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Diversity of fish caught using gill nets in Lake Sentarum, West Kalimantan – Indonesia

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Abstract. Lake Sentarum National Park (LSNP) is a Ramsar site located in the Upper Kapuas Regency, Province of West Kalimantan, Indonesia. This national park is an unique freshwater fish habitat formed by flat basin or floodplain with fluctuated water level throughout the year in response to rainfall and supply of water from the Kapuas River system. This study aims at describing the fish diversity variation in the LSNP caught using gill nets during high water period (rainy season) in March, June, October 2013, and June 2014 and during low water period (dry season) in March 2014. Samples were taken in three locations, i.e. River Tawang (outlet), Lake Pengembung, and Lake Belida. Six orders, 15 families, and 39 fish species were found. The total number of species found during the low water depth period was less (20 species) than that during high water depth period (32 species). ‘Flood-pulse’ cycle and the corresponding rise and drop of water level in the floodplain area, sustained by aquatic productivity and habitat diversity, are considered to be the responsible hydrologically controlled seasonal variation in the study area.

Keywords: Lake Sentarum National Park, seasonal fish diversity, flood-pulse cycle habitat

1. Introduction

Lake Sentarum National Park (LSNP) is located in the Upper Kapuas (Kapuas Hulu) Regency, Province of West Kalimantan, Indonesia. Geographically the LSNP is located between 00°45’ – 01°02’ N and 111°55’ – 112°26’ E. The lake topography is generally formed by flat basin or floodplain surrounded by mountains, i.e., Lanjak Mountains to the North, Muller Mountains to the East, Madi Highland to the South, and Kelingkang Mountains to the West. High rainfall rate greatly influences conditions of the LSNP (Anonymous, 2012) with an annual rainfall depth of 3700 mm. Rainfall in the area is influenced by the El-Niño – Southern Oscillation with a bimodal pattern in which the first peak of rainfall usually occurs in December–January, the second peak in March–April, and the driest month is around June–August [14].

During the rainy season, lakes in the LNSP are inundated resulted from runoff from the surrounding mountains and inflow from Kapuas River entering the lake region. The region, which is mainly lowland basin, is inundated with the depth of 6 – 14 m for about 9 – 10 months in a year. The



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main contributor to inundation of the lakes, however, is not from local rainfall. The lake filling and emptying processes are driven by the interaction of water levels in the lakes and the Kapuas River as a result of rainfall rate in both upstream and downstream region of the Kapuas catchment [16]. From the radar data analysis, Hidayat *et al* [14] showed that the lakes become confluent and extends into the riparian forest during the peak of the high-water period. The area of open water inundation varied from 400 to 1,000 km² with an average depth of 2.9 m [15]. This radar-based analysis, however, missed the driest period due to the low temporal resolution of the image series. During the dry season, most parts of the lake area are dry with only channels and small portion of permanent lakes remain [1]. Based on radar images, Hidayat *et al* [15] estimated that the LNSP could store water as much as 3 million m³ during a relatively dry period in September 2009 to 3 billion m³ during a wet period in April 2009 (table 1).

Table 1. Lakes area, depth, and volume of the LSNP derived from radar images [15]. Depth data of Lake Belida was used as a reference in this estimation.

Date	Area (m ²)	Depth (m)	Volume (m ³)
Aug/19/2007	4.7 x 10 ⁸	1.47	6.86 x 10 ⁸
Jan/4/2008	7.4 x 10 ⁸	2.21	1.64 x 10 ⁹
Oct/6/2008	5.3 x 10 ⁸	3.54	1.88 x 10 ⁹
Apr/8/2009	5.8 x 10 ⁸	5.12	2.95 x 10 ⁹
Oct/9/2009	4.5 x 10 ⁸	0.01	3.02 x 10 ⁶
Feb/24/2010	7.1 x 10 ⁸	2.87	2.05 x 10 ⁹
Oct/12/2010	1.0 x 10 ⁹	2.63	2.62 x 10 ⁹

Lakes that are only inundated by rainfall belong to floodplain lakes. This is also stipulated in the Indonesian Government Regulation [2] which defines floodplain lake as a natural water reservoir, forming part of a river and whose water level is directly affected by river's water level. From the definition, it follows that floodplain lake water fluctuation will depend on the supply of water from the river and rainfall. Fluctuation of water level in an aquatic habitat is closely related to the steadiness of the life of aquatic biota in the littoral zone. According to Eikaas & McIntosh [13] and Jenkins, *et al.* [17], a great difference in rainfall rate will also modify fish community structure as a result of the change in water level and it is correlated with the change in condition and availability of the habitat.

