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Species diversity and distribution of the macro algae from Bach Long Vi Island, Vietnam

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ABSTRACT

Research results on seaweed at four cross-sections of Bach Long Vi Island from 1994 onwards have shown that 129 species of macroalgae belong to 4 phyla. Among them, Cyanobacteria has ten species, accounting for 7.75% of the total number of species; Red seaweed (Rhodophyta) has 70 species (54.26%); Brown seaweed (Ochrophyta/Phaeophyta) has 27 species (20.93%), and Green seaweed (Chlorophyta) has 22 species (17.06%). They belong to 21 orders, 42 families, and 72 seaweed genera. The number of species in the studied transects ranges from 41 species (transect 4) to 99 species (transect 2) and averages 72.25 species/transect. The similarity coefficient of seaweed species at four surveyed transects ranged from 0.26 (between transects 1 and 4) to 0.74 (between transects 2 and 3) and averaged 0.48. Of the 129 known species, there were 44 species only distributed in the intertidal zone, accounting for 34.10% of the total number of species; 108 species are only distributed in the subtidal zone (83.72%) and 26 species are distributed in both intertidal and subtidal zones (20.15%); most species distributed from the low intertidal zone downward and are concentrated mainly in the low intertidal zone and the upper range of the subtidal zone. In terms of structure, the number of taxa ranges from 2 (Cyanophyta) to 12 (Rhodophyta). On average, 5.25 orders/phylum; of families from 4 (Cyanophyta, Ochrophyta) to 25 (Rhodophyta) and 10.5 families/order; of genera from 6 (Cyanophyta) to 42 (Rhodophyta) and 18; of species from 10 (Cyanophyta) to 70 (Rhodophyta) and 32.25. The average number of species/genera is quite large (32.25). However, some genera have only one species (Hydrocoryne, Asparagopsis, Parvocaulis, etc.), and some other genera have a more significant number of species (Dictyota: 10 species; Hypnea: 8 species; Peyssonnelia: 5 species, etc.). Among the families, some have only one genus (Peyssonneliaceae, Scytosiphonaceae, Codiaceae, etc.), but others have more genera (Dictyotaceae: 5, Boodleaceae: 4, Sargassaceae: 2, etc.). The total number of orders of the four phyla (Cyanophyta, Rhodophyta, Ochrophyta, and Chlorophyta) is 21. Of which, Cyanophyta has 2 orders, accounting for 9.5% of the total number of recorded orders: Rhodophyta (12 and 57.1%), Ochrophyta (4 and 19%), and Chlorophyta (3 and 14.4%).

Keywords: Species diversity, distribution, macroalgae, Bach Long Vi Island.

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INTRODUCTION

Seaweed is a group of lower plants living in the sea, and it is an important component of marine resources. Seaweed is used as a raw material to process highly value products, such as Agar, Alginate, Carrageenan, biological compounds (amino acids, growth hormones, etc.), widely used in food, pharmaceuticals, cosmetics industries, etc. In our country today, 826 species of seaweed have been discovered [1], many of which are being exploited and used, such as Gracilaria, Hypnea, Sargassum, Laurencia, and Eucheuma, Kappaphycus [2, 3], etc. are currently being targeted for widely cultivated to serve domestic and export needs.

Bach Long Vi Island is a district in Hai Phong City, Vietnam. The scope of the conservation area is the mainland on the island and along the coast, with the outer boundary determined by the line connecting the convex points of the 30 m isobath. Geographic coordinates are determined with longitude 107°42'20" to 107°44'15" and latitude 20°07'35" to 20°08'36". The total area of the conservation area is 27,008.93 hectares, divided into three functional zones, including strict protection zone, ecological restoration zone, and development zone, ensuring sustainable socio-economic development, reasonable use of marine natural resources, serving the purposes of scientific research, education, entertainment, and tourism.

Research on biodiversity and natural resources in Bach Long Vi Island waters has long been of interest to many scientists. The research subjects are very diverse; most of them have covered the main resource groups in this area such as corals, coral reef fish, mollusks, crustaceans, echinoderms, mangrove plants, plankton, etc. in which the seaweed group is also of interest. The first published research works on biodiversity and seaweed resources in this area were Dam Duc Tien (1997) [4], Tran Duc Thanh and colleagues (2013) [5], Do Anh Duy and Do Van Khuong (2013) [6], Do Anh Duy and Do Van Khuong (2020) [7], Bui Duc Quang and Ha Quy Quynh (2013) [8].

