ความหลากหลายและการกระจายของลูกปลาในพรุควนขี้เสียน จังหวัดพัทลุง
Diversity and Distribution of Juvenile Fishes in the Khuan Khee Sean Peat Swamp, Phatthalung Province

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บทคัดย่อ

ศึกษาความหลากหลายและการกระจายของลูกปลาในพื้นที่พรุควนขี้เสียน จังหวัดพัทลุง โดยเก็บตัวอย่างด้วยเครื่องมืออวนรุน ขนาด 1x1x1 เมตร^3 ขนาดช่องตา 1 มิลลิเมตร ทุกสองเดือน ระหว่างเดือนสิงหาคม พ.ศ. 2558 ถึงเดือนมิถุนายน พ.ศ. 2559 ใน 6 สถานีสำรวจรอบพื้นที่พรุ โดยมีวัตถุประสงค์เพื่อศึกษาลักษณะทางกายภาพของพรุควนขี้เสียน ประเมินความหลากหลาย ความชุกชุม และการแพร่กระจายของลูกปลา ศึกษาโครงสร้างประชาคมของลูกปลา และประเมินความสัมพันธ์ระหว่างคุณภาพน้ำกับชนิดและปริมาณลูกปลา ผลการศึกษาพบว่า ชนิดลูกปลาที่พบรวมทั้งสิ้น 30 ชนิด จำนวน 14 วงศ์ โดยลูกปลากลุ่มวงศ์ปลาตะเพียนมีความหลากหลายของชนิดพันธุ์มากที่สุดรวม 12 ชนิด และมีปลากริมเพียงชนิดเดียวที่พบในทุกสถานีสำรวจและทุกรอบสำรวจ ค่าผลผลิตทางการประมงพบว่ามีค่าเฉลี่ย 587 ตัวต่อพื้นที่ 100 ตารางเมตร โดยพบปลาหัวตะกั่ว *Aplocheilus panchax* ปลาซิวหนู *Boraras urophthalmoides* และปลากริม *Trichopsis vittata* เป็นองค์ประกอบของโครงสร้างหลัก ซึ่งพบมากที่สุด 3 ลำดับแรก ดัชนีความหลากหลายมีค่าสูงสุดบริเวณตอนบนของพรุ และในเดือนธันวาคม พ.ศ. 2558 เส้นโค้งลำดับความชุกชุมชี้ให้เห็นว่าความชุกชุมของลูกปลาชนิดหลัก 2-3 ชนิดจะมีสัดส่วนมากกว่าร้อยละ 50 ของความชุกชุมในพื้นที่นั้น ๆ ในส่วนรูปแบบของการรวมกลุ่มของลูกปลาในพื้นที่พรุควนขี้เสียนสามารถแบ่งได้เป็น 4 กลุ่ม ซึ่งสัมพันธ์กับแต่ละช่วงเวลาในรอบปี แต่ไม่พบแนวโน้มที่ชัดเจนต่อความสัมพันธ์กับค่าคุณภาพน้ำ

คำสำคัญ: ความชุกชุม คุณภาพน้ำ รูปแบบการรวมกลุ่ม

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Abstrarct

Diversity and distribution of juvenile fishes in the Khuan Khee Sean peat swamp, Phatthalung province were studied. The samplings were conducted bi-monthly between August 2015 and June 2016 in 6 sampling stations around the peat swamp area by using the push net (1x1x1 m^3) with the mesh size of 1 mm. The objectives were to study the characteristics of Khuan Khee Sean peat swamp, to assess the diversity, abundance and distribution of juvenile fish, to study the juvenile fish community structures, and to assess the relationship between water quality parameters, species, and juvenile fish abundances. Thirty juvenile fish species in 14 families were collected with the highest diversity of species from Family Cyprinidae (12 species). Only *Trichopsis vittata* was found in every station and every survey round. The average fishery products were 587 fishes/100 m^2, in which *Aplocheilus panchax*, *Boraras urophthalmoides* and *Trichopsis vittata* were the main elements of the structure as the three most abundance species. Peaks of diversity index were observed in the station at the upper part of the swamp and in the December 2015. The ranked species abundance curves indicated the domination of few species contributed over 50% of cumulative dominance in the area. The assemblage patterns of juvenile fishes in the Khuan Khee Sean peat swamp can be categorized into 4 groups related to the temporal approach. However, there was no clear relationships with the water quality parameters.

