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Biological Resources for Development of Aquaculture in Thi Nai Lagoon, Vietnam

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Abstract: The diversity of aquatic resources in Thi Nai Lagoon decreased due to the lack of harmonious use and integrated long-term planning on the use of living resources. There remained a lack of mechanisms and regulations for coordination of activities in the lagoon by Binh Dinh Provincial People's Committee (PPC). The aim of the study was to investigate the aquatic species and water quality in Thi Nai Lagoon, Vietnam. Data were collected at 23 different points on Thi Nai Lagoon, with three replicates at each point. There were 106 species of fish presented on the lagoon and in different sizes, including 17 mollusc species and 15 crustaceans species. In the dry season, there were 167 phytoplankton species in five divisions, 10 classes in 39 orders in 59 families including 77 genus. Zooplankton had eight chordata in 10 classes of 18 orders including 44 families, 64 genus and 102 species. Arthropoda had the largest number of species, 78 species, accounting for 76.5% of total species. In the rainy season, only 48 species of Arthropoda, Cnidaria, Annelida, Chaetognatha and Rotifer were affected and some were not encountered in the wet season, such as mollusca and chordata. While water quality variables were still good for aquaculture, within permitted limits of TCVN standard and criteria, there were still problems caused by production discharges and living activities of inhabitants around the lagoon, such as sedimentary matters.

Key words: Thi Nai Lagoon, biodiversity, resources, water quality and interventions.

1. Introduction

Thi Nai Lagoon has an area of 5,060 ha, located at the river mouths of Kon and Ha Thanh, the two big rivers of Binh Dinh province, with a wide tidal flat. The ecosystem in the lagoon is quite rich and diverse. Thi Nai Lagoon has 1,000 ha of mangroves and 200 ha of seagrass, favorable for the growth and development of aquatic resources [1, 2]. The lagoon housed more than 119 species of fish, 14 species of shrimp and dozens of other valuable aquatic species [3-5]. Furthermore, Thi Nai Lagoon has been the source of income of thousands of inhabitants living along the lagoon [4-6]. Tuy Phuoc coastal region had a strong marine economy and had witnessed rapid growth of fish capture, aquaculture and tourism,

which was a sign of growth of the whole economy. However, the lack of good planning, the imbalance of investment as well as the diversity of economic actors and livelihoods on the lagoon caused the imbalance of the ecosystems. The weak management of biological resources and inadequate protection of the coastal environment also hindered effective use and sustainable development of the coastal area of Binh Dinh province and worsened the current problems [4-6]. The existing problems included: (1) lack of integrated long-term planning on the use of living resources and harmonious management between coastal and lagoon land uses; (2) lack of mechanisms and regulations for coordination among agencies under the local government—Provincial People's Committee (PPC); (3) lack of an appropriate management approach, such as community-based integrated resources use and management, which has

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not been studied yet. The aim of the study was to investigate the aquatic species and water quality in Thi Nai Lagoon, Vietnam.

2. Investigation Site and Methods

2.1 Study Site and Time

The investigation site in the study covers the entire watershed of Thi Nai Lagoon and the livelihood activities of the villagers along the lagoon.

Investigation was conducted from October 2015 to February 2016 (rainy season and collected in November) and March to September 2016 (dry season and collected in June).

2.2 Variables Measured

There were 23 points on the lagoon, positioned and marked by GPS (Fig. 1) and stated for sample collection during two seasons (dry and rainy). In each point, three samples were collected for water quality and