MATERIALS AND METHODS

Materials

Materials used for this research were collected from several projects implemented of Bach Long Vi Island from 1994 to 2023, at four transects in Bach Long Vi National Marine Protected Area.

The article is built based on the survey results at 4 transects; the first point is the coordinates and pulled perpendicular to the edge of the island to a depth of 18 m compared to 0 m of the nautical chart. Each transect has points on the intertidal (high, mid, and low tide) and subtidal zones (upper range 10 m deep and lower range). At each point, three qualitative samples were collected).

Locations of the macro algae survey transects in Bach Long Vi Island are shown in Table 1 and Figure 1.

Table 1. Coordinates of survey transects at Bach Long Vi Island

No.	Transects	Coordinates
1	1	20°7'42.49"N - 107°43'12.40"E
2	2	20°7'49.08"N - 107°43'59.96"E
3	3	20°8'29.84"N - 107°44'19.81"E
4	4	20°8'19.57"N - 107°43'49.14"E

In addition, we refer to the report: "Seaweed resources of Bach Long Vi Island by Dam Duc Tien, under the task of supporting the Senior Researcher of Vietnam Academy of Science and Technology", code: NCVCC23.03/22–23.

Sampling

Sample collecting follows the Provisional Regulations for Field Survey issued by the State Committee for Science and Technology (Vietnam) in 1981 applied for tidal zones [9], and standard methods by English et al., (1997) [10] for the subtidal zone with SCUBA equipment and water level and tidal data were derived from the tidal regime measured at Hon Dau (1994–2024) [11], underwater digital cameras (Sea & Sea, NIKONOS V of Japan, and PENTAX WG 5 from Indonesia and Olympus

TG5, Vietnam with housing). At each survey transect, four North, South, East, and West surveying main transects and some additional transects between the main transects were set up in perpendicular shoreline and stretched out to the depth without seaweeds (generally at 18 m deep). The depths of sampling sites were figured out using SCUBA depth gauges.

The fresh macroalgal samples were soaked in a solution of formaldehyde 5%, then put on Croki paper, compressed into blotting papers, dried naturally, and analyzed [12].

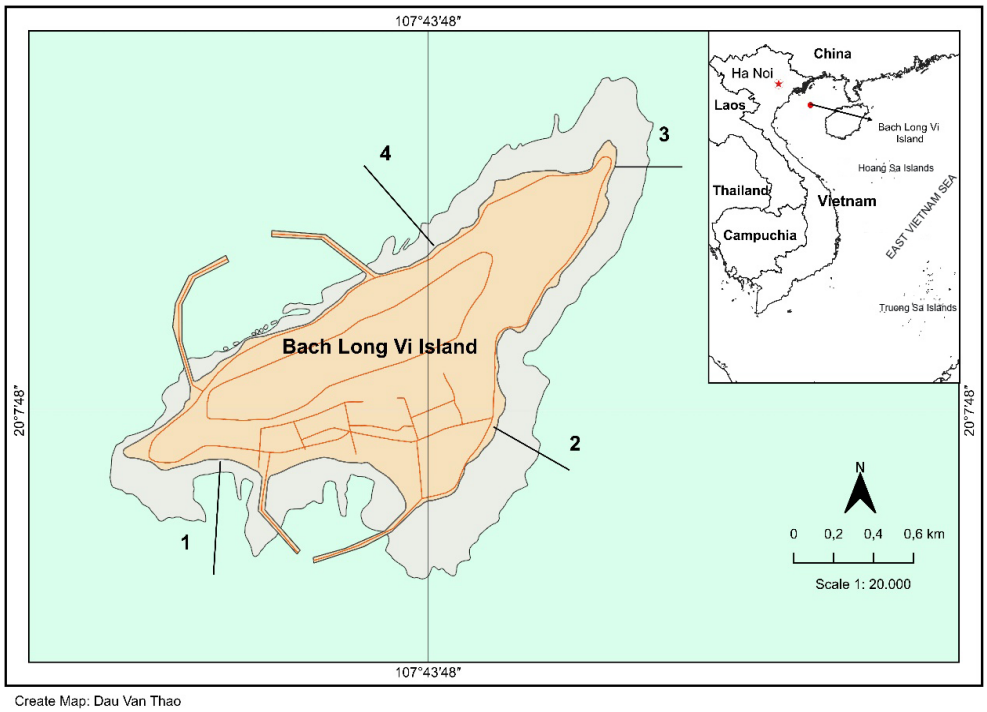

Figure 1. Locations of Macro algae survey transects in Bach Long Vi Island

Species identification

The macroalgae specimens were analyzed at the Marine Botanical Ecology and Resources Department, Institute of Marine Environment and Resources (Vietnam Academy of Science and Technology).

