CURRENT STATUS OF THE POPULATION DYNAMICS OF NILE TILAPIA (*Oreochromis niloticus*) IN BATUR LAKE, BALI, INDONESIA

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Abstract: A study aimed at evaluating the population dynamic parameters of Nile tilapia (*Oreochromis niloticus*) was conducted at Batur Lake, Bali, Indonesia from March to November 2023. The research was based on a survey, with fish samples obtained from the catch of fishermen using gillnets with a mesh size between 1.0 and 4.0 inches. The findings indicated that the population of Nile tilapia in Batur Lake was predominantly characterised by individuals with a mean length of 20.5 cm, which represented a frequency of 11.2%. The observed growth pattern was allometric (+). Analysis conducted using the FISAT Programme Package revealed that the maximum length (L∞) of the fish is 34.75 cm, with a growth rate (K) of 0.56 per year. The natural death rate (M) is 1.11 per year while the death rate due to fishing (F) is 1.35 per year. Consequently, the total death rate (Z) is 2.46 per year, resulting in an exploitation rate (E) of 0.55 for the Nile tilapia population. Currently, the Nile tilapia in Batur Lake can spawn more than once a year, with peak spawning periods occurring in March, June, September, and November. The natural mortality rate (M) is 1.11 per year and the mortality rate from fishing (F) is 1.35 per year, leading to a total mortality rate (Z) of 2.46 per year, which confirms the exploitation rate (E) of 0.55. Based on recruitment patterns, the Nile tilapia in Batur Lake is capable of spawning multiple times annually, with the busiest spawning seasons occurring around March, June, September, and November.

Keywords: Population dynamics, growth, mortality rate, Nile tilapia, Batur Lake.

Introduction

Batur Lake is a volcanic lake situated at the base of Mount Batur, which is thought to be a caldera, an ancient volcanic crater (Suryono *et al*., 2008). Located in the Bangli District at an altitude of about 1,080 m above sea level, Batur Lake covers an area of approximately 1,605 hectares or 16.05 km². Over the years, by 2005, the water level at Batur Lake had decreased by approximately one metre (Anonymous, 2010). The destruction and deforestation, coupled with the rising human settlement around the lake area, threaten the local biota, including the fish inhabiting its waters.

The current state of Batur Lake's waters involves fishing activities that employ a floating net system, primarily aimed at catching Nile tilapia (*Oreochromis niloticus*). As a closed water system without an outlet, the situation in Batur Lake is likely to worsen. However, the waters are renowned for their high fertility, providing a rich aquatic ecosystem that supports fish life (Samuel & Suryati, 2011). During a 2011 study, fishers captured 12 identified species, including Nile tilapia, Java tilapia, Java carp, snakehead, black lohan, red lohan, black cendol, red cendol, gourami, catfish, eels, and milkfish.

Additionally, two shrimp species were identified: The giant freshwater prawn and the testes shrimp (Samuel *et al*., 2011). According to information from the Fisheries Services in the Bangli District, various fish species were introduced to Batur Lake between 2004

and 2009, including Nile tilapia, Java tilapia (mujaer), Java carp (tawes), and milkfish. However, the dominant species caught by fishers in 2011 was Nile tilapia.

Nile tilapia is a significant species that plays a vital role in the local fisheries sector, encompassing both capture and aquaculture. Understanding the factors that influence survival and growth is crucial, as this information will significantly impact the health of the Nile tilapia fisheries stock and aid in the management of fish resources in various water bodies (Samuel *et al*., 2018). According to Tesfaye *et al*. (2022), the results of a study on population dynamics in Langano Lake indicated that better management is needed to anticipate the threat of overfishing. Furthermore, well-managed Nile tilapia can enhance economic benefits through sustainable cultivation techniques (Kaliba *et al*., 2006) and is important for the conservation of genetic diversity (Shechonge *et al*., 2019).

