Vietnam Journal of Marine Science and Technology; Vol. 20, No. 3; 2020: 267–276
DOI: https://doi.org/10.15625/1859-3097/20/3/15247
http://www.vjs.ac.vn/index.php/jmst

Species composition and distribution of marine macro algae at Co To and Thanh Lan archipelago

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Received: 31 December 2019; Accepted: 30 May 2020

Abstract
This paper exhibites species composition and distribution of marine seaweed at 10 sites of Co To and Thanh Lan islands in May 2019. The studies record 76 species of marine algae in the area, belonging to four divisions: Cyanophytes, Rhodophytes, Ochrophytes and Chlorophytes. Among them, five species are classified into Cyanophytes (comprising 6.6% of total species); thirty-four species into Rhodophytes (44.7%); twenty-one species into Ochrophytes/Phaeophytes (27.6%) and sixteen species into Chlorophytes (21.1%). The species composition of marine seaweeds in Co To and Thanh Lan shows significant differences as follows: 22 species (sites number 4 and 10) to 58 species (site number 2) and the average value is 38.7 species per site. Sørensen similarity coefficient fluctuates from 0.33 (sites number 5 and 10) to 0.84 (sites number 1 and 3) and the average value is 0.53. The current investigations show that four species of twenty-one species are collected in the littoral zone and forty-two species in the sub-littoral zone (in which there are thirteen species distributed in both littoral zone and sub-littoral zone). The algal flora in Co To and Thanh Lan is characterized by subtropics.

Keywords: Co To, Thanh Lan, composition, distribution, marine algae, species.

Citation: Dam Duc Tien, Nguyen Thi Mai Anh, Nguyen Manh Linh, Pham Thu Hue, Lawrence Liao, 2020. Species composition and distribution of marine macro algae at Co To and Thanh Lan archipelago. *Vietnam Journal of Marine Science and Technology*, *20*(3), 267–276.

INTRODUCTION

Marine macroalgae are not only a crucial and valuable economic component of marine resources that people around the world use in many aspects of life but also a significant object in theoretical research.

On the practical, seaweed is used as a raw material for many industries as Agar, Alginate, Carrageenan, biological compounds (amino acids, growth hormones,...). These active ingredients have been and will be widely used in various fields (textile fabric, additives for beverage industry, specialized glues, pharmaceutical preparations). In our country today, seaweed has been used in a number of industries (especially extracted glues, compounds) [1].

Co To and Thanh Lan archipelago is located in the East Sea - North Vietnam (Quang Ninh province). Currently, the studies on the seaweed in this archipelago are a few and this is the first results on the species composition and distribution of seaweed in the Co To and Thanh Lan archipelago. In recent years, many impacts (from nature and humans) have made species composition, structure, bio-reserves,... seriously reduced.

This paper presents species composition and distribution of marine macroalgae in Co To and Thanh Lan archipelago, Quang Ninh province.

MATERIALS AND METHODS

Materials

Marine macroalgal specimens were collected at May, 2019 from 10 stations of Co To and Thanh Lan archipelago of mission: "Supporting scientific research activities for senior researchers in 2019", code: NCVCC23.5/19–19. (table 1 and figure 1).

Table 1. Coordinates of survey points

No.	Template notation	Island	Coordinates
1	CT 1	Co To	20°56'54.70"N -107°44'53.01"E
2	CT 2	Co To	20°57'46.99"N - 107°45'53.41"E
3	CT 3	Co To	20°58'49.57"N - 107°46'26.30"E
4	CT 4	Co To	20°59'26.62"N - 107°46'59.17"E
5	CT 5	Co To	21°0'33.11"N - 107°45'42.47"E
6	CT 6	Co To	21°1'22.95"N - 107°44'39.52"E
7	CT 7	Co To	20°59'43.27"N - 107°44'18.98"E
8	CT 8	Thanh Lan	21°0'22.84"N - 107°48'44.56"E
9	CT 9	Thanh Lan	20°59'33.02"N - 107°49'11.77"E
10	CT 10	Thanh Lan	21°2'17.85"N - 107°49'57.31"E

