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SCIENCE AND TECHNOLOGY**

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**RESEARCH AND PROPOSED SOLUTIONS FOR
BIODIVERSITY MANAGEMENT IN THE ROCKY
INTERTIDAL ZONE OF SOME TYPICAL ISLANDS IN THE
EAST-NORTH SEA OF VIETNAM**

Major: Management of Natural Resources and Environment

Code: 98.50.101

SUMMARY OF THE DOCTORAL THESIS

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INTRODUCTION

1. The urgency of the thesis

Vietnam is a coastal country, with 3,260 km of coastline, and possesses many islands and archipelagos with many ecosystems with very high biodiversity. In particular, the intertidal reef ecosystem has very specific features in terms of ecology, environment, biodiversity, and benefits.

The tidal zone along the island is important for biodiversity and resource development, contributing to the regeneration of marine resources. The coastal area of some islands in the Northeast region is characterized by a rocky reef ecosystem, which plays an important role in biodiversity, supplementing biodiversity for neighboring ecosystems and creating livelihoods for people.

However, at present, the reef ecosystem is under many impacts from nature and human activities. Meanwhile, there have not been any in-depth studies on the intertidal zone of rocky reefs, as well as no solutions to manage and protect biodiversity in this area.

The value and the important role of rocky reef intertidal zone in terms of biodiversity, ecology, geology, and environment; along with the current status of research and management, the selection is a topic with the title *“Research and proposed solutions for biodiversity management in the rocky intertidal zone of some typical islands in the Northeast sea of Vietnam”*.

2. Research objectives of the thesis

- Assessing the biodiversity value of the rocky intertidal zone of 3 main islands in the Northeast Sea of Vietnam (Bach Long Vi, Co To, Cat Ba).

- Identify factors affecting biodiversity and propose solutions to protect, manage and conserve the biodiversity of the study area.

3. The main research contents of the thesis

Content 1: Determining the basic features of biodiversity in the rocky intertidal zone of Bach Long Vi, Co To, and Cat Ba islands.

Content 2: Determining factors affecting biodiversity in the rocky intertidal zone.

Content 3: Proposing solutions to manage biodiversity in the rocky intertidal zone.

CHAPTER 1. OVERVIEW

1.1. Research situation in the world

Research on intertidal reef ecosystems has been conducted by ecologists around the world since early. *Before 1960*: Studies mainly focused on the description of rocky intertidal reefs and speculation about the cause of the division of the intertidal zone. *Period 1960-1980*: Experimental studies with the subjects of living and migratory organisms in the rocky intertidal reefs, focusing on the predator-prey relationship, the results showed the possibility of Predation by migratory organisms is an important factor contributing to the structure of a rocky intertidal reef complexes

Period 1980-2005: Research on the role of ecosystems and external impacts. Marine ecologists focus their research on the function of the nursery and spawning grounds of some aquatic species in the rocky intertidal reefs. The research results have identified: The important role of rocky intertidal reefs in seed dispersal; Causes affecting the ability to disperse and store seed resources in the rocky

intertidal reefs; The ecological connection between the rocky intertidal reefs and the neighboring areas.

The period from 2005 to the present: Studies have provided very detailed scientific information on a rocky intertidal reef from species composition, ecological linkage, or species distribution to different tidal zones. Because there are many invasive impacts on the rocky intertidal reef, scientists have focused on research to assess the impact of the relationship between humans and the ecological environment..

1.2. Research situation in Vietnam and the study region

The first studies on the intertidal zone in Vietnam were described by Fischer in the 1950s on the communities distributed in the intertidal zone of Vung Tau. Then, a detailed study of the rocky intertidal zone of major reefs in Nha Trang Bay was carried out by Tran Ngoc Loi.

In 1961, the Soviet-Vietnam cooperation program studied the tidal zone of the Gulf of Tonkin. Several Soviet-Vietnamese studies in the waters and coastal waters of South Vietnam were carried out in the years 1980-1984. In 2005, intertidal surveys were carried out by R/V Akademik Oparin in Nha Trang and Van Phong bays. This work summarizes the results of studies on the tidal zone of Vietnam from the years 1950 to 2005. The author has summarized research results in 22 areas from North to South Vietnam. Studies have statistics that there are 1,664 species and subspecies of large benthic organisms (278 species of plants and 1,386 species of animals) distributed in the intertidal zone of Vietnam.

Quang Ninh - Hai Phong area has thousands of large and small islands with 04 island districts (Co To, Van Don, Cat Hai, Bach Long Vi). Studies on biodiversity in the intertidal zone in the East-North Sea have been carried out quite a lot, and have fully assessed the species

composition, reserves, and distribution density. However, there has not been a separate study on the rocky intertidal reefs.