Population parameters such as growth, recruitment, and mortality are essential for establishing fishing regulations related to seasons and quotas, as well as for analysing fishing strategies (Sangadji *et al*., 2022). According to Allan *et al*. (2005), Dudgeon (2005), Triyanto *et al*. (2009), and Muchlisin *et al*. (2010), the overexploitation of fish resources in inland waters has led to their degradation. Understanding these population parameters is vital for developing effective fishing regulations regarding seasons and quotas, as well as for analysing fishing strategies.

The study of the population dynamics of Nile tilapia in Batur Lake, particularly concerning the parameters of growth, mortality, recruitment, and exploitation rate since the fish were stocked, has never been conducted. This research is necessary to understand the condition and growth of introduced fish, particularly the dominant Nile tilapia, so that these fish can thrive in their environment and be effectively managed.

Therefore, research on the growth parameters, mortality, and exploitation rate of Nile tilapia in Batur Lake is necessary. The aim of this study is to gather data on the growth parameters, mortality rates, and exploitation levels of Nile tilapia. This information will be valuable for the management and development of Nile tilapia in Batur Lake, ensuring that the species is both sustainable and exploited in a responsible manner.

Materials and Methods

The study was conducted at Batur Lake, located in Bangli Regency, Bali Province (Figure 1). It took place from March to November 2023. The samples of Nile tilapia used in this study were sourced from the catches of fishermen employing gillnets with mesh sizes ranging from 1.0 inches to 4.0 inches (1, 2, 3, and 4 inches). Fishermen set the gillnets at various locations on Batur Lake, specifically in the villages of Songan (Ulun Danu), Toya Bungkah, Pura Jati, Buahan, and Trunyan.

The total number of fish used in this study was 7,027. The number of fish measured each month is as follows: March (531 fish), April (568 fish), May (666 fish), June (727 fish), July (787 fish), August (821 fish), September (913 fish), October (1,005 fish), and November (1,009 fish). The largest length recorded was 20.5 cm, occurring with a frequency of 12.2%. The equipment used for measuring fish length included a measuring tool comprising a ruler and measuring board, calibrated in centimetres (cm) with an accuracy level of 0.1 cm. For measuring weight, a digital scale was employed, using grammes (g) with an accuracy level of 0.1. The catchability coefficient of the fishing gear was calculated using the formula proposed by Sparre and Venema (1999), namely:

$$q = F/f \qquad (1)$$

where q = catchability coefficient, F = fishing mortality, f = number of effort units.

The length and weight data of Nile tilapia were then examined to determine their growth patterns, either at the same rate (isometric, b=3) or at different rates (allometric, b≠3), using the formula suggested by Effendie (1979).

$$W = a* L^b \qquad (2)$$

where W = weight of fish (g), L = total length (cm), and a and b = constant values. The constant value of b obtained from the above equations was then tested for accuracy against the value b = 3 using the "t-test". According to Gayanillo et al. (1996), Jackson and Harvey (1997), Sparre and Venema (1998), Essington *et al.* (2001), Kapuscinski *et al.* (2012), and Clarito and Suerta (2021), fish growth is described by the Von Bertalanffy model. Estimations of growth parameters from the Von Bertalanffy model, specifically the asymptotic total length (L∞) and the growth coefficient (K) were derived using the ELEFAN I programme (1987) within the FISAT software package (Gayanillo *et al.*, 1995). The value of t_0 (age at the time of zero length) was calculated using the Pauly equation (1984), namely:

$$\text{Log } (-t_0) = - 0{,}3922 - 0{,}2752 \text{ Log } (L∞)$$
$$-1{,}038 \text{ Log } (K) \qquad (3)$$

