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Morphological and distribution characteristics of *Halophila beccarii* Aschers., 1871 in the Cau Hai lagoon, Thua Thien Hue province, Vietnam

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ABSTRACT

Halophila beccarii Aschers., 1871 was one of the seagrass species that was vulnerable and threatened list by the International Union for Conservation of Nature (IUCN). During the survey period from March 2018 to September 2019, our results showed that *H. beccarii* was widely distributed in the Cau Hai lagoon and concentrated mainly in the Southeast area of the lagoon. The distribution of *H. beccarii* was seasonal. The species' growth started from the early rainy season of the previous year until the end of the dry season of the following year. However, the period when the species had a high cover, biomass, and shoot density was from September 2018 to March 2019, and those values peaked in January 2019. The lowest cover and shoot density were recorded in November 2019, while the lowest biomass was in July 2019. The rainfall had a close positive correlation with the biomass of *H. beccarii*, while water salinity and water temperature were moderate negatively correlated with the biomass of the species.

Keywords: *Halophila beccarii*, Cau Hai lagoon, seagrass, morphological characteristic.

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INTRODUCTION

Seagrasses are flowering plants that live completely submerged in brackish water and marine environments [1]. In the world, there are 72 seagrass species belonging to 13 genera and 6 families. They are distributed in tropical and temperate regions [1, 2]. Seagrasses, mangroves, and coral reefs are three ecosystems that are closely related to each other. That plays an important ecological role in marine and ocean ecosystems [3]. Seagrasses are a source of food, shelter, and nursery for aquatic animals [4]. However, the coverage area of seagrass bets has been seriously decreasing. In 2010, the global seagrass cover was estimated at 600,000 km² [5], but the seagrass coverage area decreased to 266,562 km² [6]. Therefore, activities to prevent the decline in the distribution area of seagrass beds are rarely necessary.

Among 13 seagrass genera, *Halophila* is the largest genus, including 17 species, presenting in 5/6 global seagrass ecoregions [7]. *H. beccarii* is a seagrass species of the *Halophila* genus. It was commonly found in sheltered intertidal areas such as estuaries, mangroves, and lagoons. The species are widely distributed in the Indo-Pacific region, especially in Southeast Asian countries [2]. *H. beccarii* was found on muddy-sandy bottom mixed with clay and silt [8, 9]. *H. beccarii* could grow to form mono-species meadows; however, the species was also found growing with other species to form mixed-species meadows [8, 9]. *H. beccarii* was a small and delicate seagrass species; on the other hand, its populations had low genetic diversity [10, 11]; thus, *H. beccarii* was very vulnerable to adverse environmental impacts. Currently, the distribution of *H. beccarii* has been at an alarming rate. The species has been listed as a threatened and vulnerable species by the IUCN (International Union for Conservation of Nature) [2]. However, *H. beccraii* species grows abundantly in some countries in Southeast Asia [8], including Vietnam [12].

In Viet Nam, *H. beccarii* was found along the coast from Quang Ninh to Da Nang [13], especially the species were abundant in the Tam Giang - Cau Hai system, Thua Thien Hue province [14–16]. Cau Hai lagoon is the largest of the four lagoons, a Wetland Nature Conservation area. The lagoon had quite a high biodiversity [17], with nine species of submerged aquatic vegetations reported [18], in which *H. beccarii* was one of the dominant species [12]. Therefore, information about distribution, reproduction, and ecology is necessary to conserve and develop *H. beccarii* meadows in tropical lagoons. This study aimed to evaluate the distribution of *H. beccarii* and examine the effect of water salinity, water temperature, and some weather factors (air temperature, precipitation) on the distribution of the seagrass *H. beccarii* species in the Cau Hai lagoon.

MATERIALS AND STUDY METHODS

Study area

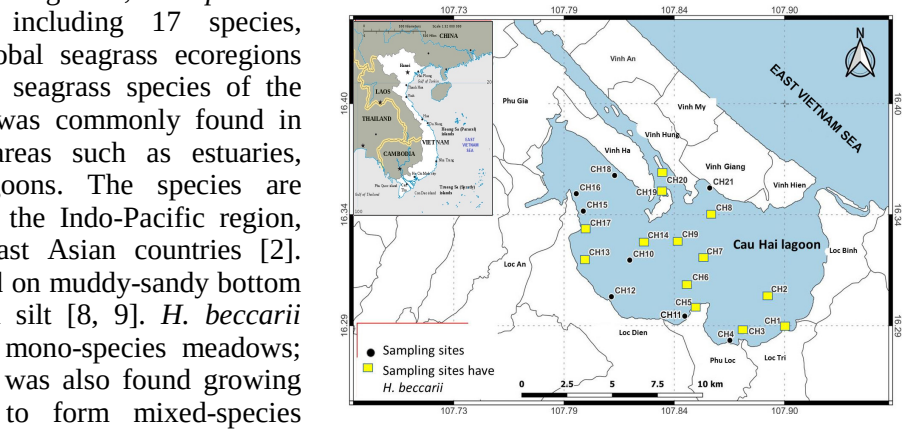

Figure 1. Sampling sites in the Cau Hai lagoon

The study was carried out in the Cau Hai lagoon (16º19’22”N, 107º50’59”E), Thua Thien Hue province, from March 2018 to November 2019. We conducted 11 sampling trips at 21 sites across the lagoon, (Fig. 1, Table PL1) based on the distribution records of *H. beccarii* in previous studies [12, 18].

