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Aquatic plants as niche for lay eggs and raising juveniles by freshwater fish in three swamp habitats in South Kalimantan, Indonesia

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Abstract. *Dharmono, Mahrudin, Irianti R, Fajeriadi H. 2022. Aquatic plants as niche for lay eggs and raising juveniles by freshwater fish in three swamp habitats in South Kalimantan, Indonesia. Biodiversitas 23: 1520-1526.* Swamp is an area that is almost always waterlogged throughout the year, making it a very unique ecosystem. There is a wide variety of ecosystem services provided by swamp ecosystems, one of those is a habitat of freshwater fish, which is related to the presence of swamp vegetation. This study aimed to investigate swamp plants used as niches for freshwater fish to lay eggs and raise its offspring in three swamp areas in three regencies (i.e., Hulu Sungai Utara Regency, Tanah Laut Regency and Barito Kuala Regency) in South Kalimantan Province, Indonesia. Purposive random sampling was conducted in each swamp by observing and documenting the types of plants where fish eggs and offspring were found. We recorded 26 species of aquatic plants used by 17 species of swamp fish to lay eggs and raise offspring/fry. *Eichhornia crassipes* was the most widely used aquatic plant species with 100% of all freshwater fish species found (17 fish species), followed by *Pistia stratiotes* by 70.6% (12 fish species) and *Cyperus digitatus*, *Lemna minor*, *Nelumbo nucifera*, *Utricularia aurea* and *Crinum asiaticum* with each used by 52.9% (9 fish species). These plant species favored by fish need to be maintained and controlled to support the population of the fish.

Keywords: Swamp plants, stand and raise, young fish

INTRODUCTION

Based on the 1971 Ramsar Convention, a swamp is defined as an area that is almost always waterlogged throughout the year, naturally formed on relatively flat or sunken land with mineral deposits or peat and overgrown with vegetation (Matthews 2013). Swamps are waterlogged, acidic, anoxic, and oligotrophic ecosystems (Too et al. 2021). Swamps ecosystems as floodplain areas provide a wide variety of ecosystem services (Phiri et al. 2021), including maintaining hydrological and carbon cycles between land and atmosphere (Ohkubo et al. 2021), medium of seeds distribution (Lei and Middleton 2021), and the habitat of aquatic plants and animals (Padil et al. 2021). For example, a study in the Tripa peat swamp forest, Indonesia, recorded 41 species of herbaceous plants (Djufri et al. 2016).

Despite their importance, in the last decades, swamp ecosystems, particularly in the tropics, have been pressured by various human activities such as logging, deforestation and degradation, and land conversion, making it prone to large fires, especially during the dry season (Kubik et al. 2020). This phenomenon causes changes in the environment and climate (Lei and Middleton 2021), thus affecting the carbon cycle of the swamp ecosystem (Liu et al. 2020) and threatening its biodiversity, including the vegetation (Paul et al. 2020). The continuing habitat loss in the swamp ecosystem could result in biodiversity loss before it is known their species diversity (Barletta et al. 2010). Therefore, prudent management of aquatic habitats, including swamp ecosystems, is needed to conserve aquatic biodiversity (Ndehedehe et al. 2020)

Peat swamp ecosystem is one of the unique habitats that has high species endemism (Joni et al. 2015). Different vegetation in this ecosystem indicates niche formation due to unique biotic and abiotic factors, which are mainly caused by the waterlogged condition and highly acidic water and soils. However, small-scale spatial variations show the stochastic nature of the vegetation (DiMichele et al. 2017). Niche area and trophic diversity can indicate resource use according to trophic availability, regardless of size or sex (Correia 2002). For instance, ridge-hollow swamps can generate ecological niches in strongly acidic aqueous media with specific aquatic plants and animals that may live in the area (Rybina et al. 2014). According to Kłosowski and Jabłońska (2009), habitat conditions in water bodies are distinguished based on the dominance of aquatic plant species associated with particular habitats. For example, bitter-fruited and sweet-fruited vegetation might require different ecological niches (Vihotogbé et al. 2019).