Related studies show that the islands in the Northeast, with the majority of limestone islands or rock bottom shelf, have created quite wide reef tidal flats, the widest is Bach Long Vi up to 500m. The intertidal reefs with their characteristics (large impact of tides, temperature, etc.) create their typical biodiversity in this area.

- *Biodiversity in Co To intertidal zone*: Studies from 1973 to 2000 in Co To - Thanh Lan have recorded 97 species of zooplankton; 208 species of benthic animals belonging to 128 genera, 63 families, of which: Molluscs 151 species, of class Crustaceans 36 species, phylum 15 species and echinoderm 5 species, 102 hard corals belonging to 13 families, 37 genera. Recent studies have recorded: 15 species of mangroves; 66 species of seaweed; 213 species of phytoplankton; 97 species of zooplankton; 208 species of benthic animals; 76 species of hard corals; 133 reef fish species. The average number of benthic animals was 717 fish/m² and the weight was 42.95 g/m².

- *Biodiversity in Cat Ba intertidal zone*: Studies on biodiversity in Cat Ba intertidal zone have recorded 79 species of seaweed, 207 species of phytoplankton, 79 species of zooplankton, 81 species of hard coral, and 196 fish. Benthic invertebrates have 532 species belonging to 270 genera, 115 families, and 11 classes of 4 phyla: Arthropods; Molluscs, and echinoderms in Cat Ba waters. There were mollusks (261 species), worms (145 species), crustaceans (113 species), and echinoderm (13 species); the number of macrobenthos in the intertidal ecosystem reached an average of 173.25 individuals/m².

- *Biodiversity of Bach Long Vi intertidal zone*: There have been many studies on biodiversity in the Bach Long Vi sea area. Of which, studies have recorded that in the Bach Long Vi intertidal zone, there are 312 species of wildlife, including 3 species of aquatic animals, 109 species of crustaceans, 121 species of mollusks, 29 species of echinoderms; 46 species of seaweed; 59 species of economic value; 11 species are recorded in the Vietnam Red Book (2007) and 1 species in the IUCN Red List (2012).

1.3. Current status of biodiversity management in the rocky intertidal zone

- The system of legal documents on biodiversity management is quite complete, such as Law on Fisheries 2017, Law on Biodiversity 2008, Decree 42/2019/ND-CP dated May 16, 2019, of Government... However, there is no separate management regulation for rocky intertidal reefs.

- The rocky intertidal reefs and islands in the Northeast have been concerned and managed. However, in many places, the management is still not strict, so many reefs are still invaded by socio-economic activities.

CHAPTER 2. RESEARCH SUBJECTS AND METHODS

2.1. Research subjects

Biodiversity in the intertidal zone, focusing on macrobenthic, seaweed, and some economic fish species in Co To sea.

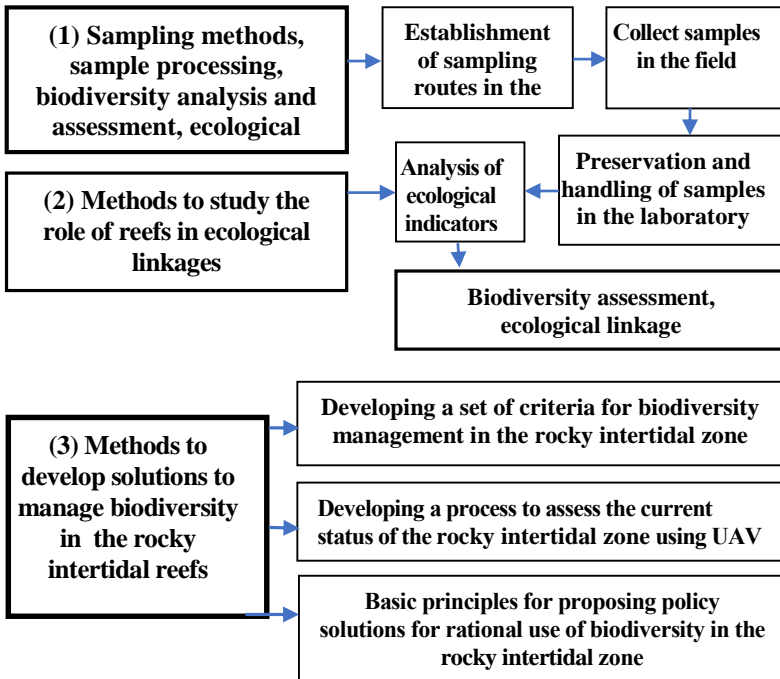
2.2. Research area

Intertidal reefs at three islands in the Northeast, including Bach Long Vi, Cat Ba (Hai Phong City), and Co To (Quang Ninh Province).

