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Biological environmental survey in Cat Ba Island

Abstract

Cat Ba Island has a significant biodiversity value as it is home to a number of rare and endangered species of plants and animals, with the world's rarest primates the Golden-headed Langur. According to the study results, Cat Ba place have listed 2,380 species of animals and plants including: terrestrial plants 741 species; living animals in the forest area 282 species; mangrove plants 30 species; seaweeds 79 species; phytoplankton 287 species; plank tonic animals 98 species; sea-fish 196 species; corals 154 species. It is identified as one of the areas of highest biodiversity importance in Vietnam and is recognized as a high priority for global conservation.

Keywords: mangrove, seagrass, coral reef, phytoplankton, cat ba island

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Doan Quang Tri,[1,2] Tran Hong Thai[2]
[1]Ton Duc Thang University, Vietnam
[2]Vietnam Meteorological and Hydrological Administration, Vietnam

Correspondence: Doan Quang Tri, Sustainable Management of Natural Resources and Environment Research Group, Faculty of Environment and Labour Safety, Ton Duc Thang University, Ho Chi Minh City, Vietnam, Email doanquangtri@tdt.edu.vn

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Introduction

Biosphere reserves Cat Ba Island has been recognized as a UNESCO World on December 02nd, 2004. It is the 4th world's biosphere reserve in Vietnam. Biosphere reserves Cat Ba archipelago including great majority of Cat Ba Island in Cat Hai district, Hai Phong city, Vietnam. Cat Ba Island is considered the richest marine biological system because of its diversity in the North of Vietnam. On the previous study,[1] they found the Langur distribution and forest cover in Cat Ba Island (Figure 1). The objective of this study was shown the distribution of mangrove, seaweed/seagrass, coral reefs and phytoplankton in Cat Ba Island.

Figure 1 The white-headed langur (Trachypithecus poliocephalus), an endemic species from Cat Ba Island.[1]

Materials and methods

Description of the study area

Cat Ba is the largest of 336 islands in the Cat Ba Archipelago, and also the second largest limestone island (200 km^2) in the coastal zone of Vietnam.[2] It is located in the north-east of Vietnam in the northern section of the Tonkin Gulf and adjacent to Ha Long Bay (the world natural heritage site) (Figure 2). The total natural land area of Cat Ba Archipelago Biosphere Reserve is 26,240 ha, of which land area (island) is 17,040 ha and 9,200 ha of sea. Cat Ba Island is considered the richest marine biological system because of its diversity in the North of Vietnam.[3–7]

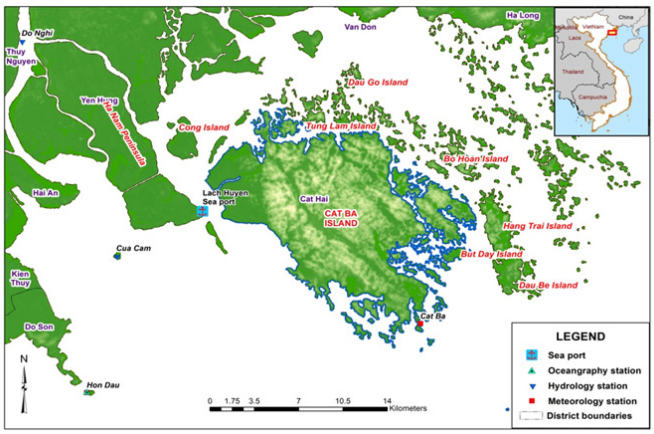

Figure 2 Cat Ba Island.

Methods of field survey

Mangrove: All mangrove species that were identified in the survey sites were recorded. Also to obtain quantitative data, a 10m x 10m quadrate was set at a location that was representative of the site, and the following information was recorded: species composition, canopy height (highest and lowest), stem diameter (1.3 m from ground) and density (No. of stems/100 m^2).

Seaweed/seagrass: All seaweed/seagrass species that were identified in the survey sites were recorded. Samples were collected and preserved in a 10% formalin solution for further analysis at IMER's laboratory. Except sites AL11, survey was conducted only along the shoreline (underwater survey was not possible due to very low water visibility). Sites AL11 was surveyed by scuba diving.

Coral Reefs: Coral survey was conducted by squba diving at sites AL11. Species composition and live coral coverage were recorded at 5m interval along a 100 m line transect.

Phytoplankton: The qualitative Phytoplankton samples were collected by towing a plankton net (mesh size: 20µm, diameter: 20cm) several times in the vertical direction. Quantitative samples

were collected from the surface by collecting 1L of surface water in the PVC bottle. All samples were preserved in 3ml Lugol solution for further analysis at IMER's laboratory.

Demersal fish: Demersal fish was collected with a trawling net (mesh size: #15, width: 5m). Each trawl was conducted for 15 minutes at a speed of approximately 2 miles/hour. All collected species were measured (total length) and weighted, then preserved in 10% formalin solution for further analysis at IMER's laboratory.

