
Assessment on seasonal variation of fish in the mangrove area, eastern Thailand

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Abstract A total of 1,655 individuals fish representing 33 families and 54 species were found. The family Gobiidae was dominant with 6 species (11%) followed by Ambassidae, Blenniidae, Engraulidae, Leiognathidae and Siganidae with 3 species (6%) and other families with one or two species each. One blackish water fish, *Neostethus lankesteri* was newly recorded in Rayong River and Trat mangrove area. In terms of water quality that related to the fish species, the distribution of fishes in the study areas were separated into 2 main groups of mangrove area of mainstream or canal ecosystem, was influenced by salinity and mangrove area of coastal ecosystem which influenced by the sea directly. Additionally, it found that many species of fishes had potential for commercial culture such as *Terapon jarbua*, *Abudefduf vaiqiensis*, *Siganus fuscescens*, *Neostethus lankesteri*, *Ambassis kopsii* and *Osteomugil cunnesius*.

Keywords: Fish biodiversity, Seasonal variation, Mangrove area, Eastern Thailand

Introduction

The mangrove forest ecosystem is an important natural resource and enormous benefits to aquatic animals. Because it is a habitat, shelter, breeding ground, laying egg area, and food source for various types of aquatic larvae that economic importance. Moreover, the mangrove forest is an important ecosystem in reducing wind intensity and slowing down the storm speed before landing (Petsut, 2008). Also, the mangrove forest decreases coastal erosion and acts as filter pollution not to contaminate directly into the seawater (Mangrove resources conservation office, 2013). Mangrove forest ecosystems are a high biodiversity source of aquatic animals, which is extremely important to local communities. Especially the various economic aquatic animals that the local people can use for food, fisheries and make money all year round (International Union for Conservation of Nature (IUCN), 2007).

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In recent times, the mangrove forest has been transformed continuously due to its exploitation in various activities, the encroachment of mangrove forests for aquaculture, housing, and industrial plants. Including natural causes such as coastal erosion, the mangrove forest, especially the eastern region, has been severely damaged and has reduced the mangrove area (Luangprasert, 2007; Ratmuangkhwang *et al.*, 2014). This ecological change directly affects the living of aquatic animal resources and significantly affects the decline in aquatic animal resources (Hogarth, 1999).

Therefore, in making the best utilization of limited natural aquatic resources, especially fish resources. There is a need to have a sufficient resource database, especially for the use of new economic fish aquaculture to increase income opportunities. The ecological data of fish species is needed to simulate aquaculture systems, information on species, quantity, and distribution of economic fish species. Establishing these critical databases requires field-based research, which studies “assessment on seasonal variation of fish in the mangrove area, eastern Thailand.” The study aimed to collect the data of fish resources in mangrove ecosystems in the eastern region of Thailand (Chonburi Province, Rayong Province, Chanthaburi Province, and Trat Province) to process and create a database of fish resources in the eastern region.

Materials and methods

Study areas

Mangrove forest areas in the eastern part of Thailand in Chonburi Province, Rayong Province, Chanthaburi Province, and Trat Province were studied. The approximate length of the coastline is 527 km (Figure 1), dividing the sampling point according to the ecological characteristics and covering the area with different environmental conditions. It can be divided into 8 stations as follows.

ST1 Rong Poa mangrove area, Banglamung District, Chonburi Province [13.042208N / 100.923452 E] is a mangrove forest that grows on a small canal directly connected to the sea and is a regenerated mangrove forest directly influenced by wastewater from communities and homes.

ST2 Sattahip mangrove area, Sattahip District, Chonburi Province [12.688855N / 100.978792E] is a mangrove forest that grows on sandy beaches and rocky shores. The area is strong waves and winds that continue almost all year round—the sea influences mangrove forests only at the highest tide.