Keywords: abundance, water quality, assemblage patterns

Introduction

Tropical peat swamp is a unique ecosystem, which more than 60% is found in Indo-Malayan region and largely in Indonesia and Malaysia (Page *et al*., 2006; Yule, 2010). In Thailand, the total covered area of the peat swamps (“Phru” in Thai language) is estimated about 64,500 ha, where more than 95% ubiquitously distributed in the southern region and the small portion is in the eastern region (Nagano *et al*., 2013). Similar to peat swamps elsewhere in the Southeast Asia, this habitat type in Thailand is under threatened, which mostly due to land reclamation and agricultures (Yule, 2010). Water in the peat swamp is always waterlogged and characterized by the acidic and nutrient poor condition. The fishes live in this ecosystem, therefore, must well adapt to this harsh condition, in which some species are monotypic and live exclusively in peat swamps, such as Nieuhof's walking catfish *Clarias nieuhofii*, Angler catfish

Chaca bankanensis, striped glass catfish *Kryptopterus macrocephalus*, needlefishes *Hemiramphodon pogonognathus* and fighting fish *Betta pi* (Vidthayanon, 2002).

The peat swamp (Phru) is also an important fishing ground in Thailand. A number of peat swamps, e.g. Phru Khuan Khee Sean in Phatthalung Province, Phru Toh Dang in Narathiwat Province, Phru Kaun Kreng in Nakhon Si Thammarat Province and Phru Samed in Trang Province. These peat swamps are underwent the intensive fishing pressures. The fish catched from the Phru Kaun Kreng, for example, are around 3,500 metric tons annually and cost more than 170 million Thai Baht per year (Nakhon Si Thammarat Inland Fisheries Research and Development Center, 2018). This is, therefore, raised the concern in a proper fisheries management program for the sustainable exploitation in such habitat, which understanding in diversity, abundance, distribution and community structure of the fishes, are among important issues. These understandings could be started in the early life-stage fishes since they reflect the spawning success and assure the recruitment to the exploited populations (Quist *et al*., 2004). Moreover, spatio-temporal variations of diversity and abundance of the juvenile fishes are generally high due to the behavioral and environmental features (Hsieh and Lo, 2019).

Diversity and distribution in the early life stage of fishes have been conducted in various type of habitats in Thailand, for example, river-floodplains (Suksri and Boonsong, 2018), reservoirs (Jutagate *et al*., 2016), coastal areas (Sichum *et al*., 2013) and continental shelves (Munk *et al*., 2004) but never in peat swamps. Regarding the overlook to the fishes during the early life stage in the peat swamps, though providing goods and services to the system, this study aims to outline (i) the diversity indices of the juvenile fishes in the studied peat swamp and (ii) the distribution or their assemblage patterns in the spatio-temporal approach.

Materials and Methods

1. Study area

The Khuan Khee Sean peat swamp, or Phru Khuan Khee Sean, is a wetland within Thalenoi Non-Hunting Area, the first Thailand Ramsar site in Phatthalung Province (Figure. 1). This peat swamp covers the area about 17 km^2 out of 460 km^2 of the Thalaenoi with water depth ranges of the swamp *per se* is between 0.1 and 2.0 m. Data sampling was conducted in 6 sampling stations every two months between August 2015 and June 2016 (Table 1), including the inlet-, outlet- and open water-zones of the swamp.

