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; planktonic 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

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.

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 km²) 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.3-5

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 m²).

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 scuba 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.

| 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.

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.
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 membranacea 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           | 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           | Pocillopora decussata | Not listed |
| 7           | Galaxea astreata | Not listed |
| 8           | Galaxea fascicularis | Not listed |
| 9           | Pectinia lactuca | Not listed |
| 10          | Pectiniidae | Echinophyllia aspera | Not listed |
| 11          | Fungiidae | Lithophyton undulatum | Not listed |
| 12          | Sympelasma robusta | Not listed |
| 13          | Lobophyllia hattai | Not listed |
| 14          | Mycedium elephantotus | Not listed |
| 15          | Sympylisia hemprichii | Not listed |
| 16          | Symphyllia, agaria | Not listed |
| 17          | Merulinidae | Menulina ampliata | Not listed |
| 18          | Favia maritima | 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 favinus | Not listed |
| 25          | Cyphastrea serailia | Not listed |
| 26          | Echinopora lamellose | Not listed |
| 27          | Platypoia daelella | 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   | Bastrychia binderi         | Not listed              | AL3, AL5, AL7, AL10    |
| 2      | Polysiphonia sertularioides | Not listed | AL1, AL2, AL10          |
| 3      | Delesseriaceae | Caloglosa ogasawaraensis  | Not listed              | AL2, AL3, AL7          |
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).

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.