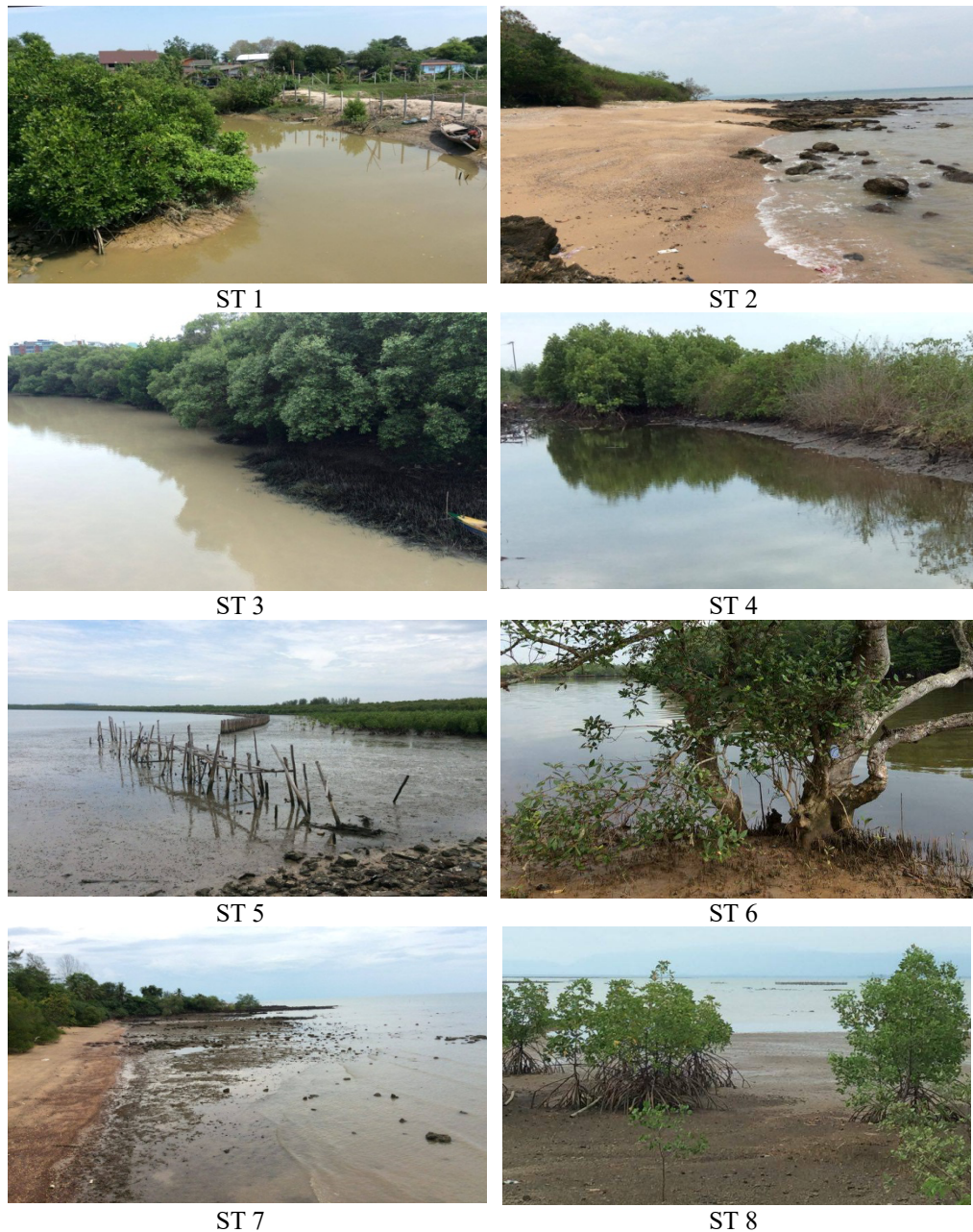


Figure 1. Study areas in the eastern part of Thailand in Chonburi Province, Rayong Province, Chanthaburi Province, and Trat Province

ST3 Rayong estuary mangrove area, Mueang District, Rayong Province [12.666646N / 101.243625E] is a mangrove forest that grows at the estuary.

Moreover, freshwater is drained from irrigation. Therefore, the salinity changes over time between 0-30 ppt.

ST4 Pra Sae estuary mangrove area, Klaeng District, Rayong Province [12.697166N / 101.694850E] The Black Forest is a mangrove forest that grows at the estuary, directly connected to the sea. The salinity in this area was unchanged, an average of 30 ppt.