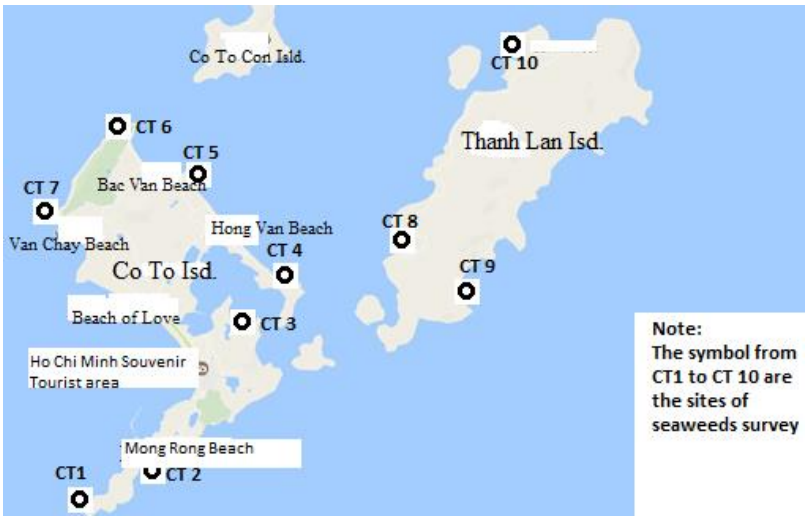

Figure 1. Sites of seaweed survey in Co To - Thanh Lan archipelago

Sampling method

Normative Act of Committee for Science and Technology of Government State specimens collection during the field survey (1981) [2] (for tidal zone) and the standard method of English et al., (1997) [3] (for subtidal zone) were used in the survey. The specimens in the subtidal zone were collected by SCUBA divers. We used SCUBA diving equipment, underwater digital camera OLYMPUS (Tokyo, Japan) for collecting samples and taking pictures.

The freshly collected marine macroalgal samples were soaked in a solution of formaldehyde 5%, the specimens were then put on Croki paper, compressed into blotting papers, dried naturally and identified.

Species identification

The marine macroalgal specimens were analyzed at the laboratory of 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 [4–8].

Distribution study

Geographical distribution

Geographical distribution in this study referred to the spatial horizontal distribution of marine macroalgae.

To study the geographical distribution of marine macroalgal communities, similarity index (Sorensen Similarity Index) was calculated according to the formula $S = 2C/A+B$, *where: A* and *B* are the numbers of species in sample sites *A* and *B*, respectively and *C* is the number of species shared by two sampling sites (*A* and *B*) [9].

When the coefficient value approaches 1, these sampling sites show a strong similarity; when coefficient value approaches 0, these sample sites are less similar.

The floral characteristic was calculated by the Cheney formula (1977). This method involves calculating the sum of the number of species of Rhodophytes, Chlorophytes and dividing this into the number of species of Phaeophytes. If the ratio is < 3, then the flora is recognized as subtropical flora. If the ratio is between 3 and 6 the flora is recognized as mixed flora, and if the ratio > 6 it is recognized as the tropical flora [10].

Vertical distribution

Determining the vertical distribution of marine macroalgae was based on the principle of the partitioning (zonation) of the tidal zone as used by Feldmann (1937) [11], Stephenson (1949) [12] and Pham Hoang Ho (1962) [13]. Under this scheme, the coastal zone is arbitrarily partitioned into many different areas depending on the tidal level such as high tide, mid-tide and low tide. Water level and tidal data were derived from the tidal regime measured at Hon Gai in 2019 [14].

RESULTS AND DISCUSSION

Species composition

Based on the analysis of marine macroalgal samples collected during field surveys in May 2019 at 10 stations and from a review of published data, we identified a total of 74 species species of marine algae are recorded in the study area, belonging to four divisions: Cyanophytes, Rhodophytes, Ochrophytes and Chlorophytes. Among them, four species are classified into Cyanophytes (comprising 5.4% of total species); thirty-four species into Rhodophytes (45.9%); twenty-one species into Ochrophytes/Phaeophytes (28.4%) and fifteen species into Chlorophytes (22.3%) (table 2).