Specimens were classified based on criteria relating to the morphology and anatomy of specimens under a LEICA microscope. The scientific names used follow national and international authors [13–19].

Distribution study

Geographical distribution

The geographical distribution of marine macroalgae, referred to as its geographical distribution, is indicated by a similarity index (Sorensen Similarity Index) that is calculated according to the formula $S = 2C/(A + B)$, *where* A and B are the numbers of species in sampling transect A and B, respectively, and C is the number of species shared by the two sampling transects (A and B). In the range from 0 (zero) to 1 (one), when the coefficient (S) value approaches to one (1), these sampling sites show a strong similarity. When the coefficient value reaches zero (0), these sampling transects are less similar [20].

Vertical distribution

Determining the vertical distribution of marine macroalgae is based on the principle of the partitioning (zonation) of the tidal zone as used by Feldmann (1937) [21]. Under this

scheme, the coastal zone is arbitrarily partitioned into many different areas dependent on tidal levels such as high tide, mid-tide and low tide. Water level and tidal data were derived from the tidal regime measured at Hon Dau.

The spatial distribution data were processed using Excel to obtain the final values.

Based on the documents of Nguyen Van Tu and colleagues (2013) [22], some additional information was searched.

RESULTS AND DISCUSSION

Species composition

Based on the analysis results from marine macroalgae surveyed samples in Bach Long Vi Island and references, we have recorded 129 species of seaweed belonging to 4 phyla. Cyanobacteria has 10 species, accounting for 7.75% of the total number of species; red seaweed (Rhodophyta) has 70 species (54.26%); brown seaweed (Ochrophyta/Phaeophyta) has 27 species (20.93%) and green seaweed (Chlorophyta) has 22 species (17.06%) (Table 2).

Taxon structure

The research results in Table 2 show that overall structure, the phyla's order taxa range from 2 (Cyanophyta) to 12 (Rhodophyta) and averages 5.25 orders/phylum. Similarly, the number of family taxa from 04 (Cyanophyta, Ochrophyta) to 25 (Rhodophyta) and 10.5 family/order. The number of genus taxa, from 06 (Cyanophyta) to 42 (Rhodophyta) and 18.0 genus/family. The number of species taxa from 10 (Cyanophyta) to 70 (Rhodophyta) and 32.25 species/genus.

Table 2. Species composition and distribution of macro algae in Bach Long Vi Island

No.	The name of the taxa	Geographical distribution				Vertical distribution	
		1	2	3	4	TZ	STZ
	Cyanophyta						
	Nostocales						
	Nostocaceae						
1	*Hydrocoryne enteromorphoides* (Grunow ex Bornet & Flahault) Umezaki & M. Watanabe	+	+			+	
	Rivulariaceae						
2	*Calothrix contarenii* Bornet & Flahault		+	+	+	+	
	Oscillatoriales						
	Microcoleaceae						
3	*Microcoleus lyngbyaceus* Kützing ex Forti	+			+	+	
	Oscillatoriaceae						
4	*Lyngbya majuscula* Harvey ex Gomont		+	+		+	
5	*Lyngbya sordida* Gomont, 1892			+		+	
6	*Oscillatoria bonnemaisonii* P. Crouan & H. Crouan ex Gomont	+			+	+	
7	*Oscillatoria corallinae* Gomont ex Gomont			+		+	
8	*Oscillatoria margaritifera* Kützing ex Gomont			+		+	
9	*Oscillatoria miniata* (Zanard.) Hauck	+	+			+	
10	*Phormidium corium* Gomont ex Gomont			+		+	
	Rhodophyta						
	Bonnemaisoniales						
	Bonnemaisoniaceae						
11	*Asparagopsis taxiformis* (Delile) Trevisan	+	+	+	+		+
	Ceramiales						

