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Current Status of the Marine Ecosystems and Their Vulnerability Under the Climate Change Impacts in the Catba World Biosphere Reserve

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Abstract

Cat Ba Islands have been considered as the world biosphere reserved by UNESCO in 2004 due to its spectacular landscape and invaluable characteristics of terrestrial and marine ecosystems. The marine ecosystems surrounding Cat Ba Islands consist of three key ecosystems such as coral reefs, mangrove forest and seagrass beds. They play as the crucial habitats for 985 associated marine species and contribute marine ecosystem services for local communities.

Though, there are several threats on the health of marine ecosystems in this region, the climate change has been rated as the critical impact in relation with the abnormal weather conditions (fresh water runoff due to heavy rain, sea surface temperature increasing, saline intrusion, coastal erosion…). According to the climate change scenarios, the sea level rise in this area may reach 65cm up to 100m and the sea surface temperature increase from 1.6 - 3.5°C. If these scenarios come true, the consequences will damage the marine ecosystems in several manners.

The tendency of reduction in the live coral coverage of 50% from 1999 - 2004 related with the white worldwide coral bleaching phenomenon of 1997 - 1998 (abnormal sea surface water increased) or changes occurred in the hard coral communities where the coral branching colonies have been replaced by the massive coral colonies. In recent years, the saline intrusion in combination with the coastal erosion lead to reduce the mangrove area with the ratio of 1 -2 ha/year and negative changes also happen with the breeding grounds for the marine species associated with the existing mangrove trees. For the seagrass beds, the sea level rise directly impacts on specific areas where the seagrass normally can be found at the intertidal or low tide areas. This will generally prevent the photosynthesis processes in marine plants and bury the seagrass on the muddy layers. Thus, the seagrass beds in the Cat Ba islands may be extinction in the near future as well.

Key words: marine ecosystems, climate change, biosphere reserve

1. Introduction

Climate change is a natural phenomenon. Climate keeps changing all the time. The fact that climate changes is not in itself a threat, because, obviously, in the past human beings have adapted to all kinds of climate changes (Dasgupta et al, 2007). However, the ratios of climate change at the present time many times higher than the past. The main reason is caused by emissions of greenhouse gases have increased markedly since the early 20th century. This phenomenon is the real threats to the natural landscape, biodiversity and other natural resources of coastal and marine areas. According to the UN Convention on Climate Change (United Nations Framework Convention on Climate Change), the climate change is "a change of climate which it directly or indirectly by

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human activities, as change the composition of the global atmosphere and adds to the natural changes in climate observed at time series". Vietnam has been rated as the 5th country in the world to be seriously affected by climate change effects, especially at the coastal areas and remote islands due to the highly dense population distributed at the areas and there were no planned coastal development in the past did consider climate change. Therefore, it is likely that plans will not fit in the new situation or make the situation worse if they cannot adapt (UNEP, 2010).

The Cat Ba Islands covers an area of over 400 km2 with 388 islands and islets, is a high biodiversity center, associated with many favorable conditions and great potential for conservation and development of marine eco-tourism. Cat Ba Islands with the special values of landscape, ecology as the largest tropical rain forest on limestone Islands in Vietnam, mangrove forest with beautiful scenery, large coral reefs, is a concentration place of the entire typical ecosystem types of marine and insular ecology in Viet Nam. In 2004, Cat Ba was awarded as the world biosphere reserve by UNESCO to contribute as a safe buffer zone for Ha Long Natural World Heritage Site located at the northern part (Fig. 1).

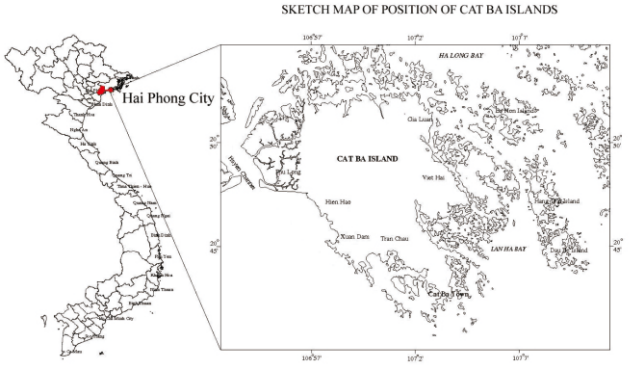


Fig. 1. Location of Catba world biosphere reserve.