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 furca*, *Procentrum micans* and *Dinophysis caudata* 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 domimante 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.
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   | Rhizophoraceae | Rhizophora stylosa   | Not listed             | AL1, AL2, AL3, AL5, AL7 |
| 3   | Kandelia obovata | Not listed           | AL10                   |
| 4   | Bruguiera 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    | Acrastichium aureum | Not listed             | AL10                    |
| 8   | Verbenaceae    | Cleodendrum inerme  | Not listed             | AL2, AL10               |
| 9   | Euphorbiaceae  | Exocarcaria agallocha | Not listed                        | AL3, 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 |
|-----|----------------|-------------------------------|-----|----------------|-------------------------------|-----|----------------|-------------------------------|
| 1   | Paralia sulcata | 42                            | 11  | Chaetoceros lorencius | 83                            | 4   | Ceratium macroceros | 124                          |
| 2   | Hyalodiscus stelliger | 43                            | 3   | Chaetoceros paradoxus | 84                            | 4   | Ceratium massilense | Phylum - Dicytophyceae |
| 3   | Cyclotella striata | 44                            | 9   | Chaetoceros rostratus | 85                            | 2   | Ceratium asymmetricum | Dictyocha fibula |
| 4   | Cyclotella contorta | 45                            | 3   | Chaetoceros substrulis | 86                            | 3   | Ceratium tripitos   | Dictyocha speculum |
| 5   | Cyclotella sp. | 46                            | 2   | Biddulphia regia | 87                            | 10  | Prorocentrum micans | Phylum - Cyanophyceae |
| 6   | Caciodiscus asteromphalus | 48                            | 3   | Biddulphia reticulum | 88                            | 1   | Prorocentrum rathayum | Trichodesmium erythraeum |
| 7   | Caciodiscus occlus-iridis | 49                            | 1   | Hemialus sinensis | 90                            | 127 | Trichodesmium erythraeum | Oscillatoria sp. |
| 8   | Caciodiscus radiatus | 50                            | 1   | Ceratoula bergonii | 91                            | 1   | Dinophysis caudata | Phylum - Chlorophyceae |
| 9   | Caciodiscus granii | 51                            | 1   | Ceratoula compacta | 92                            | 1   | Dinophysis cf. rotundato | Pedasiastrum simplex v. simplex |
| 10  | Caciodiscus cf. subtilis | 52                            | 1   | Ditylum brightwelli | 93                            | 4   | Noctilucina scintillans | Pedasiastrum duplex v. duplex |
| 11  | Caciodiscus sp. | 53                            | 6   | Eucampia zoilus | 94                            | 4   | Gonyaulax sp. | Scenedesmus sp. |
| 12  | Laudenia borealis | 54                            | 3   | Cladocodium bicocauum | 95                            | 9   | Gonyaulax polygramma | 133                          |
| 13  | Skeletonema costatum | 55                            | 5   | Palmeria hardmarniana | 96                            | 1   | Gonyaulax spinifera | Staurastrum sp. |
| No. | Scientific name                  | No. of identified survey sites | No. | Scientific name                  | No. of identified survey sites | No. | Scientific name                  | No. of identified survey sites |
|-----|----------------------------------|--------------------------------|-----|----------------------------------|--------------------------------|-----|----------------------------------|--------------------------------|
| 14  | Leptocylindrus danicus           | 3                              | 56  | Thalassionema frauenfeldii       | 12                             | 97  | Gonyaulax sp.                    |                                |
| 15  | Guinardia flaccida               | 8                              | 57  | Navicula membranacea             | 7                              | 98  | Gonyaulax verior                 |                                |
| 16  | Guinardia striata                | 12                             | 58  | Navicula cancellata              | 2                              | 99  | Gonyaulax rotundata              |                                |
| 17  | Bacteriastrium varians           | 5                              | 59  | Trichodesmium lepidoptera        | 1                              | 100 | Gonyaulax diegensis              |                                |
| 18  | Bacteriastrium hyalinum          | 5                              | 60  | Pleurosigma affine               | 4                              | 101 | Protoperidinium steini           |                                |
| 19  | Thalassiosira eccentrica         | 2                              | 61  | Pleurosigma angulatum            | 1                              | 102 | Protoperidinium conicum          |                                |
| 20  | Thalassiosira lineata            | 6                              | 62  | Pleurosigma sp.1                 | 7                              | 103 | Protoperidinium crassipes        |                                |
| 21  | Thalassiosira sp.                | 2                              | 63  | Pleurosigma sp.2                 | 1                              | 104 | Protoperidinium divergens        |                                |
| 22  | Arthrospira platensis            | 2                              | 64  | Pleurosigma naviculaceum         | 4                              | 105 | Protoperidinium depressum        |                                |
| 23  | Rhizosolenia robusta             | 3                              | 65  | Pleurosigma pelagicum            | 4                              | 106 | Protoperidinium elegans          |                                |
| 24  | Rhizosolenia setigera            | 2                              | 66  | Amphiprora alata                 | 1                              | 107 | Protoperidinium oceanicum        |                                |
| 25  | Rhizosolenia hyalina             | 4                              | 67  | Nitzschia laeziana               | 6                              | 108 | Protoperidinium ovum             |                                |
| 26  | Proboscia alata                  | 9                              | 68  | Nitzschia longissima             | 2                              | 109 | Protoperidinium pelliculatum     |                                |
| 27  | Proboscia alata f. indica        | 1                              | 69  | Nitzschia longissima v. reversa  | 1                              | 110 | Protoperidinium pentagonum       |                                |
| 28  | Proboscia alata f. gracillina    | 1                              | 70  | Nitzschia sigma                  | 4                              | 111 | Protoperidinium leonis           |                                |
| 29  | Proboscia alata f. genuina       | 1                              | 71  | Nitzschia sigma v. intercedens   | 1                              | 112 | Protoperidinium spinulosum       |                                |
| 30  | Chaetoceros affinis              | 12                             | 72  | Pseudonitzschia sp.1             | 8                              | 113 | Protoperidinium spheeroides      |                                |
| 31  | Chaetoceros affinis v. willei     | 1                              | 73  | Pseudonitzschia sp.2             | 2                              |     | Phylum - Dinophyceae             |                                |
| 32  | Chaetoceros abnormis             | 5                              | 74  | Surirella ovalis                 | 5                              | 114 | Protoperidinium sp.              |                                |
| 33  | Chaetoceros curvitatus           | 4                              | 75  | Surirella gemma                  | 2                              | 115 | Peridinium quinquecarnne         |                                |
| 34  | Chaetoceros compactus            | 3                              | 76  | Cambylococcus echinoidis         | 3                              | 116 | Scrippsia sp.                    |                                |
| 35  | Chaetoceros compressus           | 7                              | 77  | Cambylococcus undulatus          | 1                              | 117 | Alexandrium sp.                  |                                |
| 36  | Chaetoceros constrictus          | 12                             |     | Phylum - Dinophyceae             |                               | 118 | Alexandrium pseudogonyaulax      |                                |
| 37  | Chaetoceros decipiens            | 1                              | 78  | Ceratium breve                   | 3                              | 119 | Goniodoma polyedricum            |                                |