No.	The name of the taxa	Geographical distribution				Vertical distribution	
		1	2	3	4	TZ	STZ
	Ceramiaceae						
12	*Centroceras clavulatum* (C. Ag.) Montagne	+	+				+
13	*Ceramium deslongchampsii* Chauvin ex Duby	+	+		+	+	+
14	*Ceramium diaphanum* (Lightfoot) Roth			+			+
	Delesseriaceae						
15	*Hypoglossum barbatum* Okamura			+	+		+
	Rhodomelaceae						
16	*Acanthophora muscoides* (Linnaeus) Bory	+		+		+	+
17	*Bostrychia moritziana* (Sonder ex Kützing) J. Agardh		+	+		+	+
18	*Bostrychia radicans* (Montagne) Montagne			+		+	+
19	*Herposiphonia tenella* (C. Agardh) Ambronn		+		+		+
20	*Laurencia nangii* Masuda		+	+		+	+
21	*Laurencia natalensis* Kylin	+	+				+
22	*Laurencia obtusa* (Hudson) Lamouroux,			+			+
23	*Leveiliea jungermannioides* (Mart, et Hering) Harvey	+	+	+	+		+
24	*Polysiphonia fragilis* Suringa		+				+
25	*Polysiphonia subtilissima* Montagne			+	+		+
26	*Eutrichosiphonia tapinocarpa* (Suringar) Bustamante & Cho	+	+			+	+
27	*Tolypiocladia calodictyon* (Harvey ex Kützing) P. C. Silva		+				+
28	*Tolypiocladia glomerulata* (C. Agardh) F. Schmitz		+	+			+
	Spyridiaceae						
29	*Spyridia filamentosa* (Wulfen) Harvey		+	+		+	+
	Wrangeliaceae						
30	*Wrangelia argus* (Montagne) Montagne	+		+		+	+
	Corallinales						
	Hydrolithaceae						
31	*Harveylithon samoënse* (Foslie) A. Rösler, Perfectti, V. Peña & J. C. Braga	+					+
32	*Hydrolithon boergesenii* (Foslie) Foslie		+	+			+
	Họ Lithophyllaceae						
33	*Amphiroa fragilissima* (Linnaeus) J. V. Lamouroux		+	+		+	+
	Lithothamniaceae						
34	*Melyvonnea erubescens* (Foslie) Athanasiadis & D. L. Ballantine	+				+	+
	Gelidiales						
	Gelidiaceae						
35	*Gelidium pusillum* (Stackhouse) Le Jolis	+	+	+	+	+	
	Gelidiellaceae						
36	*Gelidiella acerosa* (Forsskål) Feldmann & Hamel	+	+	+	+	+	
37	*Parviphycus trinitatensis* (W. R. Taylor) M. J. Wynne	+	+	+	+	+	
	Pterocladiaceae						
38	*Pterocladia parva* E. Y. Dawson		+	+	+	+	
39	*Pterocladiella caerulescens* (Kützing) Santelices & Hommersand		+			+	
40	*Pterocladiella capillacea* (S. G. Gmelin) Santelices & Hommersand	+		+		+	+
	Gigartinales						
	Caulacanthaceae						