2.3. Research space

The research space is limited to the intertidal zone at the island's reefs according to the concept of Vaillant (1899).

2.4. Research Methods: The general scheme of the research methodology for the thesis is summarized as follows:



CHAPTER III. RESEARCH RESULTS AND DISCUSSION

3.1. Current status of biodiversity in the rocky intertidal zone of the study area

3.1.1. Current status of macrobenthic in the study area

3.1.1.1. Diversity of species composition and distribution of benthic animals

The survey results on benthic animals distributed in the rocky intertidal reefs in the study area recorded 170 species belonging to 81 families, 38 orders, 9 classes, and 4 branches. There were Mollusca 92 species, accounting for 51.1% of the total species; phylum Annelids (Annelida) 29 species (17.0%); phylum Echinodermata 26 species (15.3%), phylum Arthropoda 23 species, (13.5%).

Among the 9 classes of benthic intertidal animals, the gastropod class (Gastropoda) accounted for the highest number of species with 49 species (accounting for 28.8% of the total species); class Bivalvia 41 species (24.1%); class Polychaete 29 species (17%); class Soft crustacean (Mollacostraca) 23 species, (13.5%). The remaining classes include Sea cucumbers, Sea stars, sea urchins, snake tails, and many species with few species, ranging from 3 species to 9 species/class (Figure 3.1).

The number of species in each study area is very different. The analysis results showed that Bach Long Vi (BLV) recorded 102 species, Co To (Cô Tô) recorded 71 species and Cat Ba (Cát Bà) recorded 61 species.

The structure of species composition also differs between the study areas, specifically:

(1) *Bach Long Vi*: Molluscs 68 species (accounting for 66.67%), echinoderms 14 species (13.73%), Arthropods 11 species (accounting for 10.78%), Worms 9 species (8.82) %).

(2) *Co To*: Molluscs 23 species (accounting for 32.39%), echinoderms 19 species (26.76%), crustaceans 17 species (23.94%), Worms 12 species (16.9%).

(3) *Cat Ba*: Molluscs 34 species (accounting for 55.74%), echinoderms 11 species (18.03%); Crustaceans 08 species and Polychaetes 08 species (13.11%).

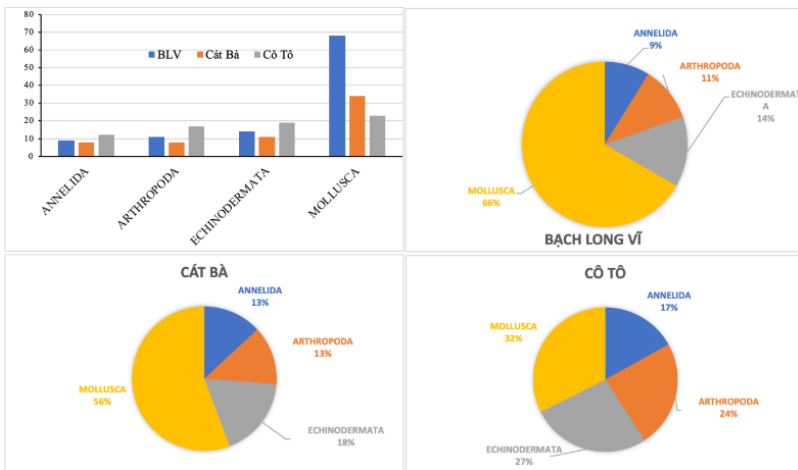


Figure 3.1. Structure of species composition according to taxon level
3.1.1.2. Biodiversity of benthic fauna in the study area

In the study areas, there are benthic organisms that are relatively different in density and mass. The density and biomass of benthic animals fluctuate in space and time. The density and biomass of benthic animals recorded in the areas are as follows:

(1) BLV density ranges from 6-28 individuals/m²; the average biomass was 42.6g/m², especially the biomass 1,120g/m² due to the presence of *Gafrarium pectinatum* (Bop).

(2) Co To average density is 132.3 fish/m², and biomass is 52.6 g/m².

(3) Cat Ba density ranges from 16-25 fish/m², with an average of 21.2 fish/m².