Study methods

Collecting samples in the field

We surveyed with the sampling frequency every two months. We used a boat to go to the

sampling sites. The coordinates of the sampling sites were fixed by Garmin GPSMAP®78 (Garmin-USA, Taiwan) during the study period. The water environment parameters for each sampling site, such as salinity, temperature, pH, and turbidity, were determined by HORIBA multi-parameter meter (HORIBA Advanced Techno Co., Ltd, Tokyo, Japan). The water column depth was measured by the Handy Depth Sounder Hondex PS-7 hand-held depth detector (Honda Electronics Co., Ltd, Tokyo, Japan). At each sampling site, the biomass of *H. beccarii* (roots, shoots, leaves, flowers, and fruits) was collected inside 3 standard squares (0.5 m × 0.5 m), which were randomly arranged inside meadows. *H. beccarii* samples were washed with water in the lagoon and put in plastic bags with waterproof labels. Samples were stored in a cool box before being brought to the laboratory for 24 hours. Coverage of *H. beccarii* was determined in the field by the standard square method following the guidelines of Mckenzie (2003) and McKenzie & Campbell (2002) [19, 20].

In the laboratory

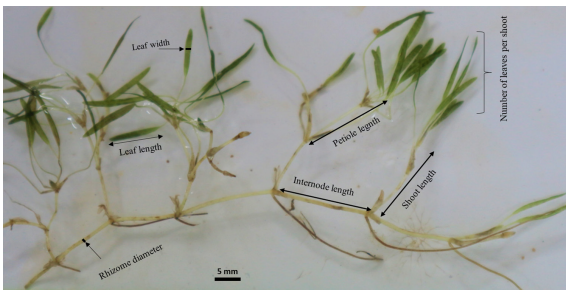

Figure 2. Measurement of morphological characteristics of the *H. beccarii* species [*Photo by:* Dang Thi Le Xuan]

After collection, *H. beccarii* samples were brought to the laboratory within 24 hours, then stored in a refrigerator compartment. The number of leaves per shoot and the number of shoots were carefully counted and recorded. For each standard square, 30 shoots were randomly taken and determined the shoot length, leaf length, leaf width, and petiole length (Fig. 2). Morphological characteristics of *H. beccarii* were measured using an electronic caliper (Mitutoyo 530-104, Tokyo, Japan) based on the guide method of Short and Duarte [21]. Study samples were clean and washed with tap water, then dried at 60 ºC until the constant weight and weighed to determine dry biomass (g DW m^{-2}) [22].

Data analysis

IBM SPSS Statistics Version 20 software was used to analyze study data and design the graphs. Data before analysis were tested for normal distribution by Shapiro-Wilk Test. Because the variables were not normally distributed; thus, the differences between the variables were analyzed using the Friedman ANOVA, the post-test by Wilcoxon matched pairs, and the correlation between the variables was tested by the Pearman method.

The distribution map of *H. beccarii* in the Cau Hai lagoon was built using QGIS 3.6 software. Using the Inverse Distance Weighting (IDW) interpolation algorithm integrated into QGIS 3.6 to create the map. The formula for calculating the interpolated value of the unknown point was:

$$Z_0 = \frac{\sum_{i=1}^{N} z_i . d_i^{-n}}{\sum_{i=1}^{N} d_i^{-n}}$$

in which: Z_0*:* the interpolated value was found at the point to be calculated; z_i*:* the sample value was known at point *i*; d_i*:* distance from point to be calculated to known point *i*; *n:* number of points known sample value; *N:* constant WD.

STUDY RESULTS AND DISCUSSION

Morphological characteristics of *H. beccarii* in the Cau Hai lagoon

In the Cau Hai lagoon, *H. beccarii* had a shoot length of 2.3–49.1 mm, and an average of 15.1 ± 0.3 mm (Fig. 3A). The number of leaves

per shoot was 4–12 leaves. The rhizome consisted of numerous internodes, with a length of 6.6–30.7 mm and an average of 16.7 ± 0.3 mm, Fig. 3B. Rhizome diameter from 0.25–1.0 mm, and an average of 0.6 ± 0.01 mm.

The leaves of *H. beccarii* were an elongated elliptical shape, with a slightly lanceolate apex, Fig. 3C. The leaf length ranged from 2.0–25.9 mm, and the average was 17.4 ± 0.1 mm; leaf width was from 0.3–2.6 mm, and the average was 1.7 ± 0.01 mm. The blade had 3 longitudinal veins, the veins ran parallel and converged at the apex, and the leaf had no transverse veins, Fig. 3C. The leaves of *H. beccarii* had a long petiole; the petiole was longer than the blade. The petiole length was from 3.7–39.0 mm, with an average of 18.9 ± 0.3 mm, Table 1.

