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Assessment of the changes in the structure of mangroves based on stand age in Bang La, Hai Phong, Vietnam

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ABSTRACT

The mangrove forest area in Bang La (Hai Phong) is 370 ha, and tree density is 5,885 individuals/ha, distributed along the upper bank of the Van Uc River with high tidal flats. Detected 20 species of mangrove plants belonging to 19 genera, 16 families, and two divisions. The survey results show that the Bang La mangrove forest ecosystem has three forest types, the forest community is older than 15 years old, the forest community is from 10 to 15 years old, and the forest community is less than 10 years old. *Kandelia obovata*, *Sonneratia caseolaris*, and *Rhizophora stylosa*, is the dominant plant species. In each forest biome of different ages, there are different dominant species. The general composition formula for the study area is 47.2 Ko + 46.9 Sc + 1.8 Ks + 2.1 Ai + 2.0 Ac. The paper results showed that the more than ten years mangrove community is a stable forest biome. Mangroves from 10 years old should be planned with different species to increase the diversity in species structure and enhance the ability to stabilize the community and withstand changes in coastal habitats.

Keywords: Mangrove forest, forest community, Bang La, Hai Phong.

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INTRODUCTION

Mangrove forest is a typical plant structure of tropical and subtropical coastal areas [1, 2]. The mangrove ecosystem is an ECOTONE (ecological buffer or transition zone); these areas are exposed at low tide and submerged during high tide. Mangroves provide valuable agricultural products, habitats, and habitats for many species of plants and animals, and it is susceptible to human and natural influences [3]. Every year, natural disasters cause significant damage to coastal residents, and the development of shrimp farming and fishing ponds directly affects the mangrove area, structure, and quality of their ecosystem.

The Bang La mangrove forest is between Do Son Cape and the Dai Hop mangrove forest (north bank of Van Uc River). The Van Uc estuary is funnel-shaped with shoal islands in front of the river mouth, partially blocking the strength of the waves. On the other hand, the Do Son cape extending to the sea has created a small bay in the Bang La area. The Van Uc River mouth silt often accretes this bay, so the sedimentation rate is fast [4]. This process contributes to creating a shallow alluvial flat along the coast of Bang La dike, and there is a tidal flat 1.1 km away from the national dyke toward the sea. It is favorable conditions for the growth of mangroves. Thus, afforestation in Bang La and Dai Hop has brought high efficiency. Mangroves develop with a breathing root system (pneumatophore) like sediment traps, so in many areas near the dyke, the elevation of the bottom base has been raised, then according to the natural succession process, some mangrove species are adapted to characteristics of the bottom substrate will migrate and grow in new environments to replace pioneering species [5]. The rapid growth of mangroves and changes in the seabed have changed the structure of mangrove flora in the area. In particular, the Bang La mangrove forest plays a vital role in the coastal protection system of Hai Phong [6].

This paper will contribute to assessing the current structural status of the Bang La mangrove forest to identify evidence of structural changes according to mangrove ages. The result also suggests the succession process of planted forests in Bang La as a database for managing, conserving, and developing mangroves to minimize the impact of climate change and natural disaster risks.

MATERIALS AND METHODS

Materials

The primary source of material in this study is inherited from the results of measurement, survey, and sampling from 2020 to 2021 of two scientific research projects of Hai Phong City with code ĐT.MT.2019.842 and ĐT.MT.2019.849.

Data were collected during three survey trips in the study area.

Study site: Mangrove forest in the Bang La area.

Research period: Survey in the dry season (April) and the rainy season (September) in 2021.

Research object: Mangrove plants in Bang La Ward, Do Son District, Hai Phong, with three forest ages (Figure 1):

Forests older than 15 years: *Kandelia obovata*, *Rhizophora stylosa.*

Forest from 10–15 years: *Sonneratia caseolaris*.

Forests less than 10 years: *Sonneratia caseolaris*.

Methods

Mangrove survey method: Based on WWF documents [7] and the linear survey method of S. Aksornkoae [8]: In areas where mangroves have a wide width, survey lines are established perpendicular to the shoreline and extending to the riverside forest, so three survey routes are established: route 1, route 2, and route 3 (Figure 2).

The mangrove structure was observed following Nguyen Nghia Thin's method [9]: Around 20 sampling plots in each sampling station with 10 m × 10 m quadrats and only live trees with a diameter at breast height (DBH) ≥ 5 cm were recorded. At each plot, the following indicators were measured: stem diameter

(DBH), height (H), density, canopy cover, and composition species. The survey location was determined by the Garmin Etrex 10 satellite navigation device.