The marine resources in this area are characterized by distinct features: (1) Areas with high biological diversity; (2) approved World Biosphere Reserve; (3) Rapidly growing forms of tourism. Though, there are several driven factors cause the degradation of marine resources at the ecosystem levels but the climate change can make the critical threats with two major challenges: (1) Pressure on ecosystems have been damaged by pollution, the destruction and fragmentation of habitats or the overexploitation of natural resources; (2) The planned coastal development in the past did not consider climate change. Therefore, it is likely that plans will not fit in the new situation or make the situation worse if they cannot adapt. This paper intends to contribute a revision of current status of key marine ecosystems and their vulnerability under the climate change impacts. Thus, it provides the scientific baselines for managing adaptation through ecosystem based concept.

2. Biodiversity values of the Cat Ba island

1) 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 1053 species are terrestrial species occupies 51.7% of the total species while the marine species occupies 48.3% with 985 species (Table 1).

Table 1. The species composition recorded in Cat Ba island.

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

(Source:Thanh, 2002)

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 humans. 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.

2) Diversity of major marine ecosystems

Coral reefs:

Mainly distribute 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, Coc Cheo. The coral reef areas are the major fishing grounds for reef fisheries due to high values of the coral reef fishes and associated reef species (Fig. 2).

Fig. 2. Distribution of coral reefs in Cat Ba island (Quan, 2012).

The coral reefs in Cat Ba - Halong area are represented for the fringing reef types and two addition types of islandish 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.

Mangrove forest:

The mangrove forest and the coral reefs are the invaluable natural resources of the tropical countries in gerneral and Cat Ba in particular. They play as the sources of genetic reservation, increasing of the natural biomass and stablization 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 (Fig. 3).

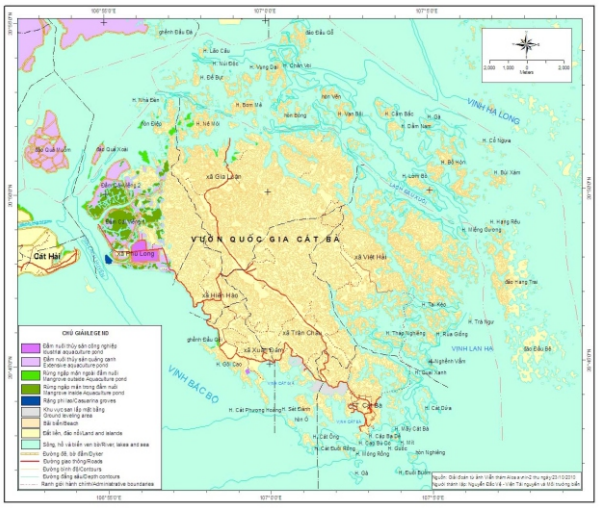


Fig. 3. Distribution of mangrove forest in Cat Ba island (Quan, 2012)

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). 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.

Seagrass bed:

Seagrass distribution in Cat Ba Island in the narrow range like leopard style mainly on tidal marshes (with the carpet of mangroves) in Gia Luan and in aquaculture pomds 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 (Fig. 4).

