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Length-Weight Relationship and Condition Factor of Introduced Red Devil Cichlid *Amphilophus labiatus*, in Lake Sentani, Indonesia

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ABSTRACT

Papua's freshwater ecosystems in the western part of New Guinea have begun to record widespread introductions of invasive species over the past decade. This lake's most dominant and common exotic species is *Amphilophus labiatus* (Günther, 1864). A study was conducted to document the length-weight relationship and condition factor of these fish in Lake Sentani. From June to August 2019, fish were caught using floating gillnets at six locations around the lake. Total length (TL) (mm), body depth (mm), and body weight (grams) were measured, and condition factor based on gender, body weight, and body length were observed in 345 fish, including 264 males and 81 males. The growth pattern of *A. labiatus* is positively allometric, with b values ranging from 3.19 to 3. 20 and coefficients of determination (r^2) ranging from 0.84 to 0.87. Although the average body length of *A. labiatus* males was shorter than females, condition factor (CF) values were not significantly different between the sexes and ranged from 0. 64 to 2.03 (0.97 ± 1.17, mean ± sd). For males, it went from 0.67 to 1.19 (0.94 ± 0.13 mean ± sd). However, monthly CF data show a significant decrease in CF in August, suggesting that spawning events occur in late July or early August. *A. labiatus* grows well and colonizes habitats throughout Lake Sentani.

Key words: freshwater fish; introduced species; New Guinea; Papua; threat

INTRODUCTION

The easternmost province of Indonesia, Papua, has a high level of biodiversity. Supriatna (1999) reported that Papua has about 250 freshwater and 1200 marine fish. It recorded 400 freshwater fish species in New Guinea, with around 60 % of fish being endemic species (Allen *et al*., 2002). Four genera of New Guinea's freshwater fishes helped define endemism areas: *Melanoatenia, Mogurnda*, *Allomogurnda*, and *Hephaestus* (Polhemus *et al*., 2004). The freshwater and brackish water fishes comprise 8% of the total vertebrate fauna of Papua (Allison, 2007). Aquatic habitats in New Guinea are categorized into seven significant habitats, one of which is upland lakes, and Lake Sentani is included in this category. However, it is not considered a truly upland lake because it lies at 75 m above sea level and is relatively close to the coastline in Jayapura Regency, close to Jayapura City, the primary human population center of the regency (Allen, 1991). The lake also serves to support the primary freshwater fishery in the region. The lake is about 9,630 ha in surface area and ranges from 2–24 km wide, with a maximum depth of 52 meters in the western part of the lake,

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in the Doyo area (Umar *et al*., unpublished data). The lake's surface area has been shrinking over the last ten years because of erosion, sedimentation, and other human activities in and around the lake, documenting that the lake surface has decreased by about 100 ha (Indrayani *et al*., 2015).

The lake has ten native species (3 species are endemic to the lake) and eight native diadromous species. Beginning in 1937, some exotic species have been introduced to lakes and rivers in Papua by inland fishery development programs for food and economic subsistence under the sponsorship of the Indonesian government and the Food and Agriculture Organization (FAO) of the United Nations, including introductions of aquaculture species into Lake Sentani (FAO of the United Nations, unpublished data). Fish introductions have continued since that time, either intentionally or accidentally, into Lake Sentani. In the last ten years, more introduced species have been found in the lake, and at present, more than half of the fish biomass in the lake is introduced (Ohee, 2013; Ngamelubun, 2017; Ohee *et al*., 2018; Tupen, *et al*., 2016). One of the introduced species is *Amphilophus labiatus*.

A. labiatus is originally from Lake Managua and Lake Nicaragua in Nicaragua, Central America (Barlow & Munsey, 1976). It has been introduced to some parts of the world, including Hawaii, Puerto Rico, Singapore, Queensland, Australia, and Indonesia (Froese and Pauly, 2020, Adjie & Fatah, 2015; Ariasari *et al*., 2018; Nico, *et al*., 2020), and most recently, it was introduced to Lake Sentani, Indonesian New Guinea at around 2008. Since it was introduced, the species' population has increased sharply, becoming the most abundant and dominant exotic fish in the Lake (Ohee *et al*., 2018). The population of native fish species in Lake Sentani has been markedly decreasing over the last 20 years as the populations of exotic species have increased. The endemic Sentani Rainbowfish, *Chilatherina sentaniensis* (Weber, 1907), has probably been extinct since around 2006 since there have been no reported incidences of its capture since then.