ST5 Laem Sing estuary mangrove area, Laem Sing District, Chanthaburi Province [12.491882N / 102.040625E] is a mangrove forest that grows in the mud beach, and the sea bottom soil is a very thick mud formation. The area is a conservation zone, so it is highly productive.

ST6 Tha Mai mangrove area, Tha Mai District, Chanthaburi Province [12.616772N / 101.960155E] is a mangrove forest that grows at the estuary. The change in water salinity depends on the opening-closing of the floodgates. Salinity is between 0-30 ppt.

ST7 Ao Cho mangrove area, Mueang District, Trat Province [12.058299N / 102.549400E] is a mangrove forest that grows on sandy beaches and the rocky coastline. The area found several types of economic seaweed.

ST8 Laem Thian mangrove area, Mueang District, Trat Province [12.087797N / 102.568257E] is a mangrove forest that grows on a sandy beach. Most of the mangrove forests have been transformed into aquaculture farms such as shrimp farms.

Study of water quality in mangrove forests

Seawater samples were collected in the mangrove forests at a depth of approximately 30 centimeters from the water surface. Seawater samples were collected in the same locations as the fish samples were collected at 8 areas, with 3 samples in each area. Seawater samples were collected every 4 months, for a total of 3 times, in April (summer), August (rainy season), and December (winter) in 2017. Ten water quality data parameters were collected, including water turbidity using HACH 2100Q, water salinity using Refracto-salinometer, water pH using pH meter, and dissolved oxygen using Thermo Scientific Genesys 20. In addition, alkalinity was collected by titration method, ammonia by Modified indophenol blue method, nitrite by Sulfanilic acid method, nitrate by Cadmium-copper column method, orthophosphate by ascorbic acid method (APHA, AWWA, WEF, 2012).

Study on species diversity, density, and distribution of fishes

Fish samples were collected using a beach seine of 1 x 1 mm mesh size (wide 10 m, depth 2 m), dragging the sample for a distance of 10 m, 3 times at each area. All samples were preserved in 10% formaldehyde solution. Fish samples were collected every four months: April, August, and December 2017. Fish species were identified using relevant research papers such as Kottelat *et al.* (1993), Carpenter and Niem (1999a, 1999b, 2001), Matsuura and Kimura (2005), and original description. A taxonomic list of fish species was classified by Nelson (2006). The fish samples were measured for standard length (SL) in centimeters and weight in grams to study the structure of fish populations and the distribution of fish in each season.

Data analysis

Data were analyzed by descriptive statistics, i.e., highest-lowest value, mean, percentage, and standard deviation, to describe an overview of trends in water quality changes in each season. The ecological indices, including Diversity index, Evenness index, and Dominant index, were analyzed according to Krebs (1989; 1999). Statistical differences of the average water quality in each season, the average density of fish, and the average of the ecological indices were analyzed with one-way ANOVA analysis at a 95 percent confidence level. The relationship between environmental factors, average density of fish, and ecological index were analyzed. The conditions were tested for parametric statistical conditions before the analysis. If the data has a normal distribution, Pearson correlations statistics were used to analyze. Spearman correlation statistics were used to analyze if the data has an abnormal distribution.

Results

Water quality changes in mangrove areas

The water quality parameters of the mangrove areas in the study areas between April and December 2017 were summarized in Table 1. The water salinity in the mangrove areas varied on average throughout the three seasons between 0-33 ppt, with salinity in each area being statistically different ($P < 0.05$). In addition, the water turbidity varied across the three seasons between 5.0–328.0 NTU ($P < 0.05$), with the highest value in the rainy season and the lowest value in winter. pH, total hardness, and alkalinity were different mean variables between the three seasons ($P < 0.05$), with the highest values in summer and the lowest value in the rainy season. Dissolved oxygen averaged between 4.27–9.37

mg/L, which was considered to be in the appropriate standard. In terms of nutrients, nitrites, nitrates, and orthophosphates were analyzed. The value of nutrients was in the appropriate standard, but total ammonia was above average in summer.