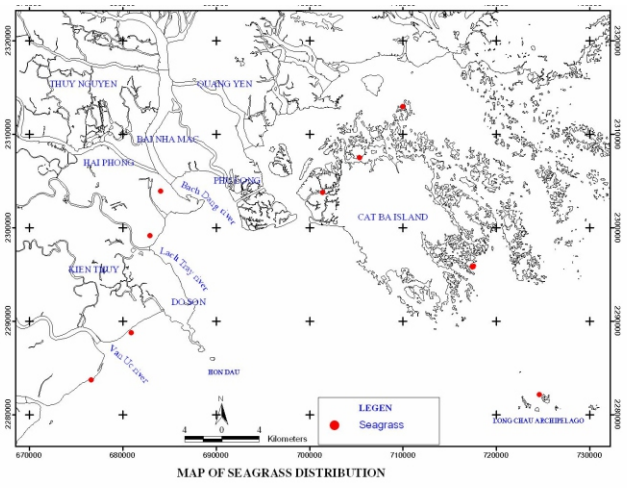


Fig. 4. Distribution of seagrass in Cat Ba island (Quan, 2012).

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.

Marine kaster lake:

It can be rated as the unique chracter for the Ha Long - Cat Ba area. Up to date, 62 lakes have been recorded with more than 30 lakes were initially assesed in Lanha bay and adjacent areas (Thanh, 2002). The lakes have relatively small area in range of 0.8ha to 28.8ha. Biodiversity in these lakes are rarely diverse and need more studies about the evolution and speciation because they are almost isolated with the waters outside. Furthermore, the beautiful landsacape made by the lakes favors the development of the eco-tourist activities of the Cat Ba island.

3. Vulnerability and impacts of climate change on marine ecosystems

1) Climate change scenarios in the Cat Ba - Ha Long Bay and the Red River Delta

Up to date, there are no specific studies on climate change and the effects of climate change to biodiversity of the Cat Ba. However, some studies at a broader level have been carried out including the Red River delta area and / or for the whole territory of Vietnam. Most important publications named: "Climate change scenarios and sea level rise for Vietnam" by the Ministry of Natural Resources and Environment, published in 2009 and the climate change 2007: Working Group II: Impacts, Adaptation and Vulnerability (ML Parry and Intergovernmental Panel on Climate Change. Working Group II., 2007). Accordingly, the scenarios of climate change and sea level rise for Vietnam in the area is calculated based on the extent of greenhouse gases released to the environment at the time of 2020, 2050 and 2100 (Table 2).

Table 2. Climate change scenarios in red river delta

Scenario	Average annual increasing of temperature (^{o}C) to compare with period 1980-1999			Sea level rise (cm) to compare with period 1980_1999		
	2020	2050	2100	2020	2050	2100
B1	0,5	0,9	1,6	11	28	65
B2	0,5	1,2	2,4	12	30	75
A2	0,5	1,3	3,1	12	33	100

(Source: MONRE, 2009)

Where:

B1: low emission scenarios, describe a perfect world relative development in the direction of the least greenhouse gas emissions, very low population growth and rapid economic change in the direction and information services, the international agreement to reduce the emission of greenhouse gases to be fully implemented.

B2: medium emissions scenario, describes the rapidly developing world, the population increased continuously but at a rate lower than A2; emphasis on local solutions instead of global economic stability, society and the environment; average level of economic development; technological change slower than B1.

A2: high emissions scenario describes a heterogeneous world on a global scale, with a very high population growth, slow technological innovation or the maximum use of fossil energy.

2) Impacts of climate change on marine biodiversity at the global level

Biodiversity on earth has been under pressure from the people, climate change reinforces the degree of threats. Climate change, especially the increase in temperature affects the reproductive period and the migration of many species, growth up period, the incidence of parasitic infection and creates more new diseases. It is possible in the future; the distribution of the species on earth, along with the density and number of individuals of the species will have been changed by the change of their habitat. The component of most ecosystems today is likely to change and that change is a serious threat to the species with narrow distribution (as the endemic), or species currently at risk of extinction. Furthermore, the invasive species will thrive in the new situation, and that's one of the long-term consequences that ecosystems suffer (Fig. 5).

