USING ECOLOGICAL AND SOCIO-ECONOMIC INDICATORS TO ASSESS THE SUSTAINABILITY OF THE RED RIVER DELTA BIOSPHERE RESERVE VIETNAM

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ABSTRACT

The Red River Delta Biosphere Reserve has been recognized as model of sustainable development since 1989 when Xuan Thuy Ramsar Site was founded. However, a number of studies have showed issues of "unsustainable development" such as water pollution, overuse of agrochemicals (VEPF, 2005), mangrove deforestation (Beland et al. 2006), poverty differentiation in the area (EJF, 2003). This has raised a question of whether the study area has been sustainable developed. The objectives of this study, therefore, are to define the sustainability of a biosphere reserve; construct a conceptual framework to select indicators for sustainability and propose indicators for sustainability assessment of the study area. I used keywords to search and collect documents that answer two questions: what are the definitions of sustainable development and how one can evaluate it. I mainly used the approach proposed by Annette Schmidt (2004) to review literature.

In this study, the sustainability of a biosphere reserve was defined as the mitigation between conservation of biodiversity and sustainable use of natural resources through time. In other words, a sustainable biosphere reserve will have well-conserved biodiversity and sustainable economic development and social stability. The generally conceptual framework to select a set of ecological and socioeconomic indicators for sustainability can be summarized as vision->guideline-> objectives->standards->indicators.

I proposed two sets of indicators for biodiversity conservation and use of natural resources. The first comprises four indicators: percentage of planted mangrove, number of species in planted mangrove, number of endangered/threatened species in planted mangrove and number of endangered/threatened species within the Biosphere Reserve. The latter consists of ten indicators: concentration of pesticide, concentration of herbicide, dissolved oxygen

concentration, phosphorus concentration, suspended solids, concentration of antibiotics in fishponds, percentage of agriculture affected by salt intrusion, percentage of mangrove enclosed by dike, percentage of mangrove converted to fish ponds and percentage of intertidal area under intensive collection.

This sustainability assessment of the Biosphere Reserve was limited by the availability and quality of data, time constrain and personnel capacity. For a fully completed picture of the Biosphere Reserve, further research is needed. It is also necessary to establish database for the Biosphere Reserve through activities such as inventory on fauna both endangered species and commercial species, flora especially mangrove, water quality, land, demography, economy, society.

INTRODUCTION

The Provincial Trans-boundary Coastal Wetland Biosphere Reserve in the Red River Delta (Red River Delta Biosphere Reserve) is the third biosphere reserve in Vietnam to be approved by UNESCO in December 2004. However, the first conservation effort was initiated long before the establishment of the biosphere reserve. It encompasses the area known as the Xuan Thuy Ramsar Site that was designated for the conservation of wetland ecosystems in 1989. During the past 20 years, the biosphere reserve area has also been considered as an area of sustainable development. UNESCO recognizes the Red River Delta Biosphere Reserve as a model for sustainable regional development. A biosphere Reserve is defined as "areas of terrestrial and coastal ecosystems promoting solutions to reconcile the conservation of biodiversity with its sustainable use of natural resources" in which a three-function driven approach (protection, development promotion and logistic support) can operate through flexible zoning (core, buffer and transition areas) (www.unesco.org).

Nevertheless, several studies have also documented issues of "unsustainable development" in the area such as low income, gender inequity and the degradation of wetland ecosystems. Fifteen years after the implementation of Ramsar Convention, wetlands of the Red River Delta have suffered from pollution from agrochemicals (VEPA, 2005). In Thai Binh Province alone, 152-268 metric tons of chemicals were used to annually 1990-1995. During rain season, concentrations of pesticide in the area at low tide have exceeded permitted limits. Beland et al. (2006) reported that 440 ha of mature mangrove were lost between 1986 and 1992 in the Giao Thuy- core area of the biosphere reserve. Beside this, EJF (2003) recorded increases in socioeconomic differentiation through land agglomeration and increased poverty among the poor owners of aquaculture ponds.

A number of studies have aimed to evaluate the current development status of the area within the Biosphere Reserve. For example, EJF (2003) and Berland et al. (2006) examined the environmental and socioeconomic impacts of shrimp aquaculture, especially those on mangrove deforestation. Vietnam Environmental Protection Agency (2003) identified three main activities that threatened wetland biodiversity: dike construction, aquaculture and hunting of migratory birds. Nguyen et al (1999), Pham et al. (2002), Truong (2002) and Hoang (2002) identified five anthropogenic drivers of degraded wetland ecosystems. They are population pressure, overexploitation of fishery, mangrove deforestation and overexploitation, destruction of wetland habitats and environmental pollution. None of the mentioned research has assessed all aspects of sustainable regional development of the area.

Therefore, this study attempts to use the criteria of sustainable development to assess the sustainability of the Red River Delta Biosphere Reserve. The objectives of my study include 1) define the sustainability of a biosphere reserve; 2) to construct a conceptual framework to select a set of ecological and socioeconomic indicators for sustainability; 3) to select a suitable set of ecological and socioeconomic indicators for the Red River Delta Biosphere Reserve.

I will examine status of the Biosphere Reserve in a context of the Renovation since 1989 until present.

STUDY AREA

Biophysical Conditions

The biosphere reserve covers five districts of Thai Thuy, Tien Hai, Giao Thuy, Nghia Hung and Kim Son in three provinces of Thai Binh, Nam Dinh, and Ninh Binh (Table 1 and 2) located in Red River Delta (Figure 1). The coast is constantly modified by soil erosion and accretion, with the accretion speed generally being twice as fast as the erosion. The coastal zone of Red River Delta extents from Do Son to Lach Truong with a total length of 145 km, and with a width that ranges from 500 m in Van Ly to 15,000 m in Ba Lat. The total mudflat area is 452,000 ha in which the upper mudflat is partly covered by mangroves. The lower mudflat has no mangroves and has a total area of 264,000 ha. The system carries 114 million tons of alluvium sediments which are divided into branches of the river mouths in the following proportion: Luoc river: 10 - 15 %; Tra Ly: 10 - 15 %; Cua Day (Nam Ha):30 - 40 %; Cua Ba Lat: 40 - 45 %. Sediments from Ba Lat mouth creates the largest mudflat with the upper area of 9,412 ha and the lower area of 5,513 ha.