Table 1 Location and detail of sampling stations for juvenile fish study in Phru Khuan Khee Sean, Thailand, between August 2015 and June 2016

Station	Co-ordinates	Detail
1	7°51'41.21"N 100°6'38.41"E	Upper part of the swamp, which is the inlet from Phru Kuan Kreng (i.e. the large peat swamp that connects to Phru Khuan Khee Sean)
2	7°50'7.42"N 100°7'31.10"E	Upper part of the swamp, which is the inlet from Klong Koowa Canal (i.e. transition to freshwater)
3	7°49'23.95"N 100°6'47.24"E	Middle part of the swamp, which is the outlet to Klong Takreng Canal (i.e. transition to freshwater)
4	7°49'34.00"N 100°7'50.96"E	Middle part of the swamp
5	7°49'13.62"N 100°7'14.21"E	Middle part of the swamp, which is the outlet to Klong Kreng Canal (i.e. transition to freshwater)
6	7°47'30.26"N 100°7'11.78"E	Lower part of the swamp, which is the outlet Thalaenoi (i.e. transition to freshwater)

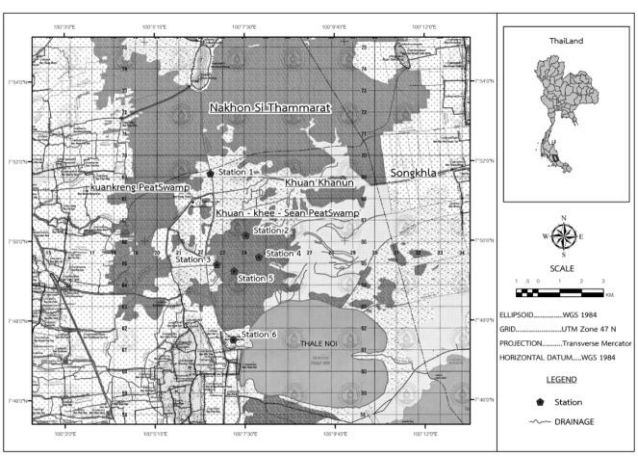

Figure 1 Location and map of Phru Khuan Khee Sean, where sampling stations (black dots) are indicated

2. Sampling protocols

The juvenile fishes were collected by push net (1x1x1 m^3) with the mesh size of 1 mm. Each replication consisted of 10 times of 1 meter-pushing-distance and there were 3 replications for a sampling. The collected juvenile fishes were preserved in 4% formalin solution and then taxonomically identified in the laboratory (Termvichakarn 2003; 2005). Water quality parameters were also collected in each sampling site by using the standard methods (APHA, 1989), in which the parameters included depth, water temperature, transparency, conductivity, turbidity, chlorophyll-a, dissolved oxygen,

pH, alkalinity, hardness, free carbondioxide, orthophosphate, total phosphorus, ammonia (NH_3-N), nitrite (NO_2-N) and nitrate (NO_2-N).

3. Data analysis

Abundance of juvenile fishes were presented as individuals per 100 m^2. Shannon-Weiner diversity index (H') and evenness index (E) were estimated according to Equations 1 and 2, respectively. (Clarke and Warwick, 1994).

$$H' = -\sum_{i=1}^{s} (P_i \log_2 P_i) \text{ ---------- (1)} \quad E = \frac{H'}{\ln(s)} \text{ ---------- (2)}$$

where, P_i is the proportion of i^{th} species in the dataset and S is the number of species. The ranked species abundance curve was applied to display relative abundance of the juvenile fishes using the cumulative abundance by rank (Clarke and Warwick, 1994). Meanwhile, the assemblage patterns of the juvenile fishes in Phru Khuan Khee Sean were examined by hierarchical clustering, by using square root transformed (Clarke and Warwick, 1994). Data analysis was conducted by using Package "vegan" (Oksanen *et al.*, 2019) in R-programs (R Development Core Team, 2019).