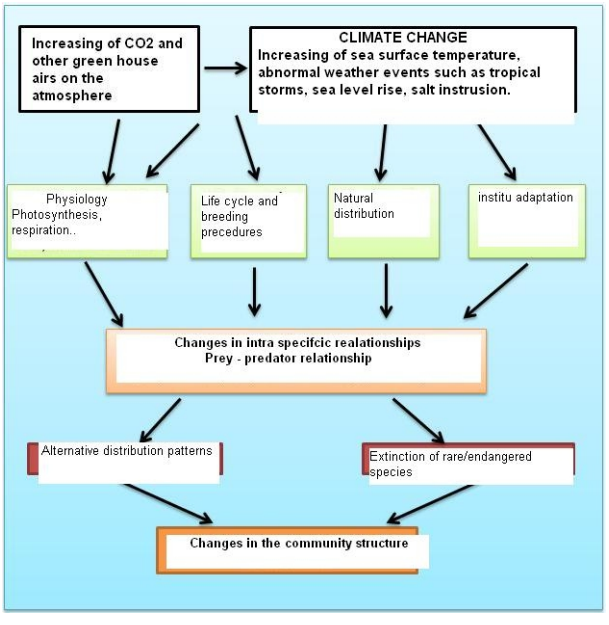
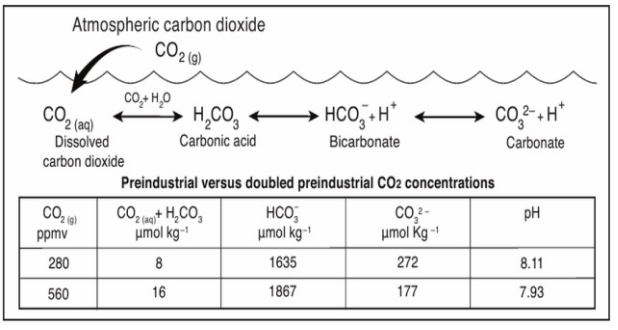


Fig. 5. Impacts of climate change on the marine biodiversity(Hughes, 2000).

3) Climate change impacts on the major marine ecosystems at the Cat Ba island

Coral reefs:

At the global level, acidification in combination with other factors such as temperature increased, the number of storms ....will increase the risk of destruction of coral reefs far more than the individual elements. The increase in the concentration of CO3 ions will reduce the ability to synthesize CaCO3, affect cell proliferation and coral skeletons. Calcification rate of most coral reefs will be reduced from 20-50% in 2050. Some evidences from previous studies noted that the growth of existing coral was reduced by about 15% but it was not clear that the sea water acidification or increased temperature or other factors to be the main cause of this phenomenon. The reduced amount of calcium in the bones cause weakens calcium skeleton and not resistant against a threat from erosion, cyclones and coral feeding organisms (Figure 6).



Preindustrial versus doubled preindustrial CO_2 concentrations

$CO_{2\,(g)}$ ppmv	$CO_{2\,(aq)} + H_2CO_3$ µmol kg^{-1}	HCO_3^- µmol kg^{-1}	CO_3^{2-} µmol Kg^{-1}	pH
280	8	1635	272	8.11
560	16	1867	177	7.93

Fig 6. Schematic diagram of CO_2 absorption in the sea water(Eakin et al, 2010).

At the local level of Cat Ba island, coral reefs form the fringing reef type at narrow area around limestone islands and distribution depth in range from the intertidal to a depth of 6m. The distribution of coral reefs concentrates in the range from 1 to 3 m depth. Because at such a low depth distribution for very vulnerable to changes in surface water temperature anomaly. A very noticeable feature is the turbidity of the water in the coral reefs in the waters of Cat Ba - Ha Long is relatively high with a large amount of suspended matter content. The coral reefs distribute in a narrow space with a maximum depth of about 7 meters (including concentrated at a depth of 1-3m) and above steep cliffs. At the present time, the number of coral species has declined dramatically with the disappearance of most of the branching coral of Acropora and significant dominant species of the genus Goniopora (Ngai and Yet, 2004). The live coral cover decreased significantly up to 50% due to various causes such as water pollution, turbidity increases (Fig. 7).

