Dominant fish species in submerged floodplains and the adjacent river in the Buaya Lake, Indragiri River basin, Sumatra Island, Indonesia

[1]Nofrizal, [1]Thamrin, [1]Zulfan Saam, [2]Romie Jonnerie, [2]Rahman Karnila, [2]Riska Fatmawati, [3]Ramses, [4]Tengku S. Raza'i

[1] Program of Doctoral Environmental Science, Post Graduate Studies, Riau University, Indonesia; [2] Faculty of Fisheries and Marine Science, Riau University, Pekanbaru, Indonesia; [3] Riau Kepulauan University, Batam City, Indonesia; [4] Faculty of Marine and Fisheries Science, Maritim Raja Ali Haji University, Tangjungpinang, Indonesia. Corresponding author: Nofrizal, aan_fish@yahoo.com

Abstract. Survey activities were carried out to identify fish species in the Buaya Lake, Indragiri River and outflow waters, in order to determine the similarity of specimens belonging to the same species, captured at different sampling locations. The difference in the development stages of the specimens identified in the three waters consist of upstream (Buaya Lake), midstream (Outlet River Lake) and downstream (Indragiri River Basin), would prove the role of the Buaya Lake in the aquatic ecosystem, as support for aquatic animal life in the Indragiri River, as the mainstream. Measurements of water parameters and fish sampling focused on six stations in Buaya Lake, one station on the outlet River and four stations on the Indragiri River. Fish samples were captured with several types of fishing gear such as lift nets, bottom traps, poles and lines that operated in the three waters. Analysis of fish samples identified morphologically using a database of FishBase. The results showed that the water temperature in Buaya Lake was higher than in the outlet river and Indragiri River. The pH of the Buaya Lake and outlet river is lower than that of the Indragiri River. Fish sampling results show that 12 species living in Buaya Lake also live in the Indragiri River. According to the analysis results, the length and weight of fish living in the Buaya Lake and outlet river are smaller than those living in the Indragiri River. This phenomenon shows that Buaya Lake is a water used for spawning and nursery ground.

Key words: biodiversity, nursery, spawning ground, swamp.

Introduction. Disrupting peat-swamp ecosystems due to deforestation, land-use change (Omokhua & Koyejo 2008; Rieley 2016), forest burning (Posa et al 2011; Prayoto et al 2017), and the development of human activities, such as transmigration, mega-rice project, and logging activities (Hergoualc'h et al 2018), is a severe problem causing the reduction of fisheries resources in Indonesia. Most local fishers recognize that their catches have decreased in number and size (Palis 2000). However, valid data on fish stocks is necessary for evaluating over-exploitation of fishery resources, in areas where the fish management on peatlands has not been optimally implemented, including the Buaya Lake ecosystem. Therefore, rapid action to collect data on fish stocks and the breeding season is needed.

Peat-swamp ecosystems play an essential role as feeding and nursery grounds for various animals; they function as a natural habitat rich in food resources. The fish living in the swamp areas are endemic and have a good adaptability to the environment (Giesen et al 2015). Peat swamps spread out from Sumatra and Borneo, to Papua, composing 35, 32 and 30%, respectively, of the total peatlands in Indonesia (Muchlisin et al 2015). Diverse freshwater fish taxa have been reported in Indonesia, counting 66, 54, and 64 families from Borneo, Java, and Sumatera, respectively (Hubert et al 2015), and most species use peat swamp ecosystems as their essential habitat. The families generally dominating the composition of fish community in peat swamp areas are the Ambassidae, Bagridae, Channidae, Cyprinidae, Elotridae, Gobiidae, Lutjanidae, and Mugilidae (Muchlisin et al 2015; Jonathan et al 2018).

Fish exploitation is conducted everywhere in peat swamp areas but is high in areas close to settlements (Nuwer & Bell 2013; Dyer et al 2016). Nets with a mesh size of 0.5-2 inches, with a length of 200-300 m are commonly used for fishing activities in peat swamp areas, which are left for 3-5 hours at the catching location (Ismail et al 2015). Most fish catches in peat swamps are consumed by local residential communities (Ismail et al 2015) or farmed as ornamental fish commodities (Husson et al 2018).

Land conversion influences the degradation of peat swamp area into agricultural land and plantations, by deforestation and burning of land. The data collected from Yaeger et al (2003) estimated that fires had damaged 4.7 million hectares of swamp and peat forest since 1997. Alisjahbana & Busch (2017) reported that when trees are cut and burned, they release stored carbon into the atmosphere and contribute to climate change. This type of incident impacts organisms living in peat swamp ecosystems, including fish, birds, flora, and others (Posa et al 2011), and the social lifestyle of fishers.