The growth performance index (Φ', phi-prime) was calculated using the equation of Pauly and Munro (1984) as follows:

$$Φ' = \text{Log}_{10}K + 2 \text{ Log}_{10}L∞ \qquad (4)$$

The natural mortality rate (M) was estimated by using an empirical model of Pauly (1980), namely:

$$\text{Log}(M) = -0{,}0066 - 0{,}279*\text{Log}(L∞) + 0{,}6543*$$
$$\text{Log}(K) + 0{,}4634*\text{Log}(T) \qquad (5)$$

where L∞ = asymptotic total length, K = coefficient of growth, and T = average water temperature of Batur Lake (22.42°C). The coefficient of total mortality (Z) was obtained from the catch curve based on the length-converted catch curve (Pauly, 1983). The calculation was performed using the computerised programme package FISAT (Gayanillo *et al.*, 1995). The fishing mortality coefficient (F) was calculated using the following equation:

$$F = Z - M \qquad (6)$$

The exploitation rate (E) was calculated using the equation (Pauly, 1980).

$$E = F/Z \qquad (7)$$

The recruitment pattern of Nile tilapia was estimated using the FISAT II program, specifically the Recruitment Pattern subprogram. This analysis aims to determine the recruitment structure of a time series of length-frequency data by identifying the number of peaks per year. The approach utilises growth parameter information in the form of L∞ and K, as provided by Gayanillo *et al.* (1995) and Ongkers (2006).

Results and Discussion

The Nile tilapia, *Oreochromis niloticus* (family Cichlidae) is commonly found in Batur Lake, Bali, as illustrated in Figure 2. This fish typically exhibits a grey or black coloration on its dorsal side, transitioning to a whitish hue on the abdomen. It features seven to eight dark transverse bars. The dorsal fin contains 15 to 16 sharp spines while the soft rays range from 11 to 13. Additionally, the anal fin consists of three spines and between eight and 11 rays.

The gill net fishing gear used by fishers in Batur Lake has a calculated catchability coefficient (q) value of 0.34, determined using the formula F = q*f. This indicates that the gill net gear captures 34% of the fish in the area. In other words, the efficiency of the gill net fishing gear in Batur Lake accounts for 34% of the total fish available. Therefore, each time the gill net fishing gear is deployed, only 34% of the entire fish population in Batur Lake is caught.

The results of the length-weight relationship analysis showed that the growth pattern of Nile tilapia in Batur Lake was positively allometric, with a b value of 3.1428 (Figure 3). This indicates that Nile tilapia in Batur Lake, on average, experience faster weight gain compared to length gain. The positive allometric growth pattern suggests that the fish are in good condition, which is generally supported by favourable environmental conditions and sufficient access to food sources. The measured Nile tilapia revealed a population dominated by individuals measuring 20.5 cm in length, which accounted for a frequency of 11.2% (Figure 4).
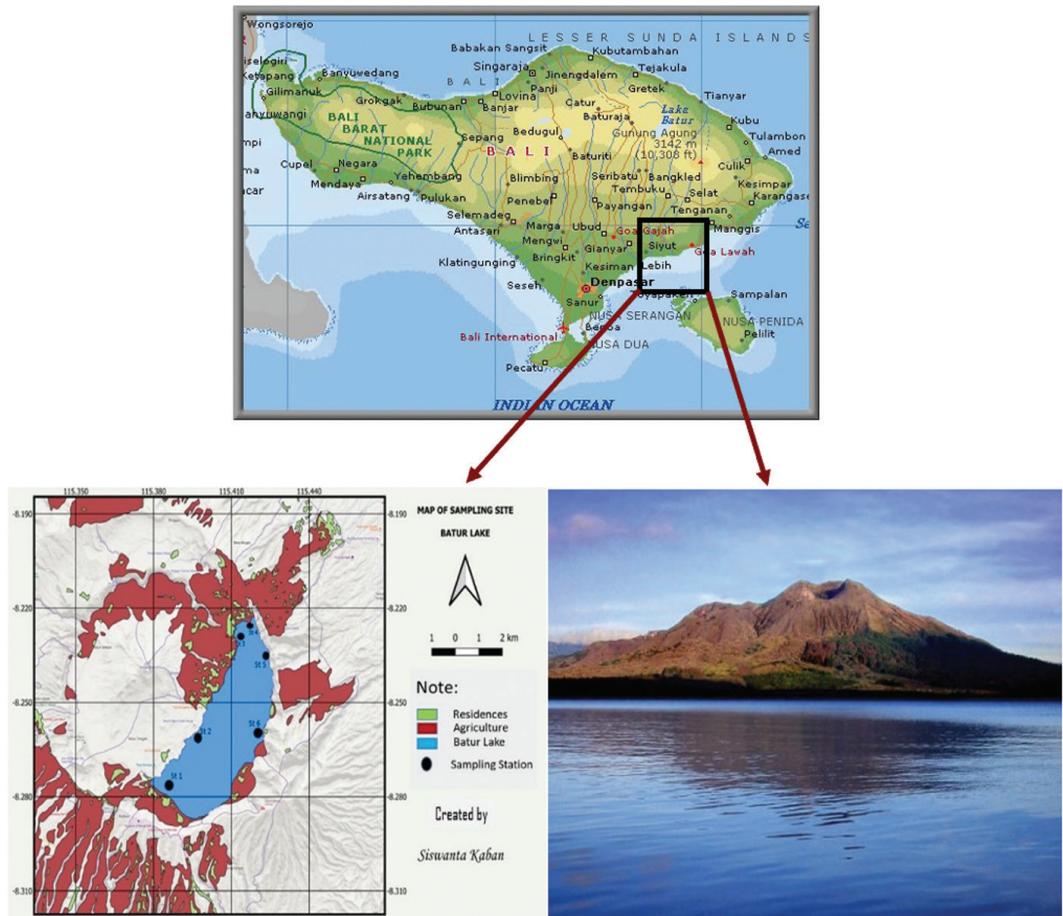
Figure 1: The research location in Batur Lake, Bali