Whetstone (2009) states that vegetation occurring in the swamp ecosystem can be classified into three groups, namely surface plants, floating plants, and submerged plants. Surface plants have roots at the bottom of the water with leaves extending upward to the water surface, for example, *Sagittaria sinensis* and *Phragmites communis*. Meanwhile, Goel (2006) stated that floating plants are plants whose roots hang in the water or do not touch the bottom of the water, for example, *Nymphaea* sp. and *Nelumbo* sp. Submerged plants are plants that live entirely in water, such as *Hydrilla verticillata*, *Najas minor*, *Chara vulgaris* and *Ceratophyllum demersum*.

Aquatic plants in the swamp ecosystem play an essential role in fish life (Kurniawan and Paramita 2019). Aquatic animals such as fish are very dependent on the presence of plants that live in swamps as a niche or micro-habitat, especially for shelter and breeding (Raharjo 2018). The abundance of aquatic plants is positively correlated with fish populations (Odum 1993). Habitats with moderate amounts of aquatic plants provide an optimal environment for many fish to increase fish diversity, feeding, growth, and reproduction. In contrast, limited or excessive vegetation cover can reduce the growth rate of fish by 75% to 85% (Ismail et al. 2018). Fish uses aquatic plants to lay eggs on the leaf surface of aquatic plants or among smooth-leaved plants on mangrove vegetation (Triyanto et al. 2019). For example, the parent fish *Clarias batrachus* and fish *Melanotaenia* sp. usually form pairs, lay eggs, and protect eggs and seeds from harm under aquatic plants (Lende and Khileri 2021).

Each type of plant has specific morphological characteristics to adapt with its habitat (Steenis 2013). In the swamp ecosystem, the morphological characteristics of swamp vegetation are thought to be used by freshwater fish species as living and growing habitats. Based on the research results of Ismail et al. (2018), no research results have been found that report certain types of plants selected by certain types of fish as a niche for laying eggs and raising its offspring. In addition, the types of plants favored by fish need to be maintained, and their fertility needs to be increased.

This study aimed to investigate swamp plants used as niches for freshwater fish to lay eggs and raise its offspring in three swamp areas in South Kalimantan Province, Indonesia. The swamps in South Kalimantan, or locally called *lebak*, provide an excellent study context since the province has a swamp area of 208.893 ha with vegetation dominated by shrubs and shrubs. We expect the results of this study can be disseminated to the people living around the swamps through raising awareness about the potential uses, threats, and conservation of swamps, especially the influence of aquatic plants on the presence of freshwater fish in swamp habitats, and even deliberately restore the degraded swamp to increase fish population.

MATERIALS AND METHODS

Study area and period

This research was carried out in three swamp habitats in South Kalimantan, Indonesia, namely Rawa Hulu Sungai Utara Regency, Rawa Tanah Laut Regency, and Barito Kuala Regency in April 2021 (Figure 1). The research site in Hulu Sungai Utara Regency is located at the coordinates of 2°36'17.10" South latitude and 115°5'54.59" East longitude at an altitude of 15-17 m above sea level (asl) with temperatures ranging from 21-35ºC and an average rainfall of 384.5 mm/year. The area of the swamp studied was 92.5 ha in the form of a lowland swamp influenced by tidal river water and rainwater with a diversity of flora dominated by aquatic herbaceous plants of Hydrocharitaceae, Cyperaceae, and Poaceae. The people who live around the swamp are farmers, swamp buffalo breeders and fishermen.

The research site in Tanah Laut Regency is located at the coordinates of 114.583° - 114.711° East longitude and 3.56309° - 3.72364° South latitude at an altitude of ±0.5-1 m asl with temperatures ranging from 21-36°C and an average rainfall of 203.8 mm/year. The area of the swamp studied was 56.7 ha in the form of a mangrove swamp, which was influenced by tides of seawater and river water with a salinity of 0-7 ppm. The diversity of flora was dominated by aquatic herbaceous plants in the form of Mangroves, Hydrocharitaceae, Cyperaceae, and Poaceae. The people who live around the swamp are farmers and fishermen.

The research site in Barito Kuala Regency is located at the coordinates of 3°15'25" - 3°20'72" South latitude and 114°38'28" - 114°68'17" East longitude at an altitude of ±0.5-1 m asl with a temperature range from 23-35°C and the average rainfall was 248.23 mm/year. The area of the swamp studied is 47.2 ha in the form of a monton swamp which is inundated throughout the year. Diversity of flora dominated by aquatic herbaceous plants in the form of Hydrocharitaceae, Cyperaceae, Poaceae, and Myrtaceae. The people living around the swamp are farming communities, seekers of galam wood and fishermen.