Species diversity of fish in the mangroves of eastern Thailand

The survey results of fish species in the study area from April until December 2017 showed that 33 families and 54 species were found. Gobiidae was the predominant family with the highest number of species, 6 species, namely *Glossogobius aureus*, *Gobiopterus chuno*, *Acentrogobius* cf. *viridipunctatus*, *Acentrogobius caninus*, *Pseudapocryptes elongatus*, and *Boleophthalmus boddarti*, followed by Engraulidae, Ambassidae, Siganidae, Leiognathidae, and Blenniidae, found 3 species in each family. Other families found only 1-2 species per family.

Table 1. Water quality in the mangrove area, eastern Thailand

water quality parameters	Season			p-value
	Summer	rainy season	winter	
Salinity (ppt)	(0 - 33)	(0 - 30)	(25 - 30)	0.002
	24.63 ± 13.78	17.50 ± 14.88	29.38 ± 1.77	
Turbidity (NTU)	(12.03 – 31.67)	(6.23 – 328.00)	(5.00 – 33.07)	0.001
	19.06 ± 8.86	78.70 ± 106.89	16.55 ± 9.05	
pH	(7.41 – 8.56)	(7.09 – 8.26)	(8.14 – 8.53)	0.000
	8.09 ± 0.44	7.84 ± 0.39	8.31 ± 0.17	
Alkalinity (mg CaCO₃/L)	(48.00 – 123.33)	(32.00 – 150.00)	(106.67 – 121.67)	0.035
	106.00 ± 23.98	95.33 ± 38.72	114.96 ± 5.99	
Hardness (mg CaCO₃/L)	(105.33 – 5,946.67)	(29.33 – 5,753.33)	(4,733.33 – 5,683.33)	0.000
	4,383.17 ± 2,380.59	3,082.92 ± 2,601.89	5,506.25 ± 314.96	
Dissolved oxygen (mg/L)	(4.27 – 8.90)	(5.13 – 9.37)	(5.83 – 8.37)	0.713
	6.88 ± 1.90	7.13 ± 1.66	7.23 ± 1.12	
Total Ammonia (mg N/L)	(0.04 – 7.91)	(0.02 – 1.70)	(0.04 – 1.36)	0.000
	4.59 ± 2.67	0.43 ± 0.57	0.36 ± 0.43	
Nitrite (mg N/L)	(0.008 – 0.135)	(0.006 – 0.328)	(0.007 – 0.040)	0.037
	0.03 ± 0.04	0.06 ± 0.11	0.01 ± 0.01	
Nitrate (mg N/L)	(0.012 – 0.145)	(0.066 – 0.512)	(0.013 – 0.068)	0.000
	0.05 ± 0.05	0.15 ± 0.15	0.03 ± 0.02	
Orthophosphate (mg P/L)	(0.022 – 0.899)	(0.030 – 0.213)	(0.013 – 0.603)	0.220
	0.17 ± 0.30	0.07 ± 0.06	0.14 ± 0.20	

The study is firstly reported of *Neostethus lankesteri* in the Rayong River, Rayong Province, and Cho Bay, Trat Province (Figure 2).

Characteristics of a taxonomic description

N. lankesteri was compressiform, body depth 16.0–23.1 %SL, body width 5.3–6.8 %SL, medium to large lateral scales, head length 24.7–32.1 %SL, head depth 11.4–16.2 %SL or 42.8–51.4 %HL, big eye, eye diameter 20.2–25.1 %HL, posterior eye length to gill opercle 41.6–52.4 %HL, upper jaw length to nostril 12.8–22.5 %HL, prepelvic fin length 24.1–23.5 %SL, preanal fin length 53.2–58.8 %SL, elongated anal fin, 13–17 rays, 1 spine on the dorsal fin, dorsal fin base length 4.3–7.8 %SL, and anal fin base length 16.2–20.3 %SL (SL=standard length, HL=head length).

Distribution

In Thailand, *N. lankesteri* has been reported in the estuary of the Chanthaburi River, the estuary of Phetchaburi River, the estuary of Mae Klong River, and the estuary of the Chao Phraya River. However, in the eastern region, *N. lankesteri* has reported only one area in the estuary of Chanthaburi River. This study was the first report in Rayong River, Rayong Province, and Cho Bay, Trat Province.