Results and discussion

Diversity of the species composition

According to previous studies, a total of 2,380 species have been recorded in Cat Ba Island. Among of them 1,053 species are terrestrial species occupies 51.7% of the total species while the marine species occupies 48.3% with 985 species (Table 1). High biological diversity of the species included in the Cat Ba Island will be a very important basis for the exploitation of natural resources to serve different purposes of human. On the other hand it provides great significance in scientific research: evolution, ecology, environmental indicators along with a wide range of species likely to play an important role in the provision of ecosystem services such as disaster prevention and source of raw materials for the chemical industry and medicine production.[8]

Table 1 The species composition recorded in Cat Ba Island[9]

Taxon	Number of species	Taxon	Species
Terrestrial plant	741	Zooplankton	79
Terrestrial animal	282	Marine fishes	196
Mangrove plant	30	Coral	154
Phytoplankton	287	Zoobenthos	538
Seaweed	79		
		Total: 2,380 species	

Diversity of major marine ecosystem

Coral reefs: Coral reefs are mainly distributed at the surrounding waters in the southeast of Cat Ba Island such as Cong La, Ang Tham, Ba Trai Dao, Van Boi, Cong Hip, Tung Ngon, and Coc Cheo. The coral reefs areas are the major fishing grounds for reef fisheries due to high values of the coral reef fishes and associated reef species (Figure 3). The coral reefs in Cat Ba - Ha Long area are represented for the fringing reef types and two addition types of islands connectivity and the unofficial atoll. Generally, along the limestone islands of Cat Ba have coral distribution at a depth of 3, 6, 9 and 11 meters. Morphology of the reef is determined mainly by the morphology of the ground slopes and partly by carbonate sediments originated from organisms on the reef. Due to changes of the environmental conditions under the impact of natural and human, coral reefs are now greatly reduced in terms of area and the level of diversity of the groups living together. The percentage of the live coral coverage occupies by less than 40%, meaning classification of medium and low level by the UNESCO criteria for assessment of the coral reef health.[8]

Table 2 shows the hard coral species identified through the field survey. Twenty-eight species and 58 species were identified at the sites AL11 respectively. The diversity at site AL11 was lower probably due to relatively turbid conditions. Within the identified species, 4 species are listed in the Vietnam Red Book namely: *Porites lobata*, *Acropora aspera*, *Acropora formosa* and *Acropora nobilis*; which are all classified as "Vulnerable". *Porites lobata* was found at the AL11 site.

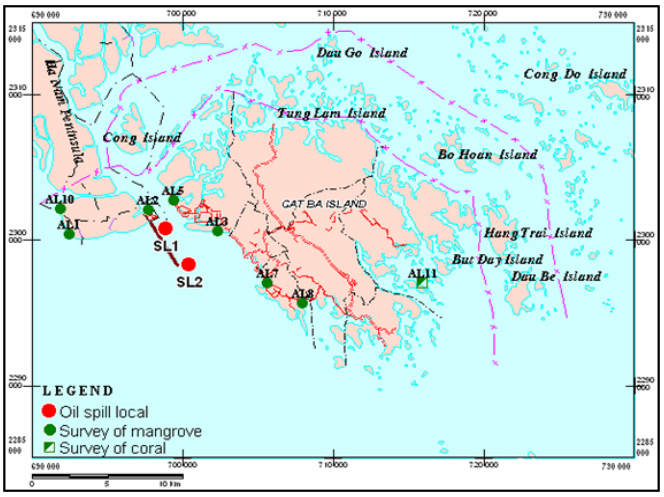

Figure 3 Locations of the field survey sites (mangrove, seaweed/seagrass and coral reef).[3]

Note 1 Coral was surveyed only at sites AL11; Site AL8 was not surveyed as the area was under construction activities.

Seagrass: Seagrasses are mainly distributed in Cat Ba Island in the narrow range like leopard style on tidal marshes (with the carpet of mangroves) in Gia Luan and in aquaculture ponds in Phu Long. A small area of seagrass distributes in the island of Long Chau (offshore) and Van Boi (Southeast of Cat Ba Island) where there are coral reefs with live coral cover is relatively high (Figure 4). There were only two species of seagrass have been identified in the island of Cat Ba such as Ruppia Maritima and Halophila beccarii. However, both species are not included in the Red Data Book of Vietnam, although the species of Halophila beccarii is classified at the level of "danger threatened" in the IUCN red list of threatened species, 2011.[8]

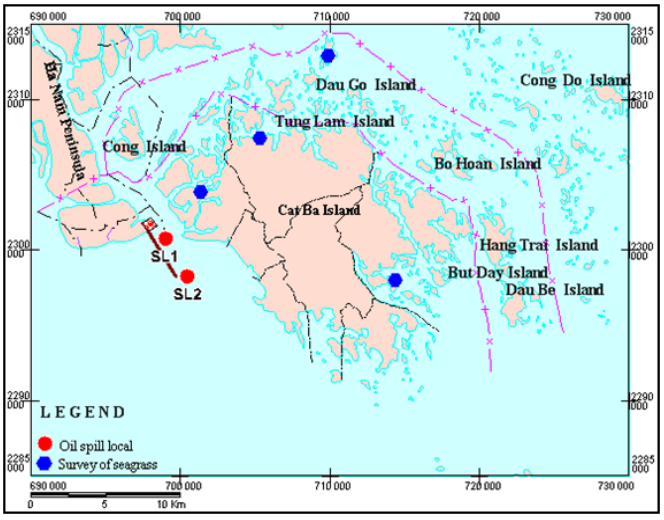

Figure 4 Distribution map of the seagrass area at Cat Ba islands.[3]