The LSNP is one of the Ramsar sites (wetland of international importance) in Indonesia located in the upper Kapuas river and noted as one of the finest freshwater fish habitats. Overall, 16 species are listed in the IUCN endangered species, 26 species are listed in CITES. Fishing is the most important activity carried out within the LSNP and gill nets are a common fishing gear used throughout the year [12]. Hence, this study is to describe the seasonal variation of fish diversity, particularly captured by fishermen using gill nets, during respective low water and high-water depth conditions in the LSNP, West Kalimantan. This observed variation is highlighted within the framework of flood – pulse concept highlighted below.

2. Materials and Methods

2.1. Study area

Lake Sentarum National Park (LSNP) is a cluster of lakes located in the middle reach or about 650 km upstream from the mouth of the Kapuas River, the longest river in Indonesia with the length of about 1,140 km. Kapuas region is a large tropical lowland area (total catchment area of 98,700 km²), and a vast reservoir that can store as much as 3 billion m³ of water [14], and consists of peat swamp forest and freshwater swamp forest. During the rainy season, the water inundated the swamp and peat forest of Lake Sentarum. On the other hand, most of the lakes are dry during the long dry season which form

the river channel, and only permanent lakes are still filled with water. The swamp forest plays an important role in providing feeding, spawning, refuge and nursing grounds for fish [37]. The Kapuas wetland produces about 18,000 ton of freshwater fish annually [6].

Fish samples were taken at three locations (figure 1). Determination of the three sampling sites was based on inlet and outlet to and from Sentarum lakes region by considering the following conditions:

1. **River Tawang:** River Tawang is a bidirectional channel which connects the lakes area to Kapuas River. The upper Kapuas waters rise and enter the lake through the Tawang river during periods of heavy rainfall or the wet season, while the water from lake flow to the Kapuas River through Tawang River during the dry season. The Tawang siphons off about one-quarter of the Kapuas floodwaters (Giesen, 1987 in [27]). The water inundates riparian zone during wet season, whereas the water remains in the middle of the river during dry season.
2. **Lake Pengembung:** Lake Pengembung is the lake that directly connected with water from River Kapuas, i.e. through River Tawang. During the high-water period, the water flooded the riparian zone.
3. **Lake Belida:** Lake Belida represents the middle part of the LSNP. This lake is directly connected to Lake Pengembung during normal to high water conditions.

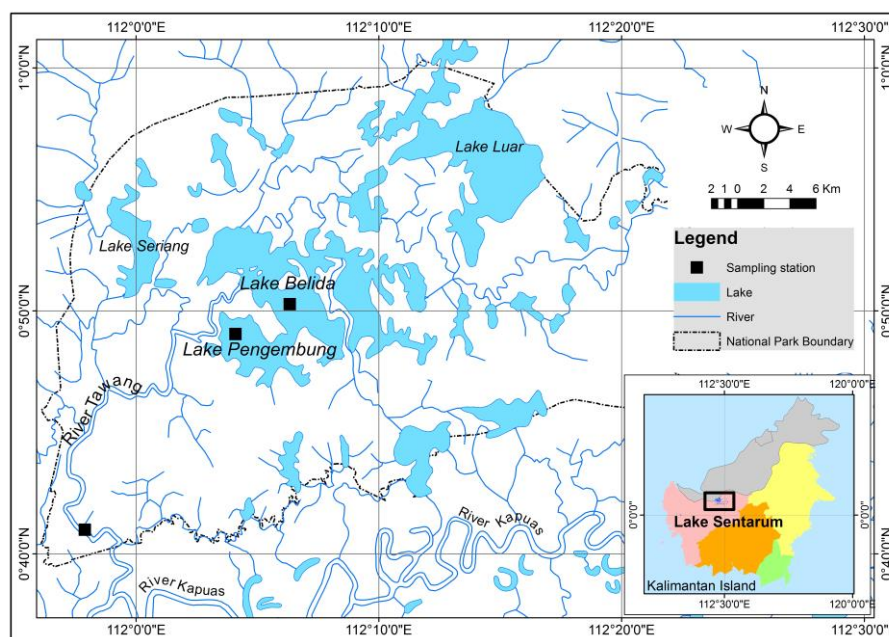


Figure 1. Map of fish sampling sites in the LSNP: River Tawang (outlet), Lake Pengembung, and Lake Belida.

2.2. Fish sampling, rainfall, and water quality measurement

Fish samples were taken both during the wet season when the water level high in March, June, October 2013, and June 2014 and during the dry season in low water condition in March 2014, respectively. Fish sampling was carried out in the night, by experimental gill net with the following specification: total length of gillnet was 350 meters and height was 2 meters. The gillnet was made of several different in mesh size in every 50 meters distance: 12.70 mm, 19.05 mm, 25.40 mm, 38.10 mm, 50.80 mm, 76.20 mm, and 88.90 mm. The Gill net was spread from water boundary to the open water with the angle of 45 – 90° towards lake's line for 12 hours.