No.	The name of the taxa	Geographical distribution				Vertical distribution	
		1	2	3	4	TZ	STZ
41	*Caulacanthus ustulatus* (Mertens ex Turner) Kützing		+			+	
	Cystocloniaceae						
42	*Hypnea charoides* J. V. Lamouroux	+	+	+			+
43	*Hypnea cornuta* (Lamx.) J. Agardh	+	+	+			+
44	*Hypnea esperi* Bory	+	+	+			+
45	*Hypnea hamulosa* (Esper) Lamouroux	+	+	+			+
46	*Hypnea nidulans* Setchell		+				+
47	*Hypnea pannosa* J. Agardh	+	+				+
48	*Hypnea spinella* (C. Agardh) Kützing		+	+		+	+
49	*Hypnea valentiae* (Turner) Montagne	+			+	+	+
	Gigartinaceae						
50	*Chondracanthus intermedius* (Suringar) Hommersand		+			+	+
	Solieriaceae						
51	*Wurdemannia miniata* (Sprengel) Feldmann & Hamel	+	+			+	+
	Gracilariales						
	Gracilariaceae						
52	*Gracilaria gracilis* (Stackhouse) Steentoft, L. M. Irvine & Farnham	+	+			+	+
53	*Gracilaria blodgettii* Harvey,	+	+				+
54	*Gracilaria vermiculophylla* (Ohmi) Papenfuss	+	+	+			+
55	*Hydropuntia edulis* (Gmelin) Gurgel & Fredericq		+	+	+		+
	Halymeniales						
	Halymeniaceae						
56	*Halymenia dilatata* Zanardini		+	+			+
57	*Halymenia maculata* J. Agardh		+	+			+
	Hildenbrandiales						
	Hildenbrandiaceae						
58	*Hildenbrandia rubra* (Sommerfelt) Meneghini	+					+
	Nemaliales						
	Galaxauraceae						
59	*Actinotrichia fragilis* (Forsskål) Børgesen	+	+	+	+	+	+
60	*Dichotomaria obtusata* (J. Ellis & Solander) Lamarck	+	+				+
61	*Dichotomaria marginata* (Ellins & Solander) Lamouroux		+	+	+		+
62	*Galaxaura rugosa* (J. Ellis & Solander) J. V. Lamouroux		+	+	+		+
63	*Tricleocarpa cylindrica* (J. Ellis & Solander) Huisman & Borowitzka		+	+	+		+
64	*Tricleocarpa fragilis* (Linnaeus) Huisman & R. A.Townsend		+	+	+		+
	Liagoraceae						
65	*Ganonema farinosum* (J. V. Lamouroux) K. C. Fan & Yung C. Wang	+	+	+			+
66	*Liagora ceranoides* J. V. Lamouroux, 1816		+	+			+
67	*Liagora divaricate* Tseng	+	+	+			+
68	*Neoizziella divaricata* (C. K. Tseng) S. M. Lin, S. Y. Yang & Huisman	+	+	+			+
69	*Trichogloea requienii* (Montagne) Kützing		+	+			+
	Nemastomatales						
	Schizymeniaceae						
70	*Titanophora weberae* Børgesen,		+	+			+
	Peyssonneliales						

No.	The name of the taxa	Geographical distribution				Vertical distribution	
		1	2	3	4	TZ	STZ
	Peyssonneliaceae						
71	*Peyssonnelia boergesenii* Weber Bosse		+	+	+		+
72	*Peyssonnelia calcea* Heydr		+	+	+		+
73	*Peyssonnelia conchicola* Piccone & Grunow	+	+	+			+
74	*Peyssonnelia inamoena* Pilger		+	+			+
75	*Peyssonnelia rubra* (Grev.) J. Agardh	+	+				+
	Rhodymeniales						
	Champiaceae						
76	*Champia parvula* (C. Agardh) Harvey		+	+			+
	Lomentariaceae						
77	*Ceratodictyon repens* (Kützing) R. E. Norris		+	+			+
78	*Ceratodictyon spongiosum* Zanardini			+	+		+
79	*Ceratodictyon variabile* (J. Agardh) R. E. Norris		+	+			+
80	*Gelidiopsis intricata* (C. Ag.) Vickers	+				+	
	Ochrophyta (Phaeophyta)						
	Dictyotales						
	Dictyotaceae						
81	*Canistrocarpus cervicornis* (Kützing) De Paula & De Clerck			+	+		+
82	*Dictyota adnata* Zanardini		+	+			+
83	*Dictyota bartayresiana* J. V. Lamouroux	+	+	+			+
84	*Dictyota ceylanica* Kützing			+	+		+
85	*Dictyota ciliolata* Sonder ex Kützing	+	+	+			+
86	*Dictyota dichotoma* (Hudson) J. V. Lamouroux		+	+			+
87	*Dictyota friabilis* Setchell		+	+			+
88	*Dictyota implexa* (Desfontaines) J. V. Lamouroux		+	+	+		+
89	*Dictyota mertensii* (C. Martius) Kützing		+				+
90	*Dictyota pinnatifida* Kützing	+	+	+			+
91	*Dictyota spinulosa* J. D. Hooker & Arnott				+		+
92	*Distromium decumbens* (Okamura) Levring				+		+
93	*Lobophora variegata* (J. V. Lamouroux) Womersley ex E. C. Oliveira	+	+	+	+		+
94	*Lobophora tsengii* D. Tien et Z. Sun	+	+	+			+
95	*Lobophora rosacea* C.W.Vieira, Payri & De Clerck	+	+	+	+		+
96	*Padina australis* Hauck	+	+				+
97	*Padina boryana* Thivy	+	+	+			+
98	*Padina gymnospora* (Kützing) Sonder		+	+	+		+
99	*Padina japonica* Yamada		+	+			+
100	*Padina minor* Yamada	+	+				+
101	*Padina antillarum* (Kuetzing) Piccone (= *Padina tetrastromatica* Hauck)		+	+	+		
	Ectocarpales						
	Scytosiphonaceae						
102	*Colpomenia sinuosa* (Mertens ex Roth) Derbès & Solier	+	+	+		+	+
	Fucales						
	Sargassaceae						