Table 3 shows the seaweed species identified through the field survey. Seventeen species belonging to 9 families were identified. Chaetomorpha capillaris and Enteromorpha compressa were the most common species. Some species such as Asparagopsis taxiformis, Colpomenia sinuosa, and Cladophoropsis membrannacea were identified at only specific sites. None of the identified species are included in the Vietnam Red Book. Some species in the Ulvaceae family are harvested for food stuffs in certain areas of Vietnam. Table 2 shows the seagrass species identified through the field survey. Only two seagrass species Ruppia maritima and Halophila beccarii were identified, which were found at sites AL10 and AL11 respectively. Halophila beccarii was record for the first time in the surveyed area. Although both species are not included in the Vietnam Red Book, Halophila beccarii is classified as "Vulnerable" in IUCN Red List.

Table 2 List of hard coral species identified through the field survey (EIA, 2011)

	Survey site	Family	Genus/species	Status in vietnam red book
1	AL11	*Acroporidae*	*Acropora pulchra*	Not listed
2		*Poritidae*	*Porites lobata*	Vulnerable
3			*Porites lutea*	Not listed
4			*Goniopora columna*	Not listed
5			*Goniopora lobata*	Not listed
6		*Agariciidae*	*Pavona decussata*	Not listed
7		*Oculinidae*	*Galaxea astreata*	Not listed
8			*Galaxea fascicularis*	Not listed
9		*Pectiniidae*	*Pectinia lactuca*	Not listed
10			*Echinophyllia aspera*	Not listed
11		*Fungiidae*	*Mycedium elephantotus*	Not listed
12			*Lithophyllon undulatum*	Not listed
13			*Sandalolitha robusta*	Not listed
14		*Mussidae*	*Lobophyllia hattaii*	Not listed
15			*Lobophyllia hemprichii*	Not listed
16		*Merulinidae*	*Symphyllia. agaricia*	Not listed
17			*Merulina ampliata*	Not listed
18		*Faviidae*	*Favia maritime*	Not listed
19			*Favia matthaii*	Not listed
20			*Favia lizardensis*	Not listed
21			*Favia maxima*	Not listed
22			*Favites abdita*	Not listed
23			*Goniastrea pectinata*	Not listed
24			*Goniastrea favulus*	Not listed
25			*Cyphastrea serailia*	Not listed
26			*Echinopora lamellose*	Not listed
27			*Platygyra daelalea*	Not listed
28		*Dendrophylliidae*	*Turbinaria peltata*	Not listed

Table 3 List of seaweed species identified through the field survey (EIA, 2011)

	Family	Genus/species	Status in vietnam red book	Identified survey sites
1	*Ceramiaceae*	*Bostrychia binderi*	Not listed	AL3, AL5, AL7, AL10
2		*Polysiphonia sertularioides*	Not listed	AL1, AL2, AL10
3	*Delesseriaceae*	*Caloglosa ogasawaraensis*	Not listed	AL2, AL3, AL7

Table Continued

	Family	Genus/species	Status in vietnam red book	Identified survey sites
4	*Dictyotaceae*	*Padina australis*	Not listed	AL11
5		*Chaetomorpha capillaris*	Not listed	AL1, AL03, AL5, AL7, AL10, AL11
6		*Ch. linum*	Not listed	AL1, AL10
7	*Cladophoraceae*	*E. compressa*	Not listed	AL1, AL3, AL5, AL7, AL10, AL11
8		*E. kylinii*	Not listed	AL1, AL10
9		*E. flexuosa*	Not listed	AL1
10		*Ulva conglobata*	Not listed	AL5
11	*Ruppiaceae*	*Ruppia maritima*	Not listed	AL10
12	*Hydrocharitaceae*	*Halophila beccarii*	Not listed	AL11

Mangrove forest: The mangrove forest and the coral reefs are the invaluable natural resources of the tropical countries in general and Cat Ba in particular. They play as the sources of genetic reservation, increasing of the natural biomass and stabilization for the shoreline. Most of the mangrove forests maintain high cover in the western side of Cat Ba Island (Phu Long Natural Reserve). In near future, the fight campaign for climate change will lean much on these green corridors (Figure 5).[8]

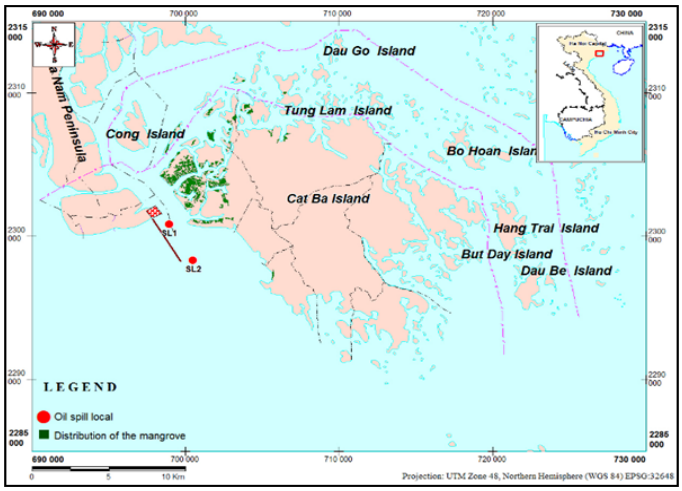

Figure 5 Distribution map of the mangrove area at Cat Ba islands.[3]