Figure 2. *Neostethus lankesteri*, 3.8 cm standard length

Seasonal distributions of fish species

From the study of the fish species distribution in each season, it was found that most of the fish species found in each season were similar due to ecological

and environmental factors such as water quality characteristics that were not significantly different. However, some areas found that environmental factors differ from each season, such as water salinity, total alkalinity, and total hardness, resulting in different fish species found in each season (Table 2).

Fish species were found in all seasons. It was found that there were 10 families and 14 species, namely *Neostethus lankesteri*, *Oryzias javanicus*, *Ambassis vachellii*, *Ambassis kopsii*, *Sillago sihama*, *Osteomugil cunnesius*, *Terapon jarbua*, *Siganus fuscescens*, *Nuchequula blochii*, *Omotubbranchus punctatus*, *Mimoblennius* sp., *Butis butis*, *Acentrogobius* cf. *viridipunctatus*, and *Boleophthalmus boddarti*. Therefore, it indicated that the species is endemic.

Table 2. Seasonal distributions of fish species in the study area

Family	Scientific name	Specimens			Total specimens	Percentage
		Summer	rainy season	winter		
Engraulidae	<i>Stolephorus indicus</i>	+		+	4	0.2417
	<i>Setipinna taty</i>		+		3	0.1813
	<i>Thryssa hamiltonii</i>			+	18	1.0876
Dorosomatidae	<i>Sardinella gibbosa</i>		+		2	0.1208
Danionidae	<i>Rasbora trilineata</i>		+		27	1.6314
Plotosidae	<i>Plotosus canius</i>	+	+		1	0.0604
Zenarchopteridae	<i>Zenarchopterus buffonis</i>	+	+		6	0.3625
Phallostethidae	<i>Neostethus lankesteri</i>	+	+	+	241	14.562
Belonidae	<i>Strongylura strongylura</i>			+	1	0.0604
Adrianichthyidae	<i>Oryzias javanicus</i>	+	+	+	298	18.006
Poeciliidae	<i>Gambusia affinis</i>			+	1	0.0604
Mullidae	<i>Upeneus traquila</i>	+			1	0.0604
Ambassidae	<i>Ambassis vachellii</i>	+	+	+	6	0.3625
	<i>Ambassis kopsii</i>	+	+	+	234	14.139
	<i>Parambassis wolffii</i>	+			8	0.4834

Family	Scientific name	Specimens			Total specimens	Percentage
		Summer	rainy season	winter		
Epinephelidae	<i>Epinephelus bleekeri</i>	+			8	0.4834
	<i>Epinephelus quoyanus</i>	+			1	0.0604
Scatophagidae	<i>Scatophagus argus</i>		+	+	5	0.3021
Lethrinidae	<i>Lethrinus lentjan</i>		+		1	0.0604
Pomacentridae	<i>Dascyllus cf. trimaculatus</i>	+			1	0.0604
	<i>Abudefduf vaiqiensis</i>	+		+	5	0.3021
Holocentridae	<i>Sargocentron rubrum</i>	+		+	3	0.1813
Scaridae	<i>Scarus ghobban</i>		+		1	0.0604
Sillaginidae	<i>Sillago sihama</i>	+	+	+	5	0.3021
Mugilidae	<i>Osteomugil cunnesius</i>	+	+	+	171	10.332
	<i>Ellochelon vaigiensis</i>		+		10	0.6042
Latidae	<i>Lates calcarifer</i>		+		2	0.1208
Sciaenidae	<i>Aspericorvina jubata</i>		+		1	0.0604
Terapontidae	<i>Terapon jarbua</i>	+	+	+	51	3.0816
Lutjanidae	<i>Lutjanus russellii</i>		+	+	6	0.3625
Gerreidae	<i>Gerres cf. oyema</i>	+		+	36	2.1752
Siganidae	<i>Siganus fuscescens</i>	+	+	+	78	4.713
	<i>Siganus javus</i>		+	+	20	1.2085
	<i>Siganus guttatus</i>		+	+	9	0.5438
Cichlidae	<i>Oreochromis mossambicus</i>		+		1	0.0604
	<i>Oreochromis niloticus</i>			+	3	0.1813
Leiognathidae	<i>Leiogathus equulus</i>	+	+		2	0.1208