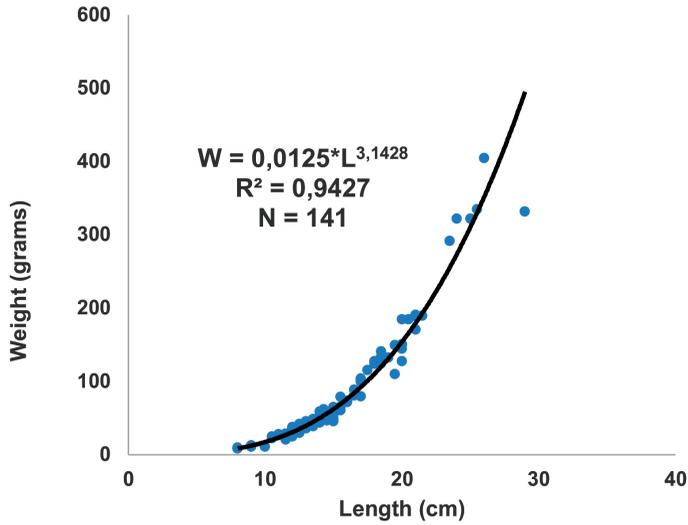Figure 2: The Nile tilapia (*Oreochromis niloticus*) from Batur Lake, Bali

Figure 3: The length-weight relationships of the Nile tilapia in Batur Lake (2023)