Data collection procedure

This research used observational techniques with descriptive analysis. The research sample was determined by purposive random sampling in each swamp by observing and documenting the types of plants where fish eggs and offspring were found. Determination of plant species using a plant observation guide by Dasuki (1994), Steenis (2013), and Shui (2019). Determination of the type of plant preferred by fish as a niche in laying eggs and raising offspring/fry was based on the finding eggs, offspring, and mother fish around the plants. Determination of the type of parent fish used fish observation guide by Saanin (1984), Moyle and Cech (1988) and Kottelat et al. (1993). The research data were analyzed descriptively.

RESULTS AND DISCUSSION

In our study, there were 26 species of aquatic plants used by 17 species of swamp fish to lay eggs and raise offspring/fry, as shown in Table 1. The number of aquatic plants used as fish niches in this study is more than in the study conducted by Ismail et al. (2018), which only found nine plant species, i.e., *Lemna minor*, *Polygonum barbatum*, *Eichhornia crassipes*, *Pistia stratiotes*, *Neptunia oleracea*, *Hydrilla verticillata*, *Salvinia molesta*, *Phragmites australis*, and *Azolla pinnata*.

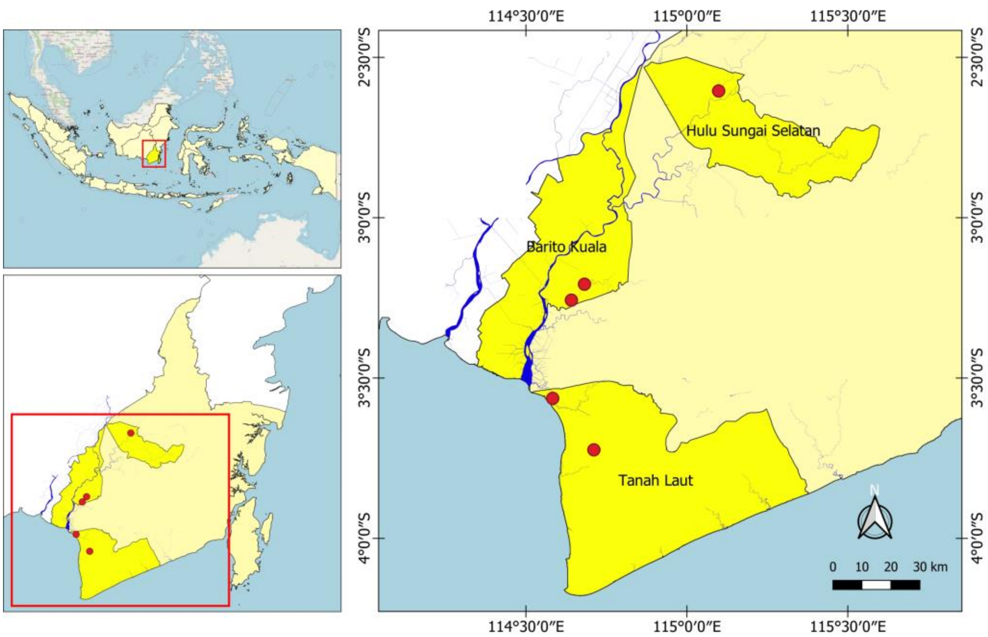

Figure 1. Map of three research locations in three regencies in South Kalimantan Province, Indonesia: Hulu Sungai Selatan, Tanah Laut and Barito Kuala.