| 38  | Chaetoceros denticulatus         | 3                              | 79  | Ceratium furca                   | 11                             | 120 | Diplopapsalis sp.                |                                |
| 39  | Chaetoceros distans              | 2                              | 80  | Ceratium deflexum                | 2                              | 121 | Diplopapsalis sp.                |                                |
| 40  | Chaetoceros dydymus              | 1                              | 81  | Ceratium fusus                   | 11                             | 122 | Zygaenobididinium sp.            |                                |
| 41  | Chaetoceros lauderi              | 1                              | 82  | Ceratium trichoceras             | 10                             | 123 | Obleo sp.                        |                                |
### 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 |
|-----|-----------------------------------------|-------------------------------|-----|-----------------------------------------|-------------------------------|-----|-----------------------------------------|-------------------------------|
| 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  | *Chlamydium biconvexum*                | 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.*                  | 2                             |
| 8   | *Coscinodiscus jonesianus* v. *commutata* | 12                         | 53  | *Pleurosigma sp.*                      | 2                             | 98  | *Peridinium sp.*                       | 1                             |
|     | **Bacillariophyceae (Diatoms)**          |                               |     | **Bacillariophyceae (Diatoms)**        |                               |     | **Bacillariophyceae (Diatoms)**        |                               |
| 9   | *Coscinodiscus marginatus*               | 1                             | 55  | *Nitzschia lorenziana*                 | 3                             | 100 | *Ganiodoma polyedricum*                | 1                             |
| 10  | *Coscinodiscus cf. subalis*              | 1                             | 56  | *Nitzschia longissima*                 | 1                             | 101 | *Lingulodinium polyedra*               | 5                             |
| 11  | *Asteromphalus cleveanus*                | 1                             | 57  | *Pseudo-nitzschia sp.* (P. cf. *pungens*) | 3                             | 102 | *Diplopsalis sp.*                      | 2                             |
| 12  | *Thalassiosira eccentrica*               | 3                             | 58  | *Camptodiscus 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 falkatum*                    | 1                             | 107 | *Pedolamprus 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  | *Bacteriastrium varians*                 | 8                             | 66  | *Ceratium massiliense*                 | 1                             | 110 | *Oscillatoria raciborskii*             | 3                             |
| 21  | *Bacteriastrium hyalinum*                | 1                             | 67  | *Ceratium tripos*                      | 3                             | 111 | *Oscillatoria sp.*                     | 6                             |
| 22  | *Pseudosolenia calcar-avis*              | 3                             | 68  | *Ceratium sp.*                         | 1                             | 112 | *Oscillatoria sp.*                     | 2                             |
| 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 | Oscillator princeps                     | 2                              |
| 24  | Rhizosolenia robusta                        | 1                              | 70  | Dinophysis caudata                          | 11                             | 114 | Lyngbya sp.                            | 1                              |
| 25  | Chaetoceros affinis                         | 8                              | 71  | Dinophysis hastata                          | 1                              | 115 | Arthospira platensis                   | 9                              |
| 26  | Chaetoceros abnormis                        | 5                              | 72  | Dinophysis doryphorum                       | 1                              | 116 | Anabaena sp.                           | 4                              |
| 27  | Chaetoceros curvatus                        | 10                             | 73  | Dinophysis sp.                              | 1                              | 117 | Anabaena cf. viguieri                  | 1                              |
| 28  | Chaetoceros coarctatus                      | 2                              | 74  | Ostmhocercus magnificus                     | 1                              | 118 | Microcystis cf. wesenbergi             | 7                              |
| 29  | Chaetoceros compressus                      | 3                              | 75  | Histioneis costata                          | 1                              | 119 | Microcystis sp.                        | 7                              |
| 30  | Chaetoceros constrectus                     | 2                              | 76  | Anphisolenia bidentata                      | 3                              | 120 | Pediastrum simplex v. simplex          | 9                              |
| 31  | Chaetoceros crinitus                        | 1                              | 77  | Gymnodinium sanguineum                      | 1                              | 121 | Pediastrum boryanum v. boryanum       | 1                              |
| 32  | Chaetoceros diversus                        | 3                              | 78  | Gonyaulax sp.                               | 3                              | 122 | Pediastrum duplex v. duplex           | 8                              |
| 33  | Chaetoceros distans                         | 1                              | 79  | Gonyaulax polygramma                        | 3                              | 123 | Pediastrum sp.                         | 3                              |
| 34  | Chaetoceros lorenzianus                     | 7                              | 80  | Gonyaulax ratundata                         | 5                              | 124 | Pediastrum tetras                      | 4                              |
| 35  | Chaetoceros subtilis                        | 9                              | 81  | Protoperidinium abei                        | 1                              | 125 | Scenedesmus sp.                        | 3                              |
| 36  | Biddulphia regia                            | 11                             | 82  | Protoperidinium cf. brochii                 | 3                              | 126 | Scenedesmus quodricauda               | 6                              |
| 37  | Biddulphia dubia                            | 1                              | 83  | Protoperidinium conicum                     | 11                             | 127 | Scenedesmus carinatus                  | 1                              |
| 38  | Biddulphia reticulum                        | 1                              | 84  | Protoperidinium claudicans                  | 4                              | 128 | Scenedesmus acuminatus var. acumin   | 1                              |
| 39  | Odontella mobilensis                        | 4                              | 85  | Protoperidinium crassipes                   | 3                              | 129 | Scenedesmus javanensis                 | 2                              |
| 40  | Bellerocrea horologica                      | 1                              | 86  | Protoperidinium divergens                   | 1                              | 130 | Staurastrum sp.                        | 8                              |
| 41  | Hemiaulus sinensis                          | 3                              | 87  | Protoperidinium elegans                     | 1                              | 131 | Palmello sp.                           | 1                              |
| 42  | Hemiaulus indicus                           | 1                              | 88  | Protoperidinium oceanicum                   | 6                              | 132 | Eudorina elegans                       | 1                              |
| 43  | Cerataulina bergonii                        | 1                              | 89  | Protoperidinium ovum                        | 1                              | 133 | Eudorina sp.                           | 4                              |
| 44  | Cerataulina compacta                        | 1                              | 90  | Protoperidinium thorianum                   | 1                              | 134 | Chlorophyceae (Chlorophyceae)          |                                |