No.	The name of the taxa	Geographical distribution				Vertical distribution	
		1	2	3	4	TZ	STZ
103	*Sargassum serratum* Nguyen Huu Dai	+	+	+			+
104	*Sargassum polyporum* Mont.	+	+	+			+
105	*Turbinaria ornata* (Turner) J. Agardh, 1848		+	+			+
106	*Turbinaria decurrens* Bory		+	+			+
	Ralfsiales						
	Ralfsiaceae						
107	*Ralfsia verrucosa* (Areschoug) Areschoug	+	+	+	+	+	
	Chlorophyta						
	Bryopsidales						
	Bryopsidaceae						
108	*Bryopsis hypnoides* J. V. Lamouroux		+	+			+
109	*Bryopsis pennata* J. V. Lamouroux		+	+	+		+
	Caulerpaceae						
110	*Caulerpa chemnitzia* (Esper) J. V. Lamouroux	+	+				+
111	*Caulerpa cupressoides* (Vahl) C. Agardh		+	+	+		+
112	*Caulerpa fastigiata* Montagne		+	+	+		+
113	*Caulerpa racemosa* (Forsskål) J. Agardh	+	+			+	+
	Codiaceae						
114	*Codium arabicum* Kützing			+		+	+
115	*Codium geppiorum* O. C. Schmidt			+		+	+
116	*Codium tenue* (Kützing) Kützing			+		+	+
117	*Codium tomentosum* Stackhouse		+	+		+	+
	Cladophorales						
	Boodleaceae						
118	*Boodlea coacta* (Dickie) G. Murray & De Toni	+	+			+	+
119	*Boodlea composita* (Harvey) F. Brand		+	+		+	+
120	*Cladophoropsis fasciculata* (Kjellman) Wille		+	+	+	+	+
121	*Phyllodictyon anastomosans* (Harvey) Kraft & M. J. Wynne		+	+	+		
	Cladophoraceae						
122	*Lychaete herpestica* (Montagne) M. J. Wynne	+	+				
	Siphonocladaceae						
123	*Boergesenia forbesii* (Harvey) Feldmann		+	+			+
124	*Dictyosphaeria spinifera* C. K. Tseng & C. F. Chang			+	+		+
	Valoniaceae						
125	*Valonia aegagropila* C. Agardh			+	+		+
126	*Valonia macrophysa* Kützing		+	+	+		+
127	*Valoniopsis pachynema* (G.Martens) Børgesen	+	+				+
	Dasycladales						
	Dasycladaceae						
128	*Neomeris annulata* Dickie			+			+
	Polyphysaceae						
129	*Parvocaulis parvulus* (Solms-Laubach) S. Berger, Fettweiss, Gleissberg, Liddle, U. Richter, Sawitzky & Zuccarello	+	+				+
Total: 129 species		56	99	92	41	44	108

Notes: The serial numbers from 1 to 4 are the survey transect numbers; TZ: tidal zone; STZ: subtidal zone.

Although the average number of species/genera is quite large (32.25), some genera have only one species (*Hydrocoryne, Asparagopsis, Parvocaulis*, etc.) and some others have a larger number of species (*Dictyota*: 10 species, *Hypnea*: 8 species; *Peyssonnelia*: 5 species, etc.). Among families, several families consist of only one genus (Peyssonneliaceae, Scytosiphonaceae, Codiaceae, etc.), but others have more ones (Dictyotaceae: 5, Boodleaceae: 4, Sargassaceae: 2…).

The total number of orders of the 4 phyla (Cyanophyta, Rhodophyta, Ochrophyta and Chlorophyta) is 21. Among them, Cyanophyta has 02 orders, accounting for 9.5% of the total number of recorded orders, Rhodophyta (12 and 57.1%); Ochrophyta (04 and 19.0%), and Chlorophyta (03 and 14.4%) (Table 3).