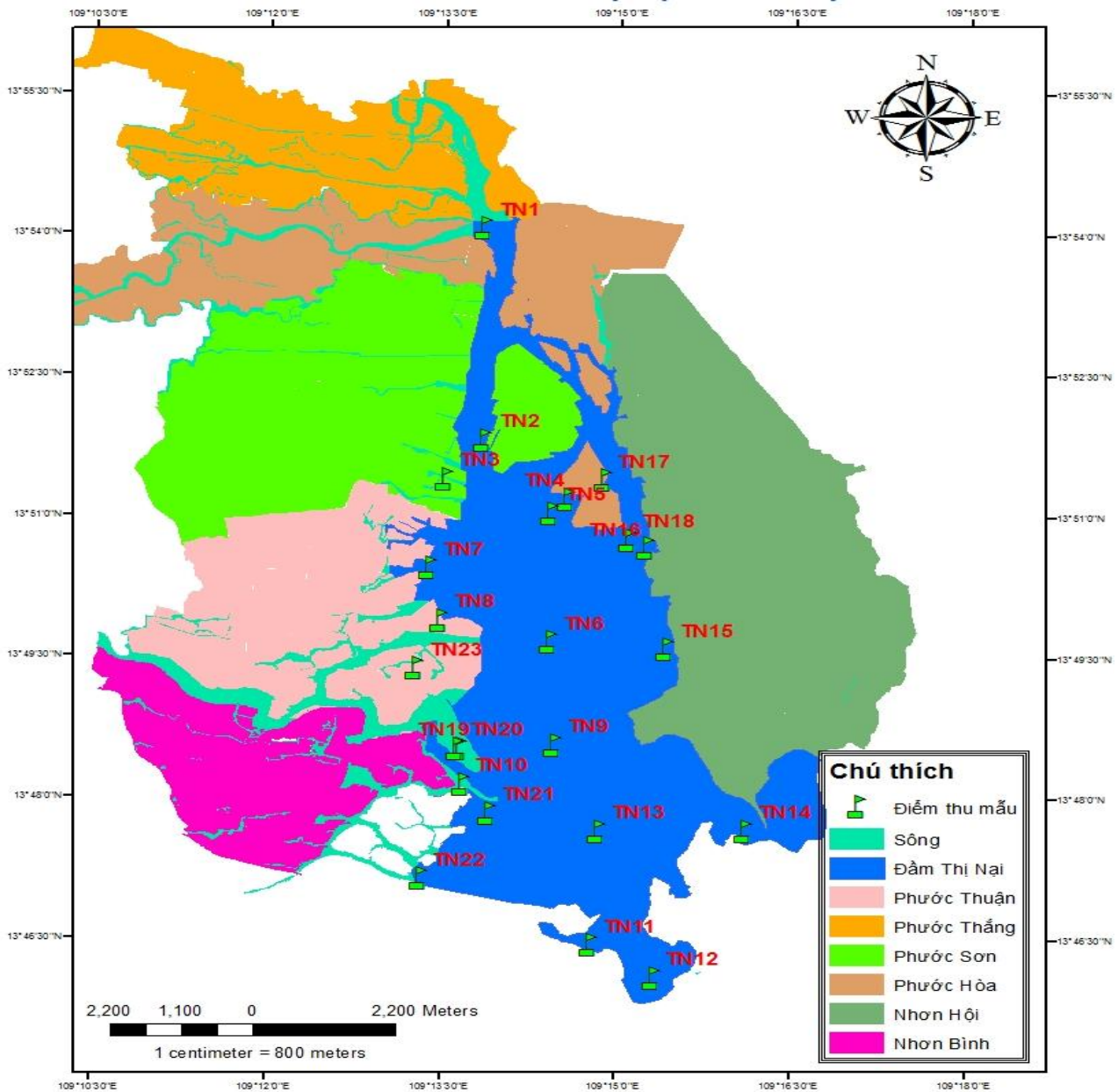


Fig. 1 GPS located different points on lagoon system.

aquatic resources analysis (assessment of different species and biodiversity) on the system. There were total 138 samples collected and analyzed.

Specimens were collected directly at the sampling sites (Fig. 1 and Table 1) by boat. Some samples were collected at local markets by fishermen caught in Thi Nai Lagoon. Species composition was determined and classified on the basis of morphology characteristics and the documents of Khang [7], Phu [8] and Dinh et al. [9].

The water quality including temperature, clarity, turbidity, conductivity (EC), total solids, total dissolved solids (TDS), pH, salinity (‰) and oxygen demand (DO) was determined by the multifunctional environmental meter (Fig. 2). The content of CaCO_3 , HCO_3^- , NO_3^- , NO_2^- , NH_4^+ , N, biological oxygen demand (BOD_5), heavy metals, organic plant protection chemicals and total coli form were analyzed in the laboratory. Before that, the water

sample would be stored at 4 °C. Then data were analyzed by SPSS 10.0 for average of variables.

3. Results and Discussion

3.1 Biodiversity of Thi Nai Lagoon

There were 106 species of fish presented in the lagoon, of which 10 species were often caught by local fishermen using traditional gears, such as grill nets, bottom nets and enclosed nets (Table 2). Some potential aquaculture species included: *Therapon jarbua*, *Mugil cephalus*, *Mulgil kelaartii*, *Cynoglossus puncticeps*, *Caranx carangus*, *Arothron immaculatus*, and a new species *Siganus oramin*.

According to the survey conducted, there were 17 species of mollusks and 15 species of crustaceans recording in Thi Nai Lagoon area (Table 3). Clam oil (*Meretrix meretrix*), bamboo clam (*Meretrix lyrata*) and green mussel (*Perna viridis*) are the most popular

Table 1 The 23 different points located by GPS on Thi Nai Lagoon.