Most of the mangrove areas distribute in Phu Long Commune with high relative density. The total area is 775.98 ha of mangrove forest is divided into two types: mangrove distribution outside the farming area (224.74 ha), mangrove distribution in ponds (551.24 ha) (Figure 6). Because mangrove forests in farming systems are relatively large so the long-term master plan and conservation of mangroves will be difficult due to satisfactorily resolve the relationship of private-public ownership. Table 4 shows the mangrove species identified through the field survey. Eleven species belonging to 9 families were identified. *Rhizophora stylosa* and *Avicennia marina* were the most common species in the survey area. None of the identified species are included in the Vietnam Red Book.[8]

Phytoplankton: Phytoplanktons are the keystone species in this habitat type, providing basic food items for the zoobenthis and fish that are the key targets of the capture fishery (Figure 7). Table 5 and Table 6 show the phytoplankton species identified through the dry and wet season surveys respectively. In the dry season, a total of 134 species were identified (Table 5). The genus Chaetoceros was found in many survey sites, which play an important role as food sources for fish and other marine species, in particular at the early stages of their life cycle. Some of the identified dinoflagellate species such as Ceratium fusus, Prorocentrum micans and Dinophysis caudate are known to cause red tide and harmful algae bloom when at high density. In the rainy season, a total of 136 species were identified (Table 6). The density of the phytoplankton has been driven by some dominante species such as Skeletonema costatum with the cell density is approximate 103 up to 4,104 cell/L; next to the Chaetoceros spp. with the density from 103 - 56,103 cell/L; Ceratium furca has the density from 2.103 to approximate of 104 cell/L (EC9 site); Oscillatoria sp.2 103 cell/L and Bacteriastrum spp. reaches 47,103 cell/L.

Mangroves in north of Cat Ba Island — Mangrove swamp with a rocky outcropping in Cat Ba Island

Figure 6 Mangrove distribution in Cat Ba Island.[3]

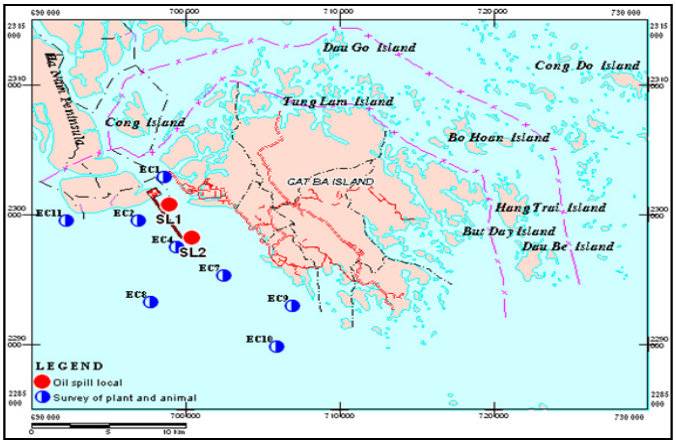

Figure 7 Locations of the field survey sites (phytoplankton, zooplankton, zoobenthos, demersal fish and other zoobenthos).[3]

Table 5 to Table 6 shows the number of phytoplankton species and cell density at each survey site. For the dry season, the number of species ranged between 32 and 57 species. While there was no clear spatial trend in the cell density, relatively high levels were recorded at the EC4 and EC8 sites. The seasonal variation shows a clearly trend of reduction both interm of species composition and cell density. However, the number of species is slightly lower in rainy season while the cell density rapidly reduces up to 98.42% at the EC8 site to 22.3% at the EC11 site.

Table 4 List of mangrove species identified through the field survey

No.	Family	Genus/species	Status in vietnam red book	Identified survey sites
1	*Sonneratiaceae*	*Sonneratia caseolaris*	Not listed	AL10
2		*Rhizophora stylosa*	Not listed	AL1, AL2, AL3, AL5, AL7
3	*Rhizophoraceae*	*Kandelia obovata*	Not listed	AL5, AL10
4		*Bruguirea gymnorrhiza*	Not listed	AL1, AL3, AL7
5	*Aviceniaceae*	*Avicennia marina*	Not listed	AL1, AL2, AL3, AL5, AL7
6	*Myrsinaceae*	*Aegiceras corniculatum*	Not listed	AL1, AL3
7	*Pteridaceae*	*Acrostichum aureumh*	Not listed	AL10
8	*Verbenaceae*	*Cleodendrum inerme*	Not listed	AL2, AL10
9	*Euphorbiaceae*	*Excoecaria agallocha*	Not listed	AL3, AL5
10	*Malvaceae*	*Hibiscus tiliaceus*	Not listed	AL5

Table 5 List of phytoplankton species identified through the field survey (in dry season)