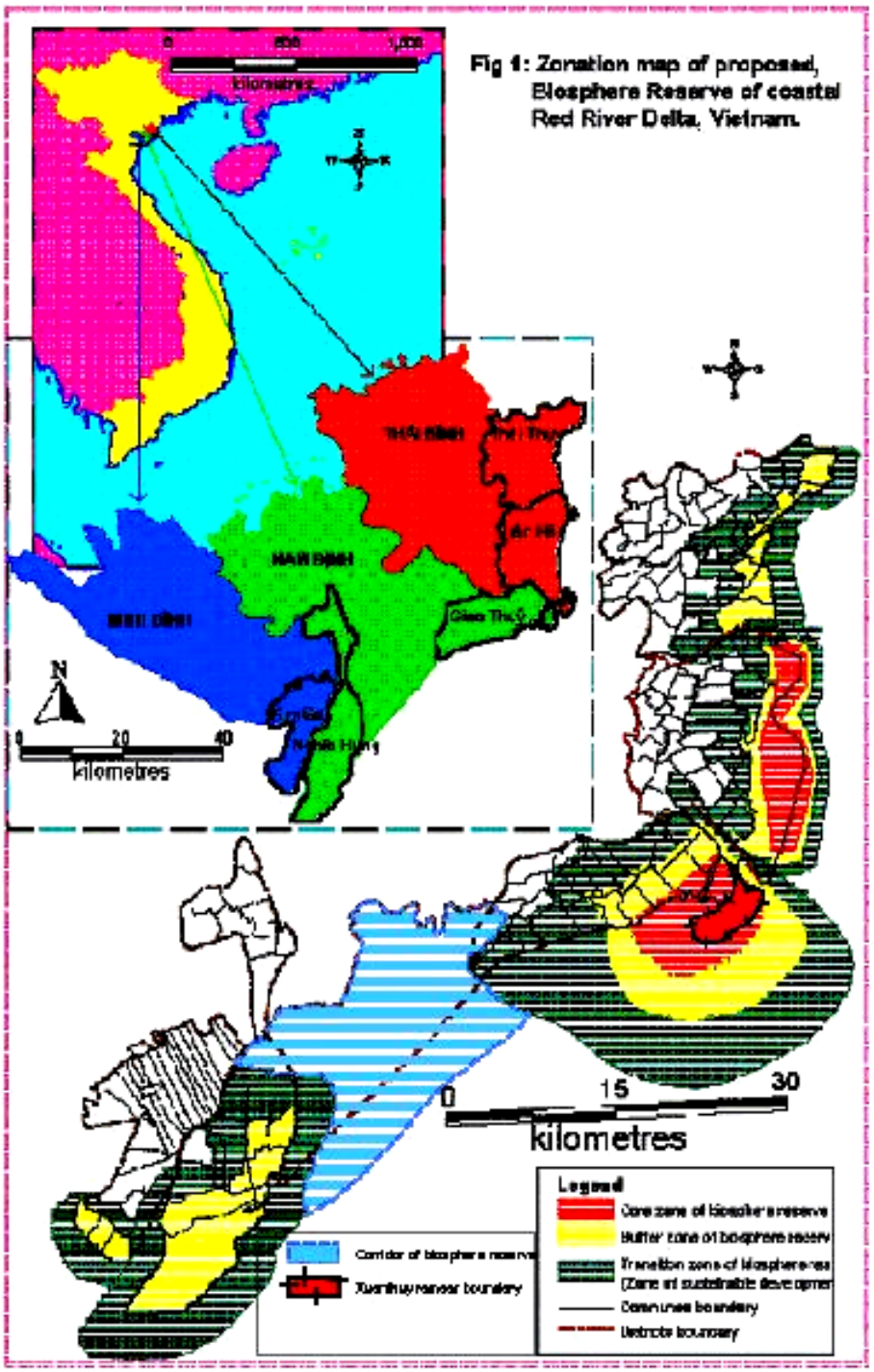

Figure 1: The study area- Red River Delta Biosphere Reserve and its three zones (Source: CERE, 2004)

Table 1: Coordinates of the central points of the biosphere reserve (CERE, 2004)

Individual reserves	Zoning function	Latitudes (degree, minute, second)	Longitudes (degree, minute, second)
Thai Thuy	Core zone Buffer zone Transition zone	20 28 05 – 20 37 05	106 42 00 – 106 34 30
Tien Hai	Core zone Buffer zone Transition zone	20 10 00 – 20 15 00	106 20 00 – 106 32 00
Giao Thuy	Core zone Buffer zone Transition zone	20 10 00 – 20 15 00	106 20 00 – 106 32 00
Nghia Hung	Core zone Buffer zone Transition zone	20 09 30 – 20 15 00	106 18 00 – 106 30 00
Kim Son	Core zone Buffer zone Transition zone	19 54 30 – 19 38 15 19 55 30 – 20 01 40 19 53 50 – 19 57 27 19 58 30 – 20 02 00 19 53 00 – 19 55 49	106 01 35 – 106 05 50 106 01 40 – 106 05 30 106 01 25 – 106 05 44 106 01 10 – 106 05 44 106 01 25 – 106 05 40

The horizontal extension of the coastal area is estimated to be 345 ha per year for the upper mudflat and 200 ha per year for the lower section of the mudflat. However there are high erosion rates in the Red river Delta, for example in Van Ly the erosion rate for the upper mudflat is 3.09 m/yr and the erosion rate for the lower section is 2.65 m/yr. The salt intrusion into the river is estimated to be 10 -15 km or even 15 -20 km up the Van Uc mouth in the winter. The salinity may be reduced to 0.1 % - 0.4 % in the raining season in Day, Ba Lat and Van Uc river mouths. The climate in the Red River Delta is typical of a tropical monsoon area which is characterized by cold winter, wet, humidity at the end of the season and hot summer with high precipitation. The problem with the highest consequence in the Delta is natural catastrophes that occur each year due to heavy rain and strong winds that cause damage to coastal areas in June, July and August.