Code	GPS: Coordinates		Sampling and places
	Latitude	Longitude	
TN1	13 °54'03.8"	109 °13'49.8"	Water, fish, bivalvia, crustacea at Kon river mouth
TN2	13 °51'48.5"	109 °13'50.4"	Water, fish, bivalvia, crustacea at Chim dunes
TN3	13 °51'23.6"	109 °13'30.2"	Water, fish, bivalvia, crustacea in aquaculture canals
TN4	13 °51'10.9"	109 °14'33.3"	Water, fish, bivalvia, crustacea at Trang dunes-Phuoc Hoa
TN5	13 °51'02.0"	109 °14'25.2"	Water, fish, bivalvia, crustacea and sea grass
TN6	13 °49'39.61"	109 °14'24.57"	Water, fish, bivalvia, crustacea at the middle of lagoon
TN7	13 °50'26.6"	109 °13'22.2"	Sea grass, water, fish, bivalvia, crustacea
TN8	13 °49'53.4"	109 °13'28.1"	Water, fish, bivalvia, crustacea, seagrass at mangroves
TN9	13 °48'33.94"	109 °14'27.56"	Water, fish, bivalvia, crustacea under Thi Nai brigde
TN10	13 °48'08.7"	109 °13'40.2"	Water, fish, bivalvia, crustacea at Ha Thanh river mouth
TN11	13 °46'26.07"	109 °14'46.46"	Water, fish, bivalvia, crustacea at fishing port
TN12	13 °46'5.51"	109 °15'19.01"	Water, fish, bivalvia, crustacea at estuaries
TN13	13 °47'38.86"	109 °14'50.68"	Water, fish, bivalvia, crustacea at lagoon middles in south
TN14	13 °47'39.52"	109 °16'6.15"	Water, fish, bivalvia, crustacea at water creeks
TN15	13 °49'35.6"	109 °15'25.4"	Water, fish, bivalvia, crustacea at aquaculture areas
TN16	13 °50'40.2"	109 °15'14.9"	Water, fish, bivalvia, crustacea at aquaculture areas
TN17	13 °51'23.2"	109 °14'52.0"	Water, fish, bivalvia, crustacea at mangroves
TN18	13 °50'45.4"	109 °15'05.9"	Seagrass, water, fish, bivalvia, crustacea
TN19	13 °48'31.58"	109 °13'38.94"	Seagrass, water, fish, bivalvia, crustacea
TN20	13 °48'31.50"	109 °13'37.64"	Seagrass, water, fish, bivalvia, crustacea
TN21	13 °47'50.9"	109 °13'54.6"	Seagrass, water, fish, bivalvia, crustacea
TN22	13 °47'8.13"	109 °13'18.96"	Seagrass, water, fish, bivalvia, crustacea at Ha Thanh river
TN23	13 °49'22.46"	109 °13'15.91"	Seagrass, water, fish, bivalvia, crustacea at mangroves



Fig. 2 The multifunctional environmental meter.

and high economic value. In 15 crustacean species identified (Table 3), some have high economic value, such as tiger shrimp, earth shrimp, blue crabs and green crabs, etc.. And there are some species famous among tourists, such as *Ranina ranina*, *Penaeus monodon*, *Perna viridis*, *Meretrix meretrix*, especially cultured in brackish water due to their sweet and aroma, and thus it would be very favorable to develop culture using enclosed net or pond system.

Table 2 Composition of fish in Thi Nai Lagoon (10/2015 and 6/2016).