Tabel 1. Plant species used by fish to lay eggs and raise offspring/fry in three swamps in South Kalimantan Province, Indonesia

No.	Plant species	Fish species																
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	*Azolla pinnata*		F													F	F	
2	*Caladium* sp.		F							F						F		F
3	*Cyperus digitatus*		E	E	F	E				F			F			F	F	F
4	*Diplazium esculentum*	F	E	E				F						F		F		F
5	*Phaspalum conjugatum*	F		E	F	E		F		F				F			F	
6	*Eichornia crassipes*	F	E	E	F	F	E	F	F	F	E	F	F	F	F	F	F	E
7	*Hydrilla verticillata*														F			
8	*Hydrocharis Morsus*	F						F						F		F		F
9	*Hymenachne amplexicaulis*	F	E	E		E		F						F		F		E
10	*Ipomoea aquatica*		E	F	F				F	F		F			E		F	
11	*Lemna Minor*		E	E	F	E					E	F			F	F		E
12	*Lemna perpusilla*														F	F		E
13	*Limnocharis flava*	F						F						F		F	F	F
14	*Megathyrsus maximus*				F	F				F								
15	*Nelumbo nucifera*		F	E	F	E	E					F				F	F	F
16	*Neptunia oleracea*			F			F		F							F		E
17	*Nymphaea alba*		F	E	F						F		E		F	F		E
18	*Nymphaea lotus*															F		E
19	*Pistia stratiotes*	F	E	F	F	E		F	F			F		F		F	F	F
20	*Salvinia minima*		E	F					F							F		F
21	*Salvinia molesta*									F		F			E	F	F	E
22	*Salvinia natans*		E	E		E			F	F						F	F	E
23	*Stenochlaena palustris*	F						F		F			F	F		F	F	F
24	*Utricularia aurea*	F	E	E	F	E		F						F		F		F
25	*Zoysia matrella*	F		F				F	F					F		F		E
26	*Crinum asiaticum*		E		F				F			F	F	F	E		F	E

Notes: E = eggs, F = fry

A	*Channa striata*	G	*Channa micropeltes*	M	*Channa lucius*
B	*Anabas testudineus*	H	*Cyprinus carpio*	N	*Rasbora argyrotaenia*
C	*Trichogaster trichopterus*	I	*Pampus argenteus*	O	*Mystus scopoli*
D	*Rasbora dusonensis*	J	*Clarias batrachus*	P	*Osteochilus hasselti*
E	*Trichogaster pectoralis*	K	*Criptopterus* spp	Q	*Oxyeleotris marmorata*
F	*Helostoma temminckii*	L	*Hemibagrus nemurus*		

Based on research conducted in April 2021, it can be seen that the presence of fish in swamp plants had two forms, namely in the form of eggs (indicated by the presence of foam around the plants) and in the form of offspring/fry (Table 1 and Figure 2). This finding suggests that the reproduction period of freshwater fish is different or happening not at the same time. This is in accordance with Setyaningrum and Wibowo (2017) who reported the reproductive ability of 5 fish species (i.e., *Cyprinus carpio, Barbonymus gonionatus, Osteochilus vittatus, Oreochromis niloticus,* and *Clarias gariepinus*), which showed a difference in reproduction period. Devkota and Kathayat (2020) explained that climate change greatly affects the reproduction, development, structure, and abundance of freshwater fish populations. In addition, the reproductive potential of fish depends on the development of the gonads until the fish spawn and produce seeds. Based on information from the people living in the three swamp areas studied, the breeding season for fish in the area indicated by the presence of fish eggs and offspring/fry is from February to August.

Niche signifies animal habitat in its biotic and abiotic environment in relation to food and its enemies (Odum 1993). Based on this concept and Figure 3, it can be seen that the most widely used aquatic plant by fish that live in swamps as a niche for laying eggs and rearing offspring was *Eichornia crassipes* with 100% of all freshwater fish species found (17 fish species), followed by *Pistia stratiotes* by 70.6% (12 fish species), *Cyperus digitatus* 52.9% (9 fish species), *Lemna minor* 52.9% (9 fish species), *Nelumbo nucifera* 52.9% (9 fish species), *Utricularia aurea* 52.9% (9 fish species), *Crinum asiaticum* 52.9% (9 fish species), *Diplazium esculentum* 47.1% (7 fish species), *Hymenachne amplexicaulis* 47.1% (8 fish species), *Ipomoea aquatica* 47.1% (8 fish species), *Nymphaea alba* 47.1% (8 fish species), *Salvinia natans* 47.1% (8 fish species), *Stenochlaena palustris* 47.1% (8 fish species), *Paspalum conjugatum* 47.1% (8 fish species), *Bulbostylis juncoides* 41.2% (7 fish species), *Limnocharis flava* 35.6% (6 fish species), *Salvinia molesta* 35.3% (6 species fish), *Hydrocharis morsus* 29.4% (5 fish species), *Neptunia oleracea* 29.4% (5 fish), *Salvinia minima* 29.4% (5 fish), *Caladium* sp. 23.5% (4 fish), *Azolla pinnata* 17.6% (3 fish species), *Lemna perpusilla* 17.6% (3 fish species), *Bulbostylis barbata* 17.6% (3 fish species) and *Nymphaea lotus* 11.8 % (2 fish species). Meanwhile, the plant least used by fish for laying eggs and raising offspring was *Hydrilla verticillata*, with only 1 species of fish (5.9%).