Daily rainfall estimates were obtained from Tropical Rainfall Measuring Mission (TRMM 3B42-v.7 rainfall product) through Giovanni online data system, developed and maintained by NASA. Lake's water level was measured using a pressure sensor installed near Lake Belida.

Temperature (T) and Dissolved Oxygen (DO) were measured by Horiba U-10 Water Quality Checker in each location.

3. Results and Discussion

3.1. Water fluctuation

Since the LSNP is a floodplain lake, the water depth and water level vary depending on the season. There will be low water condition in the dry season and high water in the rainy season. The habitat description of the three sites: Tawang river, Lake Pengembung, and Lake Belida during the dry and wet season can be seen in table 2.

Table 2. Habitat Description of River Tawang, Lake Pengembung, and Lake Belida

Station	Dry Season Area	Wet Season Area
1. Tawang River	Remain water in the main channel Mean depth: 1.4 m Mud bottom Littoral fringes area at limit of retreating water	Rapid and turbulent flow Flooded grassland in the littoral zone Mean depth: 8.5 m Vegetated fringes
2. Lake Pengembung	Pool dry out almost a half Mean depth: 0.8 m Mud & sand bottom Connected to Tawang River through a narrow channel	More open water and deeper Mean depth: 3.0 m Standing vegetation Submerged vegetation Free tree trunks and debris from aquatic vegetation Mud bottom
3. Lake Belida	Shrink and very shallow pool Mean depth 0.5 m Mud and sand bottom	More open water and deeper Mean depth: 2.35 m Standing vegetation Submerged vegetation Flooded grass and bush scrub in littoral zone Free tree trunks and debris Mud bottom

The fluctuation of water depth of three studied sites: Tawang, Pengembung, and Belida are shown in figure 2, which demonstrates that the peak level occurred between March and June 2013 and started to decrease in July 2013. The lowest water was in March 2014. These are substantiated and detailed in Figure 3 indicating the dry or rainy seasons more vividly.

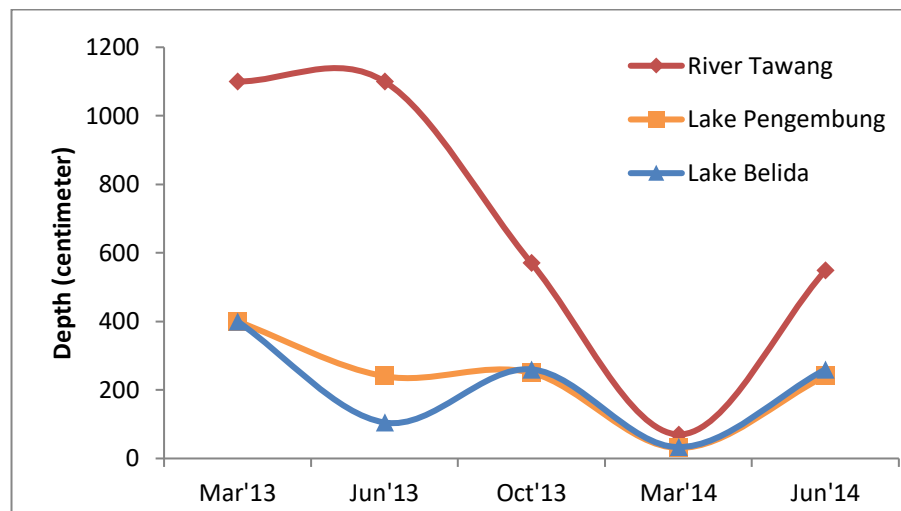


Figure 2. The water depth of River Tawang, Lake Pengembung, Lake Belida

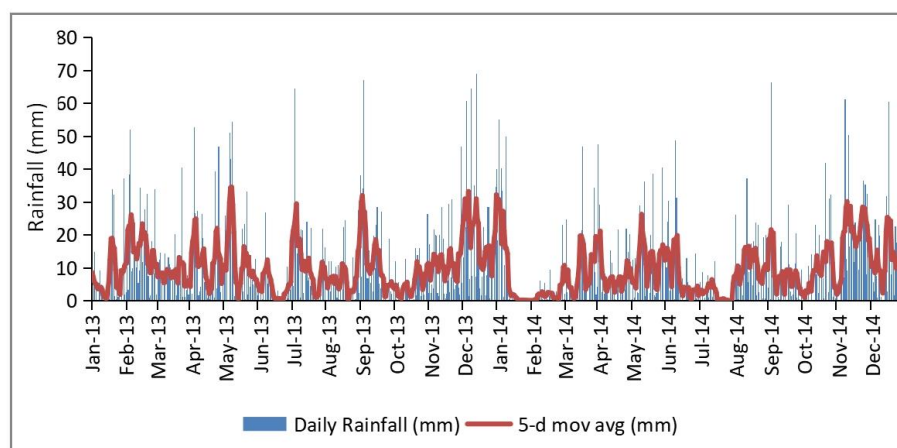


Figure 3. Rainfall depth from TRMM rainfall estimates over the LSNP in 2013 and 2014. The bold red line indicates 5-days moving average.