Family	Scientific name	Specimens			Total specimens	Percentage
		Summer	rainy season	winter		
	<i>Nuchequula blochii</i>	+	+	+	29	1.7523
	<i>Secutor megalolepis</i>			+	4	0.2417
Platycephalidae	<i>Cociella punctata</i>	+			1	0.0604
Blenniidae	<i>Omobranchus ferox</i>	+		+	19	1.148
	<i>Omobranchus punctatus</i>	+	+	+	25	1.5106
	<i>Mimoblennius sp.</i>	+	+	+	59	3.565
Butidae	<i>Butis butis</i>	+	+	+	29	1.7523
	<i>Butis koilomatodon</i>	+		+	26	1.571
Gobiidae	<i>Glossogobius aureus</i>	+			3	0.1813
	<i>Gobiopterus chuno</i>			+	5	0.3021
	<i>Acentrogobius caninus</i>		+		3	0.1813
	<i>Acentrogobius cf. viridipunctatus</i>	+	+	+	174	10.514
	<i>Pseudapocryptes elongatus</i>	+			1	0.0604
	<i>Boleophthalmus boddarti</i>	+	+	+	4	0.2417
Channidae	<i>Channa striata</i>	+			1	0.0604
Cynoglossidae	<i>Paraplausia blochii</i>	+	+		1	0.0604
Total 33 families, 54 species		33	32	30		

Ecological structure of seasonal fish species

The comparison of the ecological structure consists of fish population density, fish yield, and ecological index, including diversity index, evenness index, and dominance index (Table 3). It was found that the 3 ecological indices of mangrove fish in each season were not statistically different ($p>0.05$). The

mean diversity index was ranged from 1.11–1.51, the mean evenness index ranged from 0.27–0.46, and the dominance index averaged ranged from 0.54–0.73.

The fish yield and density data showed that the fish yields in each season of the study area were not statistically different ($p>0.05$), with mean values in the range of 2.51–4.72 kg/rai. Nevertheless, in terms of density, it was found that the average density was 2.97 ± 2.77 number/m² in summer. It was higher than other seasons. In the rainy season and winter, the average density was 1.00 ± 0.65 and 0.90 ± 0.74 number/m², respectively, which were not statistically different ($p>0.05$). In Overview, it can be indicated that the ecological population structure of fish in each season was not statistically different ($p>0.05$), except that the fish density in summer was significantly higher than in other seasons. Because small fish fry was found more than in other seasons, such as *Ambassis vachellii* found more than 270 specimens, and *Oryzias javanicus* found more than 250 specimens.

Table 3. Differences in the ecological structure of seasonal fish species

Ecological structure	season		
	Summer	rainy season	winter
Density (number/m ²)	2.97 ± 2.77^a	1.00 ± 0.65^b	0.90 ± 0.74^b
Fish yield (kg/rai)	3.80 ± 3.32^a	4.72 ± 3.86^a	2.51 ± 2.21^a
Diversity index	1.11 ± 0.54^a	1.34 ± 0.59^a	1.51 ± 0.39^a
Evenness index	0.27 ± 0.16^a	0.38 ± 0.20^a	0.46 ± 0.19^a
Dominance index	0.73 ± 0.16^a	0.63 ± 0.20^a	0.54 ± 0.19^a

Remark: Horizontally different English alphabets mean statistically different at 95% confidence level, 1 rai = 0.16 hectare

The relationship between ecological structure and seasonal environmental factors

In summer, the relationship between ecological structure and environmental factors found that the fish yield and the ecological indexes did not correlate ($p>0.05$) with the water quality factor. However, fish density factors were related to 4 environmental factors: salinity, alkalinity, total hardness, and nitrate. Density highly correlated with salinity in the opposite direction ($r = -0.709$), as same as in alkalinity ($r = -0.937$) and total hardness ($r = -0.715$). The high correlation of nitrate was in the same direction as density ($r = 0.815$).