$$W = 0{,}0125*L^{3{,}1428}$$
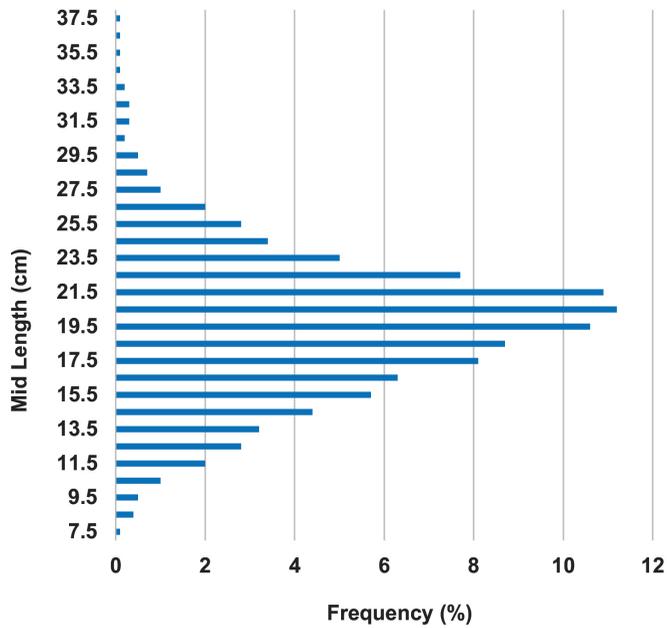$$R^2 = 0{,}9427$$
$$N = 141$$

Figure 4: Size distribution of the total length of the Nile tilapia in Batur Lake, Bali

The study of the monthly fish catch rates, conducted using the FISAT programme, revealed that the growth pattern of Nile tilapia in Batur Lake conformed to the Von Bertalanffy equation, expressed as Lt = 34.75(1 - exp(-0.56*(t - (-0.28)))) (Figure 5). The growth model indicated that Nile tilapia in Batur Lake can grow up to 34.75 cm, with a growth rate coefficient (K) of 0.56 per year. The growth coefficient (K) is a curvature that provides insight into how quickly a species can reach its asymptotic length (L∞) (Pauly, 1983; Sparre & Venema, 1999). In contrast, Nile tilapia in Paniai Lake, Papua can grow up to 37.28 cm, with a growth rate coefficient (K) of 0.50 per year (Samuel *et al.*, 2018). The maximum length
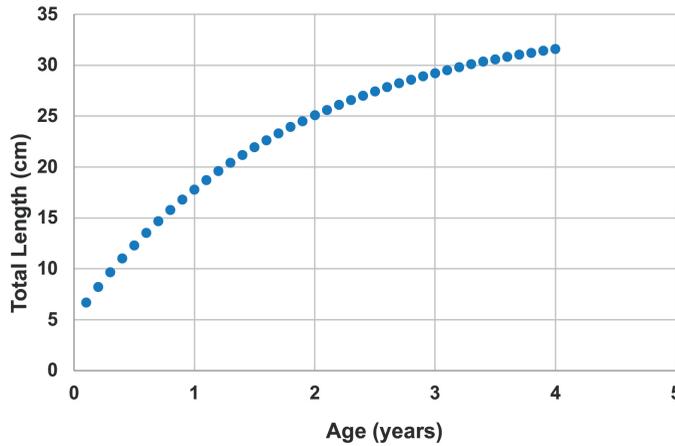
Figure 5: The growth curve of the Nile tilapia (*Oreochromis niloticus*) in Batur Lake, Bali with *Von Bertalanffy* equation: Lt = 34.75(1-exp(-0.56*(t-(-0.28)))

of fish in the Bilibili Reservoir, South Sulawesi varies from 43.0 cm and has a growth rate of 0.3 cm per year (Amir, 2006). Several factors contribute to the differences in the maximum length of the fish. According to Welcomme (2001) and Froese (2006), variations in fish size can arise from adaptations to abiotic conditions such as water temperature and food availability.

Nile tilapia (*Oreochromis niloticus*) in Batur Lake is the result of fish introduced by local agencies, specifically the Inland Fisheries Service of the District of Bangli, Bali. Observations indicate that the stocked Nile tilapia can tolerate the lake's water quality conditions, allowing them to adapt and proliferate. It was noted that fishers primarily catch Nile tilapia using gillnets. The growth index value (Φ', phi-prime) of Nile tilapia in Batur Lake is 2.83 (Table 1). This growth index is higher than that of Nile tilapia in Tempe Lake (2.35) but lower than that of Nile tilapia in the

Malahayu Reservoir (3.41). This suggests that the growth performance of Nile tilapia in Batur Lake is better than that in Tempe Lake but lower than in Malahayu Reservoir.