Mean temperature is about 23-24 ^{o}C. The difference between winter and summer is about 12 ^{o}C. The extreme cold has been recorded to be about 4-5 ^{o}C. Hoarfrost or rime is seldom, but cause large scale damage of vegetable crops, especially in young stages, if occurred.

The coastal area is usually affected by typhoons and storms during July-October. During this period strong winds with a velocity of 40-50 m/s may be accompanied by heavy rain of 200-300 mm per hour posing a serious threat to buildings and human safety. The rain can fall at rates up to 400-500 mm per hour during these storms. On average, the storm constitutes 25-30 % of the total rainfall during the summer. The maximum tidal amplitude is approximately 4m. The elevation ranges from 0 to 3 m.

Table 2: Sizes of the central point of the biosphere reserves (CERE, 2004)

Individual reserves	Zoning function	Terrestrial area (ha)	Marine area (ha)	Total (ha)
Thai Thuy	Core zone	4,604	1,463	6,067
	Buffer zone	5,230	3,234	8,463
	Transition zone	6,234	4,345	10,579
	Subtotal			25,109
Tien Hai	Core zone	3,000	1,000	4,000
	Buffer zone	6,600	2,450	9,050
	Transition zone	8,500	4,500	13,000
	Subtotal			26,050
Giao Thuy	Core zone	3,100	1,000	4,100
	Buffer zone	6,000	2,250	8,250
	Transition zone	6,727	4,456	11,183
	Subtotal			23,533
Nghia Hung				
	Buffer zone	4,432	1,800	6,232
	Transition zone	6,345	3,400	9,745
	Subtotal			15,977
Kim Son				
	Buffer zone	3,454	1,400	4,854
	Transition zone	6,634	3,400	10,034
	Subtotal			14,888
Grand total				105,557

The coastal areas of the districts have been listed as key coastal wetland sites in the Delta by Birdlife International (Pederson et al. 1996). This area is well known for its abundant

biodiversity, especially for endangered migratory water bird species such as black-faced Spoonbill (*Platalea minor*), Nordmann's Greeshank (Tringa guttifer), Asian Dowitcher and Sauder's Gull (Pederson et al. 1996). During 6-8 December 1999, 43 birds of Black-faced spoon bill were recorded at Xuan Thuy National Park.

Socio-economic Conditions

The biosphere reserve is among the most densely-populated areas of the country- Red River Delta (Table 3). It is situated in the Red River Delta that is the political and cultural center of Vietnam.

Table 3: Population of the central point of the biosphere reserve (CERE, 2004)

Individual reserves	Zoning function	Population (number of people)	Number of households	Number of poor households	Commune
Thai Thuy	Core zone	-	-	-	
	Buffer zone	8,952	4,436	50	Thuy Truong, Thuy Xuan
	Transition zone	34,353	12,213	135	Thuy Hai, Thi Tran Thai Thuy, Thai Do
	Subtotal	43,305	16,649	185	
Tien Hai	Core zone	-	-	-	
	Buffer zone	7,654	3,453	69	Nam Hung, Nam Phu, Nam Thinh
	Transition zone	14,395	6,495	112	Nam Hung, Nam Phu, Nam Thinh
	Subtotal	22,049	9,948	181	
Giao Thuy	Core zone	-	-	-	
	Buffer zone	3,456	3,212	32	Giao Thien, Giao An, Giao Lac, Giao Xuan
	Transition zone	11,232	2,312	1,123	Giao Thien, Giao An, Giao Lac, Giao Xuan
	Subtotal	14,688	5,524	1,155	
Nghia Hung	Core zone				
	Buffer zone	2,132	978	32	Nam Dien, Rang Dong
	Transition zone	11,232	532	121	Nam Thang, Nam Phu, Nam Loi, Nam Hoang, Nam Hai
	Subtotal	13,364	1,510	153	
Kim Son	Core zone	-	-	-	
	Buffer zone	7,314	3,679	653	Kim Hai, Kim Trung, Kim Dong
	Transition zone	27,355	11,650	72	Kim My, Kim Tan, Con Thoi, Binh Minh
	Subtotal	34,669	15,329	725	
Grand total		128,075	48,960	2,399	

METHODOLOGY

In order to achieve the research objectives, I focus on two questions: what the definitions of sustainable development are, especially the sustainability of a biosphere reserve, and how one can evaluate sustainable development. To answer these questions I reviewed literature using key words.

To answer the first questions I searched for literature using key words of "sustainable development", "sustainability of biosphere reserve". For the second question, I used key words "measure sustainable development", "assess sustainability of biosphere reserve", "indicators for sustainability". Major documents and their findings on these two questions are listed below.

- Brundtland, B. 1987. Development and international economic co-operation: Environment. Report of the World Summit on Environment and Development. United Nations. This document, also known as Brundtland's report, is the first to propose the concept of sustainable development. "Sustainable development is development that meets the present needs without compromising the ability of future generations to meet their own needs". It initiated a great numbers of studies on sustainable development around the globe.
- UNESCO, 2006. Indicators of sustainability: Reliable tools for decision making. Policy Briefs. No. 1. UNESCO further characterizes into three dimensions: environment, society and economic. This approach has been widely used when defining sustainable development and assessing the sustainability.
- Parris, T.M. and R.W.Kates, 2003. Characterizing and measuring sustainable development. Annual Review Environmental Resource, vol. 28, pp 559-586. Claiming that the concept of sustainable development is broad and ambiguous, the authors used

taxonomy to review twelve dominant examples of characterizing and measuring sustainable development. It divides sustainable development into “what is to be sustained” and “what is to be developed”. The first covers nature, life support systems and community and the latter consists of people, economy and society. The paper also analyzed how goals, indicators and targets selected in these examples.

- Thiersen, A. and M. Walser, 1997. Sustainable regional development: the squaring of the circle or a gimmick. Enterpreneuership and Regional Development. Vol. 9, No. 2, pp. 159-173. Thiersen and Walsen define and distinguish the sustainable regional development with sustainable development at global and national scale.
- Schmid, A. 2004. Sustainable development in the biosphere reserve Entlebuch: A conceptual framework for the assessment of sustainability. Schmid constructed a framework to assess the sustainability of the biosphere reserve Entlebuch.