Moreover, the population trends of two other endemic species, Red Rainbowfish (*Glossolepis incisus* Weber, 1907) and Sentani Goby (*Glossogobius sentaniensis* Hoese & Allen, 2015), as well as an economically critical native species, the Sentani Gudgeon, *Oxyeleotris heterodon* (Weber, 1907) have all been decreasing in the lake. Given the apparent aggressive replacement of native species in the lake, biological parameters such as reproduction and growth are of interest to provide information to aid in its eradication or control. This research presents data on the length-frequency and morphologic measures of length-weight relationship and condition factor among both male and female *A. labiatus* in Lake Sentani. The biology of *A. labiatus* has been studied in Kedung Ombo Reservoir in Central Java, Indonesia (Adjie & Fatah, 2015). However, it is the first study of its type for the species in Lake Sentani, located east of the Wallace Line, where this introduced neotropical cichlid is interacting with and disrupting endemic and native species status in the lake.

MATERIAL AND METHODS

Study sites

The research was conducted in Lake Sentani from June to August 2019. Fish samples were collected from Puay, Ayapo, Asei, Hobong, Ifale, and Yakonde (Figure 1). The fish collection started three months after a catastrophic flood in the watershed of Lake Sentani, in March 2019, when the lake's water level increased by 2 to 3 meters and did not subside much during the three months of the survey. The catastrophic rain event changed the lake physically and ecologically, with organic and inorganic sediments flowing into the lake due to abundant runoff from the watershed.

Sampling procedure

Fish were captured using floating gillnets with 2.5-inch or 3.0-inch mesh nets 50 meters long and 2 meters deep at each location. Fish sampling was repeated three times at each location in three different months. A net was set at a depth around

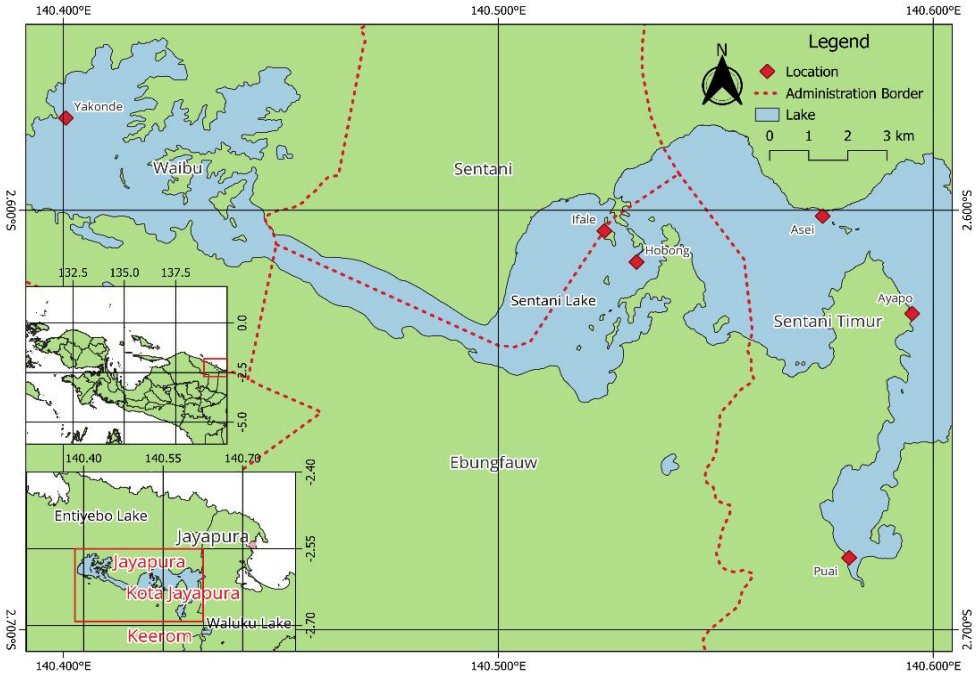

Figure 1. Six research locations in Lake Sentani, including Puay in the south, Ayapo and Asei were in the east, Hobong and Ifale in the north, and the west location was in Yakonde.