Table 2 presents the population parameters of Nile tilapia in Batur Lake, derived from the analysis results and calculations. Using the FISAT II programme to analyse the parameter values of L∞, K, and the mean water temperature, we determined that the natural mortality of Nile tilapia in Batur Lake (M) is 1.11.

Furthermore, model analysis using the length-converted catch curve indicated that the total mortality (Z) is 2.46. The fishing mortality (F), calculated using the equation F = Z - M was found to be 1.35. Consequently, the exploitation rate (E), calculated as E = F/Z is 0.55. This exploitation rate of 0.55 suggests that the level of exploitation of Nile tilapia in Batur Lake has exceeded the optimum value (E = 0.5). Therefore, it is imperative to reduce the amount

Table 1: Parameter values of the Nile tilapia in Batur Lake and other water bodies

Waters Body	L∞ (cm)	K (yr^{-1})	Φ'	Z (yr^{-1})	M (yr^{-1})	F (yr^{-1})	E	Source
Batur Lake	34.75	0.56	2.83	2.46	1.11	1.35	0.55	
Batur Lake	41.45	0.52	3.01	2.06	0.96	1.10	0.54	Samuel & Suryati, (2012)
Tempe Lake	31.76	0.22	2.35	1.02	0.51	0.51	0.50	Samuel *et al.* (2010)
Malahayu Reservoir	38.90	1.70	3.41	4.80	2.43	2.37	0.49	Purnomo (2011)

Table 2: Analysis results of growth parameter, mortality, and exploitation rate of Nile tilapia
(*Oreochromis niloticus*) from Batur Lake, Bali

No.	Parameters	Symbol	Values
1	Asymtotic length	$L\infty$	34.75
2	Growth coeficient	K	0.56
3	Age at size 0 cm	to	-0.28
4	Natural mortality	M	1.11
5	Fishing mortality	F	1.35
6	Total mortality	Z	2.46
7	Exploitation rate	E	0.55

of fishing gear in Batur Lake, particularly the gillnets used for Nile tilapia. However, the local Fisheries Service's introduction activities have led to an increase in the Nile tilapia population in Batur Lake, alleviating concerns about overexploitation.

The recruitment analysis results for tilapia in Batur Lake, based on length data analysed using the FISAT II application, indicated that the highest recruitment value, (15.98%) occurred in March during the rainy season. For further details, refer to Figure 6. The figure shows that Nile tilapia in Batur Lake exhibited four peaks of recruitment throughout the year, suggesting that they may spawn more than once annually.

We suspect that the spawning season of Nile tilapia in Batur Lake is closely linked to the transitions between the dry and rainy seasons, specifically around March and June, with the rainy season also influencing spawning around September and November. This phenomenon could be related to fluctuations in lake water levels during periods of rise and fall. Similar patterns were observed in *kapiek* (*Puntius schwanefeldi*) (Yusnita & Arnentis, 2002) and botia (*Botia macrachantus*) (Nurdawati, 2005), where spawning was also affected by water levels and occurred during the rainy season. Ongkers (2006) notes that recruitment patterns are correlated with the timing of spawning.