I mainly applied the framework proposed by Annette Schmid (2004) to my research. This is because her project had similar research questions, objectives and research object: biosphere reserve. The basis for the formulation of the key-indicator is a methodology developed by Sachverständigenrat für Umweltfragen and is called "vision oriented development of indicators" (Schmidt, 2004). Before indicators can be identified, guidelines, objectives and standards have be derived from the vision of sustainable development (vision->guideline-> objectives->standards->indicators).

The Red River Delta biosphere reserve was recognized to promote the reconciliation between biodiversity conservation and sustainable use of natural resources in the area. Therefore, consequences of conservation activities and the utilization of natural resources will set the relationship between these two aspects of the biosphere reserve. I selected representative

activities of the two aspects of the biosphere reserve and construct a set of criteria for our evaluation. The indicators of sustainability will then be derived from them.

To examine three dimensions of sustainable development that are associated with these activities, I analyzed the following studies on the coastal zone of the Red River Delta: Beland, M. et al. 2006; EJF, 2003; Hoang, V.T., 2002; Nguyen, X. H and Nguyen Xuan Quynh, 1999; Pham, B.Q. et al., 2002; Pedersen, A et al. 1996; Truong, T.T.H., 2002; Vietnam Environmental Protection Agency, 2003; and Vietnam Environment Protection Agency, 2005. I was interested in current status of ecology/environment, society and economy of the biosphere reserve area.

The preliminary review of major papers showed the ambiguity of the sustainable development concept. As a result, a clearer definition of sustainable use of natural resources is necessary. It is also important to distinguish sustainable regional development with other scales.

RESULTS

Sustainable Development

In 1992, 179 countries at the World Summit in Rio de Janeiro agreed on a global goal: sustainable development. The most commonly cited concept of "sustainable development" was first stated in the Brundtland report which defined "sustainable development as development that meets the needs of present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987).

Since the first World Summit in 1992, the concept of sustainable development has been developed and applied at various scales depending on project objectives. Reviewing twelve efforts to characterize and measure sustainable development around the world, Parris and Kates (2003) draw three conclusions. First, there is extraordinarily broad list of items to be sustained and to be developed. This seems to be due both to the inherent ambiguity of sustainable

development and to specifics of individual characterization and measurement efforts. Secondly, few of the efforts are explicit about the time frame of sustainable development. When time frame is addressed at all, there is a clear bias toward the present or the near term. Third, the vast majority of the efforts are deductive, or top-down, in nature. They establish definitions of sustainability on the basis of first principles or negotiated consensus and then let these definitions drive their choice of indicators.

In this research, we analyzed selected indicators regarding the three problem dimensions of the concept to assess the sustainability of the biosphere reserve. Sustainable development concept encompasses three problem dimensions that should be addressed in parallel (Thierstein and Walser, 1997): ecology, economic and society (Daly, 1992).

- Economical dimension: The problem of efficiency dictates the necessary optimal possibility for the use of all natural resources: the focus is on allocation. Allocation refers to the relative division of the resource flow among the alternative product uses.
- Ecological dimension: The contingency problem describes the necessity to limit the total amount of overall non-sustainable resources: focus is on scale. Scale refers to the physical volume of the throughput, the flow of matter-energy from the environment raw materials, and back to the environment as wastes.
- Social dimension: The problem of distribution clearly defines the necessity of a relatively equal distribution of all resources, so that social and spatial cohesion are guaranteed: the focus is on distribution. Distribution refers to the relative division of the resource flow, as embodied in final goods and services, among alternative people.

Once we decide the approach to the concept of sustainable development, the next step in our analysis is to determine the scale at which we perform our evaluation of sustainability.

Sustainable Development at Regional Level

As a biosphere reserve within the UNESCO World Network of Biosphere Reserves, Red River Delta is expected to be a model of sustainable regional development. In this study, it is essential to distinguish between global and regional scale of sustainable development. The differences are three fold (Nijkamp, Lasschuit and Soeteman 1992: 42).

- The global system is a closed system dependent on sunlight, while regional economics and ecology are more or less open. Policy measures undertaken in the region may or may not hinder the development process of the neighboring countries or other regions.
- Contrary to global system, regions have elected legislative bodies and legitimate authorities that have to represent the local commons and must deal with conflicting situations.
- Normally regions have different economics, ecological and social resources.

In this study, I am using the concept of sustainable regional development with three dimensions (ecology, economics, and society) as definition of the sustainability of the Red River Delta Biosphere Reserve. Because a biosphere reserve is considered as a model of sustainable regional development, I am conducting analysis at regional scale.

Sustainable Use of Natural Resources

Sustainable use of natural resources is one of the two aspects of a biosphere reserve. Different organizations define natural resources differently. UNESCO considers "materials occur in nature and are essential or useful for human, such as water, air, land, forests, fish and wildlife, topsoil and minerals" as natural resources (www.unesco.org). Using a regulatory approach, the US Environmental Protection Agency define natural resources as "land, fish, wildlife, biota, air, water, groundwater, drinking water supplies, and other such resources (including the resources of

the exclusive economic zone) belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by, the United States, any state or local government or Indian tribe, or any foreign government". From any standpoint, natural resources by their definition give their values for human use (www.epa.gov).

Natural resources can be categorized as renewable and non-renewable resources. Renewable resources are generally living resources, which can restock (renew) themselves if they are not over-harvested. Renewable resources can restock themselves and be used indefinitely if they are used sustainably. Once renewable resources are consumed at a rate that exceeds their natural rate of replacement, the standing stock will diminish and eventually run out. The rate of sustainable use of a renewable resource is determined by the replacement rate and amount of standing stock of that particular resource (www.wikipedia.org). Non-renewable resources are usually non-living resources that can not regenerate themselves.