In the rainy season, it was found that the water quality factors were not related to the density and fish yield. However, water quality factors were related to the ecological population structure, i.e., the diversity index highly correlated with the water salinity ($r = 0.771$), while the evenness index highly correlated in the same direction as the pH ($r = 0.736$) and dissolved oxygen ($r = 0.773$). The dominance index highly correlated in the opposite direction to pH ($r = -0.736$) and dissolved oxygen ($r = -0.773$).

In the winter, it was found that the water quality factors were not related to the density and fish yield. However, water quality factors related to the ecological population structure: pH highly correlated with the evenness index ($r = 0.754$) in the same direction, and it was high in the opposite direction to the dominance index ($r = -0.754$). In overview, it can be concluded that Environmental factors in each season were related to changes in fish population structure.

Table 4. Relationship between ecological structure and environmental factors in summer

Environmental factors	Correlation coefficient (r)				
	Density	Fish yield	Diversity index	Evenness index	Dominance index
Salinity	-0.709*	0.416	0.474	0.517	-0.517
Turbidity	-0.520	0.659	0.188	0.200	-0.200
pH	-0.594	0.689	0.674	0.662	-0.662
Dissolved oxygen	-0.295	0.591	0.397	0.428	-0.428
Alkalinity	-0.937*	0.108	0.153	0.299	-0.299
Hardness	-0.715*	0.427	0.489	0.532	-0.532
Nitrite	0.154	-0.399	-0.510	-0.459	0.459
Nitrate	0.815*	-0.427	-0.642	-0.690	0.690
Total Ammonia	0.065	0.018	0.507	0.458	-0.458
Orthophosphate	-0.008	-0.346	-0.379	-0.309	0.309

Remark * = Ecological structure and environmental factors were statistically correlated at 0.05 level of significance.

Table 5. Relationship between ecological structure and environmental factors in rainy season

Environmental factors	Correlation coefficient (r)				
	Density	Fish yield	Diversity index	Evenness index	Dominance index
Salinity	0.113	0.270	0.771*	0.695	-0.695
Turbidity	-0.514	0.102	0.275	0.557	-0.667
pH	-0.136	0.579	0.693	0.736*	-0.736*
Dissolved oxygen	-0.507	0.598	0.679	0.773*	-0.773*
Alkalinity	-0.025	-0.064	0.386	0.569	-0.569
Hardness	0.192-	0.184	0.641	0.598	-0.598
Nitrite	0.120	-0.461	-0.604	-0.506	0.506
Nitrate	-0.224	-0.396	-0.679	-0.565	0.565
Total Ammonia	-0.222	-0.413	-0.505	-0.283	0.283
Orthophosphate	-0.043	-0.520	-0.606	-0.519	0.519

Remark * = Ecological structure and environmental factors were statistically correlated at 0.05 level of significance.

Table 6. Relationship between ecological structure and environmental factors in winter

Environmental factors	Correlation coefficient (r)				
	Density	Fish yield	Diversity index	Evenness index	Dominance index
Salinity	-0.063	0.382	-0.195	0.066	-0.066
Turbidity	0.182	0.465	-0.364	-0.240	0.240
pH	-0.741	0.124	0.532	0.754*	-0.754*
Dissolved oxygen	-0.436	0.489	0.180	0.408	-0.408
Alkalinity	-0.195	0.157	-0.470	-0.174	0.174
Hardness	0.005	0.484	-0.246	0.001	-0.001
Nitrite	0.135	-0.421	0.090	-0.153	0.153
Nitrate	-0.142	-0.608	0.272	0.045	-0.045
Total Ammonia	-0.254	-0.268	0.083	0.007	-0.007
Orthophosphate	-0.042	-0.563	0.181	-0.055	-0.055

Remark * = Ecological structure and environmental factors were statistically correlated at 0.05 level of significance.