The study investigated the damage to the swamp system, due to deforestation, land-use change, forest fires, and an increase in the human population, and the decline in fish diversity. People who catch fish admit there has been a decrease in their catch, both in quantity and size. This study aimed to identify the diversity of fish species and the ratio of length and weight of fish, to determine the relationship between fish groups that populate the Buaya Lake and the Indragiri River, as a primary habitat. These data strongly support the conservation of fish in the peat-swamp because they can be a basis for regulating fishery, fishing season, and the size of catches.

Material and Method. Samplings were conducted in the Buaya Lake, Indragiri River, and channels joining them in Bandar Alai Kari Village, Kuantan Tengah District, Kuantan Singingi Regency, in a rainy season (July-December 2020), in order to investigate the fish fauna reported by local fishermen (Figure 1). Samplings were carried out at 12 stations. 6 were located on the Buaya Lake, 4 on the Indragiri River, and 1 on the channels joining them. The positions of sampling stations were determined following a sampling guidance. The sampling point was determined according to the interviews on fishermen who usually catch fish in Buaya Lake and the Indragiri River. The sampling point is the area where the fishing gear was set. The interviews also determined the species of fish they were targeting and those they commonly caught with the fishing gear they operated.

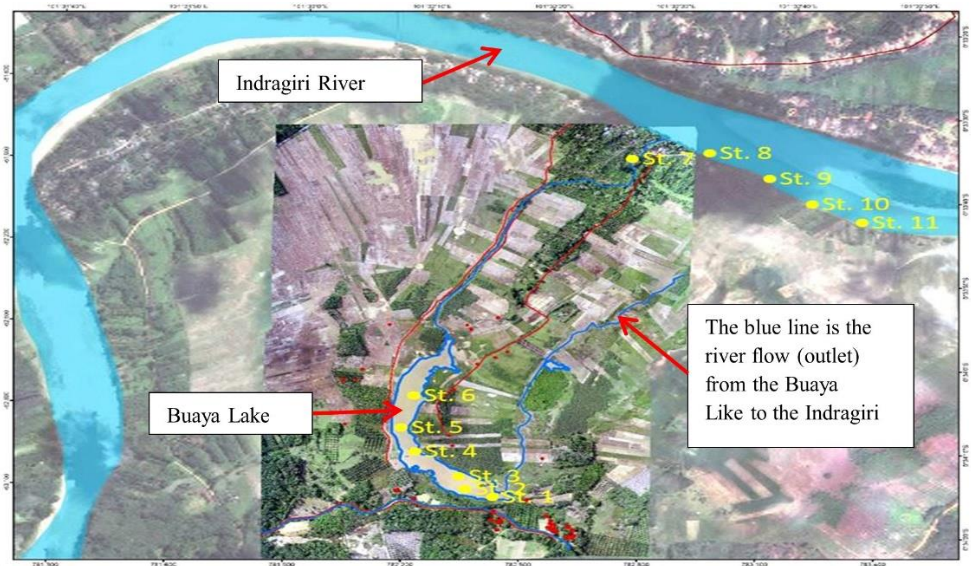

Figure 1. Research and sampling locations in the Buaya Lake, Outlets River, and Indragiri River areas (St. is the station for fish sampling and water quality measurement).

Measurement of water temperature and pH. Temperature and pH are water indicators that affect fish biology and life (Nyanti et al 2018). Temperature affects swimming activity, speed, and endurance (Nofrizal et al 2019; Nofrizal & Arimoto 2011; Nofrizal et al 2020), and pH affects physiology, stress status, and growth performance (Mota et al 2018). Therefore, temperature data is required as an indicator of fish habitats in the waters of the study location. They measured temperature and pH using a digital water checker (Hanna HI991301 portable waterproof pH/EC/TDS meter). Temperature and pH were measured at each station (Figure 1) with ten replications per station to obtain the mean value of the two parameters.

Fish sampling. The study used three fishing gears for sampling fish: bottom traps, pole, and lift nets (Figure 2). Taking fish samples is adjusted to the conditions of the location and the characteristics of the fishes. Maximum sampling results can be obtained. Bottom traps are used to sample the bottom fish species, while the lift net is used for sampling fish on the surface of the water. Pole and line are used to sample fish in wide and deep water locations. Constructing the lift net used uses a bamboo stalk and frame, with a net size of 300 x 300 cm^2, with a mesh size of the webbing of 1 cm. The lift net was the operated stationery and it was hauled every hour (Figure 2a). The bottom traps consisted of 6 stainless-steel frames and wrapped with a 0.5 cm mesh size webbing. The bottom trap had six funnels for fish to enter. The mouths of the funnels were of 22 cm on the outside and 20 cm on the inside. The traps were operated using bait and hauling every 12 hours (Figure 2b). Meanwhile, pole and line used a rod of 165 cm in length. The hook of pole and line was number 10 in size (Titanium M Keiryu, Carbon Hook, Tornado). The line of pole and line was monofilament, of 0.45 mm in diameter (Shino Super Pro, 38.5 lbs) (Figure 2c).