No.	English name	Scientific name	No.	English name	Scientific name
1	Fish sand	<i>Eugomphodus tricuspidatus</i>	54	Pink fish with silver stripes	<i>Lutjanus argentimaculatus</i> Forssk
2	Stingray	<i>Dasyatis varidens</i> Garman	55	Pink spot fish	<i>Lutjanus russelli</i> Bleeker
3	Fish porridge	<i>Elops saurus</i> Linnaeus	56	Pink goldfish with matte stripes	<i>Lutjanus lineolatus</i> Rüppell
4	Big porridge fish	<i>Megalops cyprinoides</i> Broussonet	57	Star fish	<i>Pomadasys hasta</i> Bloch
5	Shell fish	<i>Escualosa thoracata</i> Val.	58	Long summer snout	<i>Letherinus miniatus</i> Bloch & Sch.
6	Green scales	<i>Herlotsichthys quadrimaculatus</i> Ruppell	59	Summer fish scales red	<i>Lethrinus haematopterus</i> T. & S.
7	Herring	<i>Sardinella sindensis</i> Day	60	Silverfish	<i>Argyrosomus argentatus</i> Houttuyn
8	Sardines dots	<i>Konosirus punctatus</i> Tem. & Sch.	61	Silver thieves	<i>Nibea coitor</i> B. & H.
9	Fish tire	<i>Thryssa hamiltonii</i> Gray	62	Yellow goldfish	<i>Upeneus vittatus</i> Forsbcal
10	Indian anchovy	<i>Stolephorus indicus</i> Van Hasselt	63	Catfish	<i>Caranx carangus</i> Bloch
11	Japanese anchovy	<i>Stolephorus japonica</i> Schlegel	64	Black fins	<i>Carangoides praeustus</i> Bennett
12	Yellow snapper	<i>Setipinna taty</i> Cuv. & Val.	65	Eastern raccoon fish	<i>Scomberoides orientalis</i> T. & S.
13	Snook	<i>Chanos chanos</i> Forskal	66	Orange striped fish	<i>Seriola dumerili</i> Risso
14	Sliced fish	<i>Notopterus notopterus</i> Pallas	67	Large paralysis	<i>Leiognathus equulus</i> Forskal
15	Trash fish	<i>Saurida tumbil</i> Bloch & Schneider	68	Parrotfish	<i>Leiognathus ruconius</i> H.
16	Crucian carp	<i>Carassius auratus</i> Linnaeus	69	Green parrot	<i>Leiognathus splendens</i> Cuv.
17	Carp	<i>Cyprinus carpio</i> Linnaeus	70	Long spiny goby	<i>Gerres filamentosus</i> Cuv.
18	Swishfish	<i>Leiocassis truncatus</i> Regan	71	Silverfish	<i>Monodactylus argentus</i> Linnaeus
19	Fish	<i>Plotosus angullaris</i> Bloch		Pangasius fish	<i>Platax orbicularis</i> Forskal
20	Catfish	<i>Clarias</i> sp.	72	Brown fish	<i>Scatophagus argus</i> Linneus
21	Chinese fish	<i>Arius sinensis</i> Lac.	73	Butterfly fish with a striped tail	<i>Chaetodon bellamaris</i> Saele
22	Pla yang wave	<i>Echidna polyzona</i> Rich	74	Zebra butterfly fish	<i>Parachaetodon ocellatus</i> Cuv. & Val.
23	Giant calendar fish	<i>Evenchelys macrurus</i> Bleeker	75	3-striped fish	<i>Aphyosemion trilineatus</i> Wang
24	Worm eels	<i>Moringua macrocephalus</i> Bleeker	76	Fish injections	<i>Leptoscarus vaigiensis</i> Q. & G.
25	Fish teeth	<i>Pisodonophis boro</i> H. & B.	77	Lure fish	<i>Callionymus hindsi</i> Wang
26	Snout	<i>Ophichthys apicalis</i> Bennett	78	Fish balls	<i>Siganus guttatus</i> Bloch
27	Pineapple fish	<i>Muraenesox cinereus</i> Forskal	79	Blue-spotted rabbitfish	<i>Siganus javus</i> Linnaeus
28	Tail tailed fish	<i>Tylosurus strongylurus</i> Van Hasselt	80	Fish pits	<i>Trichiurus haumela</i> Forslcal
29	Mackerel	<i>Hemirhamphus sinensis</i> Gunther	81	Anabas	<i>Anabas testudineus</i> Bloch
30	Needle fish	<i>Hemirhamphus gaimardi</i> Cuv. & Val.	82	Salmon	<i>Bostrichthys sinensis</i> Lac.
31	Swimmer fish fins	<i>Zenarchopterus ectuntio</i> Ham.	83	Humpback fish	<i>Butis butis</i> Buch. et Ham.
32	Lime fish	<i>Syngnathus pelagicus</i> Linnaeus	84	Goblin eye valve	<i>Oxyurichthys tentacularis</i> Cuv. & Val.

(Table 2 continued)