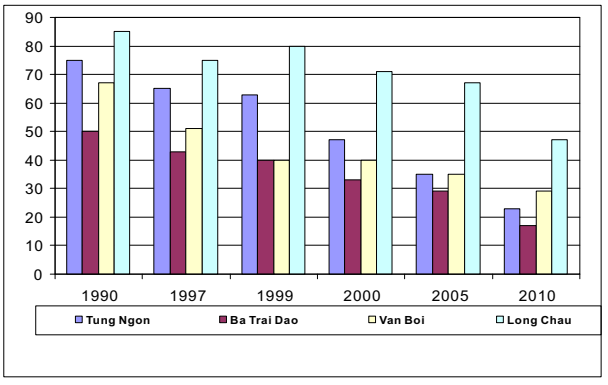


Fig. 7. Temporal changes in live coral coverage at Cat Ba islands(Quan, 2012).

In the future, sea level rise 65 cm (B1), 75 cm (B2) and 100 cm (A2) in 2100, along with an increase in temperature from 1.6 to 3.1°C, the ability of the reefs to be destroyed completely seems very high. Some areas have well-developed coral and low water turbidity located far inland as Long Chau island, the temperature rise and ocean acidification will become the main causes of the degradation in the health of coral communities here.

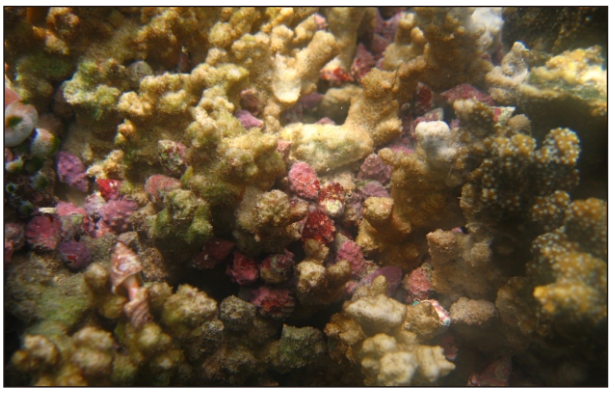


Fig. 8. Outbreaks of the Gastropod Drupella spp - coral eater after the white bleaching event of 1997 - 1998 at coral reef sites of Cat Ba Islands (Quan, 2002).

Seagrass bed:

The seagrass species normally distribute at the intertidal area, where day long road out of the water or the water level is very shallow at low tide, so that the temperature at that time seems relatively high. Moreover, the seagrass species also have temperature tolerance limit, if the limit passes over for a long time will cause the death of seagrass. Temperature also affects the distribution of seagrass through the impact on grass seed germination processes. The sea level rise impacts on the seagrass through a reduction in the amount of light for photosynthesis process of grass, which affects the distribution and productivity. If sea level rises of around 50cm, the growth of grass in the future will be reduced from 30-40%. Sea level rise also increases the tidal flow, thereby limiting the depth to which seagrass can be distributed to and reduction of seagrasses's distribution area. Sea level rise causes salinization of the brackish water basins in coastal estuaries or bays. As salinity increases, some seagrasses react by reducing the growth rate of seedlings; and dispersal areas (Tien, 2002).

Compared to the climate change scenarios for Vietnam, this is one of the biggest challenges to the seagrass beds at Cat Ba islands. With the temperature increases from 1.6 to 3.1 °C and the sea level increase 65-100cm, the estimated number of about 50% of the total area of seagrass in the area would be destroyed. Moreover, in addition to the climate change, the growing pressures from the needs of economic development, environmental pollution ... Thus, the distribution area of sea grass rapidly decreases and in danger of being completely disappears if no further emerging solutions to protect this important marine ecosystem.

Fig. 9. Degradation of the seagrass bed (Ruppia maritima) at Cat Ba island in relation with saline intrusion (Luong, 2011).