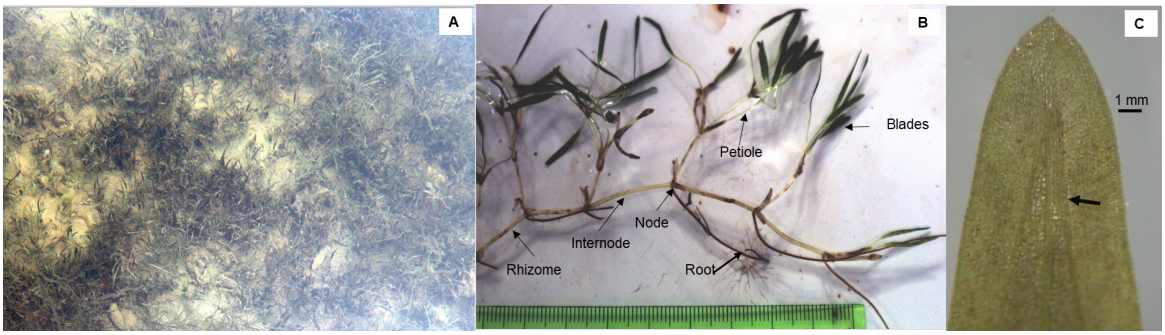

Figure 3(A–C). H. beccarii meadow in the Cau Hai lagoon (A); morphology of *H. beccarii* (B); apex with veins (C) [*Photo by:* Dang Thi Le Xuan]

Table 1. Morphological characteristics of *H. beccarii* in the Cau Hai lagoon

Characteristics	Range	Mean ± SE, *n* = 300
No. of blades/whorl	4–12	-
Leaf width (mm)	0.3–26	1.7 ± 0.01
Leaf length (mm)	2.0–25.9	17.4 ± 0.1
Potiole length (mm)	3.7–39.0	18.9 ± 0.3
Shoot length (mm)	2.3–49.1	15.1 ± 0.3
Internode length (mm)	6.6–30.7	16.7 ± 0.3
Rhizome diameter (mm)	0.3–1.0	0.6 ± 0.01

Table 2 showed that *H. beccarii* grew in Cau Hai lagoon to have the highest number of leaves, reaching 12 leaves, while in other studies, the number of leaves was 10 leaves [23, 24], 8 leaves [8]. *H. beccarii* was distributed on coasts and islands of India; the number of leaves was 4–6 [25]. The leaf length of *H. beccarii* in this study was similar to the leaf length of the species recorded in Bakkhali Estuary, Bangladesh [8] and Con Chim (Thuy Tu lagoon, Vietnam) [15], while some other studies showed that the leaf length of the species was of 7.6–16 mm [23–26]. The leaf width of *H. beccarii* was similar to that recorded in other distribution regions, but the petiole length was significantly longer than some previously reported [24, 25, 27], Table 2. The internode length of the rhizome was also similar to that recorded in the Philippines (10–30 mm) [26], Banglades (10–30 mm) [8], and Myanmar (10–25 mm). The internode length of the *H. beccarii* recorded in Con Chim (23.1 mm) [15], and another study (16.5–25 mm) [23, 25] was significantly shorter than this study. In general, *H. beccarii* distributed in the Cau Hai lagoon had the size of the leaf, and petiole, and the shoot was longer than recorded in previous studies.

Table 2. Comparison of morphological characteristics of *H. beccarii* in the Cau Hai lagoon with previous studies

Number leaves per shoot	Leaf length (mm)	Leaf width (mm)	Petiole length (mm)	Shoot length (mm)	Internode length (mm)	Rhozime diameter (mm)	Study areas	References
3–10	12	1.5	4–13	-	-	-	Mandovi estuary, Goa, India	[24]
10	8–15	1–2	-	-	10–30	1.0	Mångove, estuary, lagoon in Philippines	[26]
-	6–13	1–2	10–20	-	-	-	South Coast of China, Bengal bay	[27]
4–8	10–25	2	30	-	10–30	1.0	Bakkhali Estuary , Banglades	[8]
-	9.2–22.8	0.6–1.8	-	2.7–18.3	7.5–23.1	-	Con Chim, Thuy Tu lagoon, Vietnam	[15]
4–10	7–15	1–3	-	-	10–25	1.0	Kalegauk island, Myanmar	[23]
2–6	4.7–7.6	0.8–3.9	5.7–12.7	-	6.2–16.5	0.2–0.4	Port Blair, Andaman and Nicobar island, India	[25]
4–10	13	1–2	-	-	-	-	-	[21]
4–8	20–30	2–4	15–20	-	10–20	-	Vietnam	[13]
4–12	2.0–25.9 (17.4 ± 0.1)	0.3–2.6 (1.7 ± 0.01)	3.7–39.0 (18.9 ± 0.3)	2.3–49.1 (15.1 ± 0.3)	6.6–30.7 (16.7 ± 0.3)	0.3–1.0 (0.6 ± 0.01)	Cau Hai lagoon, Vietnam	This study

Note: (-): no data.