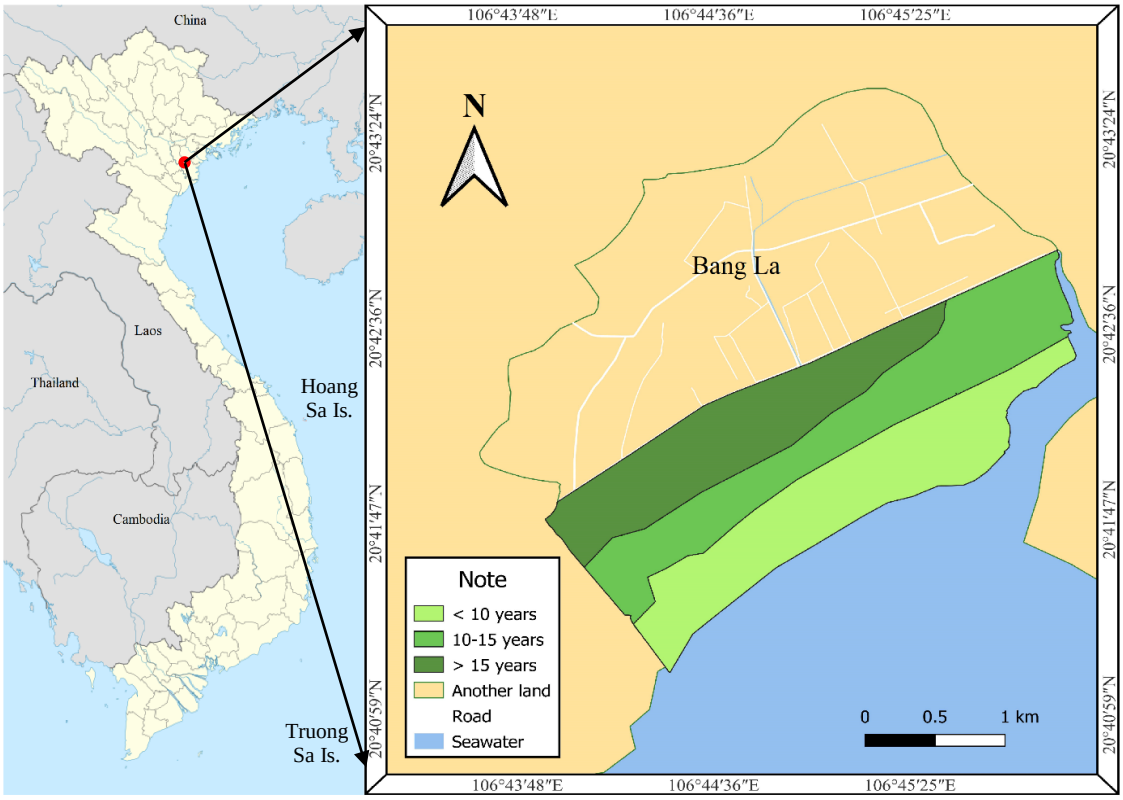

Figure 1. Location of mangrove forests of different stand ages at Bang La

Table 1. Coordinates of survey sites

Route 1	Latitude - Longitude	Route 2	Latitude - Longitude	Route 3	Latitude - Longitude
1.1	20°41’40.56”N - 106°44’52.80”E	2.1	20°41’54.41”N - 106°45’21.02”E	3.1	20°41’58.38”N - 106°45’35.07”E
1.2	20°41’44.77”N - 106°44’50.32”E	2.2	20°41’59.61”N - 106°45’17.88”E	3.2	20°42’00.32”N - 106°45’33.20”E
1.3	20°41’48.58”N - 106°44’47.76”E	2.3	20°42’12.78”N - 106°45’10.04”E	3.3	20°42’05.47”N - 106°45’30.17”E
1.4	20°41’52.61”N - 106°44’44.97”E	2.4	20°42’16.16”N - 106°45’09.25”E	3.4	20°42’09.90”N - 106°45’27.98”E
1.5	20°41’57.40”N - 106°44’40.71”E	2.5	20°42′20.26”N - 106°45’05.25”E	3.5	20°42’12.67”N - 106°45’26.03”E
1.6	20°42’4.06”N - 106°44’35.50”E	2.6	20°42’26.12”N - 106°45’05.35”E	3.6	20°42’19.72”N - 106°45’21.22”E
1.7	20°42’8.51”N - 106°44’32.67”E	2.7	20°42’26.90”N - 106°45’00.14”E	3.7	20°42’25.10”N - 106°45’16.87”E
1.8	20°42’12.55”N - 106°44’27.88”E	2.8	20°42’28.66”N - 106°45’00.59”E	3.8	20°42’31.72”N - 106°45’09.78”E
1.9	20°42’14.11”N - 106°44’27.82”E			3.9	20°42’33.55”N - 106°45’10.18”E