No.	Scientific name	No. of identified survey sites	No.	Scientific name	No. of identified survey sites	No.	Scientific name	No. of identified survey sites	No.	Scientific name
Phylum- Bacillariophyceae			**Phylum- Bacillariophyceae**			**Phylum - Dinophyceae**			**Phylum - Dinophyceae**	
1	*Paralia sulcata*	1	42	*Chaetoceros lorenzianus*	11	83	Ceratium macroceros	4	124	Pyrophacus horologicum
2	*Hyalodiscus stelliger*	1	43	*Chaetoceros paradoxus*	3	84	Ceratium massiliense	4	**Phylum - Dictyochophyceae**	
3	*Cyclotella striata*	3	44	*Chaetoceros rostratus*	9	85	Ceratium asymmetricum	2	125	Dictyocha fibula
4	*Cyclotella comta*	6	45	*Chaetoceros subtilis*	3	86	Ceratium tripos	3	126	Dictyocha speculum
5	*Cyclotella* sp.	1	46	*Biddulphia regia*	2	87	Prorocentrum micans	10	**Phylum - Cyanophyceae**	
Phylum- Bacillariophyceae			47	*Biddulphia reticulum*	3	88	Prorocentrum rhathymum	1	127	*Trichodesmium erythraeum*
6	*Coscinodiscus asteromphalus*	12	48	*Odontella mobiliensis*	1	89	Prorocentrum sp.	2	128	*Oscillatoria* sp.
7	*Coscinodiscus oculus-iridis*	6	49	*Hemiaulus sinensis*	1	90	*Dinophysis caudata*	10	**Phylum – Chlorophyceae**	
8	*Coscinodiscus radiatus*	1	50	*Cerataulina bergonii*	1	91	*Dinophysis mitra*	1	129	*Pediastrum simplex v. simplex*
9	*Coscinodiscus granii*	1	51	*Cerataulina compacta*	1	92	*Dinophysis cf. rotundata*	1	130	*Pediastrum duplex v. duplex*
10	*Coscinodiscus cf. subtilis*	3	52	*Ditylum brightwellii*	1	93	*Noctiluca scintillans*	4	131	*Pediastrum* sp.
11	*Coscinodiscus* sp.	1	53	*Eucampia zoodiacus*	6	94	*Gonyaulax* sp.	4	132	*Scenedesmus* sp.
12	*Lauderia borealis*	5	54	*Climacodium biconcavum*	3	95	*Gonyaulax polygramma*	9	133	*Scenedesmus quadricauda*
13	*Skeletonema costatum*	8	55	*Palmeria hardmaniana*	5	96	*Gonyaulax spinifera*	1	134	*Staurastrum* sp.

Table Continued

No.	Scientific name	No. of identified survey sites	No.	Scientific name	No. of identified survey sites	No.	Scientific name	No. of identified survey sites	No.	Scientific name
14	*Leptocylindrus danicus*	3	56	*Thalassionema frauenfeldii*	12	97	*Gonyaulax scrippsae*	2		
15	*Guinardia flaccida*	8	57	*Navicula membranacea*	7	98	*Gonyaulax verior*	1		
16	*Guinardia striata*	12	58	*Navicula cancellata*	2	99	*Gonyaulax rotundata*	2		
17	*Bacteriastrum varians*	5	59	*Tropidoneis lepidoptera*	1	100	*Gonyaulax diegiensis*	4		
18	*Bacteriastrum hyalinum*	5	60	*Pleurosigma affine*	4	101	*Protoperidinium steinii*	5		
19	*Thalassiosira eccentrica*	2	61	*Pleurosigma angulatum*	1	102	*Protoperidinium conicum*	10		
20	*Thalassiosira lineata*	6	62	*Pleurosigma* sp.1	7	103	*Protoperidinium crassipes*	8		
21	*Thalassiosira* sp.	2	63	*Pleurosigma* sp.2	1	104	*Protoperidinium divergens*	6		
22	*Arthrospira platensis*	2	64	*Pleurosigma naviculaceum*	4	105	*Protoperidinium depressum*	1		
23	*Rhizosolenia robusta*	3	65	*Pleurosigma pelagicum*	4	106	*Protoperidinium elegans*	3		
24	*Rhizosolenia setigera*	2	66	*Amphiprora alata*	1	107	*Protoperidinium oceanicum*	3		
25	*Rhizosolenia hyalina*	4	67	*Nitzschia lorenziana*	6	108	*Protoperidinium ovum*	9		
26	*Proboscia alata*	9	68	*Nitzschia longissima*	2	109	*Protoperidinium pellucidum*	11		
27	*Proboscia alata f. indica*	1	69	*Nitzschia longissima v. reversa*	1	110	*Protoperidinium pentagonum*	1		
28	*Proboscia alata f. gracillima*	1	70	*Nitzschia sigma*	4	111	*Protoperidinium leonis*	2		
29	*Proboscia alata f. genuina*	1	71	*Nitzschia sigma v. intercedens*	1	112	*Protoperidinium spinulosum*	1		
30	*Chaetoceros affinis*	12	72	*Pseudonitzschia sp.1*	8	113	*Protoperidinium sphaeroides*	6		
31	*Chaetoceros affinis v. willei*	1	73	*Pseudonitzschia sp.2*	2	**Phylum - Dinophyceae**				
32	*Chaetoceros abnormis*	5	74	*Surirella ovalis*	5	114	*Protoperidinium* sp.	8		
33	*Chaetoceros curvisetus*	4	75	*Surirella gemma*	2	115	*Peridinium quinquecorne*	2		
34	*Chaetoceros compactus*	3	76	*Campylodiscus echeneis*	3	116	*Scrippsiella* sp.	1		
35	*Chaetoceros compressus*	7	77	*Campylodiscus undulatus*	1	117	*Alexandrium* sp.	2		
36	*Chaetoceros constrictus*	12	**Phylum - Dinophyceae**			118	*Alexandrium pseudogonyaulax*	4		
37	*Chaetoceros decipiens*	1	78	*Ceratium breve*	3	119	*Goniodoma polyedricum*	5		
38	*Chaetoceros denticulatus*	3	79	*Ceratium furca*	11	120	*Diplopsalis* sp.	5		
39	*Chaetoceros distans*	2	80	*Ceratium deflexum*	2	121	*Diplopsalopsis* sp.	2		
40	*Chaetoceros dydimus*	1	81	*Ceratium fusus*	11	122	*Zygabikodinium* sp.	1		
41	*Chaetoceros lauderii*	1	82	*Ceratium trichoceros*	10	123	*Oblea* sp.	2		