Table 2. Species composition and distribution of marine macroalgae at Co To - Thanh Lan

No.	Taxa	Geographical distribution										Vertical distribution	
		1	2	3	4	5	6	7	8	9	10	a	b
	Cyanophyta												
	Oscillatoriales												
	Oscillatoriaceae												

1	*Oscillatoria corallinae* Gomont ex Gomont	+	+	+					+	+			+	
2	*O. limosa* J. Ag. ex. Gomont	+	+	+						+	+		+	
3	*Lyngbya aestuarii* Liebman ex Gomont		+	+	+								+	
4	*Aphanocapsa litoralis* Hansgirg	+	+	+	+	+	+						+	
	Rhodophyta													
	Acrochaetiales													
	Acrochaetiaceae													
5	*Acrochaetium colaconemoides* Pham - Hoang Ho	+		+	+	+			+	+	+		+	+
6	*Acrochaetium crassipes* (Børgesen) Børgesen	+											+	+
7	*Acrochaetium secundatum* (Lyngbye) Nägeli	+				+	+	+					+	+
	Bonnemaisoniales													
	Bonnemaisoniaceae													
8	*Asparagopsis taxiformis* (Delile) Trevisan	+	+	+	+	+	+	+	+	+	+			+
	Ceramiales													
	Ceramiaceae													
9	*Ceramium macilentum* J. Agardh	+		+			+	+					+	+
10	*Ceramium cingulatum* Weber Bosse			+		+				+				+
	Rhodomelaceae													
11	*Acanthophora spicifera* (Vahl) Børgesen	+	+	+	+			+	+					+
12	*Laurencia microcladia* Kützing	+	+				+	+			+		+	+
13	*Leveillea jungermannioides* (Hering and G. Martens) Harvey	+			+	+	+	+	+	+			+	+
14	*Polysiphonia sertularioides* (Grateloup) J.Agardh		+	+	+	+	+	+					+	+
15	*Polysiphonia subtilissima* Montagne	+			+	+		+	+	+	+			+
16	*Polysiphonia scopulorum* Harvey			+		+	+	+	+					+
	Corallinales													
	Corallinaceae													
17	*Amphiroa fragilissima* (Linnaeus) Lamouroux	+	+	+		+		+	+	+	+			+
18	*Jania pedunculata var. adhaerens* (Lamouroux) A. S. Harvey, Woelkerling and Reviers	+		+			+	+	+	+				+
19	*Corallina officinalis* Linnaeus	+		+		+	+			+	+			+
20	*Lithophyllum okamurae* Foslie	+		+			+	+						+
	Gelidiales													
	Gelidiaceae													
21	*Gelidium crinale* (Hare ex Turner) Gaillon	+	+	+		+	+	+					+	
22	*Gelidium divaricatum* G. Martens	+	+	+									+	
23	*Gelidium pulchellum* (Turner) Kützing		+	+			+						+	