For natural resources to be sustainably used, management rules should be applied (Schmid, 2003). These rules include:

- Regeneration rule: renewable resources can only be used to the level that they still maintain the ability to regenerate
- Substitution rule: non-renewable resources are replaced through or by renewable resources
- Conservation rule: quality of the resources is to be conserved
- Assimilation rule: applied for decomposable pollution. The amount of pollution that emits into the ecosystem should only be controlled at the level that they can be absorbed by the environment. In other words, pollution emission should be lower than the absorption capacity of the ecosystems.

- Accumulation rule: applied for non-decomposable pollution. The amount of pollution that emits into the ecosystems should be maintained at the level that they do not adversely affect the human, animals and plants.

In addition to the management rules, there are strategies to minimize the utilization of natural resources in the following hierarchy

- Reduce strategy: the first priority, reduce the period of the natural resource use
- Substitute: the second priority, substitute nonrenewable by renewable resources
- Design: the third priority, improve and increase the use of technology measures to reduce the burden on the environment

The above characteristics of sustainable use of natural resources will be used to analyze economic activities and explore whether they are progressing towards the sustainable use.

How to evaluate the sustainability of Red River Delta Biosphere Reserve

I examined three most prominent activities in the Red River Delta: mangrove restoration, agriculture and aquaculture. Since the restoration of mangroves and their functions will sustain the biodiversity of the coastal zone, an assessment of this activity will be directly related to the conservation of biodiversity in Red River Delta Biosphere Reserve. The other two groups of activities, agriculture and aquaculture, can reveal patterns of the use of natural resources within the study area. In sections below I will examine these three activities and summarize the most important features that can be used to select indicators of sustainability.

Restoration of Mangroves

Mangrove ecosystem is comprised of the mangrove forest and the adjacent intertidal area that is the transitional zone between terrestrial and marine ecosystems. Mangroves are highly complex and productive ecosystem that prevents coastal erosion, encourage sediment deposition and

accretion. They also provide food, shelter and sanctuary for birds and mammals, spawning, nursery and foraging area for a wide variety of marine organisms.

There have been several projects of replanting mangrove along the coast of the provinces of Thai Binh and Nam Dinh (Table 4). Actions have been taken in and around the biosphere reserve to protect and replant mangrove. Before 1990, funding for mangrove reforestation come from Vietnamese government. One of the most prominent conservation efforts was sponsored by Danish Red Cross to reforest mangrove in Thai Binh Province since 1994. The project expanded to Nam Dinh Province sin 1997. The areas covered by mature mangrove increased 441 ha during 1992 and 2001 as a result of reforestation project funded by Danish Red Cross and Xuay Thuy National Park (Beland et al. 2006). Other organization have contributed to reforestation of mangrove in the biosphere include Japanese Red Cross, Japanese Action for Mangrove Reforestation (ACTMANG), United Kingdoms Children Fund, United Kingdom OXFARM and Airden and Sweden Red Cross.

Table 4: Area of mangrove reforestation in the Red River Delta Biosphere Reserve (Source: Phan, N.H., 1999)

Province	District	Area of replanted mangrove (ha)					
		Before 1990	1994	1995	1996	1997	1998
Thai Binh	Thai Thuy	850	700	300	700	1000	
	Tien Hai	2012				400	
Nam Dinh	Giao Thuy		1300	300	700	400	650
	Nghia Hung	2000	2000			390	141
Ninh Binh	Kim Son	50				200	200

Mangrove reforestation is critical to restore the ecological functions of mangroves, creating habitats for mangrove species including migratory birds. The functions of mangroves are correlated with the dimensions of sustainable development. They include in the ecology dimension the ecological function, in the economic dimension the production and regional

economy function, and in the social dimension the education and research as well as the protection function (Schmid, 2003). In connection with the multi-functionality of the mangroves, the following main issues are identified within the Red River Delta Biosphere Reserve.

Ecology

Table 4 shows frequent and substantial new plantations of mangrove species in the biosphere reserve. This activity, however, does not always result in the restoration of ecological functions of mangroves. The most prominent reason for this is the conflict of construction of sea dike and aquaculture ponds with mangrove reforestation. Mangroves have been planted outside sea dike system along the coastal area of the biosphere reserve to stabilize soils and protect dikes from wave, storms and other natural disaster. Traditionally, once the outer land is stabilized by mangroves, new sea dikes are constructed, resulting in death of planted mangroves (Table 5). Local people have reclaimed new land through this procedure for settlement and agriculture. Several communes of Nghia Hung districts were developed through dike construction from 1960 through 1982.

Table 5: Construction of sea dike in Nghia Hung district (Census Department of Nghia Hung, 2002)

Year(s) of construction	Name of reclaimed area	Area (ha)
1930-1931	Vanh island	184
1960	Rang Dong	1350
1964	Nghia Phuc commune	200
1978	West Nam Dien commune	560
1982	East Nam Dien commune	650
Total		2944

In 1996, area of mangrove in Nghia Hung district was estimated to only be about 1300 ha, most of which were under 30 years old (Pedersen et al. 1996). In 2004, about 600 ha of planted mangroves in Nghia Hung district died due to dike construction. Other factors resulting in modest success of mangrove reforestation are mono-cultivation of mangrove, deforestation of

mangrove for coal/charcoal and diseases on newly planted mangroves, which lead to low ratio of survival mangrove plants until maturity. The further expansion of aquaculture in mangrove areas in the transition zone of the biosphere reserve has also been threatening restoration of mangrove functions.

Therefore, long-term planning of reforestation in relation with aquaculture and dike construction is critical to mangrove reforestation. Planting a diversity of mangrove species planted, reinforce regulations to regulate deforestation and wisely use pesticide will help to increase effectiveness of reforestation activity.

Economic

Mangroves have important roles in the local economy. The main issues of the production function are the sustainable use of charcoal/coal, honey, incentive program for mangrove reforestation. According to Phan (1999), to reduce investment on reforestation, it is necessary to maintain 30-40 young plants per hectare with 15-20 m pacing for natural regeneration. Cutting mangroves in alternative bands of 35-40 m and replanting at these cleared sites will also be cost-effective.