Table 6 List of phytoplankton species identified through the field survey (in rainy season)

No.	Scientific name	No. of identified survey sites	No.	Scientific name	No. of identified survey sites	No.	Scientific name	No. of identified survey sites
Bacillariophyceae (Diatoms)			**Bacillariophyceae (Diatoms)**			**Bacillariophyceae (Diatoms)**		
1	*Paralia sulcata*	2	46	*Eucampia cornuta*	1	91	*Protoperidinium pellucidum*	6
2	*Melosira granulata*	2	47	*Eucampia zoodiacus*	2	92	*Protoperidinium pentagonum*	2
3	*Melosira granulata v. angustissima*	6	48	*Climacodium biconcavum*	1	93	*Protoperidinium punctulatum*	1
4	*Cyclotella comta*	11	49	*Palmeria hardmaniana*	4	94	*Protoperidinium spinulosum*	6
5	*Coscinodiscus asteromphalus*	11	50	*Thalassionema nitzschioides*	5	95	*Protoperidinium sphaeroides*	1
6	*Coscinodiscus oculus-iridis*	4	51	*Thalassionema frauenfeldii*	11	96	*Protoperidinium sp.*	1
7	*Coscinodiscus jonesianus*	1	52	*Pleurosigma affine*	2	97	*Protoperidinium sp.1*	2
8	*Coscinodiscus jonesianus v. commutata*	12	53	*Pleurosigma sp.*	2	98	*Peridinium sp.*	1
Bacillariophyceae (Diatoms)			54	*Pleurosigma sp.1*	1	99	*Alexandrium sp.*	1
9	*Coscinodiscus marginatus*	1	55	*Nitzschia lorenziana*	3	100	*Goniodoma polyedricum*	1
10	*Coscinodiscus cf. subtilis*	1	56	*Nitzschia longissima*	1	101	*Lingulodinium polyedra*	5
11	*Asteromphalus cleveanus*	1	57	*Pseudo-nitzschia sp.1 (P. cf. pungens)*	3	102	*Diplopsalis sp.*	2
12	*Thalassiosira eccentrica*	3	58	*Campylodiscus echeneis*	1	103	*Diplopsalopsis sp.*	2
13	*Thalassiosira lineata*	12	59	*Ceratium breve*	2	104	*Zygabikodinium sp.*	1
14	*Thalassiosira sp.*	2	60	*Ceratium deflexum*	1	105	*Pyrophacus horologium*	1
15	*Lauderia borealis*	11	61	*Ceratium extensum*	1	106	*Pyrophacus sp.*	7
16	*Skeletonema costatum*	11	62	*Ceratium falcatum*	1	107	*Podolampas bipes*	1
17	*Guinardia flaccida*	5	63	*Ceratium furca*	11	**Cyanophyceae (Cyanobacteria)**		
18	*Guinardia striata*	2	64	*Ceratium fusus*	4	108	*Trichodesmium erythraeum*	2
19	*Dactyliosolen mediterraneus*	2	65	*Ceratium trichoceros*	6	109	*Oscillatoria limosa*	3
20	*Bacteriastrum varians*	8	66	*Ceratium massiliense*	1	110	*Oscillatoria raciborskii*	3
21	*Bacteriastrum hyalinum*	1	67	*Ceratium tripos*	3	111	*Oscillatoria sp.1*	6
22	*Pseudosolenia calcar-avis*	3	68	*Ceratium sp.*	1	112	*Oscillatoria sp.2*	2