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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.

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 | Sparidae | Sparus latus | 1 | 6 | 6.5 | Not listed |
| | Taenioididae | Trypauchen vagina | 2 | Total: 12.97 | Ave.: 6.5 | Not listed |
| | Eleotridae | Bostrichthys sinensis | 1 | 23 | 13 | Critical |
| EC1 | 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 |
| EC2 | Cynoglossidae | Symphurus orientalis | 1 | 11 | 9.5 | Not listed |
| | 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 | Vulnerable |
| | Sciaenidae | Nibea albiflora | 1 | 26 | 23.5 | Not listed |

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. These led to the discovery of new species of Goniurosaurus (Figure 8) and Sphenomorphus. 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, 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.
| Survey site | Family | Genus/species | No. of individuals | Total and ave. wet weight (g) | Average length (cm) | Status in vietnam red book |
|-------------|--------|---------------|--------------------|-------------------------------|--------------------|-----------------------------|
| EC1         |   | Muraenesocidae | Muraenesox cinereus | 1 | 36 | 25 | Not listed |
| EC1         |   | Toeniodaeidae | Trypauchen vagina | 2 | Total: 25.4 | 13 | Not listed |
| EC1         |   | Eleotridae | Bostrichthys sinensis | 1 | Total: 42 | 12.5 | Critical |
| EC1         |   | Sciaenidae | Nibea soldado | 26 | Total: 93.37 Ave: 3.59 | 7.2 | Not listed |
| EC1         |   | Siganidae | Siganus fuscescens | 1 | 7.5 | 8 | Not listed |
| EC2         |   | Bagridae | Cranoglanis sinensis | 9 | Total: 400 Ave: 44.4 | 22.3 | Not listed |
| EC2         |   | Bothidae | Arnoglossus tenius | 3 | Total: 3.13 Ave: 1.04 | 5 | Not listed |
| EC2         |   | Clupeidae | Anodontostoma chacunda | 2 | Total: 30 Ave: 15 | 16.7 | Vulnerable |
| EC2         |   | 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**

| Scientific name | IUCN | VNRB | CITES | Dec. 32 |
|-----------------|------|------|-------|--------|
| 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 | |

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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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