Based on Figures 2 and 3, it can be inferred that March 2013 was a transition period from rainy to the dry season. June 2013 was the start of the dry season, but it was still relatively high in water depth (figure 2). This means that June 2013 still can be considered as rainy season. However, the dry season can be assumed from June to August 2013. The period of October 2013 was the transitional season with relatively high water resulted from high previous month's rainfall rate to dry season before it had then risen again by high rainfall in December 2013. Dry season occurred in March 2014 as a consequence of low rainfall from mid-January towards the end of February 2014. A similar pattern showed that the water depth in March 2014 was the lowest (figure 2 & 4). On the other hand, April to June 2014 was the period of the rainy season that raised the lake's water level. Water level recedes in the end of June to early July, followed by a long low-level period from July to November 2014 (figure 4).

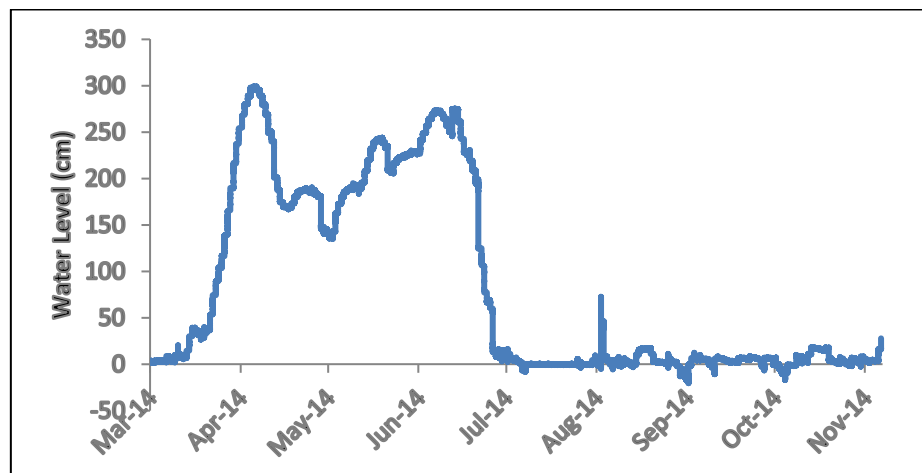


Figure 4. Water level condition based on the pressure sensor readings at a monitoring station near Lake Belida from March – November 2014.

3.2. Fish diversity

Based on fish sampling in 2013 and 2014, six orders, 15 families, and 39 fish species were found. Three families with the highest number of species were Cyprinidae (20 species), Siluridae (5 species), and Bagridae (3 species) as shown in Figure 5.

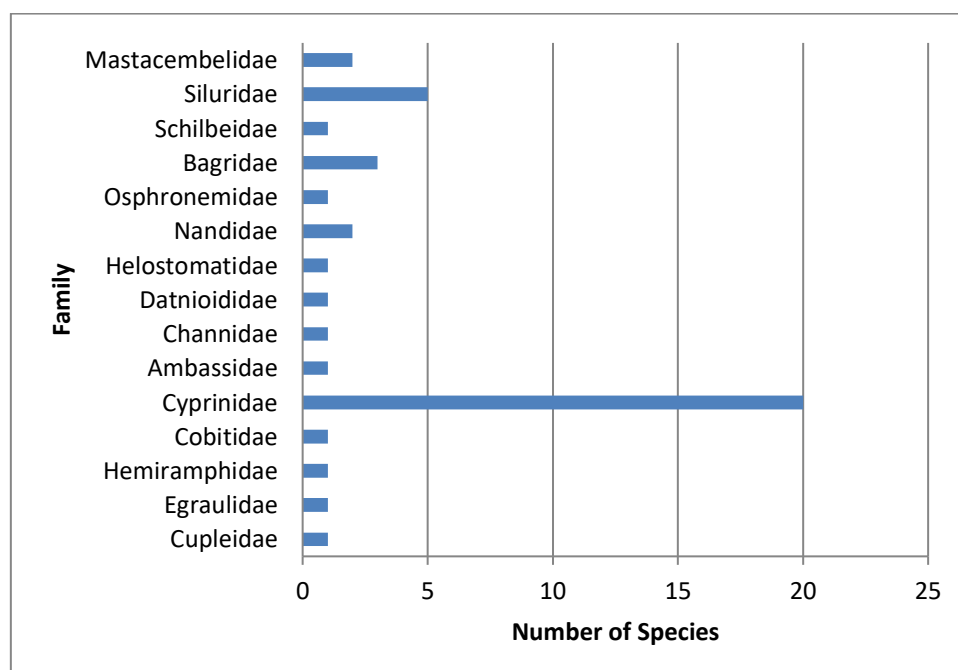


Figure 5. Number of fish species in each family found in the LSNP during surveys in 2013 and 2014.

