available resources gathered (published and unpublished), a total of 8 seagrass species were recorded and identified over time in Laguindingan, Misamis Oriental and Kauswagan, Lanao del Norte (Fig. 4). Overall, the number of seagrass species represents 50% of the total number of species found in the Philippines.

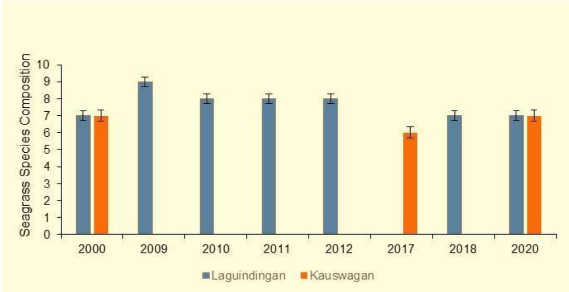

Fig. 4. Number of seagrass species identified through time. Bars indicates the Standard Error (SE).

Over time, a fluctuating trend in the number of seagrass composition was observed in both of these areas. Aside from the substrate type, other environmental factors like seasonal variation could be affecting seagrass species composition between years such that seagrass grow abundantly during summer (March to May) and thus a good rating was recorded or due to variations in seasonal tropical monsoon occurrences.

The same fluctuating pattern has also been observed in the abundance of seagrass species (Fig. 5). But, a notable decreasing trend has been observed in Kauswagan, Lanao del Norte with highest (68%) seagrass cover during a 2017 assessment period and lowest (35%) during the 2020 assessment.

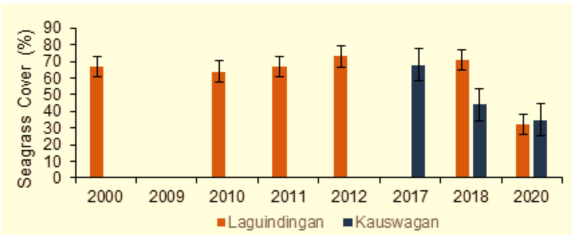

Fig. 5. Seagrass cover through time. Bars indicates the Standard Error (SE).

In terms of species diversity, a decreasing trend has also been observed over time in all areas with highest species diversity (H' = 1.43) observed in Kauswagan during the 2017 assessment period and lowest (H' = 0.44) in Laguindingan during the 2020 assessment period (Fig. 6).

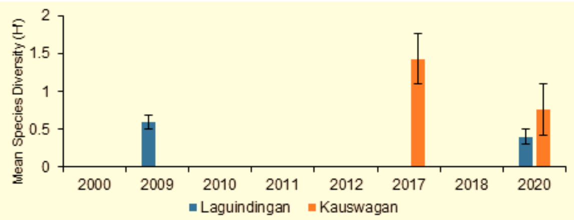

Fig. 6. Species diversity of seagrass through time. Bars indicates the Standard Error (SE).

Recent reports show that seagrass species diversity is highest in the Philippines (19 species) compared to other Southeast Asian region with lowest in Brunei (7 species) (Lamit *et al.,* 2017). The Philippines also had the largest seagrass extent compared to other Southeast Asian region with seagrass meadows constituting at least 24% of its territorial waters (Fortes *et al.,* 2018). However, the observed decreasing trend in species diversity over time in these areas could have been a result of human alteration of the physical environment whether directly or indirectly. Human impacts to seagrass distribution, diversity and health are profound and occur at several scales, most notably manifesting in the near absence of seagrasses in industrialized ports and other areas of intense human coastal development (Orth *et al.,* 2006).

Seagrasses are being lost rapidly in developed and developing parts of the world (Short *et al.*, 2006b), with only occasional efforts at mitigation and restoration. Direct impacts include dredging, filling, land reclamation, and some fisheries and aquaculture practices. Indirect impacts such as nutrient and sediment loading from the watershed, removal of coastal vegetation and hardening of the shoreline, result in reduced water clarity which initiates the process of seagrass decline, as seagrasses are particularly sensitive to light limitation (Short *et al.,* 2007).

Furthermore, although the effects of global climate change on seagrasses are difficult to document, but whether they manifest as sea level change, heat stress, radiation exposure, or increased storm activity, all largely diminish seagrass habitat, distribution and diversity (Short *et al.,* 2007).

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