Results

There were 21,128 juvenile fishes from 30 species and 14 Families found in this study. These juvenile fishes were from Family Cyprinidae (12 species) followed by Osphronemidae (4 species), Gobiidae (2 species) and Channidae (2 species), in which the remaining 10 Families contained 1 species each (Table 2). *Trichopsis vittata* was found in every sampling events followed by *Aplocheilus panchax*, *Boraras urophthalmoides*, *Lepidocephalichthys hasselti* and *Dermogenys pusilla*, which the frequency of occurrence were 91.7%, 80.6%, 63.9% and 61.1%, respectively. Station 1 obtained most species richness (23 species) and there were 10 to 15 species in the remaining stations (Table 3). Meanwhile, species richness peaked in August 2015 (16 species) and ranged from 9 to 14 species for the remaining sampling months.

In terms of abundance (individuals per 100 m^2), *A. panchax* (171) was the most abundance, followed by *B. urophthalmoides* (140) and *T. vittata* (136), meanwhile the abundances of 21 out of 30 species were less than 10 individuals per 100 m^2 (Table 4). Abundance by sampling events ranged from 49 to 1,850 individuals per 100 m^2 from station 5 in August 2015 and station 2 in April 2016, respectively (Table 5). Trends of diversity indices conformed to the trends of species diversity and abundance. Shanon-diversity index was over 1.0 and peaked in station 1, meanwhile it was December 2015, when the highest Shannon-diversity index was observed (Table 6). Neither stations nor months showed their evenness index closed to 1. Station 3 and December 2015 showed the highest values.

Table 2 Collected juvenile fishes from Phru Khuan Khee Sean, Phatthalung Province, Thailand, between August 2015 and June 2016

Family/Specie	Station						%F
	1	2	3	4	5	6	
1) Grey Featherback, *Notopterus notopterus* (Pallas, 1769)	----+-	-----+	------	-----+	-----+	------	11.11
2) Tai kardsilm, *Amblypharyngodon chulabhornae* Vidthayanon & Kottelat, 1990	---+--	------	------	------	------	------	2.78
3) Least rasbora, *Boraras urophthalmoides* (Kottelat, 1991)	++++++	++-+++	++-+++	++++++	++--++	++-+--	80.56
4) Blackline rasbora, *Rasbora borapetensis* Smith, 1934	------	------	------	------	------	--+---	2.78
5) Meyrsi rasbora, *Rasbora myersi* Brittan, 1954	---+--	------	------	------	------	------	2.78
6) Sumatra rasbora, *Rasbora sumatrana* (Bleeker, 1852)	------	------	------	------	---+--	------	2.78
7) Scissor-tailed rasbora, *Rasbora trilineata* Steindachner, 1870	--++--	--+---	-+++++	---++-	++-++-	--++-+	47.22
8) Siamese glass fish, *Parachela siamensis* (Günther, 1868)	--+--+	-----+	-----+	------	-----+	------	13.89
9) Beardless Barb, *Cyclocheilichthys apogon* (Valenciennes, 1842)	--+--+	------	------	------	------	------	8.33
10) Repassan, *Cyclocheilicthys repasson* (Bleeker, 1853)	------	------	------	------	------	-----+	2.78
11) Barb, *Labiobarbus siamensis* (Sauvage, 1881)	------	------	------	------	------	--+--+	5.56
12) Green tiger barb, *Puntigrus tetrazona* (Bleeker, 1855)	---+--	------	------	------	---+--	------	5.56
13) Swamp barb, *Puntius brevis* (Bleeker, 1849)	---+--	------	------	------	------	------	2.78
14) Seren, Lepidocephalichthys hasselti (Valenciennes, 1846)	--+++-	---+++	++++++	-++++-	++--+-	++++--	63.89
15) Butter catfish, *Ompok bimaculatus* (Bloch, 1794)	-----+	------	------	------	------	------	2.78
16) Walking catfish, *Clarias macrocephalus* Günther, 1864	+-----	+-----	------	------	------	------	5.56
17) Bumblebee goby, *Brachygobius xanthomelas* Herre, 1937	+-----	------	------	------	------	------	2.78
18) Glass Goby, *Gobiopterus brachypterus* (Bleeker, 1855)	--+---	------	------	------	------	------	2.78
19) Mozambique tilapia, *Oreochromis mossambicus* (Peters, 1852)	--++--	------	------	------	------	------	5.56
20) Ricefish, *Oryzias minutilus* Smith, 1945	------	------	------	------	------	+-----	2.78