Cyprinidae was the family found at all sampling locations during high water condition as well as during low water condition. Cyprinidae is the largest freshwater fish family in the world, except in Australia, Madagascar, New Zealand, and South America [21]. Zakaria and Ismail [41] added that Cyprinidae is the largest freshwater fish family in South-East Asia. Nguyen & De Silva [30] also emphasized that fish species in Asia is dominated by Cyprinidae (about 1000 species). In Lower Mekong river, the Cyprinidae contribute 42.44% to fisher catch [29]. Therefore, it is understandable that Cyprinidae was found in all sites of LSNP and all season.

Figure 6 shows the relation between the water depth and fish species abundance in its family found in River Tawang, Lake Pengembung and Lake Belida, respectively. Overall, a total number of species found during low depth condition was less (20 species) than that of high-water condition (32 species). The difference in the species abundance may indicate the depth associated fish diversity. Depth may affect floodplain lake fish assemblages indirectly. Miranda [28] stated that the depth could drive many physical and chemical variables which contributed to the fish assemblages in floodplain lake. Eikaas & McIntosh [13] and Jenkins *et al* [17] stated that very high difference in rainfall rates could change fish community structure as a result of the change in water level which is directly correlated to the change in condition and availability of the habitat. Kottelat *et al* [22] and Junaidi [18] added that more habitat variation would result in more presence of fish species which, in turn, will increase the fish diversity.

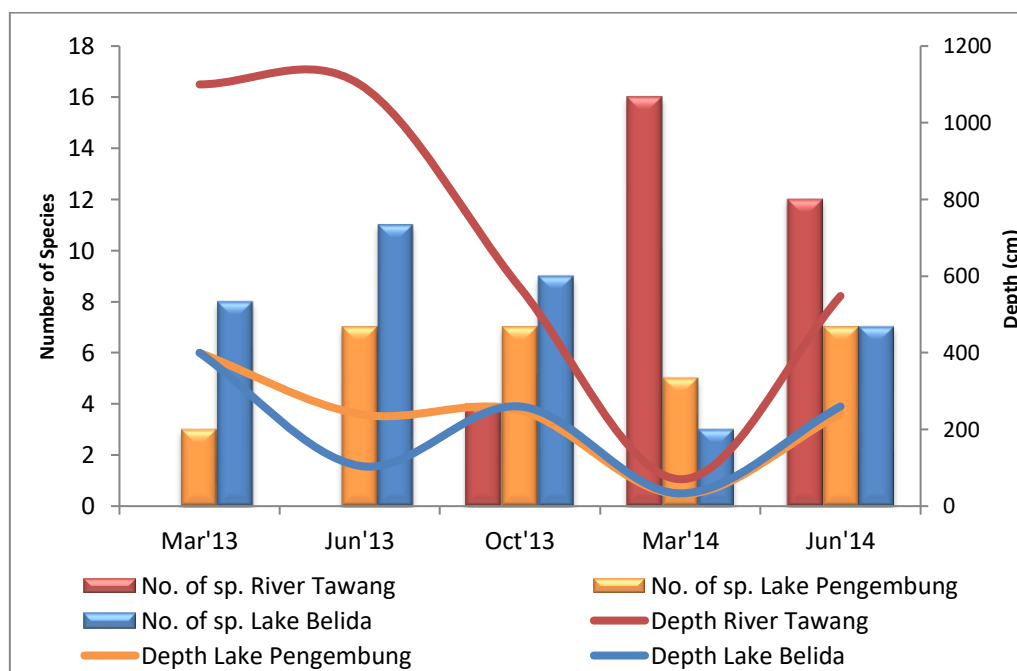


Figure 6. Water depth and number of fish species found in River Tawang (red), Lake Pengembung (orange), and Lake Belida (blue).

During the dry season, water volume is small and found only in the main river, lake basin, and oxbow lakes; while during the rainy season it overflows the floodplains, lakes, ponds, and stream channels [39]. These conditions will induce a diverse availability of habitat for aquatic organisms and will enable many fish species in some ways to utilize those areas to sustain their life processes such as spawning [10], juvenile rearing [32], [35], feeding, and habitat for mature fishes [5]. Some fish species migrate to those areas to accomplish functions in their life cycle. This notion is supported by Lucas *et al* [20] that fish migration can be stimulated by the following factors:

- a. Internal factors, *e.g.*, genetic and ontogenic factors, starvation and metabolism balance, homing, and avoiding predators;

- b. External factors, *e.g.*, lights, temperature, hydrology and meteorology, water quality, and food availability.