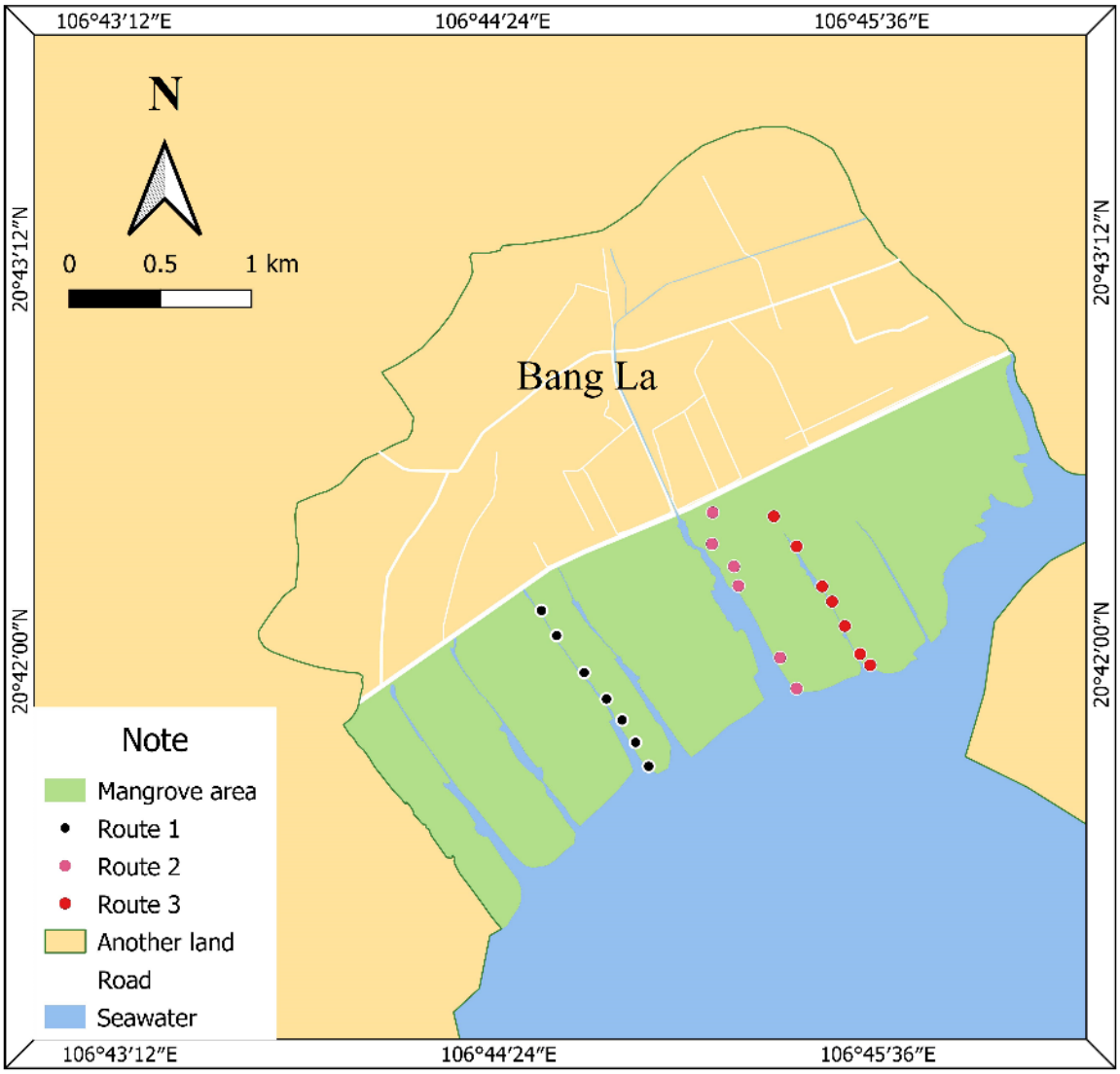

Figure 2. Locations of sampling sites

Species classification: Follows the general principles of plant classification. The classification documents were consulted according to the reports of Pham Hoang Ho [10–12], Phan Nguyen Hong [3], Vo Van Chi and Duong Duc Tien [13].

Determine the coverage: The coverage of the mangrove was determined using the pictures captured from the ground up to the canopy then estimated using ImageJ software.