The distribution of *H. beccarii* in the Cau Hai lagoon

The survey period showed that the seagrass *H. beccarii* was widely distributed in the Cau Hai lagoon, present in 13/21 sampling sites (Fig. 2). The study results showed that the average value of cover, biomass, and shoot density of *H. beccarii* was determined to be 37.8 ± 3.4%, 13.6 ± 1.6 g DW m^{-2}, 1924 ± 211 shoot m^{-2}, (mean ± SE, n = 143). The distribution of *H. beccarii* in Cau Hai significantly changed spatially and temporally. The results of ANOVA Friedman analysis showed that the meadows of the *H. beccarii* species had a significant difference in coverage ($\chi^2_{(12,\ n\ =\ 11)} = 42.6$, $p < 0.0001$), biomass ($\chi^2_{(12,\ n\ =\ 11)} = 41.5$, $p < 0.0001$) and the shoot density ($\chi^2_{(12,\ n\ =\ 11)} = 41.9$, $p < 0.0001$) at sampling sites. Coverage, biomass, and shoot density of the species were higher at sites in the Southeast of the lagoon, such as at *CH*1, *CH*2, *CH*3, and *CH*9. The highest was at the *CH*1 site at 76.2 ± 29.8%, 26.2 ± 6.1 g DW m^{-2}; 3,388 ± 635 shoot m^{-2}. In the Northwest area of the lagoon, *H. beccarii* meadows had the cover, biomass, and shoot density had low values; the lowest was recorded at *CH*17 of 6.4 ± 6.4%, 1.36 ± 1.36 g DW m^{-2}, 755 ± 755 shoot m^{-2}, respectively, (mean ± SE, n = 11).

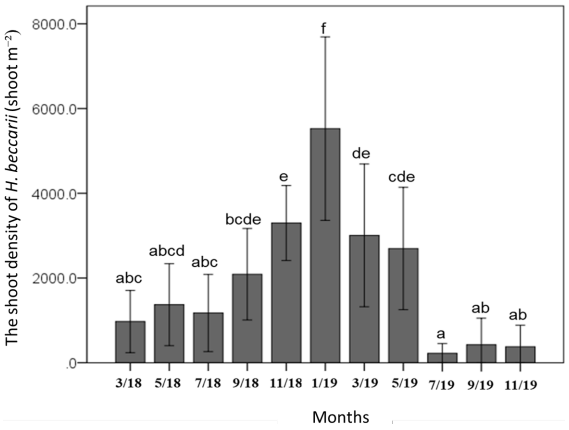

Figure 4. The shoot density of *H. beccarii* in the Cau Hai lagoon

The distribution of *H. beccarii* also had a clear change in temporal. *H. beccarii* meadows had a significant difference in coverage ($\chi^2_{(10,\ n\ =\ 13)} = 53.3$, $p < 0.0001$) (Figs. 5–6), shoot density ($\chi^2_{(10,\ n\ =\ 13)} = 57.2$, $p < 0.0001$) (Fig. 4), and biomass ($\chi^2_{(10,\ n\ =\ 13)} = 66.9$, $p < 0.0001$) (Figs. 7–8) in months. The highest coverage, shoot density, and biomass of *H. beccarii* were recorded in January 2019 at 77.1 ± 10.2%

(Fig. 6A); 5,527 ± 1,082 shoot m^{-2} (Fig. 4), and 39.4 ± 8.5 g DW m^{-2} (Fig. 8A), respectively.

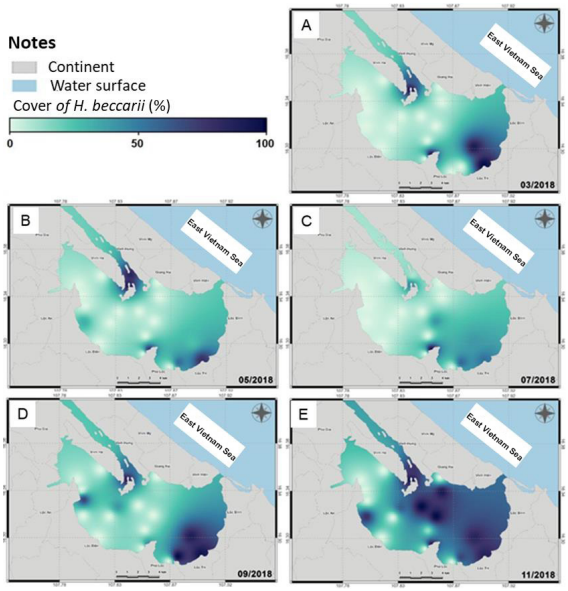

Figure 5(A–E). The map of cover of *H. beccarii* in the Cau Hai lagoon in 2018. Mach (A); May (B); Junly (C); September (D); and November (E)

The coverage and shoot density of *H. beccarii* were lowest in July 2019 at 4.9 ± 2.6% (Fig. 6D) and 224 ± 115 shoot m^{-2} (Fig. 4), respectively. The lowest biomass was 2.3 ± 1.6 g DW m^{-2} in November 2019 (Fig. 8F), (mean ± SE, n = 13). In 2018, the cover of *H. beccarii* increased from March to November. Seagrass *H. beccarii* meadows peaked in coverage, biomass, and shoot density in January 2019; those values gradually decreased in the following months. The lowest biomass of the species was in November 2019. Our study results and the records of Phan Thi Thuy Hang (from 2015 to 2018) [12, 14] showed that the distribution of the seagrass *H. beccarii* in Cau Hai was unclearly seasonal. The species' growth started in the early rainy season of the previous year until the end of the dry season of the following year. However, the period of the abundant growth of the species with high biomass and coverage coincided with the rainy season (from November 2018 to March 2019). The study results showed that the biomass of *H. beccarii* was lower than that recorded in Tam Giang - Cau Hai (206.6 ± 17.6 g DW m^{-2}) [16]. In Thi Nai lagoon, the *H. beccarii* meadows were found in the rainy season [28], with the biomass significantly lower (23.27 ± 1.52 g DW m^{-2}) [16] compared with the results in this study.