Fish migration from and to the floodplain is influenced by water levels supported by aquatic productivity and habitat diversity as well as other hydrological phenomena that are occurred in the region. This corresponds with the 'Flood-pulse Concept' which explains the cycle of rising and drop of water level in floodplain area, sustained by aquatic productivity and habitat diversity [4], [19], and hydrological phenomena leads the behaviour of many tropical river floodplain ecosystems, including fish migration into or from floodplain area [23], [24], and [38], [39]. During the low water level period, when water in floodplain areas starts to decline or even dries out, some fish species migrate back to the main river, and some other species settle in the lake that is still inundated.

River Tawang (outlet) had the highest number of fish species both during the low water in dry season and high-water condition in wet season with 15 and 16 species, respectively (table 3). An exception was the sampling in October 2013, the highest number of fish species was found at Lake Belida. It can be due to the fact that fish may be concentrated in deep pools, microhabitats or main river course during the dry season [8]. The River Tawang always retains water including during dry season due to its connection with the Kapuas River that makes the supply of water is always available compared to Lake Pengembung and Lake Belida. The temperature (T) in River Tawang is lower (27.4-28.2°C) and Dissolved Oxygen (DO) is higher (3.84-5.42 mg/L), compared to Lake Belida (T: 28.9-33.8°C; DO: 0-3.50 mg/L). This guarantees that fish life is relatively unobstructed when the depth is lowered during the dry season.

During high water, species abundance in Lake Pengembung and Lake Belida were higher compared to the low water condition. Some of the fishes are migrated from the main river to these lakes because of enlarged habitat by the deep lake. Such a kind of lake provides fewer variable environments, clearer water, and a wider range of microhabitats than shallow lakes [28]. During the rainy season, water flows and inundates lakesides, so it enlarges fish habitat that also functions as a source of food. According to Welcomme & Halls [40], each species has certain characteristics and flooding type that is different from that of other species. Tropical floodplain fishes and also fish communities in Europe and Danube lakes are classified in relation with a lake ecology guild, as riverine or white fish; eurytopic or grey fish; and limnophilic or black fish [7], [31]. White fish make only limited use of the floodplain; Black fish mostly live on the floodplain, they tolerate high temperatures and low dissolved oxygen, tend to leave the floodplain when the water is too low. Grey fish live in the rivers but move on to the floodplains during flooding [31]. The fishes in three studied sites were classified to that classification to correlate their distribution during the seasons (table 3). It is interesting to note the omnipresent of species found in the three studied sites under both high and low water conditions as listed in Table 3.

Table 3. List of fish species found at each sampling station during high water condition/wet season and low water condition/dry season. The sampling sites are denoted by Twg (Tawang River), Pgb (Lake Pengembung), and Bld (lake Belida).

No	Latin Name	Order	Family	Fish Guilds	High water / wet season			Low water / dry season		
					Twg	Pgb	Bld	Twg	Pgb	Bld
1	<i>Clupeichthys bleekeri</i>	Clupeiformes	Clupeidae	G	v	v	v			
2	<i>Lycotrichia crocodilus</i>	Clupeiformes	Engraulidae	G			v			
3	<i>Hemirhamphodon pogonognathus</i>	Cyprinodontiformes	Hemiramphidae	B				v		
4	<i>Botia hymenophysa</i>	Cypriniformes	Cobitidae	G				v		
5	<i>Amblyrhynchichthys truncatus</i>	Cypriniformes	Cyprinidae	G			v			
6	<i>Barbichthys laevis</i>	Cypriniformes	Cyprinidae	W	v					
7	<i>Barbodes schwanenfeldi</i>	Cypriniformes	Cyprinidae	W	v		v		v	
8	<i>Cyclocheilichthys armatus</i>	Cypriniformes	Cyprinidae	G	v	v	v			
9	<i>Labiobarbus festivus</i>	Cypriniformes	Cyprinidae	G				v		
10	<i>Labiobarbus ocellatus</i>	Cypriniformes	Cyprinidae	G	v			v		
11	<i>Luciosoma trinema</i>	Cypriniformes	Cyprinidae	G		v	v	v		
12	<i>Osteochilus kahajanensis</i>	Cypriniformes	Cyprinidae	G						v
13	<i>Osteochilus melanopleura</i>	Cypriniformes	Cyprinidae	G		v	v	v		
14	<i>Osteochilus microcephalus</i>	Cypriniformes	Cyprinidae	G			v			
15	<i>Osteochilus schlegelii</i>	Cypriniformes	Cyprinidae	G		v	v	v	v	
16	<i>Osteochilus triporos</i>	Cypriniformes	Cyprinidae	G	v	v	v			
17	<i>Parachanna oxygastroides</i>	Cypriniformes	Cyprinidae	G	v	v	v	v		
18	<i>Puntioplites waandersi</i>	Cypriniformes	Cyprinidae	W	v	v	v	v	v	
19	<i>Puntius achisporus</i>	Cypriniformes	Cyprinidae	W			v			
20	<i>Puntius eugrammus</i>	Cypriniformes	Cyprinidae	W			v			
21	<i>Rasbora agryrotaenia</i>	Cypriniformes	Cyprinidae	G				v		
22	<i>Rasbora bankanensis</i>	Cypriniformes	Cyprinidae	G	v					
23	<i>Paradoxodacna piratica</i>	Perciformes	Ambassidae	G			v			
24	<i>Channa striata</i>	Perciformes	Channidae	B						v
25	<i>Daniolepis microlepis</i>	Perciformes	Daniolepididae	B		v			v	
26	<i>Helostoma temminckii</i>	Perciformes	Helostomatidae	B			v	v	v	v
27	<i>Pristolepis fasciata</i>	Perciformes	Nandidae	B	v		v			
28	<i>Osphronemus goramy</i>	Perciformes	Osphronemidae	B		v				
29	<i>Mystus baramensis</i>	Siluriformes	Bagridae	G	v	v	v	v		
30	<i>Mystus micracanthus</i>	Siluriformes	Bagridae	G	v					
31	<i>Mystus nemurus</i>	Siluriformes	Bagridae	G	v		v	v		
32	<i>Pseudeutropius brachypterus</i>	Siluriformes	Schilbeidae	G		v	v	v		
33	<i>Belodontichthys dinema</i>	Siluriformes	Siluridae	G		v				
34	<i>Kryptopterus apogon</i>	Siluriformes	Siluridae	G	v	v	v			
35	<i>Kryptopterus lais</i>	Siluriformes	Siluridae	G			v			
36	<i>Kryptopterus schilbeides</i>	Siluriformes	Siluridae	G		v				
37	<i>Ompok hypophthalmus</i>	Siluriformes	Siluridae	G	v	v	v	v		
38	<i>Macrognathus maculatus</i>	Synbranchiformes	Mastacembelidae	G			v			