Mangrove forest structure: The mangrove forest structure was estimated by the Importance Value Index (IVI) according to Curtis and McIntosh [14] with the formula determined as follows:

$$IVI_A = RF_A + RD_A + RBA_A$$

where: IVI_A: Important index of the species *A*; RF_A: Relative frequency of the species *A*; RD_A: Relative density of the species *A*; RBA_A: The relative basal area of species *A*.

Total *IVI* of a community = 300 %

The community structure formula was determined by the species which has $IVI \geq 5$ %

and the *IVI* of species is constant for that species in the community structure formula.

RESULTS

Diversity of species composition of Bang La mangrove forest

The 20 mangrove species were determined in the Bang La mangrove area, comprising 15 families and two phyla (Table 2). The phylum Polypodiophyta has only 1 species belonging to 1 family, and 1 class; Magnoliophyta is dominant with 14 families, 18 genera, and 19 species.

Among the 20 species of mangroves mentioned above, they are divided into 2 groups:

True mangrove species group consists of 8 species compared to 36 valid mangrove species in Vietnam, accounting for 22.22% of the total number of valid mangrove species nationwide and 40% of the total number of mangrove species in Bang La.

Associates mangrove species consist of 12 species compared to 7associatedes mangrove species in Vietnam, accounting for 17.14% of the total number of the associated species in mangroves nationwide and accounting for 60% of the total number of mangrove species in Bang La.

There are 20 species in the Bang La mangrove area so, which is a high diversity. According to Pham Nhat's standards for assessing and monitoring of mangroves [15], mangroves are high diversity when the forest has more than ten species. Although the Bang La mangrove forest is planted, the diversity is high which shows the diversity of mangrove plants participating and migrating into the mangrove forest area is relatively high.

Table 2. Species composition of the mangrove at the Bang La

Division	Order	Family	Species
Magnoliophyta	Lamiales	Acanthaceae	*Acanthus ilicifolius*
		Aviceniaceae	*Avicennia marina*
		Verbenaceae	*Clerodendrum inerme*
	Magnoliales	Annonaceae	*Annona glabra*
	Asterales	Asteraceae	*Pluchea pteropoda*
			Wedelia biflora
			Tridax procumbens
	Mytarles	Combretaceae	*Terminalia catappa*
		Sonneratiaceae	*Sonneoratia apetala*
			Sonneratia caseolaris
	Solanales	Convolvulaceae	*Ipomoea pes-caprae*
	Fabales	Fabaceae	*Derris trifoliata*
	Malvales	Malvaceae	*Hibiscus tiliaceus*
	Ericales	Myrsinaceae	*Aegiceras corniculatum*
	Poales	Cyperaceae	*Cyperus malaccensis*
		Poaceae	*Cynodon dactylon*
			Paspalum vaginatum
	Malpighiales	Rhizophoraceae	*Kandelia obovata*
			Rhizophora stylosa
Polypodiophyta	Polypodiales	Pteridaceae	*Acrostichum aureum*

Distribution characteristics

Considering the three ages, the morphological structure of the communities has apparent differences in the number of main stratifications and the number of species, and the density decreases gradually towards the sea. From the shore to the sea, the characteristics of the bottom structure and environmental conditions, such as wave energy and the tidal

inundation time, have changed significantly. Therefore, there is a difference between the communities according to different ages. Therefore, the authors divided this area into three forest communities with different ages of mangroves (Figure 3).