3.1.2. Current status of seaweed in the rocky intertidal zone of the study area

The results of the seaweed survey in the intertidal zone of reefs in three study areas have detected 92 seaweed species belonging to 34 genera, 22 families, 14 orders, 4 classes, 2 subclasses, and 04 phyla.

Rhodophyta and Phaeophyta/Orchophyta predominate with 44% and 34% of the total species, respectively, Chlorophyta accounts for 21% and Cyanobacteria with 1 %.

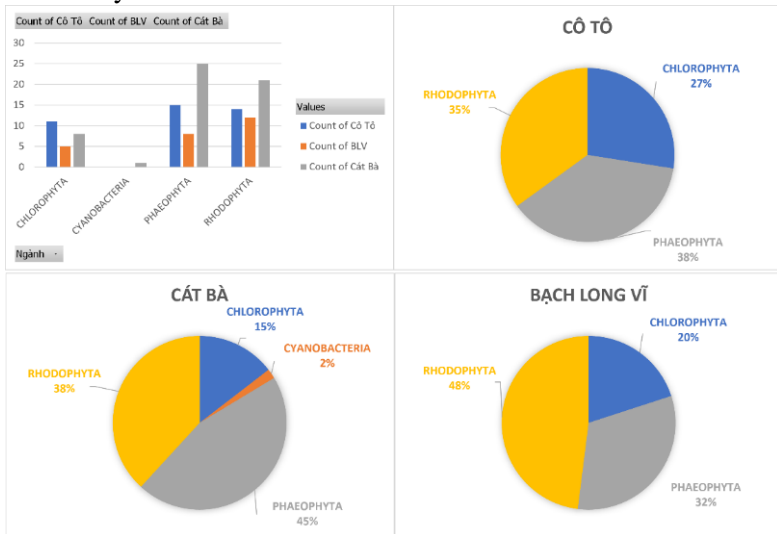


Figure 3.10. Structure of seaweed species composition according to the taxonomic level

The distribution between the Algae phyla differed significantly between the study areas: Rhodophyta was recorded in Cat Ba (21 species), Co To (14 species), and Bach Long Vi (12 species). Phaeocophyta was recorded in Cat Ba (24 species), Co To (15 species) and Bach Long Vi found only 8 species. Chlorophyta was recorded in Cat Ba (8 species), Co To (11 species), and Bach Long Vi (5 species). Cyanobacteria only recorded 01 species in the Cat Ba area (Figure 3.10).

3.1.3. Assessment of biodiversity in the study area

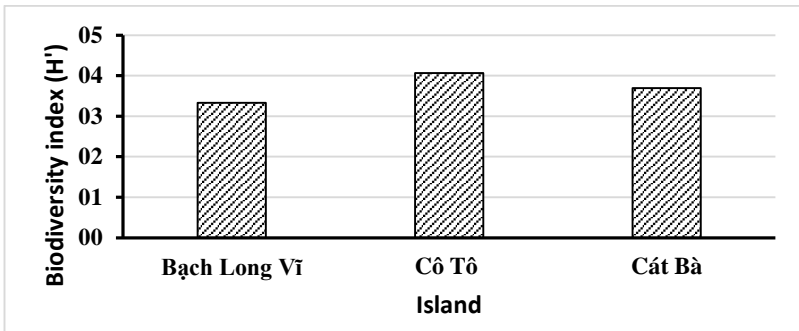


Figure 3.11. Result of biodiversity index (H') in the study area

Figure 3.11 results show that there is a difference in biodiversity index between the study areas. Co To area has the highest biodiversity index 4.06, Cat Ba is 3.70, and the lowest in Bach Long Vi is 3.33. The difference in biodiversity index between regions is due to the difference in rock bed structure and different natural conditions.

However, the results recorded on the species composition distributed in the three study areas are significantly different from the biodiversity index (H'): Bach Long Vi has a high diversity of species composition. the largest with 127 species (102 macrobenthic species and 25 seaweed species), Cat Ba with 115 species (61 macrobenthic

species and 54 seaweed species), and Co To with 111 species (71 macrobenthic species and 40 seaweed species).

3.1.4. Species of economic value

Survey results have identified 85 species of benthic animals with economic value, distributed on tidal flats, divided into groups of use values such as food (TP), medicinal herbs (DL), and cosmetics. technology (MN).

Specifically, the number of species in each class is as follows: The bivalve class has 32 species; Class gastropods 29 species; Crustaceans 10 species; Sea cucumber (9 species); Starfish (3 species); Sea urchin (2 species).

Thus, it can be concluded that Molluscs and Crustaceans dominate the structure of economically valuable species.