Table Continued

No.	Scientific name	No. of identified survey sites	No.	Scientific name	No. of identified survey sites	No.	Scientific name	No. of identified survey sites
23	*Rhizosolenia cylindrus*	1	69	*Dinophysis miles*	3	113	*Oscillatori princeps*	2
24	*Rhizosolenia robusta*	1	70	*Dinophysis caudata*	11	114	*Lyngbya sp.*	1
25	*Chaetoceros affinis*	8	71	*Dinophysis hastata*	1	115	*Arthrospira platensis*	9
26	*Chaetoceros abnormis*	5	72	*Dinophysis doryphorum*	1	116	*Anabaena sp.*	4
27	*Chaetoceros curvisetus*	10	73	*Dinophysis sp.*	1	117	*Anabaena cf. viguieri*	1
28	*Chaetoceros coarctatus*	2	74	*Ornithocercus magnificus*	1	118	*Microcystis cf. wesenbergii*	7
29	*Chaetoceros compressus*	3	75	*Histioneis costata*	1	119	*Microcystis sp.*	7
30	*Chaetoceros constrictus*	2	76	*Amphisolenia bidentata*	3	**Chlorophyceae (Chlorophyte)**		
31	*Chaetoceros crinitus*	1	77	*Gymnodinium sanguineum*	1	120	*Pediastrum simplex v. simplex*	9
32	*Chaetoceros diversus*	3	78	*Gonyaulax sp.*	3	121	*Pediastrum boryanum v. boryanum*	1
33	*Chaetoceros distans*	1	79	*Gonyaulax polygramma*	3	122	*Pediastrum duplex v. duplex*	8
34	*Chaetoceros lorenzianus*	7	80	*Gonyaulax rotundata*	5	123	*Pediastrum sp.*	3
35	*Chaetoceros subtilis*	9	81	*Protoperidinium abei*	1	124	*Pediastrum tetras*	4
36	*Biddulphia regia*	11	82	*Protoperidinium cf. brochii*	3	125	*Scenedesmus sp.*	3
37	*Biddulphia dubia*	1	**Bacillariophyceae (Diatoms)**			126	*Scenedesmus quadricauda*	6
38	*Biddulphia reticulum*	1	83	*Protoperidinium conicum*	11	127	*Scenedesmus carinatus*	1
39	*Odontella mobiliensis*	4	84	*Protoperidinium claudicans*	4	128	*Scenedesmus acuminatus var. acumin*	1
40	*Bellerochea horologicalis*	1	85	*Protoperidinium crassipes*	3	129	*Scenedesmus javanensis*	2
41	*Hemiaulus sinensis*	3	86	*Protoperidinium divergens*	1	130	*Staurastrum sp.*	8
42	*Hemiaulus indicus*	1	87	*Protoperidinium elegans*	1	131	*Palmella sp.*	1
43	*Cerataulina bergonii*	1	88	*Protoperidinium oceanicum*	6	132	*Eudorina elegans*	1
44	*Cerataulina compacta*	1	89	*Protoperidinium ovum*	1	133	*Eudorina sp.*	4
45	*Ditylum sol*	11	90	*Protoperidinium thorianum*	1			

Demersal fish: Table 7 shows the demersal fish species identified through the dry and rainy season surveys respectively. In the dry season, in general, fish diversity and abundance were significantly higher in the shallow coastal survey sites (e.g. EC1, EC2, EC4, and EC7) compared to the deeper offshore survey sites. Within the identified species, two species are listed in Vietnam Red Book namely, Bostrichthys sinensis and Anodontostoma chacunda, which were found in the shallow coastal survey sites EC1 and EC2 respectively. Bostrichthys sinensis and Anodontostoma chacunda are classified as "Critical" and "Vulnerable" respectively. In the wet season, the similar trend in term of fish diversity and abundance has been found among sampling sites (shallow sites are more abundance than the off shore sites). However there are differences in the species composition of the economic species with the distribution of the family Sciaenidae to occur in 9/11 sampling sites. This family also contributes for higher biomass of the total catch at the sampling sites of EC8, EC9 in the rainy survey.

Diversity of terrestrial animals

Cat Ba National Park is tropical moist forest on limestone, which harbors a number of endemic and rare species, foremost of which is the endemic Cat Ba Langur Trachypithecus poliocephalus poliocephalus.[10–12] These led to the discovery of new species of *Goniurosaurus*[8] (Figure 8) and *Sphenomorphus*.[13] Among the 40 reptile species recorded from Cat Ba Island, two species are listed in the IUCN Red List (2008), seven species are listed in the Vietnam Red Data Book,[14] four in the CITES appendices (2008), and five species are protected by governmental law (Decree No. 32/2006/ND-CP) (Table 8).

Notes: IUCN: IUCN Red List, VNRB: Vietnam Red Data Book: CR: critically endangered, EN: endangered, VU: vulnerable, LR/nt: near threatened; CITES: I, II = Appendix I and II; Dec. 32: Governmental Decree No. 32/2006/ND-CP: IB = Group IB (prohibited exploitation and use for commercial purpose), IIB = Group IIB (limited exploitation and use for commercial purpose); []: Only photographic record or observation.