No.	English name	Scientific name	No.	English name	Scientific name
33	Seahorse	<i>Hippocampus hystrix</i> Kaup	85	Goby ash	<i>Acentrogobius caninus</i> Cuv. & Val.
34	Striped	<i>Panchax melastigma</i> McClelland	86	Griffon sand	<i>Glossogobius giusi</i> H. & B.
35	Barracuda	<i>Sphyrena barracuda</i> Walbaum	87	Goby ginger eyes	<i>Glossogobius biocellatus</i> Cuv. & Val.
36	Fish object	<i>Mulgil cephalus</i> Linnaeus	88	Goby fish clouds	<i>Ctenogobius criniger</i> Cuv. & Val.
37	Mullet leaves	<i>Mulgil kelaarti</i> Gunther	89	Gobies java	<i>Stigmatogobius javaneus</i> Bleeker
38	Spiny fish	<i>Mulgil stronglylocephalus</i> Richardson	90	Muddy fish	<i>Periophthalmus cantonensis</i> Osbeck
39	Tropical fish	<i>Atherina duodecima</i> C. & V.	91	Blind spot flower	<i>Dendrochirus zebra</i> Cuv. & Val.
40	Fish all over eyes	<i>Atherina forskali</i> Ruppell	92	Milan fish thorn	<i>Vespicola trachinoides</i> Cuv. & Val.
41	Seabass	<i>Lates calcarifer</i> Bloch	93	Chinese walrus	<i>Vespicola sinensis</i> Bleeker
42	Fish head bare	<i>Ambassis gymnocephalus</i> Lacepede	94	Indian bottfish	<i>Platycephalus indicus</i> Linnaeus
43	Fish painted kop	<i>Ambassis kopsi</i> Bleeker	95	Japanese fish	<i>Inegocia japonica</i> Tilesius
44	Halibut	<i>Siniperca whiteheadi</i> Boulenger	96	Bottlenose fish	<i>Inegocia spinosus</i> T. & S.
45	Grouper flies	<i>Epinephelus tauvina</i> Forskal	97	Black tilapia	<i>Oreochromis mossambica</i> Peters
46	Spiny groupers	<i>Epinephelus malabaricus</i> Bloch & Sch.	98	Nile tilapias	<i>Oreochromis niloticus</i> Linnaeus
47	Fish sand	<i>Therapon jarbua</i> Forkal	99	Flounder blisters in the middle	<i>Pseudorhombus negletus</i> Bleeker
48	Fish scales large	<i>Therapon theraps</i> Cuv. & Val.	100	Striped fish	<i>Cynoglossus puncticeps</i> Rich
49	Small fish scales	<i>Therapon ruta</i> Cuv. & Val.	101	Buffalo tongue	<i>Cynoglossus monopus</i> Bleeker
50	Fish paint	<i>Apogonichthis brachygrammus</i> Jenkins	102	3-spiny puffer fish	<i>Triacanthus brevirostris</i> Sch.
51	Fish painted on tails	<i>Apogon amboinensis</i> Bleeker	103	Horned hornbill	<i>Lactoria diaphana</i> Bloch & Sch.
52	Silver fish	<i>Sillago sihama</i> Forkal	104	Turtle-shell turtle	<i>Chelonodon patoca</i> Hamilton
53	Stingray fish	<i>Sillago maculata</i> Q. & G.	105	Mussel topper	<i>Arthron immaculatus</i> Bloch & Sch.
			106	Grilled puffer fish	<i>Arothron reticularis</i> Bloch & Sch.

Table 3 Composition of mollusc and crustaceans species in Thi Nai (10/2015 and 6/2016).

No.	English name	Scientific name	No.	English name	Scientific name
Molluscs			Crustaceans		
1	Clam oil	<i>Meretrix meretrix</i>	18	Black tiger shrimp	<i>Penaeus monodon</i>
2	Bamboo clam	<i>Meretrix lyrata</i>	19	Fried shrimp	<i>Penaeus semisulcatus</i> De Haan
3	Otters	<i>Anadara subcrenata</i> (Lischke, 1869)	20	Silver Shrimp	<i>Penaeus merguensis</i>
4	Phi (sea jelly)	<i>Sanguinolaria diphos</i> (Linne ù, 1771)	21	Smaill shrimp	<i>Metapenaeus ensis</i>
5	Eunuch dress	<i>Sanguinolaria</i> sp.	22	Mud crab	<i>Scylla paramamosain</i> (Estampador, 1949)
6	White cry, round spell	<i>Placuna placenta</i> (Linne ù, 1758)	23	Intestine	<i>Acetes japonicus</i> (Kishinouye, 1905)
7	Black pepper	<i>Placuna</i> sp.	24	Shrimp peeled in the bowl	<i>Oratosquilla oratoria</i> (de Haan, 1844)
8	Green mussel	<i>Perna viridis</i>	25	Blue crabs	<i>Portunus pelagicus</i> (Linnaeus, 1766)
9	Black spot	<i>Xenostropus atrata</i> (Lischke, 1871)	26	Ghe ìaphinit	<i>Charybdis affinis</i> (Dana, 1852)
10	Clear	<i>Glaucomomya chinensis</i> (Gray, 1828)	27	Crab cross	<i>Charybdis feriata</i> (Linnaeus, 1758)
11	Almost belcheri	<i>Crassostrea belcheri</i> (Sowerby, 1871)	28	Spotted mussels, sand crabs	<i>Portunus trituberculatus</i> (Mier, 1876)
12	Big wheel bolt	<i>Architectonica maxima</i> (Philippi, 1849)	29	Heleri crabs	<i>Charybdis helleri</i> (A. M. Edwards, 1867)
13	Snail pile	<i>Cymatium pileare</i> (Linne ù, 1758)	30	Shady	<i>Varuna litterata</i> (Fbricius, 1798)
14	Snail shell	<i>Cymatium lotorium</i> (Linne ù, 1758)	31	Sliding door	<i>Scylla olivacea</i>
15	Clamshell	<i>Tapes literatus</i> (Linne ù, 1758)	32	King crab	<i>Ranina ranina</i>
16	Ngao Hian	<i>Marcia hiantina</i> (Lamarck, 1818)			
17	Osteoarthritis rapi	<i>Rapana rapiformis</i> (Born, 1778)			