Table 2 (continue)

Family/Specie	Station						%F
	1	2	3	4	5	6	
21) Malayan halfbeak, *Dermogenys pusilla* Kuhl, van & Hasselt, 1823	-----+	------	++++++	++-+++	-+++++	+++-++	61.11
22) Blue panchax, *Aplocheilus panchax* (Hamilton, 1822)	++++++	++++++	++++++	++++++	++-+++	+-+-++	91.67
23) Swamp eel, *Monopterus albus* (Zieuw, 1793)	------	------	++----	------	-+----	--+---	11.11
24) Climbing perch, *Anabas testudineus* (Bloch, 1792)	++----	------	------	------	------	------	5.56
25) Peaceful betta, *Betta imbellis* Ladiges, 1975	++++--	++++--	------	+++---	------	-+----	33.33
26) Moonlight gourami, *Trichopodus microlepis* (Günther, 1861)	----+-	----++	------	----+-	----+-	----+-	16.67
27) Three spot gourami, *Trichopodus trichopterus* (Pallas, 1770)	+--+--	---+-+	++-+-+	-+---+	-+---+	++---+	41.67
28) Croaking gourami, *Trichopsis vittata* (Cuvier, 1831)	++++++	++++++	++++++	++++++	++++++	++++++	100.00
29) Giant snakehead, *Channa micropeltes* (Cuvier, 1831)	+-----	+-----	------	+-----	------	------	8.33
30) Striped snakehead, *Channa striata* (Bloch, 1793)	------	---++-	+-----	------	------	++----	13.89

Table 3 Number of juvenile fish species found from Phru Khuan Khee Sean during the study

Month	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Total
Aug. 2015	9	6	8	6	6	8	16
Oct. 2015	5	4	8	7	8	7	11
Dec. 2015	10	4	5	5	2	8	14
Feb. 2016	12	7	7	6	6	4	15
Apr. 2016	6	6	6	7	7	4	9
Jun. 2016	7	8	8	6	7	7	14
Total	23	13	10	11	14	15	30

Table 4 Abundance, percantage and cumulative percentage of the dominant juvenile fishes found from Phru Khuan Khee Sean during the study

Species	Abundance (individuals per 100 m^2)	%	%cumulative
A. panchax	171	29.20	29.20
B. urophthalmoides	140	23.85	53.05
T. vittata	136	23.21	76.26
D. pusilla	42	7.13	83.39
L. hasselti	29	4.88	88.27
C. striata	20	3.41	91.68
R. trilineata	15	2.54	94.22
B. imbellis	10	1.72	95.95
T. trichopterus	10	1.67	97.61
Others (21 species)	14	2.39	100.00

Table 5 Abundance of juvenile fishes collected in each sampling events from Phru Khuan Khee Sean during the study

Month	Abundance by sampling station (individuals per 100 m^2)						Avg.±SD
	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	
Aug. 2015	136	119	1,307	863	49	1,017	582±546
Oct. 2015	1,053	1,057	627	1,456	547	197	823±451
Dec. 2015	780	120	110	120	93	160	231±270
Feb. 2016	1,293	650	657	383	433	213	605±377
Apr. 2016	680	1,850	907	740	737	733	941±452
Jun. 2016	107	547	260	360	170	597	340±199
Avg±SD	675±480	724±655	644±434	654±478	338±277	486±352	587±448

Table 6 Diversity indices of the juvenile fishes study in Phru Khuan Khee Sean between August 2015 and June 2016