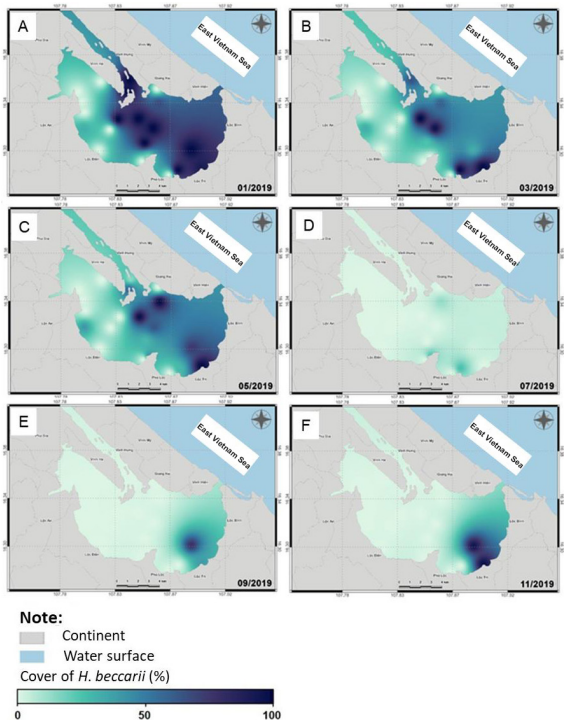

Figure 6(A–F). The map of cover of *H. beccarii* in Cau Hai lagoon in 2019. January (A); Mach (B); May (C); July (D); September (E); and November (F)

Worldwide, *H. beccarii* was widely distributed on the coast of the Indo-Pacific region [2]. The species was abundant in several countries including India [24], Sri Lanka [29], Malaysia [30], Bangladesh [8], Philippines [26, 31], Thailand [23], and Singapore [32]. In Vietnam, *H. beccarii* was common in coastal environments, especially in the Tam Giang - Cau Hai lagoon system [12, 14, 15]. Previous studies recorded that the salinity distribution of the species was 0–37‰ [8, 12, 23, 25, 33]. Therefore, the abundance of the seagrass *H. beccarii* meadows in the Cau Hai lagoon environmental condition was completely

consistent with records of the distribution of the species in the world.

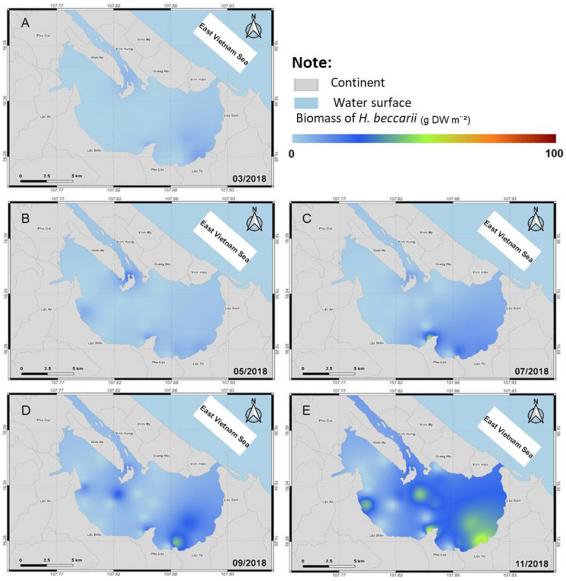

Figure 7(A–E). The map of biomass of *H. beccarii* in Cau Hai lagoon in 2018. Mach (A); May (B); July (C); September (D); and November (E)

The *H. beccarii* meadows in Cau Hai lagoon were found in mono-species and mixed-species meadows. The mono-species meadows were observed at the sampling sites Southeast of the lagoon with higher salinity (10.4–12.8‰). The remaining sites with lower salinity (7.2–10.4‰) were found to be mixed-species meadows, in which *H. beccarii* grew with freshwater species *Najas indica* (Willd.) Cham. (Fig. 9B) was most common. In addition, *H. beccarii* was also observed to grow together with the seagrass *Halodule uninervis* at the *CH*2 sampling site. *H. beccarii* occurred with the seagrass *Halophila ovata*, *H. Uninervis*, on the coast of India [9], or with *Halophila ovalis*, *H. uninervis*, on the coast of Sri Lanka [29]. In the estuarine habitats of Bangladesh, *H. beccii* grew with salt marsh plant (*Porteresia coarctata*), seaweed (*Ulva intestinalis*), mangrove species (*Avicennia alba*, *A. marina*), and seagrasses (*H. ovata*, *H. ovalis*, *H. uninervis*) [8]. On Kalegauk Island, *H. beccarii* grew with mangrove plants (*A. alba*, *A. Marina*) and seaweed species (*Ulva* sp. and *Dictyota* sp.) [23].