3.2 Water Quality in Thi Nai Lagoon

The data in Table 4 showed that in Thi Nai coastal area, the average value of environmental parameters in rainy season, such as temperature, clarity, conductivity (EC), total solids, pH, CaCO₃ concentration and HCO₃⁻, are higher than that in the dry season 2016. Average concentrations of NO₃ and NO₂ are not found in water quality samples in Thi Nai Lagoon. However, the average values of some parameters, such as turbidity, TDS, DO, NH₄⁺, total N, total P, BOD₅ and total coliform, in the rainy season in 2015 are

significantly higher than that in the dry season 2016. For example, NH₄⁺ is only determined in the rainy season with 0.18 ± 0.009 mg/L. Total N in the rainy season 2015 is 5.0 ± 0.7 mg/L which is much higher than 0.73 ± 0.12 mg/L in the dry season 2016. Similarly, P of the rainy season in 2015 is 10 times higher than that in the dry season of 2016 (1.5 ± 0.1 mg/L and 0.14 ± 0.03 mg/L, respectively). BOD₅ also shows a large difference between the two seasons with the respective values of 5.4 ± 4.3 mg/L and 0.83 ± 0.55 mg/L. There is very high number of total coliform

Table 4 Fluctuation of environmental parameters in the Thi Nai Lagoon.

Factors	Unit	Average (min-max)		QCVN08-MT:2015/BTNMT [10]				QCVN38:2	QCVN10-M
		Raining season 2015	Dry season 2016	A1	A2	B1	B2	011/BTNM T [11]	T:2015/BTN MT [12]
Temperature	°C	25.9 ± 1.14 (24.9-26.9)	27.8 ± 0.8 (27.0-28.5)						30
Clarity	cm	90.0 ± 56.6 (50.0-130.0)	113 ± 56.9 (50.0-160.0)						
Turbidity	NTU	17.35 ± 2.05 (15.9-18.8)	9.36 ± 7.96 (12.0-17.1)						
Conductivity (EC)	µS/cm	16.9 ± 23.8 (0.1-33.7)	19.5 ± 20.1 (0.1-40.3)						
Total solids	mg/L	10.1 ± 4.2 (0.1-20.2)	13.2 ± 12.5 (0.06-25.0)					1,000	
Dissolved (TDS)	mg/L	4.2 ± 4.8 (0.8-7.6)	3.5 ± 2.9 (0.5-6.4)						
pH		7.08 ± 2.22 (5.51-8.65)	7.6 ± 0.7 (7.0-8.4)	6.5-8.5	6.5-8.5	5.5-9.0	5.5-9.0		6.5-8.5
S‰	ppt	10.8 ± 0.8 (0.0-21.5)	13.7 ± 13.3 (0.0-26.5)						
CaCO ₃	mg/L	98.5 ± 12.7 (89.5-107.4)	113.4 ± 10.4 (107.4-125.3)						
HCO ₃ ⁻	mg/L	119.9 ± 15.4 (109.0-130.8)	138.1 ± 12.6 (130.0-152.6)						
DO	mg/L	6.75 ± 1.77 (5.5- 6.5)	4.5 ± 1.0 (3.5 -5.5)	≥ 6	≥ 5	≥ 4	≥ 2	≥ 4	≥ 5
NO ₃ ⁻	mg/L	-	-	2	5	10	15	5	-
NO ₂	mg/L	-	0	0.01	0.02	0.04	0.05	0.02	-
NH ₄ ⁺	mg/L	0.18 ± 0.09 (0.00-0.25)	0	0.10	0.20	0.50	1.00	1.00	0.1-0.5
Total N	mg/L	5.0 ± 0.7 (4.5-5.0)	0.73 ± 0.12 (0.62-0.86)						
Total P	mg/L	1.5 ± 0.1 (1.4-1.6)	0.14 ± 0.03 (0.11-0.16)						
BOD ₅	mg/L	5.4 ± 4.3 (2.3-8.4)	0.83 ± 0.55 (0.3-1.4)	4.00	6.00	15.00	25.00	-	-
Total coliform	MPN/100 mL	7,300 ± 5,233 (3,600-11,000)	161.7 ± 73.2 (95.0-240.0)	2,500	5,000	7,500	10,000	-	1,000

A1: water quality is well used for domestic water supply and other purposes; A2: water quality is good for domestic water supply, but suitable treatment technology must be applied; conservation of aquatic plants and animals; B1: used for irrigation or other irrigation purposes with similar water quality requirements; B2: waterways and other purposes with low quality water requirements.