24	*Gelidiella acerosa* (Forsskål) Feldmann and Hamel			+		+	+	+	+	+		+		
25	*Millerella myrioclada* (Børgesen) G. H. Boo		+			+	+	+	+	+	+	+		
26	*Gelidiella lubrica* (Kützing) Feldmann and Hamel				+		+	+	+	+	+	+		
	Pterocladiaceae													
27	*Pterocladiella caloglossoides* (Howe) Santelices			+			+					+		+
	Gigartinales													
	Cystocloniaceae													
28	*Hypnea charoides* Lamouroux	+		+		+	+	+						+
29	*Hypnea anastomosans* Papenfuss, Lipkin and P. Silva	+	+	+				+	+	+				+
	Gigartinaceae								+	+	+	+		
30	*Chondracanthus intermedius* (Suringar) Hommersand	+	+	+			+	+				+		
	Phyllophoraceae													
31	*Gymnogongrus griffithsiae* (Turner) C. Martius	+	+	+	+	+						+		
	Goniotrichales													
	Goniotrichaceae													
32	*Chroodactylon ornatum* (C. Agardh) Basson	+	+	+		+	+	+	+					+
33	*Acrocystis nana* Zanardini	+	+	+	+	+								+
34	*Gracilaria salicornia* (C. Ag.) Daws.				+	+						+		+
	Rhodymeniales													
	Rhodymenia													
35	*Bostrychia tenella* (Vahl.) J. Ag.			+		+	+	+						+
	Nemaliales													
	Galaxauraceae													
36	*Tricleocarpa fastigiata* (Decaisne) Huisman, G.H.Boo and S. M. Boo	+	+	+			+	+	+	+				+
	Peyssonneliales													
	Peyssonneliaceae													
37	*Ramicrusta calcea* (Heydrich) K. Dixon	+	+	+				+		+	+			+
	Rhodymeniales													
	Lomentariaceae													
38	*Ceratodictyon sponggiosum* Zanardini	+	+	+		+	+	+						+
	Ochrophyta/ Phaeophyta)													
	Dictyotales													
	Dictyota													
39	*Dictyota implexa* (Defontaines) Lamouroux	+	+	+										+
40	*Canistrocarpus cervicornis* (Kützing) De Paula and De Clerck						+	+						+
41	*Dictyopteris polypodioides* (de Candolle) Lamouroux	+	+	+			+	+	+	+	+			
42	*Lobophora variegata* (Lamouroux) Womersley ex Oliveira	+	+	+	+	+	+	+	+	+	+			+
43	*Padina australis* Hauck	+		+		+	+	+						+
44	*Padina boryana* Thivy	+	+	+			+	+	+	+	+			+

45	*Padina japonica* Yamada	+	+		+	+	+	+	+					+
46	*Padina tetrastromatica* Hauck	+		+			+	+	+	+	+			+
47	*Spatoglossum schroederi* (C. Agardh) Kützing	+	+	+			+	+	+					+
	Ectocarpales													
	Ectocarpaceae													
48	*Ectocarpus siliculosus* (Dillwyn) Lyngbye	+		+										+
	Sargassucaceae													
49	*Spatoglossum schroederi* (C. Agardh) Kützing	+	+		+			+	+	+	+			+
50	*Sargassum herklotsii* Setchell	+		+	+	+	+	+						+
51	*Sargassum swartzii* C. Agardh	+		+	+		+	+	+	+	+			+
52	*Sargassum cotoense* Nguyen Huu Dai				+									+
53	*Sargassum paniculatum* J. Agardh		+	+	+	+			+	+	+			+
54	*Sargassum piluliferum* (Turner) C.Agardh				+	+	+	+	+	+				+
55	*Turbinaria conoides* (J. Agardh) Kützing					+	+	+	+	+	+			+
	Scytosiphonales													
	Pseudochnoospora													
56	*Pseudochnoospora implexa* (J. Agardh) Santiañez, G. Y. Cho and Kogame	+	+	+				+	+					+
	Chnoospora													
57	*Chnoospora minima* (Hering) Papenfuss	+		+						+				+
	Scytosiphonaceae													
58	*Colpomenia sinuosa* (Mertens ex Roth) Derbès and Solier	+	+	+		+	+	+	+	+		+		+
	Sphacelariales													
	Sphacelariaceae													
59	*Sphacelaria rigidula* Kützing	+		+			+	+						+
	Chlorophyta													
	Bryopsidales													
	Bryopsidaceae													
60	*Bryopsis pennata* Lamouroux			+			+	+	+	+				+
61	*Bryopsis indica* A. Gepp and E. S. Gepp		+						+	+	+			+
	Caulerpaceae													
62	*Caulerpa chemnitzia* (Esper) Lamouroux							+						+
63	*Caulerpa racemosa* (Forsskål) J. Agardh	+	+	+										+
64	*Caulerpa taxifolia* (Vahl) C. Agardh								+					+
	Siphononales													
	Codiaceae													
65	*Codium mamillosum* Harvey	+		+										+
66	*Codium arabicum* Kützing	+		+			+	+	+					+
67	*Codium repens* P. Crouan and H. Crouan		+	+				+	+	+	+			+
	Ulvales													
	Ulvaceae													
68	*Ulva conglobata* Kjellman	+	+	+								+		
69	*Ulva lactuca* Linnaeus	+	+	+								+		