Mangrove forest:

Sea level rise is the most serious problem faced by mangroves in the future. The coastal erosion Sea level rise is the most serious problem faced by mangroves in the future. The coastal erosion and accretion depends on the geomorphological characteristics of mangroves, which affects

source sedimentation, sediment composition and mode of sediment transport. Small particles of sediment transfer and deposition in mangrove following the tidal stream at the time of high tide due to the flow slow down when exposes to the dense root system of the mangrove trees. But in terms of floods or rising sea levels, the process does not take place but happens on the contrary; the sediments are washed out from the forest causes erosion and can even destroy the root system of mangrove trees. This erosion also destroys the organic layer from the leaves and the microbial decomposition creates an important source of nutrients for the mangrove trees. In addition, storms and other extreme climate events also destroy mangrove forests through physical impacts cause erosion sediment surface, broken branches, uprooted roots… The devastated areas were also unlikely to recover due to young trees would not grow up (UNEP, 2010).

The increasing in temperature will impact to mangroves by various manners: 1. Changes in species composition of the forest; 2. Change the physical characteristics of trees such as flowering and fruiting time...; 3. Increase productivity of mangrove trees with the condition of temperature does not exceed the tolerance limit of the tree; expand distribution of mangrove trees to areas with higher latitude. The CO2 concentration in the atmosphere increases has a positive impact on the mangrove trees by increasing the productivity and growth of plants (Cuong, 2012).

In the eastern part of Cat Ba (Phu Long commune), the sea invasion push the sand dunes/sand bars towards the shore with the length of 3km covering a large area of the mangrove forest. Each year, 1 - 2 ha of mangrove died. Due to the extending of the submerge time, the seedling mangrove trees cannot attach on the substrate lead to reduction of natural recovery and increasing of the degradation trends (Quan, 2012).

Fig.10. Mass mortality of mangrove trees in relation with the sea invasion(Thanh, 2002).

4. Discussion

Due to the understanding of climate change impacts on marine resources in Viet Nam is still very limited, there is no research-depth quantitative data based on the long term monitoring at the integrated research program. Therefore, the task of assessing the adaptability of marine resources to the challenges of climate change is still very difficult with the limitation of initial outcomes. However, the results of monitoring done over many years in the waters of Cat Ba have shown that corals cannot disappear completely before the effects of climate change but it would have to adapt for changes in the community structure. For example, the dominant species changes from branching corals (more sensitive to changes in water turbidity) to massive corals (less sensitive to turbidity). This change also has the downside of it in altering the species composition of associated marine communities, meaning that the organisms on the reef resources will also alternate substantially.

The adaptation and mitigation of the consequences of climate conditions and adverse weather such as floods, droughts or storms must be the responsibility and duty of every citizen and society. Moreover, the solutions need to be adapted at the regional level and the local level as well, in order to minimize the negative impacts. The self-adaptation of the ecosystem is not enough to withstand with the impacts of climate change, especially in a long term period. The following measures should be implemented:

- Application of the PES scheme (Payment for ecosystem services) in order to cut down the CO_2 emission to the atmosphere and discharge of the pollutants to the marine environment.
- Artificial restoration of the key habitats: coral reefs, seagrass beds and mangrove forest
- Enhancement of the capacity building and public awareness (Tourist, fishery, local authority), involvement of stake holders to join the fighting campaigns for climate change.

The goal of the above adaptive measures aims to reduce the harmful aspects of climate change and minimize the risk to ecosystems, provides an opportunity to reconstruct and restore the ecosystem. The strategic adaption needs to be the necessary flexibility in the management of critical ecosystems, improve the adaptability of species and ecosystems

and minimize the social and environmental pressures. It is in need to put more efforts on studies of nature climate change in the Cat Ba world biosphere reserve, linkages of the negative effects on the coastal/marine ecosystems and poverty alleviation in region. The science sounds of management should support the ecosystem based management to deal with the balance between conservation and economic development in a high dynamic socio - economic region.

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