(7,300 ± 5,233 MPN/100 mL) in the rainy season in 2015, whereas in the dry season 2016 only 161.7 ± 73.2 MNP/100 mL. They were within the permitted limits of QCVN08-MT:2015/BTNMT [10], QCVN10-MT:2015/BTNMT [12] and QCVN38:2011/BTNMT [11]. Thus, the monitoring results showed that the seawater in Thi Nai Lagoon showed signs of slight organic pollution (especially nitrogenous compounds) and micro pollution.

Furthermore, the value of the environmental parameters has a relatively large variation between sampling sites. However, these values are within the limits of Vietnamese water quality standards, such as the seawater level of Thi Nai Lagoon was relatively high. In the rainy season, it ranged from 50.0 cm to 250.0 cm with average 137.5 cm, while in the sunny season on average 256.7 cm. Turbidity in the rainy season ranged from 2.9 NTU to 5.8 NTU with average 4.35 NTU, while in the dry season, ranged in 12.7-16.5 NTU with average 14.70 NTU. TDS were very low. In the rainy season, it fluctuated from 14.0 mg/L to 25.4 mg/L with average 19.7 mg/L, whereas, in the sunny season, fluctuated in 12.1-13.2 mg/L with 12.6 mg/L on average. The depth varied from 0.50 m to 50.00 m. Flow velocity varied from 0.00 m/s to 0.46 m/s. EC conductivity varied from 0.08 µS/cm to 40.30 µS/cm. TDS varied from 0.06 mg/L to 25.00 mg/L. It was much lower than the limit (1,000 mg/L) allowed under QCVN38:2011/BTNMT [11]. The temperature of the lagoon was within the allowed limits for shrimp culture under QCVN02-19:2014/BNN&PTNT (national technical regulation on water-based shrimp culture facilities: conditions for ensuring veterinary hygiene, environmental protection and food safety) [13]. Temperature ranged from 30.04 °C to 33.85 °C. Clear height varied from 50.00 cm to 130.00 cm, within the limits by QCVN02-19:2014/BNN&PTNT [13]. Turbidity varied from 1.20 NTU to 17.10 NTU with average 9.78 NTU. Turbidity standards are not specified in current standards or quality standards for

aquatic products, but according to the document by Le Cat et al. [14], turbidity below 45 NTU does not affect shrimp or fish. As such, turbidity levels in the Thi Nai Lagoon were still within the acceptable limits for aquaculture operations. The average pH value was 7.17 and varied from 6.10 to 8.20. Thus, according to QCVN02-19:2014/BNN&PTNT [13], Thi Nai Lagoon pH was still within the acceptable limits. Salinity fluctuations ranged from 0.00‰ to 26.30 ‰. The area of Kin river mouth was very low. Quy Nhon estuary area had the highest salinity. Alkalinity varied from 50.00 mg/L to 160.00 mg/L and is within the limit of QCVN02-19:2014/BNN&PTNT [13]. DO content varied from 3.55 mg/L to 8.92 mg/L and is still within the limit of QCVN02-19:2014/BNN&PTNT [13]. The content of NH₃, NO₃⁻, and BOD₅ were very low, within the limit of QCVN08-MT:2015/BTNMT (national technical regulation on surface water quality, column A2) [10]. The total density of coliform varied from 95.00 MPN/100 mL to 240.00 MPN/100 mL. This density was quite low as compared to the limit of QCVN08-MT:2015/BTNMT (column A2) [10]. Organic carbon content varied from 0.20% to 2.20% of dry land, with 1.07% of dry land on average. Nitrogen content varied from 0.02% to 0.06% of dry land and phosphorus varied from 0.03% to 0.08% of dry matter.

On the other hand, while most of the environmental parameters are within the safe limits, the values of some parameters exceed the limits, in the rainy season 2015, included:

(1) Average NH₄⁺ content (0.18 mg/L) with fluctuating from 0.0 mg/L to 0.250 mg/L. It exceeded the limit allowed under QCVN08-MT:2015/BTNMT (column A1: 0.1 mg/L and aquaculture: 0.1 mg/L).

(2) BOD₅ average (5.4 mg/L), fluctuating from 2.3 mg/L to 8.4 mg/L. It exceeded the limit allowed under QCVN08-MT: 2015/BTNMT (column A1: 4 mg/L; A2: 6 mg/L).