Society

The educational and research function of mangroves is to enhance the awareness of local people on values of mangroves, facilitate research on mangrove species including migratory water birds. Educational activities in the biosphere reserve, especially in the districts of Thai Thuy, Tien Hai, Giao Thuy and Nghia Hung, have mostly carried out by Mangrove Ecosystem Research Division (MERD), Vietnam National University in Hanoi. Since 1987 it has conducted variety of educational activities to enhance the awareness of local students on mangroves and their resources. The organization has also successfully held contests on mangroves in local schools of

Thai Binh and Nam Dinh province. Education for high school students can contribute to prevent over-exploitation or destructive exploitation of shellfish, bivalves, and other resources in the intertidal areas because a large part of the collectors are children. The organization also accomplished project “Improvement of local capacities for community participation in mangrove rehabilitation, protection and management” during 1997-1999. Nonetheless, educational campaigns to enhance awareness of local people, especially for aquaculture owners, on sustainably use of mangrove resources are key to restore and maintain mangrove functions.

There are recently on-going national and international donor-funded projects working on the site that brings new ideas related development and expected outcomes. Groups include Vietnam-Holland Research Cooperation: Red River Delta Research Program, 1999 – 2004; UNDP/GEF PDF-A Project ‘ Conservation of Coastal Wetlands in the Red River Delta’ 1999-2000; SARCS/WOTRO/LOICZ Core Research Project on ' Economic Evaluation of Mangrove Rehabilitation and Restoration in Nam Ha Province, Red River Delta' 1996-1999, 2000 – 2004; Mangrove Planting for Sea Dike Protection and Environmental Improvement of two Provinces Thai Binh and Nam Dinh, funded by Danish Red Cross, 1996 – 2002; Comparative Research Studies and Training for Sustainable Planning of Vietnam's Coastal Areas', funded by MacArthur Foundation 1996-1999 and others.

Mangrove reforestation thus has had positive influences on education and research functions of sustainable development in the biosphere reserve.

Agriculture

Agriculture is traditional and the most common economic activity in the Red River Delta as well as in the transition zone of the biosphere reserve. For instant, in Nghia Hung district, agriculture accounts for over 30 % of the economy in 2003 (Table 6).

Table 6: Percent earnings from each branch in the economy of Nghia Hung district, Province of Nam Dinh (Source: Vietnam Environmental Protection Agency, 2002)

Branch	Year			
	1985	1990	1995	2003
Agriculture (%)	51	47	40	32
Forestry (%)	8	8	3	3
Aquaculture (%)	23	25	32	31
Inshore fishing (%)	6	10	14	19
Handicrafts (%)	5	6	5	7
Trade and services (%)	7	4	6	8

The proportion of agriculture in the local economy, however, is declining due to reluctance on promoting agriculture in the newly reclaimed land and raising earnings from aquaculture. Rice is the major agriculture products in the biosphere reserve. From 1990 to 2002 the rice yield of Nghia Hung district nearly doubled (from 80,521 to 155.742 ton/year) (VEPA, 2003). The increases in rice productivity have two drivers, expansion of agriculture land and application of high-yield rice species, fertilizer and pesticide. There have been concerns about environmental, social and economic issues of this movement.

To structure the assessment of sustainable regional development with agriculture the multi-functionality of land use is used. The functions of agriculture were correlated with the dimensions of sustainable development. They include the ecological functions in the ecology dimension, in the economic dimension the function of production and services, and in the dimension of the social dimension the land use planning function (Schmid, 2003). In connection

with multiple functionality of agriculture, the following main issues are identified within the Red River Delta:

Ecology

Wetlands of the Red River Delta have suffered from pollution from agrochemicals (VEPA, 2005). In Thai Binh Province alone, 152-268 metric tons of chemicals were used to annually 1990-1995. During rain season, concentrations of pesticide in the area at low tide have exceeded permitted limits. Besides, after long time of cultivation, rice soils have been salinized and are not favorable for either rice or aquaculture. Main issues of ecological functions are to reduce water pollution and acidity, treatment of salinization and wise use of pesticide in rive cultivation.

Economic

Rice is cultivated on lands built after dike construction. As the brackish land area in the coastal zone has high salinity, it takes a long time for reduce soil salinity to the level that is appropriate for rice development. As the result, the chance of success is low. The main issue of production function is promotion of pig farming and other agriculture products would reduce pressure on the rice cultivation that have been affected by high salinity of the water. Irrigation plays important role in maintaining high rice productivity. However, rice cultivation in the transition zone, in my opinion, may not be effectively improve local economy. Soils of the area within the sea dike are not really appropriate for rice cultivation.

Society

Conflicts between rice farmers and aquaculture farm owners have increased due to adversely effect of aquaculture on buffer capacity of the estuary areas. The expansion of aquaculture ponds along the coast of the biosphere has destroyed the buffer area between sea water and freshwater areas and therefore has changed distribution of freshwater during high tide season (VEPA,

2003). Unfortunately, this season is also a dry season which tends to amplify the salinity intrusion into the inland rice fields. Land use planning accordingly to the distribution of three zones within the biosphere reserve may be a suitable strategy to maintain the sustainable use of coastal land.

Aquaculture and Associated Activities

Aquaculture is a rapid growing industry with high potential for environmental degradation in developing countries. In Vietnam, shrimp and farming and cultivation of bivalves are the latest development since the introduction of market-economy in mid 1980s (Kleinen, 2003). Foreign earnings from shrimp aquaculture alone were estimated about US$500 million. Aquaculture in the biosphere reserve mainly refers to shrimp and mud crab ponds. Although the government has planned to reduce adverse impacts of aquaculture on the environment, and is implementing a five million hectare reforestation program, aquaculture plans are placing intense pressure on coastal areas (EJF, 2003). The coast lines of Thai Binh, Nam Dinh and Ninh Binh are no exception. One of the most serious affect of aquaculture in the study area is the deforestation of mangroves and overexploitation of shellfish and crustacean species that are associated with aquaculture. The larvae for aquaculture ponds mostly come from local intertidal areas. This has been creating a considerable number of jobs for local people. Part of their daily activity is to collect bivalves, crustacean, mollusk and fish for local consumption and export (Table 7).