The specific records of each area are as follows: Bach Long Vi has 61 species, Co To has 36 species and Cat Ba has 30 species.

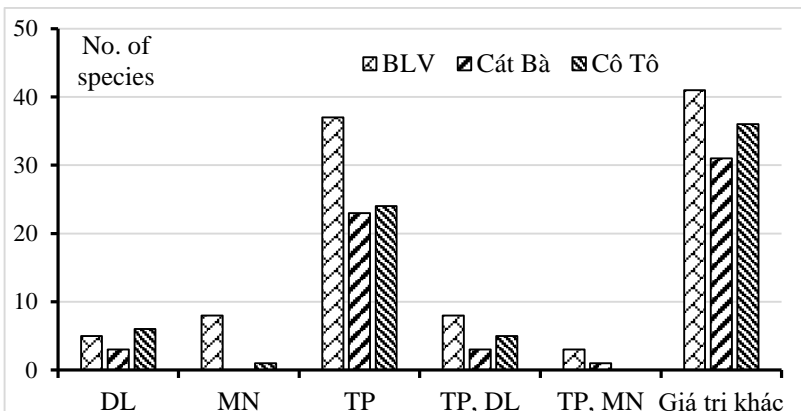


Figure 3.12. Group of benthic species with economic value in the study area

The analysis results in Figure 3.12 show that there is a big difference between groups of species with economic value in the study areas.

The group of species with food value has 69 species (81.18%), the group with medicinal value has 15 species, and 12 species with artistic value. However, there are still a large number of species whose economic value has not been determined.

Survey results on seaweed have identified 35 species with economic value, mainly food value (TP). Of these, 25 species have both food and medicinal value. The seaweed family has the highest number of species with the highest economic value with 19 species distributed in the study area.

The number of seaweed species with economic value is different between the study areas: Cat Ba has 29 species, Co To has 9 species and BLV has 5 species.

3.1.5. Rare species with conservation value

Survey results in the study areas have identified 07 rare and precious species of conservation value (Table 3.7).

Table 3.7. List of rare species in the research area

No.	Species	Vietnamese	Red List book (2007) /QĐ82/2008
1	<i>Haliotis diversicolor</i> (Reeve, 1846)	Bào ngư	CR
2	<i>Turbo marmoratus</i> (Linnaeus, 1758)	Ốc xà cừ	CR
3	<i>Tectus pyramis</i> (Born, 1778)	Ốc đụn đực	EN
4	<i>Atrina vexillum</i> (Born, 1778)	Bàn mai	EN
5	<i>Ovula costellata</i> (Lamarck, 1810)	Ốc sứ trắng nhỏ	VU
6	<i>Pteria pinguin</i> (Röding, 1798)	Trai ngọc nữ	VU
7	<i>Pinctada margaritifera</i> (Linnaeus, 1758)	Trai ngọc môi đen	VU

3.2. The ecological connection between the rocky intertidal zone and the surrounding ecosystem

The results of research on the role of reef tidal flats for 3 marine fish species in 2 main habitats: seaweed - seagrass, dead coral debris, and rocky reefs show that *Siganus fuscescen* (Dìa chám) is the dominant species with RA=45,6 % and wild distribution (FA=86,36 %) in the area which recorded the distribution of seaweed and seagrass, coral debris.

The rocky intertidal zone is a refuge for fish species, especially during the spawning season. Most of the adult fish groups are distributed in rocky reef areas, while juveniles are mainly concentrated in seagrass beds. Thus, the role of the "stopping station" or "safety roof" of the rocky intertidal zone is quite clear.

Research results have recorded a lot of juveniles and larvae of benthic species in the intertidal zone of the reef, which occurs more frequently than in the deeper tidal zone. This result proves that the reef ecosystem is the place where the spawning ground and breeding ground provide seed for the neighboring ecosystem.

The study also shows that floating fish species often have the habit of migrating according to the tides into the rocky reefs area to find food, drifting with the water. Some species rely on rocky intertidal reefs for food, sexual maturity, and reproduction. Larvae and young fisheries rely on rocks for shelter and food, and when they are adults, they move out. The rocky intertidal zone is generally a feeding ground for aquatic species, especially fish. The crustaceans and floating fish often tend to follow the tidal water into the intertidal zone in search of food.

3.3. Biodiversity loss and influencing factors

3.3.1. The degree of decline in the number of species

Comparing the results of this study with previous publications on the biodiversity of the intertidal reefs in the study areas shows that there is a decrease in both the number of species and a change in the density and quantity of two species. The group of organisms that regularly reside in the intertidal zone of the reef are benthic animals and seaweed.