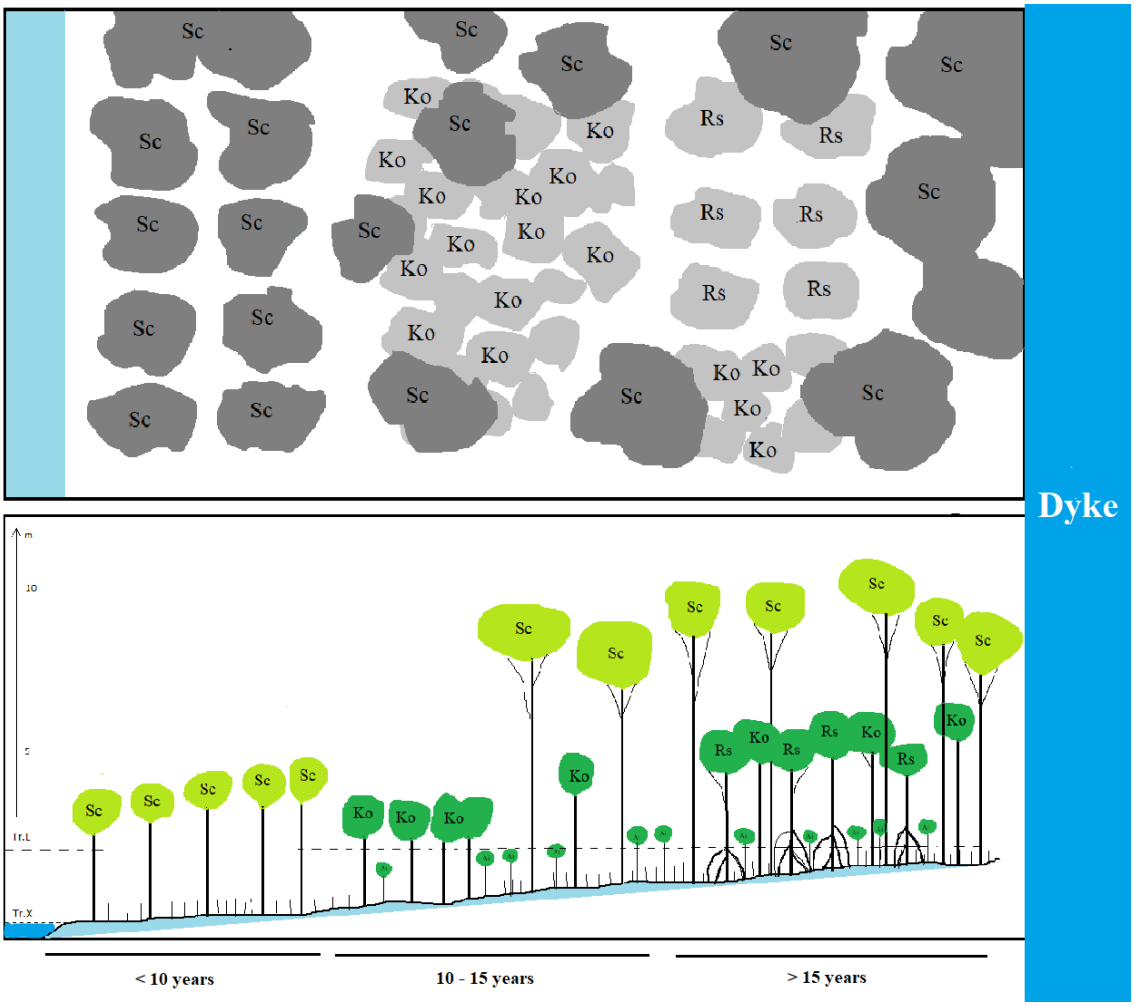

Figure 3. Horizontal (Figure A) and vertical (Figure B) maps of the mangrove forest in the study area (Tr.L: High tide, Tr.X: Low tide)

Mangrove tree community older than 15 years old

The mangrove older than 15 years was planted under program 327/CT in 1993, according to UNREDD, 2011 [16]. Currently, this biome is located adjacent to the dyke, with a width of about 400 m from the dyke bank towards the sea. *K. obovata* is the dominant species. In addition, there is also a random distribution of *S. caseolaris*, *R. stolysa*, and *A. corniculatum*, and the introduction of other mangrove plants such as *A. ilicifolius*, *A. aureum*, *C. inerme*,...

Through the survey in 7 standard plots, the species composition in this community is the most diverse compared to the species composition in other communities in the area, with 20 species of mangroves. *K. obovata* (11,100 individuals/ha) accounted for the highest percentage, interspersed with *R. stylosa* (1,700 individuals/ha), *S. caseolaris* (200 individuals/ha), under the foliage of woody plants are species such as *A. ilicifolius*,

A. aureum, *D. trifoliata*. At the points close to the dyke bank (20 m), *P. pteropoda* alternates with the *I. pes-caprae*. The canopy cover in this biome is about 72.21 %, with several plots with standards as high as 84% coverage. However, high canopy cover reduces the light intensity required for seedling regeneration and growth. Therefore, the regeneration density in this biome could be much higher or more present.

According to the research results in the biome, *K. obovata* is the dominant species in terms of composition (65%), *S. caseolaris* (26%), and other species account for a small percentage. The composition formula for forest biomes older than 15 years old is as follows: 64.93% *K. obovata* +26.25% *S. caseolaris* + 2.43% *A. ilicifolius* + 3.95% *R. stylosa* + 2.44% *A. corniculatum.*

In this area, mangrove plants are 2–4 m high, accounting for 92.33% of the trees. In this community, there is the most apparent stratification. Large trees like *S. caseolaris* are much taller (4–8 m), lower than small trees such as *R. stylosa*, *K. obovata* (2–4 m), followed by the shrub layer, which includes species such as *A. ilicifolius*, *A. corniculatum*, *A. aureum* and *P. pteropoda* (0, 5–1 m), the bottom is grass layer consisting of species belonging Poaceae such as *C. dactylon* (< 0.5 m).