Based on the study results, the morphological characteristics of aquatic plants used by fish as niches for laying eggs and raising offspring/fry were related to the leaves and roots. *Eichhornia crassipes* or water hyacinth was the most used plant species for niche by various types of swamp fish. *Eichhornia crassipes* is herbaceous plant with macrophytes or plants that float on water throughout its life. This plant has leaves arranged in a rosette, wide ovoid shape, which is very beneficial for fish to lay and attach eggs on a flat surface. In addition, the wide leaf will protect the eggs and offspring from the effects of direct sunlight. The water hyacinth root system is fibrous with many small, fertile and dense roots, which are suitable for fish to lay eggs between these small roots. In addition, there was an abundance of organic and inorganic materials needed as food sources for young fish. The black color of the roots will protect the eggs and young fish from predators. Such morphological characteristics make this plant the most preferred by freshwater fish to lay eggs and raise their young. In this study, all the 17 freshwater species recorded in this study raise their juveniles around *Eichhornia crassipes*. Our finding that *Eichhornia crassipes* serve as a niche for fish reproduction is in line with other studies, such as Ismail et al. (2018), Gettys (2009) and Whetstone (2009).

Figure 2. The presence of haruan (*Channa striata*) fish eggs and offspring in aquatic plants

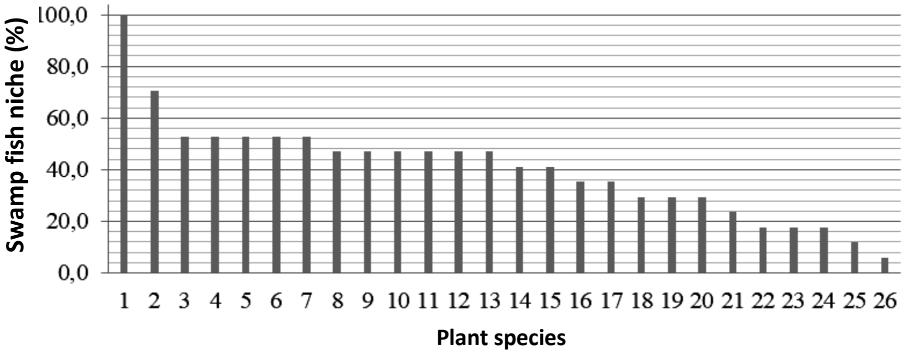

Figure 3. Percentage of fish species (of total 17 species) found in plant species in in three swamps in South Kalimantan Province

Note:

1.	*Eichhornia crassipes*	10.	*Ipomoea aquatica*	19.	*Neptunia oleracea*
2.	*Pistia stratiotes*	11.	*Nymphaea alba*	20.	*Salvinia minima*
3.	*Cyperus digitatus*	12.	*Salvinia natans*	21.	*Caladium* sp.
4.	*Lemna minor*	13.	*Stenochlaena palustris*	22.	*Azolla pinnata*
5.	*Nelumbo nucifera*	14.	*Paspalum conjugatum*	23.	*Lemna perpusilla*
6.	*Utricularia aurea*	15.	*Zoysia matrella*	24.	*Megathyrsus maximus*
7.	*Crinum asiaticum*	16.	*Limnocharis flava*	25.	*Nymphaea lotus*
8.	*Diplazium esculentum*	17.	*Salvinia molesta*	26.	*Hydrilla verticillata*
9.	*Hymenachne amplexicaulis*	18.	*Hydrocharis morsus*		

Pistia stratiotes has a single leaf type with dense leaves arrangement and dense rosettes, the leaves have spoon shape, the edges of the leaves are grooved with a smooth leaf surface and hairy stripes, the texture of the leaves is thick and soft with a length of 1.3-10 cm and a width of 1.5-6 cm. Such leaf morphology is very beneficial for fish to attach or lay eggs. In addition, the dense leaf blades or rosettes will protect the eggs and offspring from the effects of sunlight and water currents. However, the roots of this plant is at the bottom of the water, so fish cannot use it to attach or lay eggs.