10 meters or more in the lake between 4:00 and 6:00 p.m. The fish were collected between 7:00 and 9:00 a.m. the following day. Red devil cichlids *A. labiatus* were collected and counted. In addition, we measured the total length (TL) of 20 individuals from the tip of the nose to the tip of the tail fin (mm), body depth: measure the lower edge of the body and the upper edge of the widest part of the body using a measuring board and calipers, and measure the weight (in grams) using an electronic balance. Then, fish samples were stored in 10% formaldehyde for three days, and after rinsing them with fresh water, the fish's length, weight, and condition factor were analyzed in the laboratory.

Data analyses

The body length and body weight relationship is described by the allometric equation $W = aLb$ (Effendi, 1979) when W is the total weight (g), L is the total length (mm), *a* is the intercept related to body form, and *b* is the regression coefficient (Froese, 2006). The calculation was performed using Microsoft Excel 2010 for Windows. The *b* value was used to know the fish growth pattern, which is isometric if (b=3) or allometric if (b≠3). Then, a t-test was applied to determine whether the relationship was positive or negative among body length and body weight. The length-weight relationship was shown by correlation coefficient (r), where r value close to 1 means the relationship is strong. In contrast, the r value close to 0 means the relationship is fragile or no relationship. Condition factor analyses were done based on sex, body weight, and body length per month, which is described by the equation $Kn = \frac{W}{aL^b}$ (Effendi, 1979) when Kn is condition factor, W is body weight (g), L is total body length (mm), a and b are the allometric constants from the allometric equation (Effendi, 1979).

RESULTS AND DISCUSSION

Results

Length-weight relationship (LWR)

A total of 345 individuals of red devil cichlid, *A. labiatus*, including 264 males (77%) and 81

females (23%), were measured for total length (mm) and weight (g). The total length and weight of males and females of the species and combined sex can be found in Table 1. The most common fish lengths were 137 to 166 mm, with males comprising most smaller individuals.

The value of the regression slope *b* was the same for males and females, 3.19-3.20. The coefficient of determination (r^2) ranged from 0.84–0.87. Length-weight analyses showed that the growth pattern of red devil cichlid is positively allometric (Table 1).

Condition factor

The fish's mean (±SD) condition factor ranged from 0.64-2.03 (0.97±1.61). The condition factor of male *A. labiatus* ranged from 0.64-2.03 (0.97±1.17), and females ranged from 0.67-1.19 (0.94±0.13) (Table 2). The condition factor each month showed male fish had a better condition in each month than females, where males had the relatively same condition during three months, while females had a more fluctuating range, and the lowest range was 0.36-0.53 (0.41±0.04) in August (Table 3).

Discussion

Amphilophus labiatus growth in Lake Sentani was evaluated by size-frequency analysis and length-weight relationship. These data are helpful in gathering information about its invasive potential and for fishery management as well (Katsanevakis, 2006). The present study revealed that *A. labiatus* length-weight relationship (LWR) exhibits positive allometric growth (b>3), in which

Table 1. Length-weight relationships of male and female *A. labiatus* from Lake Sentani, Indonesia.

Sex	N	Total length (mm)		Weight (g)		Equation	a	b	r^2
		Min	Max	Min	Max				
Male	264	95	227	10	245	$W=0.000007L^{3.19}$	0.000007	3.19	0.84
Female	81	97	205	16	154	$W=0.000007L^{3.20}$	0.000007	3.20	0.87
Both sexes	345	95	227	10	245	$W=0.000007L^{3.19}$	0.000007	3.19	0.85

Table 2. Condition factor of male, female, and combined sex *A. labiatus* during the 2019 survey from Lake Sentani, Indonesia. There is no statistical difference (p<0.05) between mean condition factor values between males and females.

Sex	N	Condition factor		SD
		Range	Mean Value	
Male	264	0.64-2.03	0.97	0.17
Female	81	0.67-1.19	0.94	0.13
Combined sex	345	0. 64-2.03	0.97	1.61

N: number of individual, SD: standard deviation

Table 3. Condition factor of male and female *A. labiatus* in three different months, June-August 2019, of Lake Sentani, Indonesia. There is no statistical difference (p<0.05) among the mean condition factor values between males and females in those months, with the exception of females in August that are likely to be in a post-spawning phase.