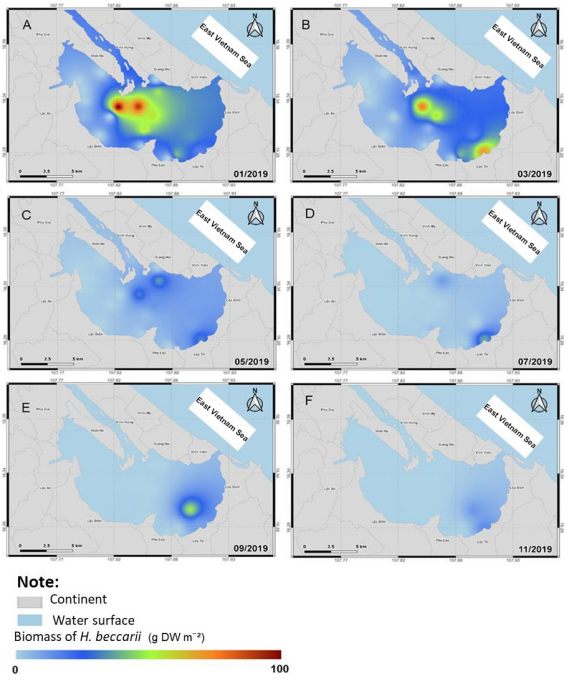

Figure 8(A–F). The map of biomass of *H. beccarii* in the Cau Hai lagoon in 2019. January (A); Mach (B); May (C); July (D); September (E); and November (F)

In Cau Hai, *H. beccarii* grew as both annuals and perennials. Most of the *H. beccarii* meadows grew as annual plants. These meadows grew and rapidly expanded their distribution when habitat conditions were advantageous; the species quickly died and disappeared when conditions were a disadvantage. *H. beccarii* presented at the edge of the lagoon, where included *CH*1, *CH*5, and *CH*20 sites grew as perennial plants. In these meadows, *H. beccarii* presented all year round, its decay occurred completely, and there were still rhizome fragments buried under the sediment found during the survey period (2018–2019) (Fig. 10).

Previous studies showed that the *H. beccarii* species also recorded growth as annual and perennial plants [23, 33, 34]. This mechanism could be a flexible adaptation of the species to habitat conditions such as estuaries, mangroves, and lagoons.

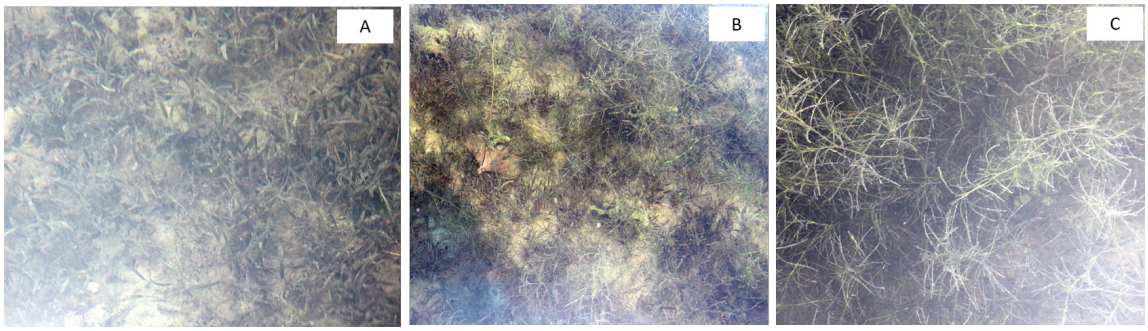

Figure 9(A–C). The seagrass *H. beccarii* meadow (A); The mixed-species meadow of *H. beccarii* and *N. indica* (B); and the waterfresh *N. indica* meadow (C) in the Cau Hai lagoon [*Photo by:* Dang Thi Le Xuan]

Figure 10. Rhizomes of the *H. beccarii* meadows which grew as a perennial plant in the decay period (July 2019) in Cau Hai lagoon [*Photo by:* Dang Thi Le Xuan]

Effects of environmental factors on the distribution of *H. beccarii* in the Cau Hai lagoon

Cau Hai lagoon is a water body with the largest water surface area of the Tam Giang - Cau Hai lagoon system. It connects with the East Vietnam Sea through the Tu Hien inlet and connects with other areas through the Thuy Tu lagoon. The lagoon receives freshwater sources to pour into the lagoon from rivers such as Dai Giang, Truoi, and Cau Hai. The Cau Hai lagoon was considered to be a typical brackish environment. The water salinity during the survey period ranged from 0.1‰ to 20.6‰, and an average of 9.3 ± 0.2‰ (mean ± SE, n = 135). In the rainy season, the freshwater from rivers caused a significant decrease in the lagoon's salinity, especially in the estuary areas where it was almost freshwater (salinity dropped to 0.1‰). During the dry season, the water environment had a higher salinity. The salinity of the lagoon was highest in September 2018 (14.8 ± 0.4‰) and lowest in January 2019 (1.5 ± 0.2‰) (mean ± SE, n = 21). The areas where the seagrass *H. beccarii* presented to have a salinity < 20‰ (Fig. 11).