In contrast, *Rasbora argyrotaenia* was found only in *Hydrilla verticillata* which uses this plant to lay eggs and raise their young. *Hydrilla verticillata* is herbaceous plant that lives in tightly spreading water. It has stems intercalated 0.7 cm - 1.4 cm with single leaf lanceolate in shape and arranged at a circular layout of 3-6 leaves, leaf margins are serrated, leaf surface with a length of 0.6-2.5 cm and a width of 1.2-5.5 cm. The root system of this plant is fibers attached at the bottom of the water. Based on these morphological characteristics, the potential of plants as a niche for laying eggs and raising offspring is only in its leaves. In addition, with a dense habitus, it will be an obstacle for medium and large-sized fish for their reproductive purposes. So that only small fish can use this plant to lay eggs and raise juveniles, which in this study was *Rasbora argyrotaenia*. Another study also found *Hydrilla verticillata* as a fish niche was also reported by Ismail et al. (2018).

Based on the description above, the morphological characteristics of shape, size and number of leaves that float on the surface and the shape and number of root fibers affected the presence of freshwater fish to lay eggs and maintain their juveniles. The larger the leaf size, the higher the number of leaves that cover the water surface, the rougher the leaf surface and edges, and the denser the root system in the water (not in the soil), the more fish is likely to lay eggs and raise young around plants with such characteristics. In addition, such morphological characteristics also will slow and calm the flow of water currents, making it suitable for laying eggs and raising fish. The dense roots in the water can hold and bind the minerals and organic matters, which might be beneficial for feeding young fish. Aquatic plants with broad leaves have an important role as oxidizing agents, so they are very efficient in binding carbon dioxide in the water and releasing it into oxygen which is beneficial for young fish.

The concept of weeds in swamp habitat, if viewed from the importance of maintaining fish diversity, might not be relevant because swamp habitat is not an area used for productive plant cultivation. The existence of aquatic plants in the swamp habitat needs to be maintained so that the freshwater fish required by the people living in the area can always be maintained and used as a source of natural animal protein. Triyanto et al. (2019), Lende and Khileri (2021) found that fish use aquatic plants to lay eggs and reproduce on the leaf surface of aquatic plants. Thus, plant species that important as habitat niches of swamp fish need to be maintained and controlled. According to Fuller et al. (1998), integrating vegetation cover and another biodiversity such as fish can assist conservation planning.

In addition, we found that each fish that lived in the swamp never used one plant simultaneously with other fishes to raise young at the same time and place. Thus, one plant is only used by one type of fish in each spawning. The diversity of aquatic plant species in swamps affects swamp fish species' activity, growth, and territorial formation. This is in line with the concept of there is no two species use the same resources simultaneously (Odum 1993), which is also true for fish using aquatic plants as niches to lay eggs and raise their young. Thus it can be said that fish choose certain plants to lay their eggs and raise their young precisely without the presence of other fish to do the same. Research by Mouton et al. (2010) shows that differences in life histories or even gene flow of fish assemblages can result in different realization niches. Haller (2009), Costa et al. (2010) and Ismail et al. (2018) stated that the abundance of aquatic plants triggers the growth and condition of fish. The limitations and excess of aquatic plants in swamp areas can reduce the abundance of fish. According to (Mirmanto 2009), the negative correlation is the existence of competition between individual seeds at the beginning of growth, not between species.

Based on the description above, it can be stated that the more aquatic plants found in the swamp will make the swamp an optimal fish niche for fish to lay eggs and raise young. This will have a positive impact on the diversity of fish in the swamp. Therefore, the existence of these plants needs to be maintained and their fertility increased to ensure the development of freshwater fish, especially those that live in swamps.

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