70	*Ulva clathrata* (Roth) C. Agardh	+	+	+			+	+	+	+	+	+	
71	*Ulva compressa* Linnaeus	+	+	+								+	
	Cladophorales												
	Cladophoraceae												
72	*Cladophora socialis* Kützing		+			+	+					+	
	Dasycladales												
	Polyphysaceae												
73	*Acetabularia caliculus* Lamouroux	+		+	+	+	+					+	
	Siphonocladales												
	Valoniaceae												
74	*Valonia aegagropila* C. Agardh	+		+					+	+		+	
	Total: 74 species	52	39	56	21	31	42	45	36	33	22	30	54

Notes: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 are sampling sections; "a" as intertidal zone, "b" as subtidal zone.

The number of marine macroalgae collected during the present study in 2019 was 7 species more than the previous survey [15].

Geographical distribution

Table 1 shows that the number of species at different sites species (sites 4) to 56 species (site 3) with the average value was 37.3 species/site.

The Sorensen Index of marine macroalgae at different sites ranged from 0.34 (between sites 3 and 4; 5 and 10) to 0.84 (between sites 1 and 3; 6 and 7) and the average value was 0.53 (table 3).

The cause of the similarity coefficient between site 5 and 10 reaches the lowest value (0.34) is the bottom floor structure. the bottom structure at site 5 is mainly rocky and the bottom structure at site 10 is sand (turbidity is often high; it is not favorable for the existence and development of seaweed).

The cause of the similarity coefficient between site number 1 and 3; 6 and 7 reaches the highest value (0.84) is the bottom structure at site 1, 3, 6 and 7 (rocks and dead corals) and The distance between a and three is very close. They are favorable conditions for the existence and development of seaweed.

Table 3. Sorensen index values between sites

	1	2	3	4	5	6	7	8	9	10
10	0.41	0.46	0.36	0.37	**0.34**	0.38	0.48	0.62	0.76	
9	0.52	0.47	0.54	0.37	0.44	0.48	0.59	0.81		
8	0.55	0.53	0.54	0.42	0.45	0.56	0.72			
7	0.68	0.55	0.65	0.36	0.55	**0.83**				
6	0.62	0.47	0.65	0.35	0.63					
5	0.48	0.43	0.51	0.58						
4	0.38	0.37	**0.34**							
3	**0.83**	0.69								
2	0.68									
1										

Vertical distribution

Based on tidal level data in May 2019 at Hong Gai, among 74 species in Tam Giang - Cau Hai lagoon, there were 20 species (occupying 27.0% of total species), distributed in intertidal zone and 43 species (58.1%) in subtidal zone (of which 11 species (14.9%) were distributed in both intertidal and subtidal zones).

The number of species distributed in the subtidal zone is significantly larger than that of the tidal zone due to the typical diurnal characteristics at the time of the lowest sprint (usually during the day) so it is difficult to

survive in the sun, especially in the summer. This is also the cause of the seaweed season in diurnal areas with daytime receding regime usually only from November to April next year (the period of low temperature and low light intensity (table 4).

The results at table 4 showed that, on the tidal area: in the high tide belt, there are usually species as *Aphanocapsa littoralis, Acrochaetium colaconemoides, Colpomenia sinuosa, Ulva clathrata,...*; in the middle tide belt (*Laurencia microcladia, Gelidium crinale, Gelidiella acerosa, Colpomenia sinuosa, Ulva conglobata,...*: in the low tide belt (*Pterocladia parva, Colpomenia sinuosa, Cladophora socialis,...*), on the sub tidal area: in the high belt there are usually species as: *Bryopsis pennata, Colpomenia sinuosa, Pseudochnoospora implexa, Turbinaria conoides,...* and in the low belt (*Tricleocarpa fastigiata, Sargassum cotoense, S. piluliferum, Ramicrusta calcea,...*). Particularly species *Colpomenia sinuosa* is distributed in all tidal ranges and upper tidal range.