No	Latin Name	Order	Family	Fish Guilds	High water / wet season			Low water / dry season		
					Twg	Pgb	Bld	Twg	Pgb	Bld
39	<i>Mastacembelus unicolor</i>	Synbranchiiformes	Mastacembelidae	G				v		
Number of species					15	16	24	16	5	3

W: White fish; G: Grey Fish; B: Black fish

The above-listed fish family and species present in each water condition/season are discussed as follows:

- a. Bagridae (Siluriformes): found at three sites in high water condition or wet season, and only found at River Tawang station during low water condition. The Bagridae is freshwater catfish species found in tropical regions of Africa, South-East Asia, and East Asia. Some species grow very large, and people hunt them for food. Some are nocturnal, while those living in turbid waters are active for the whole day. These fish species are bottom-dwellers and are omnivorous [21]. Species of this family found in Sentarum Lake area are *Mystus baramensis* (local name: landin) and *Mystus nemurus* (patik). *Mystus baramensis* is a river fish as grey fish which migrates during flood period and is marked by its presence during high water condition in all sampling stations. *Mystus nemurus* is grey river fish that migrate to the lake area (Lake Belida) during high water condition. According to Nam *et al.* [29] these fish are categorized as grey fish or short distance migrants. The species which are hunted for food is *M. nemurus*, an economically valued and favoured fish for food because of its high nutritional value and good taste [9]. Compare with another genus of *Mystus*, *M. gulio*, contains a high value of protein, micronutrients, vitamins, and minerals. This particular nutrition usually is not present in other foods [33].
- b. Clupeidae (Clupeiformes): found at three sites during high depth condition, but absent at all sites during low depth condition. This family is highly abundant and is small in size, and as grey fish, they are migratory fishes with that some species only live in rivers or river mouths. Some species are important as a food source and are present as larger aquatic animals [21]. The species found in Sentarum lakes area is *Clupeichthys bleekeri* (local name: bilis), found at all sampling stations during the wet season. As migratory fishes, they migrate for food and fill niches throughout the lakes area.
- c. Cyprinidae (Cypriniformes): found at all sites during both high and low water condition. This family is categorized as white fish or long-distance transboundary migrants [29]. During the dry season, mainly cyprinids migrate to the Kapuas River. Species that are found in Sentarum lakes area include:
 1. *Cyclocheilichthys armatus* (local name: buin/kempras), found in three sites during high water period. This fish is likely to be river fish/grey fish that makes use of floodplain area.
 2. *Osteochilus schlegelii* (kebali), found at Lake Pengembung and Lake Belida during high water condition, at River Tawang and Lake Pengembung during low water condition. It is grey river fish that migrates to floodplain area during the wet season and when the water is low, like Lake Pengembung when it is still partly inundated.
 3. *Parachela oxygastroides* (kelampak), found at all three sampling stations, and found only at River Tawang station during low water condition. It belongs to river fish that makes use of floodplain area.
 4. *Luciosoma trinema* (kenyuar), found in Lake Pengembung and Lake Belida during high water condition and found in River Tawang during low water condition. This species is a river fish that migrates during high water and when it overflows floodplain area.
 5. *Osteochilus triporos* (menyadin), found at three sites during high water condition but absent at all sites during low water condition.
 6. *Puntioplites waandersii* (umpan), found at all three sites during high water condition and found at River Tawang and Lake Pengembung during low water condition.