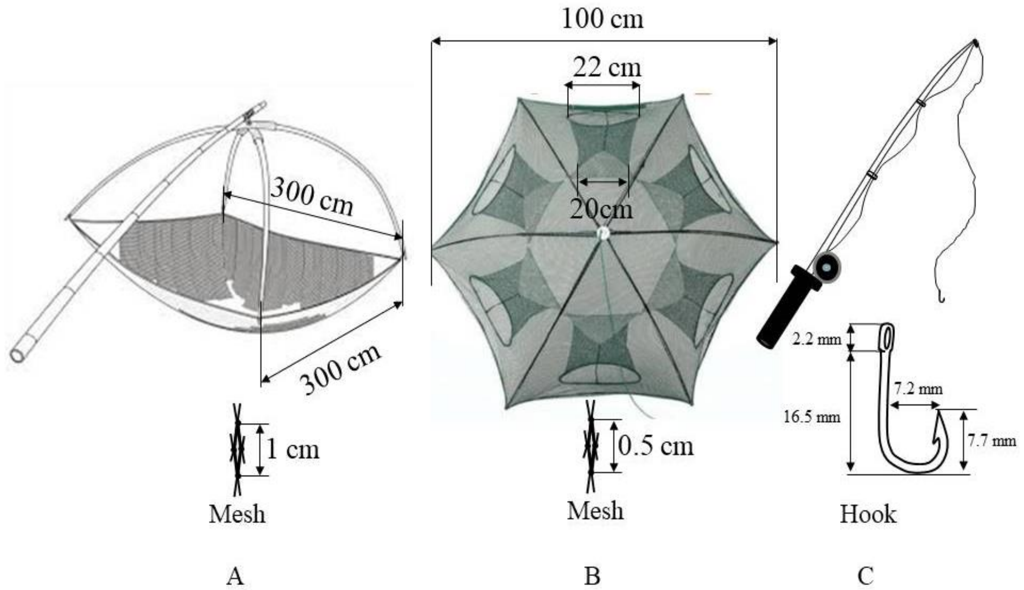

Figure 2. Fishing gear used for sampling at Buaya lake, outlet river, and Indragiri River. (A) Lift net for sampling surface fish; (B) Fish trap for sampling bottom fish; and (C) Pole and line for sampling in deep waters.

Data analysis. The taxon of each fish specimen was identified from its morphology following the "FishBase" databases (Froese & Pauly 2021). The log transformation formula was used to establish LWRs (Gupta & Tripathi 2017), as follows $W = aL^b$, and $Log\ W = Loga + bLog\ L$, where *W* is the weight of the fish (in grams), *L* is the length of the fish (in cm), *Log* is the intercept and *b* is the slope or coefficient of growth. Biologically, the relationship between the length-weight of the individual is not similar in each species, due to physiological factors. Therefore, the measurement of length or weight can be used to predict the length-weight relationships (LWRs) by utilizing the best formulation. They are used to develop indices of condition and to convert length data into estimates of biomass. Attempt to capture variability in underlying ecological processes within statistical modeling frameworks for length-weight relationships have typically relied on the inclusion of environmental variables.

Results and Discussion. Temperature and pH conditions play an essential role in the survival of fish and shrimp, and each species of fish has an optimal survival temperature. Sapkale et al (2011), explain that changes in temperature and pH can reduce hatchability and growth of fish seeds. The temperature range of these waters, including Buaya Lake, is relatively high, indicating the low turnover rate of water in Buaya Lake. Several months before the samplings, the outlet gates of channels joining the lake and the river were opened to avoid flooding. The pH condition in Buaya Lake was relatively acidic compared with the other habitats. The temperature drop occurs due to the high density of vegetation, which protect the river waters from direct sunlight. Although the water temperature of the outlet river was lower than Buaya Lake. However, the water pH in the outlet river is relatively the same as the pH of the water in the Buaya Lake. The Indragiri River has a relatively stable temperature compared to the waters of Buaya Lake and outlet river. The pH in the Indragiri River waters was higher and stable (6.00±0.00).