Table 7: Commonly exploited shellfish and their values in Vietnam currency in the Red River Delta (CERE, 2004)

Species	***Metrix sp.***	***Glauconome chinensis***	***Albrina cfr. Declivis***	***Hitula diphos***	***Solen sp.***	***Mactra aquadrangularis***	***Aloides laevis***
Purpose in use	Mainly exported for human consumption	Consumed locally by people and also fed crabs and duck	Fed locally to crab and duck	Uses locally and exported for human consumption	Uses locally for human consumption	Uses locally for human consumption	Uses locally for crab and duck
Price VND/kg	3-5,000	900	5-900	4,000	2-4,000	1,000	5-900

Products that have higher values such as *Metrix sp.* are mainly exported to other provinces or to China, and lower value ones are used to feed duck and crabs in local aquaculture ponds (Table 7). To structure the assessment of sustainable regional development with aquaculture and associated activities, I use multi-functionality of aquaculture.

Ecology

The local economy has been shifting towards increasing aquaculture practices therefore ecological functions related to aquaculture have tremendous influence on conservation of biodiversity. Design of aquaculture ponds is the first issues to be addressed. The major type of aquaculture in the area is extensive and semi-natural ponds (Table 8). Besides, major health issue of shrimp aquacultures in the biosphere is disease control. Intensive use of antibiotics in shrimp ponds leads to residues of antibiotics in water and mud, and consequently, causes bacteria resistance to antibiotics (Le et al. 2005). More environmental friendly design of the aquaculture ponds would enhance the productivity and reduce adverse impacts from use of supplementary feeding and use of chemicals, deforestation of mangrove in natural ponds.

Table 8: Aquaculture methods applied in the biosphere reserve (Source: EJF, 2003)

Intensive or extensive
Aquaculture methods are classified according to pond area, feed and chemical use, and stocking densities. Terminology varies between sources and countries, but it is of value to introduce the following definitions relevant in the context of Vietnam.

Extensive/traditional: Mangroves and intertidal areas are enclosed by dikes in large ponds to allow polyculture of naturally stocked crab, shrimp and fish. Shrimp larvae densities are 1-3/m^2. Water exchange is by tidal action. Enclosed mangroves usually die after 3-5 years.

Modified (Improved) extensive: Largely as above; stocking densities of 1-5 shrimp/m^2, with additional artificial stocking with crab, fish and shrimp. Fish and shell fish (*Abrina cf. declivis* and *Aloides laevis*) are used for supplementary feeding.

Semi-intensive: Uses small (1-5 ha) ponds from which natural vegetation is cleared and in which supplementary stocking and feeding are routine. Shrimp densities are 5-8/m2, and can occasionally reach 10-20/m^2. Ponds are often drained, dried and treated between flooding periods.

Intensive: Small (≤ 1 ha) ponds, cleared of all natural vegetation and using artificial stocking. Feeding and aeration to maintain oxygen levels are necessary.

Aquaculture also controls on other activities within the intertidal areas for larvae supply. The collection of *Metrix sp.* requires flat areas with very few or no mangrove plants. Collectors will remove young plants if needed, resulting in destruction of pioneer mangrove communities along the coast. In the longer term, fewer mangroves can be natural regenerated in the intertidal area. The degradation is more severe when collector density increases. Management and coordination of aquaculture and collection activities are key to alleviate the pressure on coastal areas of the biosphere reserve.

Economic

The main issues of production function are long-term strategy for aquaculture development in the biosphere reserve, improve quality of larvae which have been hand-collected by local people within the intertidal areas. Coordination of associated activities such as collection of shellfish and crustacean is necessary in order to maintain constant supply of these resources.

Society

Increase income for the poor aquaculture farmers is the main issue in the social dimension. In general, when the shrimp farms are successful, profits are often reinvested directly into the ponds. There is not enough money to put aside for saving. Another important issue is to reduce the conflict among natural resources users in the intertidal areas of the biosphere reserve which covers three provinces.

Indicators for sustainability of the Red River Biosphere Reserve

From all the results shown, we can see that the indicators applicable for developed will not work well for the case of the Red River Delta. From the review of literature I have found that all sustainable indicators are designed to assess the sustainability at national level. Due to the inconsistency of data on the study area, it is infeasible to create regional indicators customized for the study area. Therefore, I decided to examine national indicators of environmental sustainability and sustainable development to select a set of indicators for sustainability. The two sets of indicators for sustainability of the biosphere reserve represent effort of biodiversity conservation and the use of natural resources (Table 9).

Table 9: Proposed indicators for sustainability of the Red River Delta Biosphere Reserve

Biodiversity Conservation	Use of Natural Resources
Percentage of planted mangrove	Concentration of pesticide
Number of species in planted mangrove	Concentration of herbicide
Number of endangered/threatened species within planted mangrove	Dissolved oxygen concentration
Number of endangered/threatened species within the biosphere reserve	Phosphorus concentration
	Suspended solids
	Concentration of antibiotics in fishponds
	Percentage of mangrove enclosed by dike
	Percentage of agriculture affected by salt intrusion
	Percentage of mangrove converted to fish ponds
	Percentage of intertidal area under intensive collection