According to Nguyen Hoang Tri (1999), succession has 4 stages, *K. obovata* dominates at the end of the 2nd out of four stages [5]. It can be assessed that the Bang La mangrove forest is in the second phase of the succession process because the *K. obovata* population occupies a relatively large density in the mangrove area (11,100 individuals/ha).

Mangrove tree community from 10–15 years old

The project "Replanting mangroves to reduce risks", planted the biome, which was carried out by the Hai Phong Red Cross from 1997 to 2008 [17]. This biome is located between the forest biome older than 15 years old and the forest biome less than 10 years old, with a width of about 300 m. Here, *S. caseolaris* and *K. obovata* alternately and alternately dominate and record the distribution of *A. corniculatum.*

The species composition has six species in a survey of 5 standard plots. The two dominant species are *S. caseolaris* (600 individuals/ha) and *K. obovata* (6,500 individuals/ha). The canopy cover in this biome is about 62%, along with its average tree density of about 4,800 individuals/ha, making it easier for light to pass through the foliage. Thereby creating favorable conditions for several species under the canopy of woody trees: *A. corniculatum*, *A. ilicifolius*, *A. marina*, and *A. aureum* develop.

In this biome, *K. obovata* and *S. caseolaris* accounted for 51.4% and 48.6% of the composition, respectively, while other species accounted for a small proportion. The composition formula for forest biomes 10–15 years old is 48.58% *S. caseolaris* + 51.42% *K. obovata*.

The mangrove biome here is divided into three layers the highest layer is *S. caseolaris*, with an average height of 7–11 m and a diameter of 10–20 cm; the next floor is *K. obovata*, with a height of 0.5–1.7 m, a diameter of 1–2 cm; and the bottom floor has the appearance of *A. ilicifolius* with a height of less than 1 m.

According to Phan Nguyen Hong and Hoang Thi San, *S. caseolaris* is considered a typical species in the pioneering period in the Northern estuary area [18]. According to the natural evolution of biomes that can predict the biomes that existed before and which will replace them in the future, humans have been able to shorten the dispersal time of pioneer species in the early stages and select specific species planted at different stages in succession. Therefore, planting *S. caseolaris* both opens a new succession process and helps close the previous succession process quickly.

Mangrove tree community less than 10 years old

The *S. caseolaris* biome was planted by the "Project for Restoration and Development of Coastal and Riverside Protection Forests 2015–2020", approved by the Hai Phong Department of Natural Resources and Environment [19].

This biome is located between the forest community of 10–15 years old and the seawater, with a width of about 400 m, so this is a place directly affected by waves, wind, and currents from the sea. Here, *S. caseolaris* is the absolute dominant species.

A survey in 8 standard plots, this forest community is mainly conifer with a density of 1,350 individuals/ha, an average height of 4–6 m, and a 4–20 cm diameter. The forest cover in this area is 61.5%; however, directly affected by sea waves and high flow rate, the tree seeds are quickly swept away. Therefore, the regeneration density here is very low.

Community structure formula

According to the research results, the plant species were present in many locations, predominating in the nests (*K. obovata* accounted for 47.2%, and *S. caseolaris* accounted for 46.9%). The general composition formula for the study area is 47.2Ko + 46.9Sc + 1.8Ks + 2.1Ai + 2.0Ac**.**