(3) The average content of coliform (7,300 MPN/100 mL), ranging in 3,600-11,000 MPN/100 mL. It

Table 5 Content of heavy metals and organic plant protection chemicals in sediments of lagoon.

Factors	Unit	Average (min-max)		QCVN38:2011/BTNMT [11]
		Rainy season 2015	Dry season 2016	
Arsenic (As)	mg/kg dry soil	0.25 ± 0.15 (0.12-0.41)	0.26 ± 0.06 (0.20-0.32)	41.60
Cadmium (Cd)	mg/kg dry soil	0.15 ± 0.15 (0.02-0.31)	0.17 ± 0.03 (0.15-0.20)	4.20
Lead (Pb)	mg/kg dry soil	2.20 ± 0.50 (1.70-2.70)	2.91 ± 1.20 (1.94-4.26)	112.00
Copper (Cu)	mg/kg dry soil	19.57 ± 0.60 (19.00-20.20)	17.64 ± 8.82 (8.80-26.43)	108.00
Chlordane	µg/kg	0.116 ± 0.281 Non (0-0.980)	Non (< 0.2)	4.8
DDD	µg/kg	1.429 ± 1.485 Non (0-2.950)	Non (< 0.4)	7.8
DDE	µg/kg	0.725 ± 0.505 Non (0-1.180)	Non (< 0.4)	374.0
DDT	µg/kg	Non (< 0.008)	Non (< 0.4)	4.8
Dieldrin	µg/kg	Non (< 0.004)	Non (< 0.2)	4.3
Endrin	µg/kg	Non (< 0.004)	Non (< 1.0)	62.4
Heptachlor epoxide	µg/kg	Non (< 0.016)	Non (< 0.2)	2.7
Lindan	µg/kg	Non (< 0.200)	Non (< 0.4)	1.0

Non: not found.

exceeded the limit allowed under QCVN10-MT:2015/BTNMT (1,000 MPN/100 mL) and QCVN08-MT:2015/BTNMT (2,500-10,000 MPN/100 mL).

(4) Nitrite content (mean 0.09 mg/L) and phosphate (on average 1.54 mg/L) was higher than QCVN08-MT:2015/BTNMT (column A2).

The result in Table 5 showed the content of heavy metals and organic plant protection chemicals in sediments of lagoon. In the rainy season 2015, the content of metal Cu ranged from 8.80 mg/kg to 77.70 mg/kg dry soil. The content of metal Zn varied from 16.80 mg/kg to 132.80 mg/kg dry soil. Fe content varied from 8,185.20 mg/kg to 30,512.50 mg/kg dry land. The content of metal Pb varied from 4.26 mg/kg to 45.43 mg/kg dry soil. The content of metal Cd ranged from 0.02 mg/kg to 0.31 mg/kg dry soil through survey sites. The content of heavy metals was very low as compared to the limit allowed under QCVN38:2011/BTNMT.

In the rainy season 2015, As content ranged from 0.12 mg/kg to 0.41 mg/kg dry land; Cd ranged from 0.02 mg/kg to 0.31 mg/kg dry soil; Pb ranged from 1.70 mg/kg to 2.70 mg/kg dry land; Cu ranged in 19.00-0.20 mg/kg dry land. The content of these metals in bottom sediments was lower than the limit

allowed under QCVN38:2011/BTNMT.

The results of pesticide residue analyzes in the sediments shown in Table 5 indicated that the deposition of pesticides was not detected in most of samples in the dry season 2016. Chlordane, DDD and DDE were found in sediment samples in Thi Nai Lagoon in rainy season 2015 with 0.116 ± 0.281 , 1.429 ± 1.485 and 0.725 ± 0.505 µg/kg, respectively. These values are within the allowable limits of QCVN38:2011/BTNMT.

Therefore, the water environment in Thi Nai Lagoon has no pollution by heavy metals and pesticides.

4. Conclusions

Research shows that in the Thi Nai Lagoon, there are potential aquatic resources with 106 species of fish, 17 species of mollusks and 15 species of crustaceans. Some potential aquaculture species include: *Therapon jarbua*, *Mugil cephalus*, *Mulgil kelaartii*, *Cynoglossus puncticeps*, *Caranx carangus*, *Arothron immaculatus*, *Siganus oramin*, *Meretrix meretrix*, *Meretrix lyrata*, *Penaeus monodon*, *Ranina ranina*, earth shrimps, blue crabs and blue crabs, etc..

The monitoring results show that the water quality in Thi Nai Lagoon is suitable for aquaculture, with no pollution by heavy metals and pesticides.

However, in the rainy season, there are signs of mild organic pollution.

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