Station	Species richness	Diversity index	Eveness index
1	23	1.88	0.60
2	13	1.31	0.51
3	10	1.75	0.76
4	11	1.44	0.60
5	14	1.83	0.69
6	15	1.69	0.63

Table 6 (continue)

Station	Species richness	Diversity index	Eveness index
Aug. 2015	16	1.66	0.60
Oct. 2015	11	1.55	0.64
Dec. 2015	14	1.98	0.75
Feb. 2016	15	1.72	0.63
Apr. 2016	9	1.49	0.68
Jun. 2016	14	1.74	0.66

The ranked species abundance curves showed the similar trends for both spatial and temporal approaches as the relative steep slopes, which indicated the domination of few species that contributed over 50% of cumulative dominance (Figure 2). Four groups of assemblage patterns were divided according to the hierarchical clustering (Figure 3; Table 7), which likely to be influenced by months and followed by stations. Group 1 is highlighted by the assemblages of all stations in December 2015 and almost every sampling in station 5. This pattern was dominated by 3 species; namely, *D. pusilla, T. vittata* and *L. hasselti* (22.52, 14.56 and 13.31%). Group 2 contained the samplings for stations 1 to 4 during August and October 2015. The assemblage patterns of this group showed the high proportions of 3 species; namely, *B. urophthalmoides, A. panchax* and *T. vittata* (36.59, 35.51 and 22.12%). Group 4 was the assemblage that was a prevalence of 3 species; namely, *B. urophthalmoides, T. vittata* and *A. panchax* (28.30, 18.83 and 18.01%), which were from the samplings in April and June 2016 for stations 1 to 4 as well as in August 2015 for station 6 and October 2015 for station 5. Lastly, Group 3 was the pattern that doniated by 2 species of *A. panchax* and *T. vittata* (49.13 and 39.53%) but was not clear in spatio-temporal approach. For the relationships of water quality parameters to assemblage patterns, unfortunately that the clear relationship was not found (Figure 4), though the 2 PCA axes could explain 46.37% of variation.

Table 7 Dominant juvenile fishes in Phru Khuan Khee Sean between August 2015 and June 2016

Species	%	%cumulative
group 1		
D. pusilla	22.52	22.52
T. vittata	14.56	37.07
L. hasselti	13.31	50.38
R. trilineata	10.55	60.93
A. panchax	10.49	71.42
B. urophthalmoides	10.16	81.58
B. imbellis	9.70	91.28
others (17 species)	8.72	100.00
group 2		
B. urophthalmoides	36.59	36.59
A. panchax	35.51	72.10
T. vittata	22.12	94.22
others (14 species)	5.78	100.00
group 3		
A. panchax	49.13	49.13
T. vittata	39.53	88.67
D. pusilla	4.33	92.99
others (11 species)	7.01	100.00
group 4		
B. urophthalmoides	28.30	28.30
T. vittata	18.83	47.13
A. panchax	18.01	65.13
C. striata	11.49	76.63
D. pusilla	8.65	85.28
L. hasselti	6.84	92.12
others (7 species)	7.88	100.00