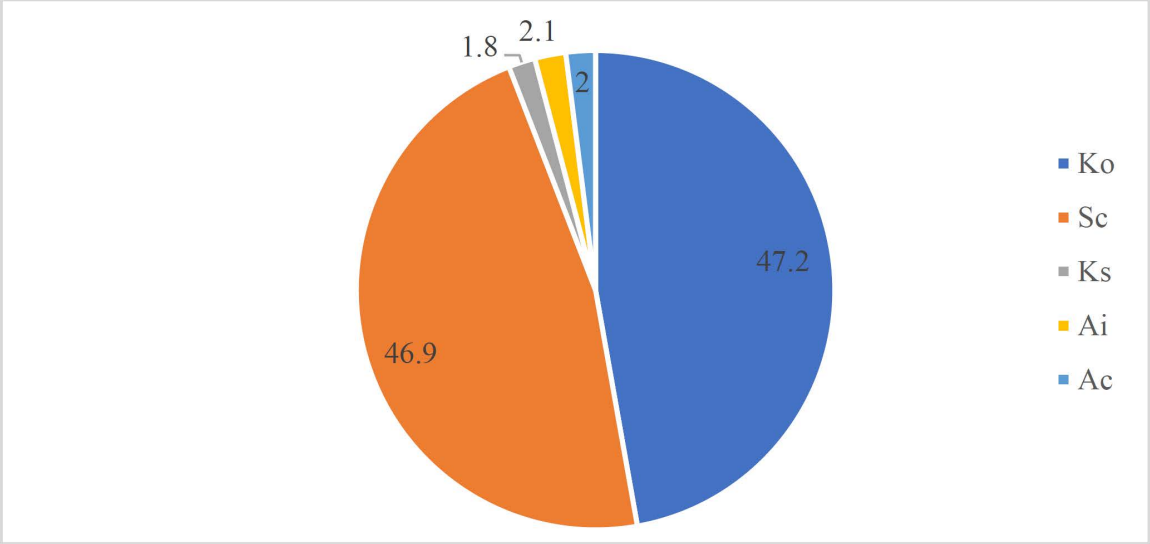

Figure 4. The dominant species of mangrove communities at Bang La

The structure of the mangrove forest at the study sites has changed according to the age of the community, which is shown in 3 types of structure as shown in Table 3.

Table 3. Composition structure by age of the mangrove at Bang La

Age	> 15 years old	10–15 years old	< 10 years old
Composition Formula	CF 1: 26.25Sc + 64.93Ko + 2.43Ai + 3.95Rs + 2.44Ac CF 2: 28.07Sc +65.14Ko + 3.39Ai + 3.4Ac	48.58Sc + 51.42Ko	100% S.c
Regeneration density (individuals/ha)	Few	150	12
Density (individuals/ha)	10.900	4.800	1.350
Number of species	20	6	2
Coverage (%)	72.21	60.10	60.38
Dominant species	*K. obovata*	*S. caseolaris, K. obovata*	*S. caseolaris*

Thus, the presence of *S. caseolaris* in all locations in the study area shows a high ability to adapt to environmental circumstances, serving as the basis for selecting species to carry out the reforestation process.

All regenerative tree species are already present in the composition of the upper tree stratum, but relatively invasive species have yet to appear. Dominating the regenerating tree nest is *K. obovata*, with a rate of over 85%. In comparison, that of *S. caseolaris* is 14.8%; the *K. obovata* can regenerate better than other species in the same site conditions. Density and regeneration density in the 10–15 years old forest community was the most stable, at 4,800 individuals/ha and 150 individuals/ha, respectively. So this helps the light to reach the plants on the lower floor, creating conditions for the seedlings to grow.

Canopy structure

From the tree height data, the Bang La mangrove forest community can be divided into three main layers (Figures 5 and 6):

Floor 1: The tree layer has a height of 6 m or more, mainly *S. caseolaris* 10 years old or more. There are trees up to 12 m high with a trunk diameter of up to 40 cm.

Floor 2: The tree layer is 2 to 6 m high and is the dominant tree layer of *K. obovata* and *R. stylosa* communities.

Floor 3: Canopy layer below 2 m, including regenerative trees of species of *S. caseolaris*, *K. obovata*, and some shrubs such as *A. ilicifolius*, *A. aureum*, and *A. corniculatum*. Although this tree layer is a little, it is crucial in creating the next layer of ecological succession and diversifying the species composition of the forest.

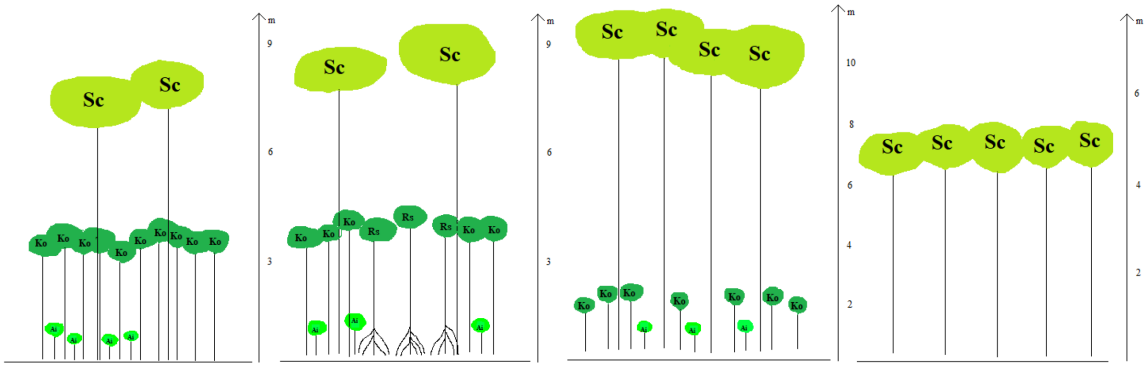

Figure 5. Vertical diagram reflecting the canopy structure of the mangrove at Bang La (a, b: Forests older than 15 years old; c: forests between 10 and 15 years old; d: forests less than 10 years old)