Table 3. The taxon structure of macro alagae in Bach Long Vi Island

Phyllum	Order		Family		Genus		Species	
	Quan-tity	Ratio (%)	Quan-tity	Ratio (%)	Quan-tity	Ratio (%)	Quan-tity	Ratio (%)
Cyanophyta	2	9.5	4	9.5	06	8.3	10	7.7
Rhodophyta	12	57.1	25	59.5	44	61.1	70	54.3
Ochrophyta	4	19	4	9.5	9	12.5	27	20.9
Chlorophyta	3	14.4	9	21.5	13	18.1	22	17.1
Total	21	100	42	100	72	100	129	100

The results in Table 2 also show that the largest number of families (5 families) belongs to the order Ceramiales; The highest number of genera (8) belongs to the family Rhodomelaceae; The largest number of species (10) belongs to the genus Dictyota. Some orders have only one family (Bonnemaisoniales, Gracilariales, and Halymeniales, etc. - belong to the Rhodophyta; Dictyotales, Ectocarpales, Fucales, etc. belong to the Ochrophyta). Some families have only one genus (Nostocaceae, Rivulariaceae, Microcoleaceae belong to Cyanophyta; Bonnemaisoniaceae, Delesseriaceae, Spyridiaceae, etc. belong to Rhodophyta and Scytosiphonaceae, Ralfsiaceae belong to Ochrophyta. Some genera have only one species (Hydrocoryne, Calothrix, Microcoleus belong to Cyanophyta; Spyridia, Wrangelia, Melyvonnea, etc. belong to Rhodophyta; Colpomenia, Ralfsia belong to Ochrophyta; Cladophoropsis, Phyllodictyon, Boergesenia, etc. belong to Chlorophyta.

Geographical distribution

The species number of macroalgae at four stations ranged from 41 sp. (transect 4) to 99 (transect 2) and averaged 72 species/transect (Table 2). The number of species in transect number 4 is the lowest is because the tidal area is narrow here; the sub-tidal part is mainly sand, which is unfavorable for seaweed growth. Most species (99) is at transect number 2 because the tidal area is enormous here. Under the tide, the bottom is hard, so it is very favorable for seaweed to grow.

The Sorensen Similarity Index (SSI) of marine macroalgae at 4 different transects ranged from 0.26 (between transects 1 and 4) to 0.74 (between transects 2 and 3), averaging 0.48 (Table 4). The differences in physical conditions and bottom structure of the different transects can explain this.

Table 4. Matrix of Sorensen Similarity Index values at surveyed transects

Transects	1	2	3	4
4	0.26	0.41	0.51	
3	0.39	0.74		
2	0.58			
1				

Vertical distribution

In Bach Long Vi Island, two substrate types related to macroalgae vertical distribution. They are rocky intertidal areas (mostly dead and original rock) and soft-bottom intertidal

areas (mainly coarse sandy bottom with other foreign objects such as shells and empty cans). The soft substrate type with less macro algae is distributed mainly in subtidal areas of transect number 4. As such, macro algae vertical distribution is mainly surveyed and studied in the rocky intertidal and subtidal transects.

Based on tidal level data (from 1994 to 2023) at Hon Dau, among 129 species recorded in Bach Long Vi, 44 species (accounting for 34.10% of total species) were found only in the intertidal zone, 108 species (83.72%) in subtidal zone, and 26 species (20.15%) recorded in both intertidal and subtidal zones.

On sea hard bottoms, macroalgae composition is abundant and common with most species discovered in the study transects (Table 5).

Table 5. Distribution of macro alagae in transects of rocky Bach Long Vi Island
[*Source:* Hon Dau regime, from 1994 to 2023]

On the tide		There is no seaweed The average value of the tropical spring tide 1.3 m
Tidal area	High tide belt	*Hydrocoryne enteromorphoides, Lyngbya majuscula, Ceramium deslongchampsii…* The average value of the equator spring tide 1.0 m
	Middle tide belt	*Lyngbya majuscula, Centroceras clavulatum, Acanthophora muscoides…* The average value of the equator neap tide 0.7 m
	Low tide belt	*Gelidiella acerosa, Gelidium pusillum Colpomenia sinuosa…* The average value of the tropical neap tide 0 m
Subtidal tide area	High belt	*Hypnea pannosa, Chondracanthus intermedius, Ceratodictyon spongiosum…* -10 m
	Low belt	*Galaxaura rugosa*, *Peyssonnelia calcea, Peyssonnelia rubra*

The transects of Bach Long Vi Island are often small, narrow in intertidal areas, and structured with tidal sandy substrates, which are unfavorable for seaweed growth. Meanwhile, large subtidal areas (especially in shallows or submerged islands) with hard bottoms and clear water are good conditions for seaweed growing. That is why Chlorophytes grow mainly in subtidal areas of Bach Long Vi Island.