Cover, biomass, and shoot density of *H. beccarii* were close positively correlated (r > 0.8, p < 0.0001, n = 39); therefore, we choose biomass as a representative parameter to consider the correlation with water environment factors. Study result showed that the water salinity and water temperature were negatively correlated with the biomass of *H. beccarii* (r = -0.3, p = 0.03, n = 39), Fig. 12A and (r = -0.4, p = 0.006, n = 39), Fig. 12B, Table 3. In addition, considering about the correlation between biomass and air temperature and rainfall, we found that the

biomass of *H. beccarii* had a close positive correlation with rainfall (r = 0.8, p = 0.05, n = 6); this was mean that in the water salinity (0–20.6‰) and water temperature (20.7–34.8 ºC) of the Cau Hai lagoon environment, the biomass of *H. beccarii* increased when the rainfall increased while the salinity and water temperature decreased. The cover and biomass of *H. beccarii* were higher from September 2018 to March 2019. The species had the highest biomass in January 2019 (39.4 ± 8.5 g DW m^{-2}) when the water environment had the lowest salinity (1.8 ± 0.1‰) and water temperature (24.1 ± 0.3 ºC) during the survey period. However, a stable low salinity was not an advantaged environmental condition for the growth of the seagrass *H. beccarii* species, shown through the distribution space of the species in the lagoon. The distribution of *H. beccarii* was concentrated in the Southeast of the lagoon, which had higher salinity, while in the Northwest area with low salinity, the presence of the species was not recorded during the survey period. In 2018, the rainfall was evenly distributed all year round; the rainfall gradually increased from March (20.1 mm) to November (484.1 mm). The phenomenon could be one of the reasons for the year-round distribution of *H. beccarii*. Conversely, in 2019, the rainfall was deficient from February to July (0–125.1 mm), but the rainfall rapidly increased to 584.5 mm in September. The extreme weather condition of 2019 was the cause for the narrowing of the distribution of *H. beccarii* in the Cau Hai lagoon.

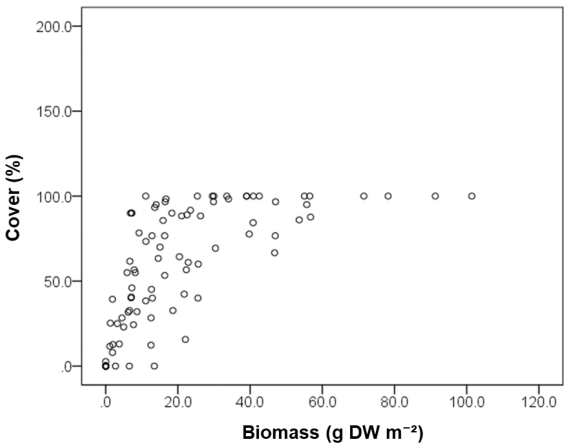

Figure 11. The correlation graph between biomass and coverage of *H. Beccarii*

Table 3. Correlation coefficient between biomass of *H. beccarii* and the salinity, temperature water environment, and rainfall

	Biomass (g DW m^{-2})
Salinity (‰)	-0.3 (Spearman, p = 0.03, n = 39)
Water temperature (ºC)	-0.4 (Spearman, p = 0.006, n = 39)
Rainfall (mm)	0.8 (Spearman, p = 0.05, n = 6)

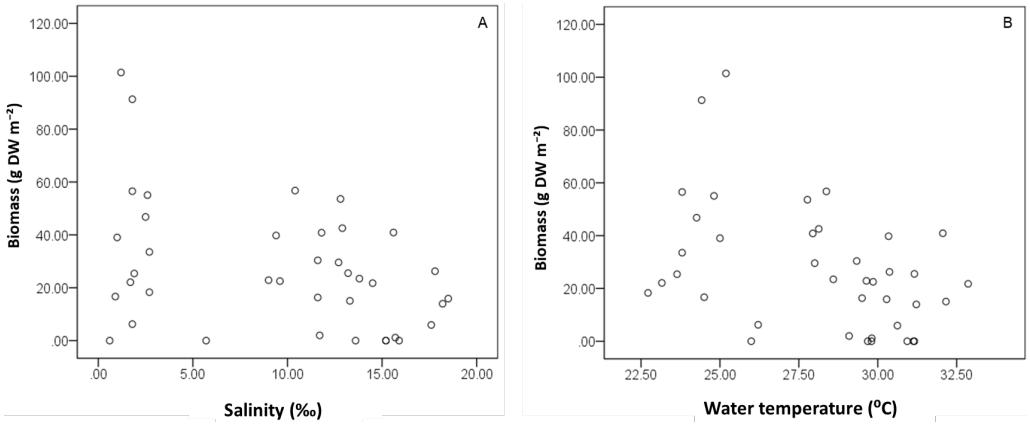

Figure 12(A–B). The graphs of biomass distribution of *H. beccarii* with water salinity (A); and water temperature (B)

CONCLUSION

The seagrass *H. beccarii* species in the Cau Hai lagoon had a large quiet range in morphological characteristics such as leaf length, leaf width, and shoot length.

In the Cau Hai lagoon, the seagrass *H. beccarii* was widely distributed and mainly concentrated in the southeast of the lagoon, while in the northwest area, the species' meadows sparsely appeared. The distribution of *H. beccarii* was unclear and seasonal. The growth season of the species started in the previous year's early rainy season (September) until the end of the following year's dry season. The period of the *H. beccarii* meadows was abundant with high coverage, and biomass coincides with the rainy season months (from September 2018 to March 2019) and the highest in January 2019.