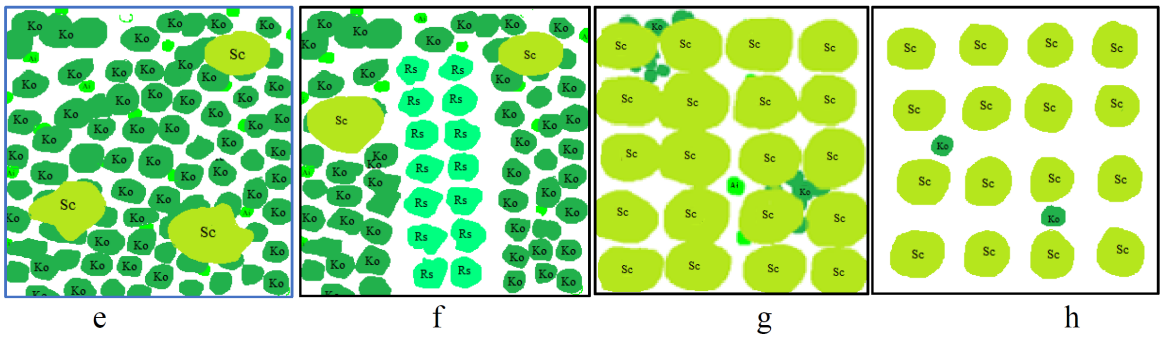

Figure 6. Horizontal histogram showing coverage of the mangrove at Bang La (e, f: Forests older than 15 years old; g: forests between 10 and 15 years old; h: forests less than 10 years old)

Density and coverage

The density of mangroves is unevenly distributed. The average density in the study plots is 5,885 individuals/ha, the highest is 27,200 individuals/ha, and the lowest is 700 individuals/ha. The density difference depends on many factors, in which the tree's age dramatically influences on the density of mangroves. In general, the density of forest trees is highest at age 15 and decreases with age, the lowest in forest communities under ten years old. However, the tree density was very high in the study plots with the presence of *Kandelia obovata*.

Coverage at locations in the area has a significant difference; the most extensive coverage is in the forest community over 15 years old (average 72.21%), from 10 to 15 years old and under 10 years old have average coverage of 60.1% and 60.38%, respectively. The average canopy cover of the study plots is 64.45%.

Table 4. Density and cover of the mangrove at Bang La

Age	Plot	Number of individuals/plot (10m×10m)	Number of individuals/ha	Coverage (%)	Average coverage (%)
< 10 years old	1.1	7	700	39.15	60.38
	1.2	8	800	47.64	
	1.3	9	900	47.38	
	2.1	32	3200	68.36	
	2.2	11	1100	78.12	
	3.1	13	1300	64.59	
	3.2	11	1100	71.16	
	3.3	16	1600	66.67	
10 - 15 years old	1.4	141	14100	47.94	60.10
	1.5	39	3900	50.89	
	2.3	9	900	52.57	
	3.4	18	1800	69.04	
	3.5	83	8300	80.07	
> 15 years old	1.6	113	11300	79.99	72.21
	1.7	30	3000	49.56	
	2.4	9	900	81.45	
	2.5	17	1700	72.31	
	2.6	88	8800	58.82	
	3.6	272	27200	84.32	
	3.7	251	25100	79.05	

CONCLUSIONS

Bang La mangrove forest has an area of 370 ha divided into three forest biomes of different ages: younger than ten years old, from 10 to 15 years old, and older than 15 years old. The species composition includes 20 species belonging to 15 plant families, of which there are eight official mangrove species and 12 participating mangrove plant species. Species such as *S. caseolaris*, *K. obovata*, and *R. stylosa* are structurally dominant. The general composition formula for the study area is 47.2Ko + 46.9Sc + 1.8Ks + 2.1Ai + 2.0Ac.

The dominant species was different in the area: *S. caseolaris* dominant in the forest community under ten years old, *S. caseolaris* interspersed with *K. obovata* was dominant in the mangrove community from 10 to 15 years old, and *K. obovata* was dominant in the mangrove biomes older than 15 years old.

Some shrubs and associated mangrove species were recorded in the forest biomes from 10 years old, which showed that the mangrove community more than ten years old is stable. That means that from 10 years old, mangroves should be planned with different species to increase the diversity in species structure to

enhance the ability to stabilize the community and withstand changes in coastal habitats.

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