Generally, the water temperature ranges from 24 to 30°C, and this condition supports fish life in tropical swamp ecosystems. The typical temperature range for fish life is between 26 and 29°C (Mutiara et al 2016). Supraba et al (2020) stated that the temperature variation in swampy river areas ranges from 23 to 32°C, with an optimal range for fish life between 28.6 and 29.6°C. Meanwhile, Nuryanto et al (2016) stated that temperatures range between 28 and 30°C are suitable for organisms in the swamp river ecosystem. The water temperature in the study area was classified as low due to the high vegetation cover so the sun does not directly get into the water. Anamulai et al (2019) stated that the high and low temperatures in swamp forest areas were generally influenced by a land cover that inhibits solar radiation. The pH conditions of the water at the research location ranges from 4 to 6, which was classified as a low pH. The decay of organic matter determines the low pH of water in swamp ecosystems, due to bacteria (Jackson & Raub 2010). Swamp waters generally have low pH conditions, which are influenced by increased bacterial activity, and pH in swamp forest areas is about 2 to 5, depending on the increased breakdown of organic matter (Yule et al 2018). According to Jackson & Raub (2010), pH in swamp forest areas is generally below 4. Low pH affects fish physiology and growth (Mota et al 2018). However, the physiological response to acid exposure in several fish species in swamp ecosystems is good (Kwong et al 2014). The response rate of fish discovered at the research location was classified as good, as evidenced by the number of 22 species reported.

Fish species in the Buaya Lake, outlet river, and Inderagiri River (mainstream). 22 species belonging to 6 orders and 10 families were sampled in the main channel of the Indragiri River. Most species came from the Cyprinidae and Siluridae. Some of the dominant species that live in the Indragiri River were also reported in several other large rivers in Riau, such as the Kampar River, the Rokan River, and the Siak River. Table 1 shows the 22 discovered species, which have economic value and are consumed by the locals.

Table 1

Fish and shrimp species found in the Indragiri River by local fishermen

No	*Order*	*Family*	*Scientific name*
1	Cypriniformes	Cyprinidae	*Amblyrhynchichthys truncatus* (Bleeker, 1850)
			Barbichthys laevis (Valenciennes, 1842)
			Barbonymus schwanefeldi (Bleeker, 1854)
			Cyclocheilichthys apogon (Valenciennes, 1842)
			Hampala macrolepidota (Kuhl & Van Hasselt, 1823)
			Osteochilus vittatus (Valenciennes, 1842)

No	*Order*	*Family*	*Scientific name*
			Oxygaster anomalura (Van Hasselt, 1823)
			Puntioplites bulu (Bleeker, 1851)
			Striuntius lineatus (Duncker, 1904)
			Rasbora cephalotaenia (Bleeker, 1852)
			Thynnichthys thynnoides (Bleeker, 1852)
2	Perciformes	Belontidae	*Trichopodus pectoralis* (Regan, 1910)
			Trichopodus leerii (Bleeker, 1852)
		Helostomatidae	*Helostoma temminckii* (Cuvier, 1829)
		Osphronemidae	*Pristolepis grootii* (Bleeker, 1852)
3	Siluriformes	Siluridae	*Hemibagrus nemurus* (Valenciennes, 1840)
			Ompok hypophthalmus (Bleeker, 1846)
		Bagridae	*Mystus nigriceps* (Valenciennes, 1840)
		Pangasiade	*Pangasianodon hypophthalmus* (Sauvage, 1878)
4	Siluridea	Loricarinae	*Pterygoplichthys pardalis* (Castelnau, 1855)
5	Mastacembeloidei	Mastecemblidae	*Mastacembelus erythrotaenia* (Bleeker, 1850)
8	Decapoda	Atyidae	*Caridina multidentata*

Several fish species living in the Indragiri River also live in the Buaya Lake and in the outlet river (connecting the Buaya Lake to the Indragiri River). Of the total number of species in the Indragiri River, 12 (54.54%) were found also in the Buaya Lake and in the outlet river, presumably due to the migration of some fish from the Indragiri River to the Buaya Lake for spawning and then to the outlet river. Therefore, the Buaya Lake is necessary for the spawning and as a nursery ground. This statement requires evidence from several indicators that strengthen this hypothesis. Out of 8 species which were caught during the sampling in the Buaya Lake, 8 were also caught in the outlet river (Table 2). Two species were not caught also in the outlet river, namely *B. schwanenfeldii* and *E. metallicus,* possibly due to the small number of sampling points in the Outlet River (which might be not representative for the local habitat.