- d. Helostomatidae (Perciformes): this family is categorized as blackfish or floodplain resident fish [29] found at three sites during low water, while during high water it was found at Lake Belida. This fish is found in channels, swamps, ponds, and lakes with a mild flow [3]. As a black fish, this fish remains in the lake during the dry season. Kottelat *et al.* [21] added that Belawan/Biawan (*Helestoma temminckii*) is found in still waters with dense vegetation. This species eats various kinds of plants and animals, and this is in line with the findings that this fish is found at all sites during low water condition as this species occupies only shallow areas. Meanwhile, during high water, it is only found at Lake Belida because of relatively deep current in the outlet (River Tawang) during wet season. *Helestoma temminckii* is an important and low-price consumption fish.
- e. Schilbidae (Siluriformes): found in Lake Pengembung and Lake Belida during high water, and found in River Tawang during low water. This family inhabits waters with very mild current and active during the night, eating detritus and other invertebrates on the bottom [21]. One species found in this study is *Pseudeutropius brachypterus* (local name: nuayang).
- f. Siluridae (Siluriformes): found at all three sites during high water period, and found in River Tawang during low water. This family is categorized as grey fish or short distance migrants [29]. The species of this family found in the Lakes area is *Kryptopterus apogon* and *Ompok hypophthalmus*. These species migrate to the lake during the high water for spawning. In the floodplain of Kampar Kiri River, *O. hypophthalmus* spawn following the hydrological pattern and flooding rate of the flooded swamp with the peak period of spawning before the maximum flood occurs or includes groups of fish that have periodic reproductive strategies [34]. The Siluridae was found during low water condition in River Tawang because this family is grey-river fish that dwells in the bottom layer of rivers and lakes and prey on smaller fishes [21]. Tomoda [36] states that the habitat of one of Siluridae species (*Silurus lithophilus*) is found along pits of gravelly banks at a depth of 2 – 4 m, which coincides with catfish habitat. The presence of Siluridae during high water level at the three sites is likely for spawning purpose. As stated by Maehata *et al.* [25], [26] one of Siluridae species, *Silurus biwaensis*, spawns in newly inundated spot, gravelly and shallow bank at the outlet of Lake Biwa (River Seta) at night when water level is rapid increasing. Tomoda [36] added that the main spawning period of one of the Siluridae species (*S. lithophilus*) occurred along pits of gravelly banks at a depth of 2 – 4 m several times during a warm night in the rainy season during the spawning period. This matches the general condition of Lake Belida and Lake Pengembung in which the water depth was 1 – 4 m in the rainy season. Siluridae has been locally known as lais, an edible and commercial fish in Borneo, especially Lake Sentarum. Mostly the fish are smoked or salted before selling in the market.

Local fishers in LSNP area mainly catch the fish to fulfill domestic people needs [11]. This may explain the reason why highly diverse types of fish caught using gill net, which is a common fishing gear used by fishers in LSNP, can be seen. Villagers caught between 5 and 15 kg of fish per gill net set [12]. The fish are mostly traded by the people around the lakes both for the benefit of daily consumption as well as for economic interests. Given the sustainability of the fish species diversity and sustaining the community livelihood, the Lake Sentarum National Park ecosystem should be managed properly from various fishing activities and also from activities around the lake that can affect the sustainability of the lake ecosystem.

4. Conclusions

In 2013 and 2014 using gill nets, we found six orders, 15 families, and 39 species of fish in Tawang River, Lake Pengembung and Lake Belida, in area of the Lake Sentarum National Park. Three families with the highest species found were Cyprinidae (20 species), Siluridae (5 species), and Bagridae (3 species). Overall, a total number of species was found, in the dry season was less (20 species) than that in the rainy season (32 species). During low water level and low water depth, the highest number of species was found in River Tawang (16 species) compared to that of Lake Pengembung (5 species)

and Lake Belida (3 species). Whereas during high water, the highest number of species was found in Lake Belida (24 species) and the lowest species was in River Tawang (15 species).

The observed species diversity in the Tawang River, Lake Pengembung and Lake Belida can very well be explained by the water level – hydrology – habitat – aquatic productivity – migration nexus as exemplified by the ‘flood – pulse’ concept. Most of the fish caught are common edible fish, and also have high economic value. The spatial and temporal species diversity is closely related to behaviour and local catch activities which require further comprehensive studies on each fish species.

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