Table 4. The distribution of seaweeds by depth in Co To and Thanh Lan (Based on tide level in Hong Gai, May 2019)

Region	Tidal belt	Featured species
On the tide		There is no seaweed 3.9 m
Tidal area	High tide belt	*Aphanocapsa littoralis, Acrochaetium colaconemoides, Ulva clathrata,…* 1.8 m
	Middle tide belt	*Laurencia microcladia, Gelidium crinale, Gelidiella acerosa, Colpomenia sinuosa, Ulva conglobata,…* 0.5 m
	Low tide belt	*Pterocladia parva, Colpomenia sinuosa, Cladophora socialis,...* 0 m Charts
subtidal tide area	High belt	*Bryopsis pennata, Colpomenia sinuosa, Pseudochnoospora implexa, Turbinaria conoides,…* -10 m
	Low belt	*Tricleocarpa fastigiata, Sargassum cotoense, S. piluliferum, Ramicrusta calcea,…*

The algal flora research

Based on Cheney's method and results obtained from table 2, We are recording that, the index $C = (34 + 15)/21 = 2.33$, This value is between 0 and 3. Thus, the algal flora in Co To and Thanh Lan is characterized by subtropics.

Discussion

From the survey results in May 2019, we was recorded 74 species of marine algae. The results from this study is more than the survey results at 2004 of Dam Duc Tien (53 species) [15] and by Do Anh Duy and Do Van Khuong (2013) (53 species) [16]. Thus, the results from this study, 21 species have been added to the list of marine algae from the Co To - Thanh Lan archipelago.

The results of this study, showed that, the number of marine algae from Co To and Thanh Lan is highest (74 species). The number of species on other islands is lower: Bach Long Vi island (46 species), Ba Mun island (11), Vinh Thuc island (68), Ha Mai island (19). The number of species in Co To and Thanh Lan highest and it is perfectly legal because: the area of Co To and Thanh Lan is larger than other islands, the substrate is composed of rocks or dead corals mostly and Co To - Thanh Lan are located far from the mainland, the impact of fresh water from the continent is negligible, water is clear, salinity is usually stable,… These factors are very favorable for the existence and development of seaweed species.

On the other hand, the numbertimes of surveys in Co To and Thanh Lan is higher than the other islands. It is also an opportunity for collecting more complete marine algae samples. The number of marine algae species on other islands may also be higher than number of species at the present, if repeated survey (table 5).

Table 5. The compression number of the marine algae species in Co To and Thanh Lan 2019 with previous studies in the Tonkin Gulf area

Area	Number species	References
Co To - Thanh Lan	53	Dam Duc Tien (2004) [15]
Tran island	34	Dam Duc Tien (2004) [15]
Co to island	53	Do Duy Anh and Do Van Khuong (2013) [16]
Co To - Thanh Lan	74	This study
Bach Long Vi island	46	Dam Duc Tien (1997) [17]
Ha Mai island	19	Dam Duc Tien (2004) [15]
Ba Mun island	11	Do Anh Duy and Do Van Khuong (2013) [16]
Vinh Thuc island	68	Do Anh Duy et al., (2019) [18]

CONCLUSION

The results at 10 sites from Co To and Thanh Lan areas and and refer to some of the available results we have identified found 74 species of marine macroalgae. They belong to 4 phyla of marine macroalgae consisting of 4 species of Cyanobacteria, representing 5.4% of the total number of species, 34 species of Rhodophytes (45.9%), 21 species of Phaeophytes (28.4%) and 15 species of Chlorophytes (22.3%). The algal flora in Co To and Thanh Lan is characterized by subtropics.

The geographical distribution of marine macroalgae at 10 sites study is not similar; they ranged from 21 species (sites number 4) to 56 species (site number 3) and the average value is 37.3 species/site. Sorensen Index of marine macroalgae at different sites ranged from 0.34 (between sites 3 and 4; 5 and 10) to 0.84 (between sites 1 and 3; 6 and 7) and the average value was 0.53.

Among 74 species of marine macroalgae at Co To and Thanh lan areas, there are 20 species (occupying 27.0% of total species), distributed in intertidal zone and 43 species(58.1%) in subtidal zone (of which 11 species (14.9%) were distributed in both intertidal and subtidal zones.

Acknowledgements: We area would like to thank the mission: “Support scientific research activities for senior researchers in 2019”, code: NCVCC23.5/19–19 for supporting this study.

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