Table 2
Species of fish caught during the sampling in both the Buaya Lake and the outlet river of the Indragiri River

No.	*Species*	*Sampling location*	
		Buaya Lake	*Outlet River*
1	*Rasbora argyrotaenia*	√	√
2	*Oxygaster anomalura*	√	√
3	*Barbonymus schwanenfeldii*	√	-
4	*Thynnichthys polylepis*	√	√
5	*Puntigrus tetrazona*	√	√
6	*Mystus alasensis*	√	√
7	*Caridina multidentata*	√	√
8	*Osteochilus vittatus*	√	√
9	*Esomus metallicus*	√	-

The square root mark (√) corresponds to the fish species caught during sampling.

At least 200-300 species of fish are scattered along with the peat-swamp waters of Borneo and Sumatera, with a distribution of 47-65 species at one location (Yule 2010). Nugroho et al (2016) reported about 29 species of swamp fish as being commonly used by the community for consumption. Ahmad & Samat (2015) reported that 22 species live in the Malaysia-Borneo peat swamps. The fish species discovered at the research location were commonly reported in several waters in Indonesia. Wibowo et al (2015) identified Sumatran peat swamp fish species and reported at least 72 species, based on DNA testing showing two new species of the new record, namely *R. pauciperforata,* and *O. eugeneiatus*.

Meanwhile, Thornton et al (2018) identified 55 species from 16 families of swamp river fish in Borneo and Sumatera. Mutiara (2017) reported about 20 species from 11 families, while according to the research conducted by Nurdawati & Prasetyo (2007), among the 75 identified species scattered in various rivers in Sumatra, mostly from the Cypriniformes order, like those found at the research location of the Inderagiri River, meaning that these species are well adapted and spreads.

Yustina (2016) stated that several species of peat-swamp fish were discovered, and about six fish species were bred for commercialization as ornamental fish and consumption fish, including *Oxyeleotris marmorata, Belandotichys dinema*, *Wallago leerii*, *Notopterus notopterus*, *Channa micropeltes*, and *Pangasius pangasius*. Ismail et al (2015) studied the richness of fish species in Malaysia, Selangor, and Borneo; the results showed that similar species were reported. Therefore, some reported species are widespread in several swamp forest locations.

Comparison of total fish length and shrimp carapace lengths in Buaya Lake, Outlet River, and Indragiri River. The comparison of the total length for fish specimens and carapace length for shrimp specimens caught in Indragiri River, Buaya Lake, and outlet river is presented in Figure 3. The fish caught during sampling in Buaya Lake and outlet river is smaller than those caught in the Indragiri River. Fish and shrimp caught during sampling indicate that the fish in Buaya Lake and the outlet rivers are young specimens and most likely spawned and hatched in Buaya Lake.

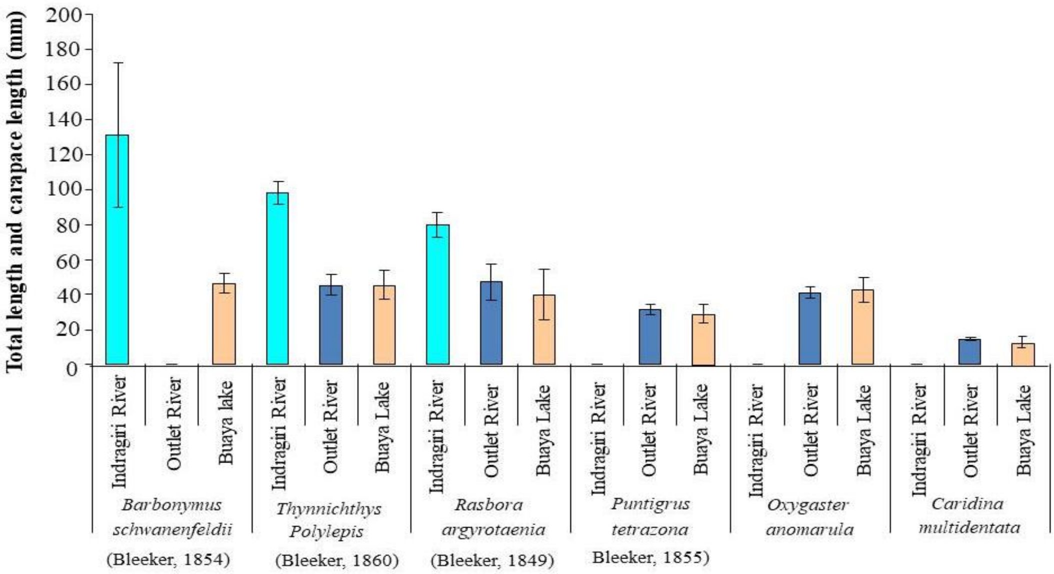

Figure 3. Comparison of fish length and shrimp carapace length of specimens caught in Buaya Lake, outlet river, and Indragiri River.