Although the statistics are not complete, the results in Table 3.13 also show the variation in the number of species, density, and quantity of two groups of organisms that regularly reside in the intertidal reefs, namely benthic animals and seaweeds. Accordingly, both groups of organisms have decreased in the number of species, density, and quantity in all three study areas. Thereby reflecting the pressure of socio-economic development on the stability of the intertidal reef system in the study area.

3.3.2. Factors affecting biodiversity in the rocky intertidal zone

3.3.2.1. Effects of natural environmental factors on biodiversity

- Affected by natural environmental factors (temperature, pH, salinity). In which temperature varies and has the greatest impact.

- Influenced by the bottom structure of the intertidal reefs: Different types of bedrock have different biodiversity indexes. The study found that the bottom bed of "rock, pebbles, sand, coral debris" has the highest biodiversity.

- Influenced by the drying time of the rocky intertidal zone: The longer the tidal flat has the longer drying time, the lower the biodiversity.

- Marine pollution has a clear impact on biodiversity.

Table 3.13. Variation of species, distribution, and resources of benthic animals and seaweeds in the study area

Parameter		Bach Long Vi Island			Cat Ba Island			Co To Island		
		1993	2008	2018-2019	1993-	2003	2018-2019	1999	2005-2015	2018-2019
No. of species	Benthic animals	76 [31]	125 [33]	102	252 [39]	109 [41]	61	165 [119]	208 [31]	71
	Seaweed	65 [120]	46 [33]	25	75 [120]	79 [31]	54	90 [119]	66 [31]	40
Density	Benthic animals (indiv./m ²)	71 [31]	900 [31]	203,37	296 [121]	279,5 [31]	21,2	-	1.323 [31]	48,67
Mass	Benthic animals (g/m ²)	8,51 [31]	1750 [31]	203,69	130,64 [121]	130,4 [31]	26,61	-	52,6 [31]	71,22
	Seaweed (g/m ²)		33 [32]	24,6			10,6			20,18
Area of ecological drive	Rocky intertidal zone (ha)	163,19 [122]	128,65 [122]	110,8	330	295	295	199,48	149,48	45,48
	Fishing port (ha)	0	29,91 [122]	74,91	12	20	40	0	2,5	6,5

Note: Numbers in [] represent reference numbers; the period 2018-2019 is the result of this study.

3.3.2.2. *Effects of human activities*

The study identified the effects of human activities on biodiversity, including (1) Destructive exploitation of marine resources; (2) Overexploitation of marine resources; (2) Construction activities of marine works.

3.4. Proposing solutions to manage the biodiversity of the rocky intertidal reefs

Summarizing the research results, 08 scientific and legal bases for the management of tidal flats and reefs have been identified, specifically:

(1) The rocky reef in the study area has high biodiversity: 262 species (172 benthic species, 92 seaweed species) have been recorded. Is a habitat with high biodiversity, a place to store genetic resources for the Gulf of Tonkin.

(2) Having high economic value for conservation with many species of economic value, conservation: 123 species (85 species of benthic animals, 38 species of algae) have been recorded. There are 6 species of benthic animals listed in the Red Book of Vietnam.

(3) Environmental value: As a living place, spawning ground, development of young, and an ideal place for fish species. Highly ecologically linked.

(4) Loss of biodiversity: There is a rapid decline in the number of species, density, and quantity of organisms.

(5) Causes of biodiversity loss: Environmental pollution, destructive exploitation, marine construction, climate change.

(6) Legal bases for protection: Views on biodiversity management of Vietnam; The system of legal documents of the state; Local writing system.

(7) Protection models implemented: In marine protected areas, national parks.

(8) Community consensus: Increasing awareness and responsibility of the community; can build a co-management model.

3.4.1. Proposing a set of criteria for sustainable use of intertidal reefs and actual testing

Based on 8 issues that have been synthesized on the scientific and legal basis for the management of tidal flats and reefs and based on 4 principles to build a set of criteria for biodiversity in the intertidal zone of reefs in the Northeast region. The Criteria set is determined to answer the core questions with 20 criteria belonging to 04 specific groups as follows: The status quo criterion group (S) includes 5 criteria; The pressure criterion group (P) has 07 criteria; The meeting criteria group (R) has 05 criteria; The group of benefit criteria (B) has 03 criteria.

Based on the selected criteria, the Ph.D. student conducted an assessment of the level of implementation, feasibility, and accuracy of the monitoring method in practice in the intertidal zone of the reef in the Bach island area. Long Vi, Co To, and Cat Ba compare and examine the applicability and practical application of the set of biodiversity criteria in the rocky intertidal zone. The assessment shows that the basic set of criteria is feasible and applicable to the tidal area of the reef.