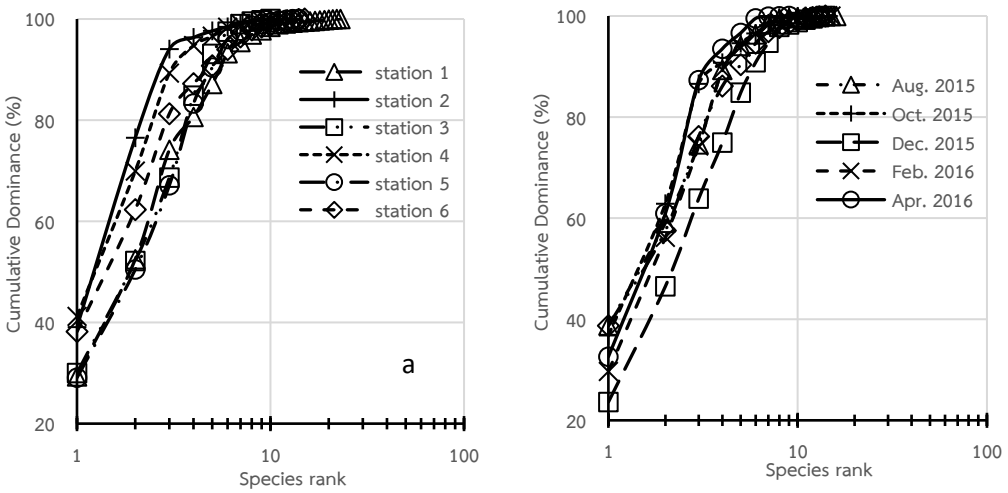

Figure 2 Rank abundance curve of juvenile fishes (a) by station and (b) by month in Phru Khuan Khee Sean between August 2015 and June 2016

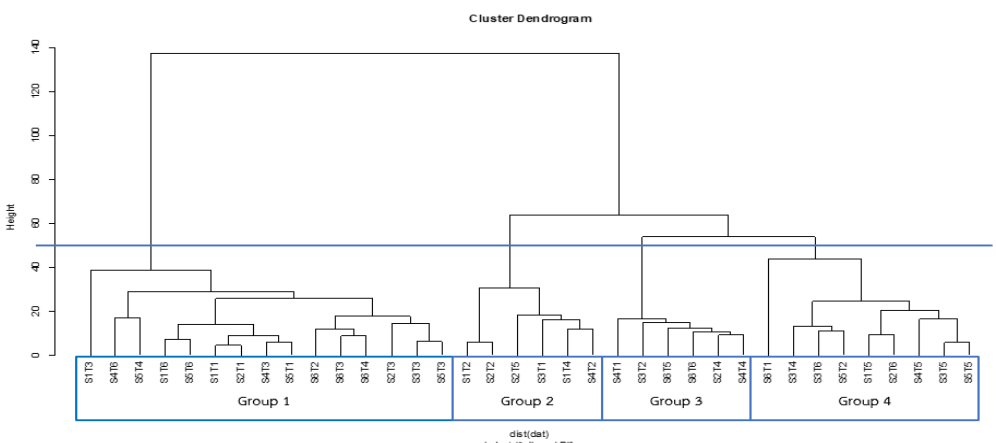

Figure. 3 Clustering of the assemblage pattern (by month and station) juvenile fishes in Phru Khuan Khee Sean between August 2015 and June 2016

Note: S1-S6 = Station 1- Station 6; T1-T6 = Aug. 2015, Oct. 2015, Dec. 2015, Feb. 2016, Apr. 2016 and Jun. 2016, respectively