The total length of *Barbonymus schwanenfeldii* in the Indragiri River was greater (131.00±41.01 mm) than in Buaya Lake (46.26±5.49 mm). The size of the fish proves that Buaya Lake is one of the spawning grounds for this species. However, further research is needed to discuss the brood fish species caught in Buaya Lake and Outlet River that have a high level of fecundity which suitable for capture. The *Thynnichthys polylepis* samples were obtained from the Indragiri River, Buaya Lake, and outlet river. The total length of *T. polylepis* in the Indragiri River has a larger average size (97.77±6.71 mm) than the fish caught in the Buaya Lake (45.33±8.38) or in the outlet river (45.40 ± 6.07 mm).

The size of *Rasbora argyrotaenia* specimens captured in the Indragiri River was of 79.62±7.34 mm in total length, while those caught in the Buaya Lake and outlet river had a size of 39.65±14.30 mm and 47.06±10.27 mm, respectively. This research has not obtained samples of *P. tetrazona*, *O. anomalura*, and *C. multidentata* species in the Indragiri River. The total length of striped fish in the outlet river is longer (31.50±3.04 mm) than the *P. tetrazona* specimens from the Buaya Lake, with an average total length of 29.00±5.45 mm. Likewise, the outlet river's shrimp size (14.64±0.93 mm) was slightly higher than for those caught in the Buaya Lake (12.32±2.00 mm). As for *O. anomalura*, the sizes of the specimens caught in the outlet river and Buaya Lake were not different.

Length-weight relationship of fish from Buaya Lake, Outlet River, and Indragiri River. The fish length and weight are indicators of their growth. When the relationship between the length and weight growth of fish is positively correlated, the fish is developing well. The length and weight indicators can also estimate the gonadal maturity level of the fish (Figure 4a-d).