Table 7 Results of demersal fish survey

Survey site	Family	Genus/species	No. of individuals	Total and ave. wet weight (g)	Average length (cm)	Status in vietnam red book
In dry season						
EC1	*Sparidae*	*Sparus latus*	1	6	6.5	Not listed
	Taenioididae	*Trypauchen vagina*	2	Total: 12.97 Ave. : 6.5	9	Not listed
	Eleotridae	*Bostrichthys sinensis*	1	23	13	Critical
	Sillaginidae	*Sillago sihama*	1	15.4	12.5	Not listed
	Eleotridae	*Butis butis*	1	4.5	5	Not listed
	Platycephalidae	*Rogadus asper*	1	12.5	11	Not listed
	Platycephalidae	*Cociella crocodila*	1	5	5.5	Not listed
	Cynoglossidae	*Symphurus orientalis*	1	4.5	3.5	Not listed
	Cynoglossidae	*Symphurus orientalis*	1	11	9.5	Not listed
EC2	*Soleidae*	*Heteromycterus japonica*	1	13	8	Not listed
	Sillaginidae	*Sillago sihama*	1	12.5	14.9	Not listed
	Clupeidae	*Anodontostoma chacunda*	5	Total: 60 Ave: 12	15.3	Vulnerable
	Sciaenidae	*Nibea albiflora*	1	26	23.5	Not listed
In rainy season						

Table Continued

Survey site	Family	Genus/species	No. of individuals	Total and ave. wet weight (g)	Average length (cm)	Status in vietnam red book
	Muraenesocidae	*Muraenesox cinereus*	1	36	25	Not listed
	Taenioididae	*Trypauchen vagina*	2	Total: 25.4 Ave. : 12.7	13	Not listed
EC1	*Eleotridae*	*Bostrichthys sinensis*	1	Total: 42 Ave: 14	12.5	Critical
	Sciaenidae	*Nibea soldado*	26	Total: 93.37 Ave: 3.59	7.2	Not listed
	Siganidae	*Siganus fuscescens*	1	7.5	8	Not listed
	Bagridae	*Cranoglanis sinensis*	9	Total: 400 Ave: 44.4	22.3	Not listed
	Bothidae	*Arnoglossus tenuis*	3	Total: 3.13 Ave: 1.04	5	Not listed
EC2	*Clupeidae*	*Anodontostoma chacunda*	2	Total: 30 Ave: 15	16.7	Vulnerable
	Sciaenidae	*Nibea albiflora*	3	Total: 17.04 Ave: 5.68	3.5	Not listed

Table 8 List of threatened reptile species recorded from Cat Ba Island[15]

Scientific name	IUCN	VNRB	CITES	Dec. 32
	2008	2007	2008	2006
Physignathus cocincinus		VU		
Gekko gecko		VU		
[Varanus salvator]		EN	II	IIB
[Python molurus]	LR/nt	CR	I	IIB
Coelognathus radiatus		EN		IIB
Ptyas korros		EN		
Bungarus multicinctus				IIB
Naja atra		EN	II	IIB
Cuora mouhotii	EN		II	

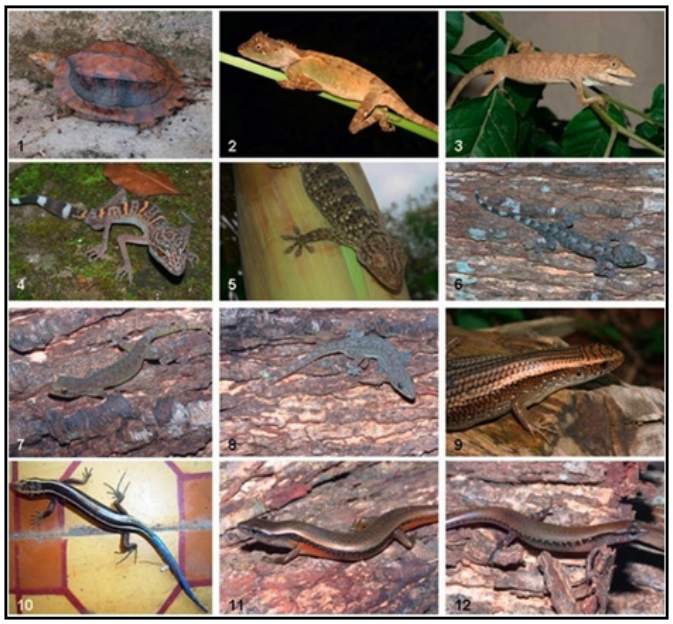

Figure 8 (1) *Cuora mouhotii*. **(2)** *Acanthosaura lepidogaster*. **(3)** *Pseudocalotes brevipes*. **(4)** *Goniurosaurus catbaensis*. **(5)** *Gekko gecko*. **(6)** *Gekko palmatus*. **(7)** *Hemidactylus frenatus*. **(8)** *H garnotii*. **(9)** *Eutropis multifasciatus*. **(10)** *Plestiodon quadrilineatus*. **(11)** *Scincella reevesii*. **(12)** *Sphenomorphus tonkinensis*.[12]

Conclusion

In this study, there are occurrences of three main key habitats: mangrove, coral reefs, and seaweeds/seagrass. These contribute for species diversity and abundance of the natural marine resources available for the local people to exploit. The distribution trends of the living resources are higher abundance in the near shore sites, lower abundance at the offshore sites. These may relate to the biological/physical driven factors such as the available of substrate/habitat, natural food resources or water current. The coastal sites provide the nursery grounds for the economic species where the mangrove forests remain as the shelters.

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Conflict of interest

The authors declare that there are no competing interests regarding the publication of this paper.

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