The distribution of *H. beccarii* was influenced by water temperature, water salinity, and rainfall. The biomass of the species was moderately negatively correlated with water salinity and temperature and closely positively correlated with precipitation.

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Appendix

Table PL1. Coordinates of sampling sites in the Cau Hai lagoon

Sampling sites	Latitude	Longtitude
CH1	16.2853	107.90081
CH2	16.301	107.89228
CH3	16.2833	107.88069
CH4	16.2787	107.87272
CH5	16.2944	107.85475
CH6	16.3069	107.85156
CH7	16.3197	107.85894
CH8	16.3414	107.86378
CH9	16.3282	107.84625
CH10	16.3184	107.82094
CH11	16.2907	107.84939
CH12	16.3003	107.81147
CH13	16.3193	107.79808
CH14	16.3277	10.8285
CH15	16.3427	107.79694
CH16	16.3514	107.79331
CH17	16.3338	107.79872
CH18	16.3604	107.81314
CH19	16.3521	107.83683
CH20	16.3614	107.83833
CH21	16.3542	107.86228

Table PL2. Average biomass (g DW m^{-2}) of *H. beccarii* in the Cau Hai lagoon

	3/18	5/18	7/18	9/18	11/18	1/19	3/19	5/19	7/19	9/19	11/19
CH1	11.1	9.2	16.4	13.9	53.6	18.3	71.5	29.9	36.2	11.1	16.5
CH2	7.2	3.2	12.9	26.3	40.8	33.6	18.6	11.1	0	46.9	13.6
CH3	0	8.2	22. 3	40.9	30.4	39.0	39.0	12.6	1.3	0	0
CH5	6.8	12.8	47.0	21.8	56.8	22.1	6.6	7.1	4.9	0	0
CH6	0	0	0	0	1.9	55.1	7.7	4.5	0	0	0
CH7	0	0	7,0	0	29.6	56.5	55.7	14.6	0	0	0
CH8	0	0	0	1,2	23.5	46.8	25.6	34.0	12.5	0	0
CH9	0	0	0	0	42.5	91.3	78.2	29.9	0	0	0
CH13	0	8.7	0	0	39.8	6,2	6.6	1.9	0	0	0
CH14	0	0	0	25.5	22.9	101.4	13.5	0	0	0	0
CH17	0	0	0	15.0	0	0	0	0	0	0	0
CH19	7.2	21.0	12.7	15.9	22.5	16.7	7.3	7.9	0	0	0
CH20	6.7	5.2	1.9	5.9	16.3	25.4	20.4	3.8	2.7	0	0

Table PL3. Average cover (%) of *H. beccarii* in the Cau Hai lagoon

	3/18	5/18	7/18	9/18	11/18	1/19	3/19	5/19	7/19	9/19	11/19
CH1	100	78.3	53.3	95	86	90	100	100	0	38.3	96.7
CH2	90	25	40	88.3	84.3	100	32.7	73.3	26.7	76.7	93.3
CH3	0	55	56.7	100	69.3	100	100	28.3	25.2	0	0
CH5	90	76.7	96.7	42.3	87.7	15,7	0	40.7	23	0	0
CH6	0	0	0	0	12.7	100	24.3	28.3	0	0	0
CH7	0	0	40.11	0	100	100	95	63.3	0	0	0
CH8	0	0	0	11.7	91.7	66.7	60	98.3	12.3	0	0
CH9	0	0	0	0	100	100	100	96.7	0	0	0
CH13	0	32	0	0	77.7	31.7	32.7	39.3	0	0	0
CH14	0	0	0	40	61	100	0	0	0	0	0
CH17	0	0	0	70	0	0	0	0	0	0	0
CH19	90	88.3	45.1	85.7	89	98.3	46	56.7	0	0	0
CH20	61.7	84.3	8	55	76.7	100	64.3	13	0	0	0

Table PL4. Average shoot density (shoot m^{-2}) of *H. beccarii* in the Cau Hai lagoon

	3/18	5/18	7/18	9/18	11/18	1/19	3/19	5/19	719	9/19	11/19
CH1	3443	3280	2508	5616	5317	2717	7688	2629	0	1697	2375
CH2	2123	1016	1619	3565	3615	3825	1327	3152	120	3837	2527
CH3	0	2208	2395	4779	2796	12508	7969	1693	1123	0	0
CH5	2123	3072	5579	1695	4484	604	0	2811	983	0	0
CH6	0	0	0	0	528	7643	991	14423	0	0	0
CH7	0	0	1168	0	4780	10651	5480	2784	0	0	0
CH8	0	0	0	440	4011	7704	2436	8504	687	0	0
CH9	0	0	0	0	4935	7243	7396	7603	0	0	0
CH13	0	1235	0	0	3243	1233	1335	1261	0	0	0
CH14	0	0	0	2108	2504	8543	0	0	0	0	0
CH17	0	0	0	3072	0	0	0	0	0	0	0
CH19	2229	5605	1752	3623	3563	3996	1827	2480	0	0	0
CH20	2717	1415	245	2259	3084	5185	2629	685	0	0	0