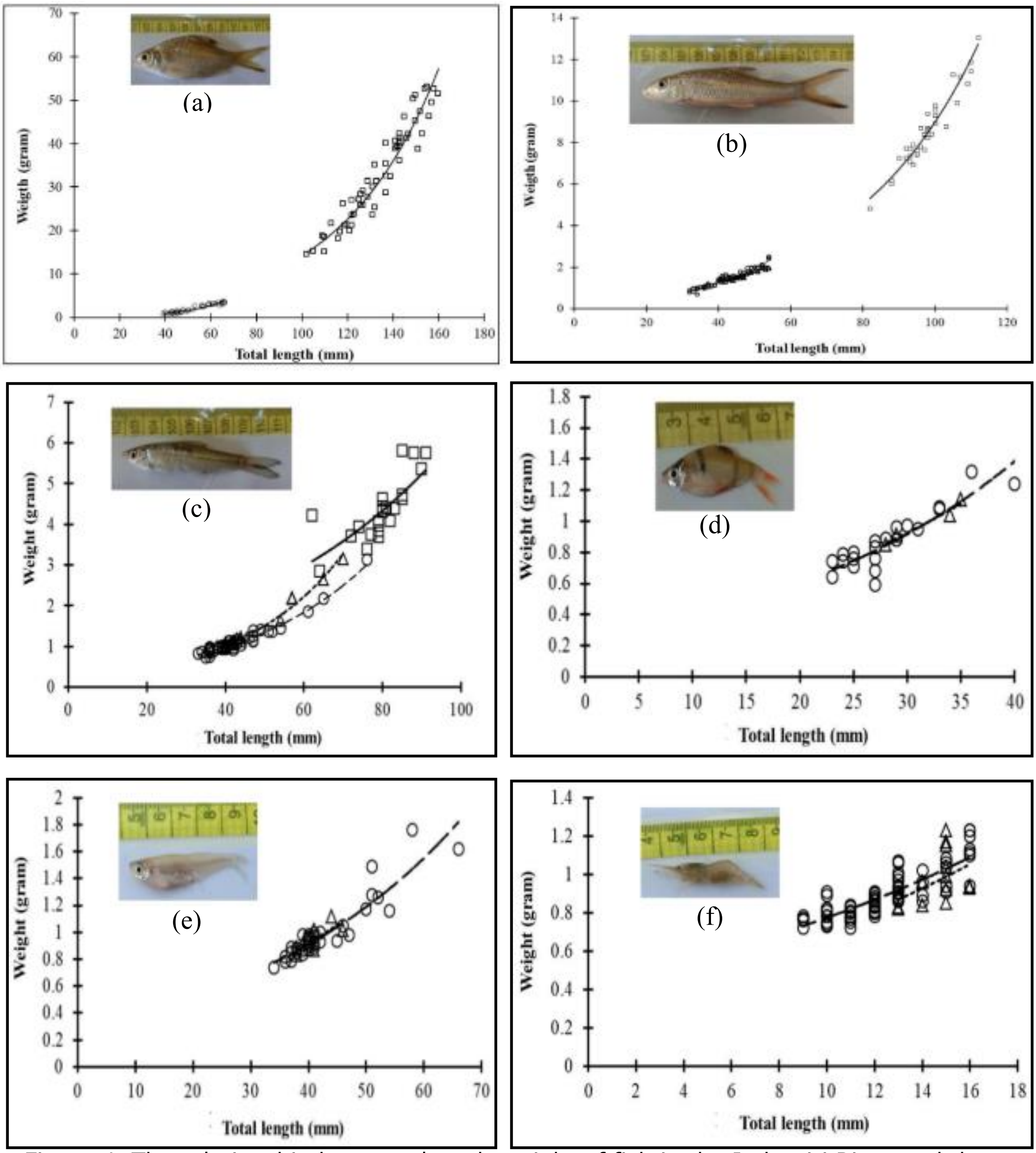

Figure 4. The relationship between length-weight of fish in the Indragiri River and the Buaya Lake. Circle marks are for species from Buaya Lake, triangle marks for species from Outlet River and square marks for species from Indragiri River. (a) *Barbonymus schwanenfeldii*, (b) *Thynnichthys polylepis*, (c) *Rasbora argyrotaenia*, (d) *Puntigrus tetrazona*, (e) *Oxygastes anomalura*, and (f) *Caridina multidentata*.

Figure 4a shows the relationship between length and weight of *B. schwanenfeldii* in the Indragiri River and Buaya Lake. Total body length and weight of *B. schwanenfeldii* in Buaya Lake were smaller than in those from the Indragiri River. The growth of *B. schwanenfeldii* from both sites was positively correlated (the longer, the heavier). The total length of *B. schwanenfeldii* in Buaya Lake is smaller than that of adult *B. schwanenfeldii*, which is between 167-280 mm (Isa et al 2012), while the length of *B. schwanenfeldii* in the study area is only about 100-160 mm. The size of *B. schwanenfeldii* shows that the fish caught in the Buaya Lake is still young. The total length and weight of *T. polylepis* living in Buaya Lake and outlet river are smaller than those living in the Indragiri River. The range of total length of the *T. polylepis* in the Indragiri River is 82-112 mm, with a weight of 4.84-13.06 g. Meanwhile, in Buaya Lake, the total length of the *T. polylepis* was only 34-54 mm, with a weight of 0.96-1.93 grams, while in the outlet river the total length ranged from 40-54 mm, with a weight of 1.37-1.96 g (Figure 4b). The size and weight ranges of *T. polylepis* in outlet river and Buaya Lake were not different. The significant difference in the size of the *T. polylepis* between the Indragiri River and the outlet river or the Buaya Lake indicates that the waters of Buaya Lake are a *T. polylepis* spawning ground. Therefore, the young *T. polylepis* is abundant in Buaya Lake, mostly juvenile. Sukimin et al (2018) obtained for *T. polylepis* a length range of 75-228 mm, with the highest frequency at 145-158 mm.

Figure 4c shows that the total length-weight relationships of *R. argyrotaenia* caught in the Indragiri River, Buaya Lake, and outlet rivers has relatively different (ANCOVA, P<0.05). Meanwhile, the relationships between the length and weight of *R. argyrotaenia* caught in the Buaya Lake and the outlet river were not different (ANCOVA, P>0.05). Consequently, the Buaya Lake is likely one of the spawning ground for *R. argyrotaenia*. The *R. argyrotaenia* were caught in the seven sampling stations; therefore, it can be concluded that *R. argyrotaenia* were scattered throughout all parts of the Buaya Lake and outlet river. Research by Rosadi et al (2014) divided the size of *R. argyrotaenia* into three groups, with the sizes of 65.76 mm (young), 116.13 mm (juveniles), and 156.63 mm (adults). The size of *R. argyrotaenia* specimens in the study area ranged from 35-100 mm, which classified them as young fish.

The length of the *P. tetrazona* sampled from the outlet river ranged from 28-35 mm. Meanwhile, the fish caught in the Buaya Lake ranged from 23-45 mm. The length and weight of *P. tetrazona* discovered in the outlet river and Buaya Lake was not different (ANCOVA, P>0.05). Adult *P. tetrazona* measures an average of 60 mm and can grow to a total length of 70 mm (Kottelat & Whitten 1996). The size of the *P. tetrazona* reported in the outlet river and in the Buaya lake shows that the *P. tetrazona* are young and juvenile.