Month	Male				Female			
	N	Range	Mean	SD	N	Range	Mean	SD
June	78	0.89-1.72	1.16	0.17	34	0.75-1.39	1.05	0.15
July	93	0.68-1.77	1.02	0.17	27	0.76-1.20	0.98	0.13
August	93	0.76-2.18	1.07	0.21	20	0.36-0.53	0.41	0.04

these fish gain weight faster than simple length (Table 1). The *b* values were within the expected range of 2.5-3.5 for most fish fields (Froese, 2006). Most fish were collected in a length range of 145-158 mm TL; males dominated the numbers of smaller-sized fish, and females the larger. This study agrees with the findings of (Hedianto, D. A., Satria, 2017) on a cichlid species from Matano Lake, Indonesia, where the determined *b* value was 3.013. (Tampubolon, *et al*., 2012) confirmed the sympatric species Midas Cichlid, *Amphilophus citrinellus* (Günther, 1864) from Ir. H. Djuanda Reservoir, Indonesia has, also positive allometric, where *b* values were 3.09, the same species had negative allometric growth (b=2.890) in Panjalu Lake, West Java (Warsa and Purnomo, 2013). Another cichlid species, a pond-reared juvenile Nile Tilapia, *Oreochromis niloticus* (Linnaeus, 1758), has close to an isometric growth (Olurin & Aderibigbe, 2006). However, the population Ir. H. Djuanda Reservoir has negative allometric growth (b=2.461) (Putri & Tjahjo, 2017). The differences in length-weight relationship within a species at different locations may be due to different factors such as habitat type and feeding habits of the fish in different locations (Karachle & Stergiou, 2012). The length-weight relationship could describe reproduction, well-being, gonad development, change of metamorphosis, and maturity (Le Cren, 1951). Additionally, Dutta (1994) also showed that various environmental factors, including temperature, oxygen concentration, salinity, and photoperiod, may influence the growth rate, while quality and quantity of food, genotype, and hormonal and physiologic conditions of fish also play a significant role in growth regulation. Similarly, the differences in food supply, population density, and temperature regularly influence fish growth rates (Weatherley & Gill, 1987, Claramunt & Wahl, 2000). None of these potential determinant factors for growth were evaluated in the present descriptive study.

Condition factor (*K*) is an index of the well-being of fish provided by the relationship between fish length and weight (Dutta, 1994). The condition factor of *A. labiatus* of Lake Sentani showed males fish have better condition than females. The mean condition factor for males and females are 0.97 and 0.94, respectively, which is still good condition for the fish (Table 2). Furthermore, the condition factor in each month shows relatively similar among males and females, except in August when females had very low condition (Kn=0.41) (Table 3). Olurin & Aderibigbe (2006) concluded that fish with a mean of condition factor more than 1.00 have good condition and health. Yongo *et al.* (2017) and Offem *et al*. (2007) found that the condition factor is significantly related to food availability. *A. labiatus* had good condition in Lake Sentani, except for females in August. This may indicate a spawning event between the July and August sampling periods.

To our knowledge, this is the first determination of length-weight relationships and condition factors for *A. labiatus* in Lake Sentani. Despite the rapid increase in the population of this fish in the lake, there has not been much work describing the population dynamics and ecology of *A. labiatus* in Lake Sentani except for a recent study of sex ratio and reproduction (Ohee, *et al*., 2020). Further studies of the length-frequency of *A. labiatus* throughout the year may better elucidate the tremendous spawning potential periods that we preliminarily conclude to be in late July or early August.

CONCLUSION

Amphilophus labiatus is the most abundant and predominant introduced species in Lake Sentani at the time of this study. We confirmed that *A. labiatus* was found to grow well and occupy most of the habitat. Good adaptive capability in new lacustrine ecosystems could influence the condition factor and thus support its abundance and dominance in the lake. Data suggest that this fish is a likely competitor to the native species with similar food preferences and could potentially threaten the native fish community and fisheries of Lake Sentani and other freshwater ecosystems across New Guinea Island.

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