3.4.2. Proposing solutions to monitor the current status of unmanned aerial vehicles

Monitoring the biodiversity of the rocky intertidal reefs with unmanned aerial vehicles (UAV) is one of the new technological

solutions to improve the efficiency of management and protection of the rocky intertidal reef ecosystem.

From the results of UAV photography at the rocky intertidal zone of Bach Long Vi island, a map of the current status of the reef tidal zone was built on an area of 30 hectares with a scale of 1:3.500 which was classified 05 objects in the table 3.16.

Table 3.16. The results of object classification on the current status map of the rocky intertidal zone which was taken by UAV at BLV

No.	Object	Area (ha)
1	Area covered by seawater	12,411
2	Sea sponge	0,101
3	Seaweed	4,102
4	Sea Oysters	0,48
5	Stone bottom	12,85
	Total	30

The accuracy test results show that: The average accuracy rate is 98.22%, of which the high tide area reaches 100%. From the above results, it is possible to use this method to build a map of the current status of rocky intertidal reefs.

From the obtained research results, an 8-step process of monitoring the intertidal reef ecosystem is proposed as follows.:

Step 1: Preparatory work.

Step 2: Set up a flight plan.

Step 3: Build a shooting flight plan.

Step 4: Check weather conditions before flying.

Step 5: Proceed to take pictures and merge them.

Step 6: Build a key to interpret the ecosystem of tidal reefs.

Step 7: Tested classification.

Step 8: Build a current status map.

3.4.3. Building specialized models to protect the rocky intertidal reef

3.4.3.1. Proposal Basis

- Planning of functional subdivisions of Bach Long Vy Marine Protected Area (BLV MPA).

- Survey results on the rocky intertidal reef area of Bach Long Vi island.

- Result of a biodiversity survey in the rocky intertidal zone of Bach Long Vi island.

3.4.3.2. Proposing functional zoning and stipulating specific activities to manage the rocky intertidal zone of Bach Long Vi

Subdivision zone I: *From the left edge of the Northwest port to the eastern tip of the island:* Area of 33.62 ha, adjacent to the Strictly Protected Zone of the BLV MPA.

Specific regulations:

(1) Zoning, organizing patrols to strictly control to prevent violations in this area.

(2) Zoning and restoring subtidal reef ecosystems.

(3) Prohibiting activities that may harm the landscape and biodiversity in this area: Construction, discharge, and mining of materials.

Subdivision zone II: *From the eastern tip of the island to Au 54:* Area of 18.55 ha and is the tidal zone of the Ecological Restoration Zone of the BLV MPA.

Specific regulations:

(1) Prohibition of exploitation of species on the strict conservation list.

(2) Other species: Regulation on the harvest season, harvest size, tidal time, and maximum quantity to be harvested.

(3) Prohibit activities that may harm the landscape and biodiversity.

Subdivision zone III: From Au 54 to the left side of the Southwest port and from the beach to the Northwest port: An area of 43.3 ha, located in the Ecological Restoration subdivision zone of the BLV MPA.

Specific regulations:

(1) Apply the same regulations as in subdivision zone II to some areas that are breeding grounds for species on the list of 22 protected species.

(2) Regulations on the harvest season, size of exploitation, time of exploitation according to the tide, and maximum quantity to be exploited.

(3) Zoning for protection or breeding, zoning for ecological farming.

(4) Prohibit and strictly handle fishing activities using the destruction and exploitation of endemic and rare species.

Subdivision zone IV: The rocky intertidal reefs located in the port lock: These are the rocky intertidal reefs located in the fishing port, thus the biodiversity management solution is not applied, This area is managed according to the regulations of the fishing port.

3.4.4. Proposing overall solutions for the management and use of the rocky intertidal reef in the study area

- *Policy solutions:* Improve the system of state management agencies on marine biodiversity at all levels and legal documents; build a mechanism for sharing benefits of biodiversity resources;

There are policies to improve the quality of life of residents on the island.

- *Solutions on organization and management*: Strengthening management coordination between central agencies and localities; Consolidating and expanding the management system of marine protected areas; Building a monitoring and evaluation system for marine biodiversity; Developing a co-management model.

- *Scientific, technological, and technical solutions*: Continue to investigate, survey, and complete the database system of biodiversity in the rocky intertidal zone along the island; Capacity building of research and management staff at all levels; Apply advanced technology and techniques to research, monitoring, evaluation and conservation management of marine biodiversity; Research and find solutions to limit the impact of climate change on biodiversity in the rocky intertidal zone.