The *O. anomalura* is the dominant fish species discovered in Buaya Lakes and outlet river. Figure 4d shows there is no significant difference in length and weight between the fish in the Buaya lake and the outlet river (ANCOVA, P>0.05). The total length of fish living in the Buaya lake ranges from 34-66 mm, while the total length of the *O. anomalura* living in the outlet river ranges from 38-46 mm. The *O. anomalura* discovered at the study location was relatively small in size. According to Hamid et al (2015), *O. anomalura* has a 92-270 mm body length, with an average of 186.6 mm. The species of *O. anomalura* living at the research location have different size characteristics, probably due to the nutrient intake and food availability (Jonathan et al 2018; Anamulai et al 2019).

Figure 4f shows that the relationship between the carapace length and weight of *C. multidentata* living in the Buaya Lake and outlet river has a positive correlation, demonstrating a good growth proportion. There was no significant difference between carapace length and body weight of *C. multidentata* living in the Buaya LAKE and outlet river (ANCOVA, P>0.05). The freshwater shrimp catches always dominated the other species in every sampling at the research location. The freshwater shrimp is the dominant species that lives on the Buaya Lake and outlet river. Uddin et al (2016) obtained data on the total length of *C. multidentata*: females measured about 12-27 cm, and males 15-25 cm. The size range of shrimp at the study location was smaller (8-16 cm).

Out of all the species of fish sampled, the level III of gonad maturity was only discovered in *O. anomalura*. Meanwhile, other species were only discovered in the level I of gonad maturity. August-September was not yet the spawning season in the Buaya Lake for several fish species discovered in the Buaya Lake, outlet river and Indragiri River. Most species of fish caught were below the size of the adult level (first maturity).

Conclusions. 22 species were sampled and identified in the Indragiri River, of which 12 were discovered also in Buaya Lake and outlet river. It was concluded that the Buaya Lake contains interactions by species and parameters of aquatic environment among these three habitats consist of upstream, midstream, and downstream. The fish and shrimp caught in the Buaya Lake and outlet river are generally small compared to the fish discovered in the Indragiri River. In addition, the juvenile fish discovered in Buaya Lake and outlet river are likely the results of spawning by fish and shrimp from the Indragiri River. The sampling time was minimal so that time series on the number and size of fish and shrimp were limited.

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Conflict of interest. The authors declare no conflict of interest.

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Authors:
Nofrizal, Program of Doctoral Environmental Science, Post Graduate Studies, Riau University. Jl. Pattimura No. 9, Gobah, Cinta Raja, Kec. Sail, Kota Pekanbaru, Riau Province, 28127, Indonesia, e-mail: aan_fish@yahoo.com
Thamrin, Program of Doctoral Environmental Science, Post Graduate Studies, Riau University, Jl. Pattimura No. 9, Gobah, Cinta Raja, Kec. Sail, Kota Pekanbaru, Riau Province, 28127, Indonesia, e-mail: thamrin@lecturer.unri.ac.id
Zulfan Saam, Program of Doctoral Environmental Science, Post Graduate Studies, Riau University, Jl. Pattimura No. 9, Gobah, Cinta Raja, Kec. Sail, Kota Pekanbaru, Riau Province, 28127, Indonesia, e-mail: zulfansaam@lecturer.unri.ac.id
Romie Jonnerie, Faculty of Fisheries and Marine Science, Riau University, Kampus Bina Widya Km 12,5 Simpang Baru, Pekanbaru, Riau Province, 28293, Indonesia, e-mail: romie.jhonnerie@gmail.com
Rahman Karnila, Faculty of Fisheries and Marine Science, Riau University, Kampus Bina Widya Km 12,5 Simpang Baru, Pekanbaru, Riau Province, 28293, Indonesia, e-mail: kumans_69@yahoo.co.id
Riska Fatmawati, Faculty of Fisheries and Marine Science, Riau University, Kampus Bina Widya Km 12,5 Simpang Baru, Pekanbaru, Riau Province, 28293, Indonesia, e-mail: riskafatmawati@lecturer.unri.ac.id
Ramses, Universitas Riau Kepulauan, Jl. Pahlawan No 99, Bukit Tempayan, Batu Aji, Batam City, 29425, Kepulauan Riau Province, Indonesia, e-mail: ramses.firdaus@gmail.com
Tengku Said Raza'i, Faculty of Marine and Fisheries Science, Maritim Raja Ali Haji University, Jl. Raya Dompak**,** Batu IX, Kec. Tanjungpinang Timur, Kota Tanjung Pinang, Kepulauan Riau Province, 29124, Indonesia, e-mail: tengku.saidrazai@gmail.com

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