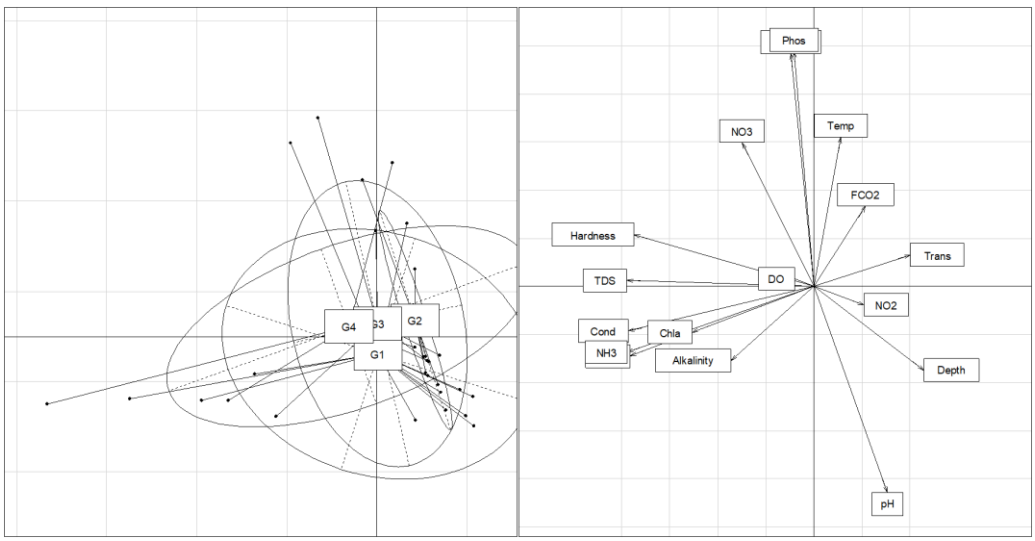

Figure. 4 Principal Component Analysis (PCA) of sampling events in each assemblage group to water quality parameters Phru Khuan Khee Sean, Phatthalung Province, Thailand

Discussion

The goods and services from peat swamps are overlooked, comparable to other aquatic ecosystems. Fish, as important goods from the system, are required clear understanding in various aspects for better exploitation and conservation. Except for the North Selangor peat swamp forest in Malaysia that habours over 100 juvenile fish species, the number of collected juvenile fish at 30 species found in this study was in the general range from 10 to 40 species found in the peat swamps elsewhere in Malaysia, depending on the swamp size and connectivity to other water bodies, e.g. rivers or brackishwaters (Sule *et al.*, 2016). These numbers reflect the fish species those can complete their reproductive cycle within the peat system. The numbers of adult fish species are, on the other hand, expected to be higher as they are always included the adult visitor from the connected aquatic ecosystem. Vidthayanon (2003) reported that, in Thailand, there are 33 stenotypic fishes for the peat swamp and more 67 fish species those can adapt to survive in this ecosystem.

The first five dominant species were the common species found in the any tropical peat swamps (Vidthayanon, 2003; Sule *et al.,* 2016). *T. vittata* is well known as an air-breather and its ecophysiological tolerances as well as all year round spawning (Schofield and Schulte, 2016), which makes the juvenile of this fish could be found in every samplings. The following two common species *viz.*, *A. panchax* and

B. urophthalmoides are known as a stenotypic fish in peat swamps, meanwhile *L. hasselti* and *D. pusilla* are generic species that can be found in various inland habitats including peat swamps (Vidthayanon, 2002). The range of Shanon diversity index found in this study were similar (1.5-2.0) to other peat swamps in Indo-Malayan region (Sule *et al*., 2016) Ahmad and Samat (2015) showed that the peat areas that are much more shady and dense with mates of submerged aquatic plants generally show higher diversity, as observed in stations 1 and 5 in this study. Rank abundance of the fish larvae in the peat swamp, as in this study, showed the similar trend as found in the adults, i.e. dominated by few species, which comprised over 50% of total abundance (Ahmad and Samat, 2015). All assemblage patterns dominated with the major abundance species albeit in different order, which implying all year round spawner of these fishes similar to many freshwater fish species in the tropics (Ng and Tan, 1997). No clear relationship between the assemblage patterns and the water quality paramenters implies the relative homogeinity of water quality in the peat swamp, similar characteristics of sampling stations as well as limited number of the fish species inhabit in the system. On the other hand, in other inland ecosysytems such as river-floodplain and reservoir, the environmental factors contribute significantly in harnessing the assemblage patterns of fish larvae (e.g. Jutagate *et al.*, 2016; Suksri and Boonsoong, 2018)

Conclusion

Results of this study confirm the importance of peat swamp in particular to the stenotypic fish species, in which their juveniles dominated in abundance all year round. Variations in abundance and diversity were found in terms of temporal approach, which likely related to peaks of spawning of their adults. Insight study on the reproductive biology of the fishes in peat swamp is, therefore, the priority to sustain the diversity and fisheries this swamp.

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