- *Solutions for propaganda, education, awareness raising, and international cooperation*: Propaganda to raise awareness and responsibility of the community; Strengthen extracurricular and curricular education on the protection of biodiversity and marine life resources at all levels.

- *Solutions to orient the planning for management and rational use of biodiversity in the rocky intertidal reefs*: Strengthening state management capacity on protection and development of aquatic resources; To step up the management and handling of violations on the protection of resources and biodiversity; Expanding international cooperation on resource management and biodiversity.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

1. The thesis has evaluated the biodiversity value of intertidal reefs of the study area in 03 main islands in the Northeast Sea, Vietnam (Bach Long Vi, Co To, and Cat Ba). The thesis focuses on analyzing two objects that regularly reside in the intertidal zone of rocky reefs, namely mangroves, and seaweeds, as a scientific basis for building a set of criteria and proposing solutions for sustainable management and development of the area. tidal reefs in the Northeast region. This study recorded 170 benthic species belonging to 133 genera, 81 families, 38 orders, 9 classes, and 4 phyla. Of which, Bach Long Vi has the highest number of species with 102 species, followed by Co To (71 species) and the smallest is Cat Ba (61 species). Also recorded 92 seaweed species belonging to 34 genera, 22 families, 04 Classes, and 02 sub-Class, 04 Divisions.

2. The intertidal reef ecosystem has a close ecological relationship with surrounding ecosystems, especially coral reef ecosystems. In the Bach Long Vi, Co To, and Cat Ba islands, the rocky intertidal reef ecosystem plays an important role in maintaining biodiversity and protecting fish populations in the life cycle of growth and development. It is the spawning ground, where the young fish state lives before migrating to other ecosystems with deeper water. At the same time, it is a feeding place for many aquatic species, of which floating fishes account for many. The rocky intertidal zone is the habitat of the broodstock populations during the spawning season, maintains traditional spawning grounds, and is a "stopping station" for fish schools to migrate from offshore waters to spawning zone produce in the southwest monsoon season.

3. The thesis has identified and evaluated the influencing factors (tidal area, natural conditions, and characteristics of the bottom structure) to the level of biodiversity in the rocky intertidal zone as well as analyzing the impacts causes of biodiversity loss in the rocky intertidal zone, such as environmental pollution, destructive mining activities, over-exploitation of marine resources.

4. This study has also proposed 4 solutions for sustainable management and use of the rocky intertidal reef, including:

(i)- Proposing a set of criteria for managing biodiversity in the rocky intertidal reefs in the Northeast sea with 20 criteria belonging to 04 specific groups as follows: the current status criterion group (S) includes 5 criteria, the group of pressure criteria (S) includes 5 criteria. P) has 07 criteria, meeting criteria group (R) has 05 criteria and benefit criterion group (B) has 03 criteria.

(ii)- Successfully built an 8-step process to monitor the status of tidal flats and reefs by unmanned aerial vehicles.

(iii)- Specialized functional zones and specific management activities have been proposed in the management of biodiversity in the rocky intertidal zone of Bach Long Vi island.

(iv)- Propose 4 overall solutions for the management and use of tidal flats and reefs in the study area.

2. Recommendations

It is necessary to continue studying and evaluating the ecological values of the rocky intertidal reefs as a basis for the development of orientations for protection planning in protected areas and outside protected areas. From there, a detailed evaluation of subdivisions zone from the rocky intertidal reef as well as the zones in the rocky intertidal reef can be obtained.

In addition to developing policies on tidal areas and wetlands, authorities at all levels need to have specific action plans and reasonable policies for the rocky intertidal zone.

THE FINDING OF THE THESIS

Based on the research results of the topic combined with the available data and documents, the Ph.D. student presented and argued to clarify two objectives. Thereby, the following new points are introduced:

- Obtain a fully updated data set on species composition and groups of species living in the rocky intertidal zone at 3 islands of Bach Long Vi, Cat Ba (Hai Phong City), and Co To (Quang Ninh province). Determining the characteristics of the system and the connection of the system between the intertidal zone of the reef and neighboring ecosystems

- Successfully developed a set of criteria for biodiversity management in the intertidal reef area based on the Status - Pressure - Response - Benefit (S-P-R-B) model for monitoring and managing biodiversity.

- Built an overall model with detailed functional zoning to serve the management of rocky intertidal reef applied to the island district level.

THE PUBLICATIONS

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