Discussion

The study of mangrove fish species in the eastern region of Thailand, Chonburi Province, Rayong Province, Chanthaburi Province, and Trat Province during April–December 2017, fish specimens and environmental factor data were collected every four months, covering the summer (April), rainy season

(August), and winter (December). From 8 sampling areas, 1,655 fish specimens were found, categorized into 33 families, 54 species. The family Gobiidae was the highest species number, 6 species (11%), which was consistent with the study of fish resources in the Kampuan canal mangrove forest, Ranong province, found that Gobiidae was the highest number of species (Ratmuangkhwang *et al.*, 2014). In addition, it was consistent with the study of fish in other communities in mangrove ecosystems (Tongnunui *et al.*, 2002; Ikejima *et al.*, 2003). Furthermore, it was consistent with Duangdee (1998) report studying fish larvae on the west coast of Thailand. The family Gobiidae was found in terms of the highest species number and quantity.

The number of fish families found in this study was similar to Viteesawat (1999), who studied fish population structure in the Tha Chin River estuary mangrove areas, Samut Sakhon Province, central Thailand. 35 families and 73 fish species were found. In addition, a study by Kiat-amornwet (2014) studied the structure of fish populations in mangrove areas of Phetchaburi estuary found 11 orders, 33 families, 54 species. The fish family number found similarly may result from similar ecosystems of mangrove areas along the upper Gulf of Thailand. For the study of fishes in mangrove areas along the Andaman Sea, Boonruang *et al.* (1994) reported fish populations in the mangrove areas of Phang Nga Bay during 1991–1993. 38 fish families and 42 species were found, and the Fish Team of the Trang Project (2002) surveyed fish species in the Khlong Sikao mangrove areas, Trang Province, which was an important fishery resource in southern Thailand, from 1996–2001 found 49 families, 86 genera, 134 species. Also, a study by Ratmuangkhwang *et al.* (2014) surveyed fish resources in the Klong Kam Phuan mangrove forest, Ranong province, found 11 orders, 39 families, and 83 species. Order Perciformes had the most significant number of species, with 52 species (63% of all species). Consistent with this study, the fish in the order Perciformes had the highest number of species, 34 species (64% of all species). The Perciformes fish are most common to marine fish species because Perciformes is the highest species number of marine and brackish water ecosystems (Nelson, 2006).

This study found that the area with the highest fish diversity was station 7 (ST7). Ao Cho mangrove area contained 21 species, possibly because the area was the most abundant mangrove forest. Moreover, the area was influenced by wind waves all year round and was a conservation area for marine resources. The mangrove forests were rich in fish resources because the mangrove forests in this area contain a wide variety of plants whose roots were suitable for shelters from pests and feed the aquatic larvae (Kiat-amornwet, 2014). In addition, the roots of mangrove trees trap nutrients and various sediments that flow from the land into the sea. Thus, mangrove trees help the coastal land be stable and improve the

water quality in the coastal areas (Anongponyoskun and Doydee, 2006; Ellison, 2008; Doydee, 2009). Effects of mangrove leaves fall over time, causing the abundance of food in the area. Therefore, it is an area suitable for the living of aquatic animals and fishes (Blaber, 2000).

The study was the additional report of *Neostethus lankesteri* in eastern Thailand. The genus *Neostethus* is the only fish species reported in Southeast Asia (Myers, 1928; Parenti, 1984). In Thailand, *N. lankesteri* has been reported in the estuary of the Chanthaburi River, the estuary of Phetchaburi River, the estuary of Mae Klong River, and the estuary of the Chao Phraya River. However, in the eastern region, *N. lankesteri* has reported only one area in the estuary of Chanthaburi River. This study was the first report in Rayong River, Rayong Province, and Cho Bay, Trat Province.

The seasonal distribution of fishes in the study area can be divided into 3 groups: (1) Fish species found in all seasons (10 families, 14 species) indicate that they were endemic fish species that lived mainly in mangrove forests all year round. It was also a fish that can be highly adaptive to resist environmental variability; (2) Fish species found only in the rainy season (10 families, 10 species) indicate that they were freshwater fish. Because in the rainy season, the water salinity was significantly reduced, especially in some mangrove areas, the salinity was reduced to 0 parts per thousand (ppt); (3) Fish species found only in summer and winter (16 families, 21 species) indicated that they were more sensitive to changes in salinity than other fish groups because of the period of statistically higher salinity than the rainy season. An average salinity was in the range of 25–30 ppt, but the water salinity level was lower in the rainy season.

Conflicts of interest

The authors declare no conflict of interest.

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