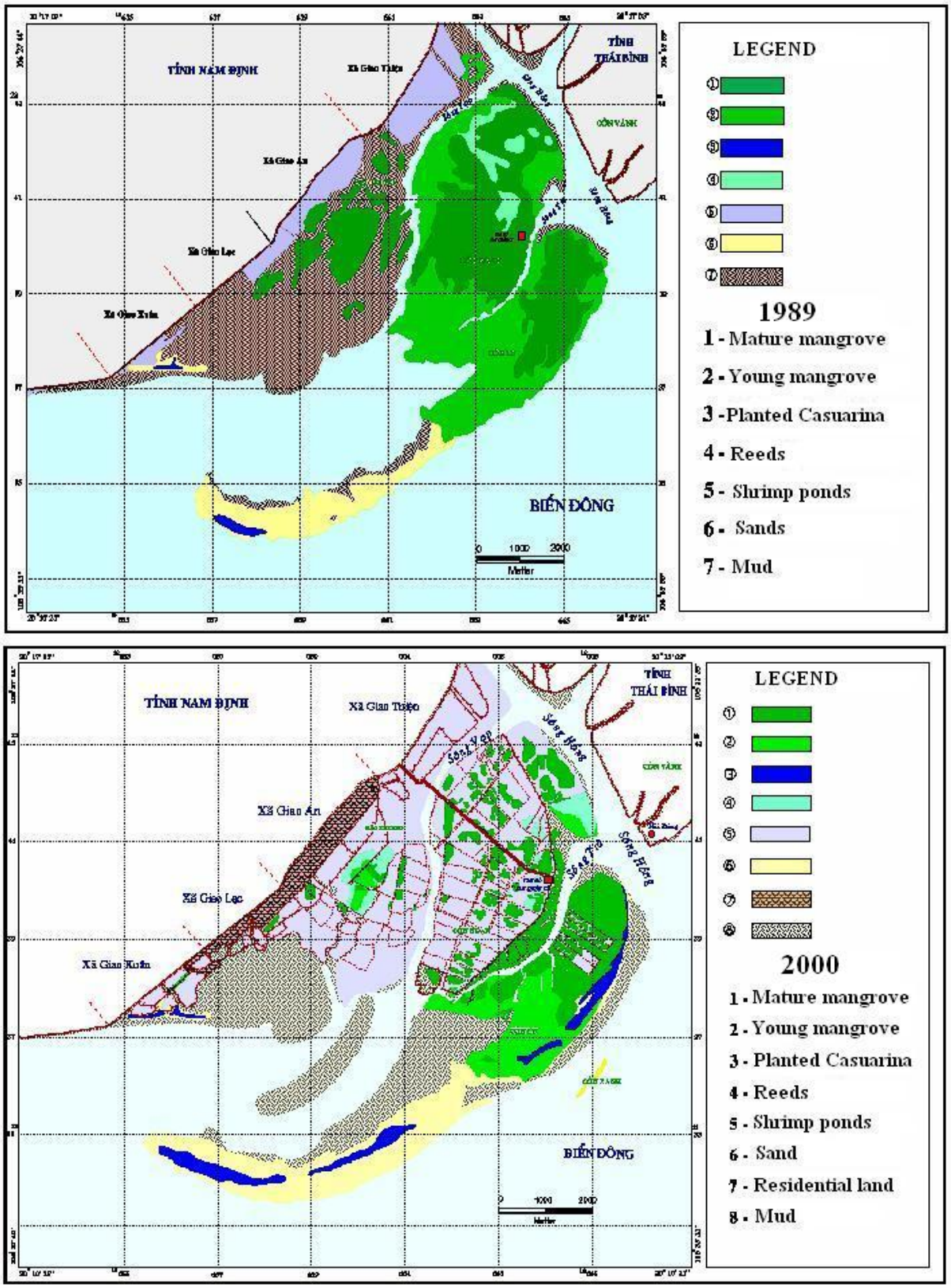

Figure 2: Land use in National Park Xuan Thuy in 1989 and 2000 (Dang A.T., 2000)

For example, the percentage of mangrove converted to fish ponds from 1986 to 2000 in Xuan Thuy Ramsar Site (later became Xuan Thuy National Park) is nearly 50 % (Figure 2).

Economic and social indicators are adapted from Nguyen, H.T. (2004) (Table 10,11)

Table 10: Proposed social indicators for sustainability of the biosphere reserve

Topic	SOCIAL- Sustainable Development Indicators
Equity	% poor households Differences between rich and poor (times) Un-employment (%) Differences of mean wages between male and female Community participation (% people participating in decision-making in communes
Health	Mal-nutrient percentage in infants (%) Death under 5 years old (%) Longevity over 60 years (%) % population using safe drinking water % population with first aid in incidence Vaccination in infants % population using birth control
Education	Children at grade 5 in schools (%) Population of high school certificates (%)
Housing	Area per person (m2)
Security	Number of crime per 100,000 people
Population	Population growth (%) Disease infection Number of conflicts

Table 11: Proposed economic indicators for sustainability of the biosphere reserve

Topic	ECONOMIC - Sustainable Development Indicators
Economic structure	GDP per capital Investment in GDP (%) Balance of import & export of goods and services
Consumption	Intermediate demand/Production value (5) Energy consumption per person (calories) % consumption of renewable energy
Waste management	Harmful waste (kg/person/year) Reuse, recycle production (kg/year)
Tourism	Number of foreign tourists per total (%) Eco-tourism areas (ha)

When combining all sets of indicators, we will be able to evaluate the current status as well as predict development scenarios of the study area. At this moment, three years after the

establishment of the biosphere reserve, my assessment is an initial step and for reference use only. Whether or not the biosphere reserve achieves sustainable development can only be verified in the future.

CONCLUSIONS

The concept of sustainable development has been used broadly and very flexibly based objectives of different interested groups. In this study, the sustainability of a biosphere reserve was defined as the mitigation between conservation of biodiversity and sustainable use of natural resources through time. In other words, a sustainable biosphere reserve will have well-conserved biodiversity and sustainable economic development and social stability. To measure the sustainability of the Red River Biosphere Reserve, I analyzed its current status under these two aspects.

The generally conceptual framework to select a set of ecological and socioeconomic indicators for sustainability can be summarized as vision->guideline-> objectives->standards->indicators. I proposed two sets of indicators for biodiversity conservation and use of natural resources. The first comprises four indicators: percentage of planted mangrove, number of species in planted mangrove, number of endangered/threatened species in planted mangrove and number of endangered/threatened species within the biosphere reserve. The latter consists of ten indicators: concentration of pesticide, concentration of herbicide, dissolved oxygen concentration, phosphorus concentration, suspended solids, concentration of antibiotics in fishponds, percentage of agriculture affected by salt intrusion, percentage of mangrove enclosed by dike, percentage of mangrove converted to fish ponds and percentage of intertidal area under intensive collection.

This sustainability assessment of the biosphere reserve was limited by the availability and quality of data, time constrain and personnel capacity. For a fully completed picture of the biosphere reserve, further research is needed.

It is necessary to establish database for the biosphere reserve through activities such as inventory on fauna both endangered species and commercial species, flora especially mangrove, water quality, land, demography, economy, society.

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