The results in Table 5 show that in the intertidal zone, the high tidal range often encounters *Hydrocoryne enteromorphoides*, *Lyngbya majuscula*, *Ceramium deslongchampsii*...; middle tidal range: *Lyngbya majuscula*, *Centroceras clavulatum*, *Acanthophora muscoides*...; low tide range: *Gelidiella acerosa*, *Gelidium pusillum*, *Colpomenia sinuosa*...; In the subtidal zone, the upper band is commonly found: *Hypnea pannosa*, *Chondracanthus intermedius*, *Ceratodictyon spongiosum*... and the lower band is *Galaxaura rugosa*, *Peyssonnelia calcea*, *Peyssonnelia rubra*...

The algal flora

Results from Table 2 show that on Bach Long Vi Island, 69 species of Red seaweed, 28 species of Brown seaweed, and 22 species of Green seaweed were discovered. According to Cheney, the ratio of the total number of Red and Green algae/Brown algae species is (69 + 28)/22 = 4.40. This ratio is between 3 and 6, so that the Bach Long Vi seaweed system is characterized by a mixed system.

DISCUSSION

Bach Long Vi is a small island. The surveyed transects are not so far apart but the number of species macroalgae is quite different (44 species in transect 4 and 99 species in transect 2). The main reason is the bottom structure. In section 4, the tidal zone is very narrow, with the bottom being bedrock and the subtidal area is steep. The bottom surface is mainly sand, so it is not

favorable for the existence and development of seaweed.

In section 2, the tidal and subtidal zones are flat and very wide, and the bottom structure is mainly bedrock, which is very convenient for the existence and development of seaweed.

The island's area is 1.78 km^2 (at the highest tide) and 3.05 (at the lowest tide). The flooded area is about 1.27 km^2, most of which is covered with seaweed.

In particular, most of the intertidal and subtidal zones of Bach Long Vi have a flat bedrock bottom that extends very widely in many directions. Under such conditions, many other macroalgae species may need to be investigated more thoroughly. At that time, this study will be some additional results.

CONCLUSION

At four Bach Long Vi Island transects, we have recorded 129 species of seaweed belonging to 4 phyla. Among them, Cyanobacteria has 10 species, accounting for 7.75% of the total number of species; red seaweed (Rhodophyta) has 70 species (54.26%); Brown seaweed (Ochrophyta/Phaeophyta) has 27 species (20.93%) and Green seaweed (Chlorophyta) has 22 species (17.06%). The Sorensen Similarity Index (SSI) of marine macroalgae at 4 different transects ranged from 0.26 (between transect 1 and 4) to 0.74 (between transect 2 and 3), averaging 0.48.

The species number of macroalgae at four stations ranged from 41 sp. (transect 4) to 99 (transect 2) and averaging 72.0 species/transect.

Of the 129 species in Bach Long Vi island, 44 species occupying 34.10% of total species were found in the intertidal zone, 108 species (83.72%) in the subtidal zone and 26 species (20.15%) in both intertidal and subtidal zones.

In terms of structure, the number of taxon orders ranges from 2 (Cyanophyta) to 12 (Rhodophyta) and averages 5.25 orders/phylum; of families from 4 (Cyanophyta, Ochrophyta) to 25 (Rhodophyta) and 10.5 families/order; of genera from 6 (Cyanophyta) to 42 (Rhodophyta) and 18.0; crab species from 10 (Cyanophyta) to 70 (Rhodophyta) and 32.25. The average number of species/genera is quite large (32.25). However, some genera have only one species (Hydrocoryne, Asparagopsis, Parvocaulis...), and some other genera have a larger number of species (Dictyota: 10 species; Hypnea: 8 species; Peyssonnelia: 5 species). Some families have only one genus (Peyssonneliaceae, Scytosiphonaceae, Codiaceae...). However, others have more genera (Dictyotaceae: 5, Boodleaceae: 4, Sargassaceae: 2...). The total number of orders of the four phyla (Cyanophyta, Rhodophyta, Ochrophyta and Chlorophyta) is 21. Of which, Cyanophyta has 02 orders, accounting for 9.5% of the total number of recorded orders: Rhodophyta (12 and 57.1%); Ochrophyta (4 and 19.0%), and Chlorophyta (3 and 14.4%).

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