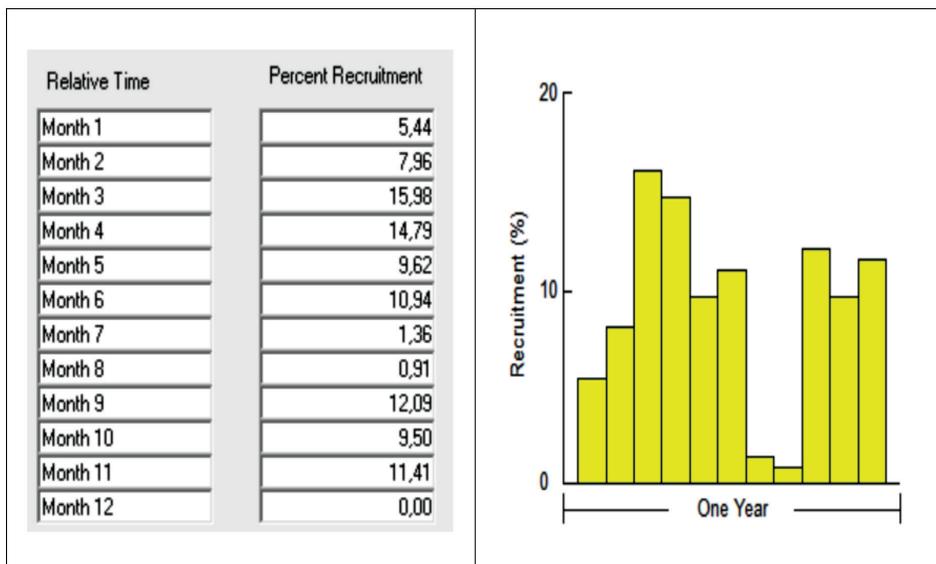| Relative Time	Percent Recruitment
Month 1	5,44
Month 2	7,96
Month 3	15,98
Month 4	14,79
Month 5	9,62
Month 6	10,94
Month 7	1,36
Month 8	0,91
Month 9	12,09
Month 10	9,50
Month 11	11,41
Month 12	0,00

Figure 6: The recruitment pattern of the Nile tilapia at Batur Lake, Bali in 2023

Nile tilapia spawning in Batur Lake is expected in March, June, September, and November, which is consistent with the spawning patterns of Nile tilapia in other lakes across Indonesia (Utomo *et al*., 1990; Samuel & Makmur, 2010). Irregular changes between the dry and rainy seasons can impact the spawning activity of motan fish, subsequently affecting their recruitment. This aligns with the findings of Subagdja *et al.* (2013), who noted that recruitment failure is influenced by several factors, including the size of the spawning stock, environmental conditions, predation, disease, and competition. The study recorded a total length of 20.5 cm for Nile tilapia, with a frequency of 11.2%. These results indicate that the Nile tilapia caught by fishermen in Batur Lake are predominantly of medium size, suggesting a potential issue of overexploitation or overfishing.

The initial study on the growth of tilapia in Lake Batur, conducted in 2011, indicated that the species could reach a maximum length (L∞) of 41.45 cm, with an annual growth rate (K) of 0.52 and an exploitation rate (E) of 0.54 per year. However, a follow-up assessment in 2023 showed that the maximum length (L∞) of the tilapia population in Lake Batur had decreased to 34.75 cm. During this period, the growth coefficient (K) increased to 0.56 per year and the exploitation rate (E) rose to 0.55 per year. The observed reduction in maximum length is suspected to result from excessive fishing, often referred to as overfishing, as indicated by the increase in the exploitation rate (E) from 0.54 per year in 2011 to 0.55 per year in 2023. According to Sparre and Venema (1999), excessive fishing efforts in specific waters can lead to a decrease in fish size.

Conclusions

The growth pattern of Nile tilapia in Batur Lake was positive allometric (b = 3.1428), with length accretion lower than weight accretion. Nile tilapia in Batur Lake can grow up to an asymptotic length (L∞) of 34.75 cm, with a growth rate (K) of 0.56 per year.

The exploitation rate (E) of 0.55 has already surpassed the optimum value (E = 0.5). Nile tilapia in Batur Lake can spawn more than once a year, with expected spawning periods in March, June, September, and November. Over the past 12 years, the size of Nile tilapia caught by fishermen in Batur Lake has decreased while the level of exploitation has increased, indicating a trend towards smaller sizes of Nile tilapia being caught in the future. The exploitation rate of tilapia in Batur Lake is above the optimum value, necessitating a reduction in fishing intensity, specifically by decreasing the number of gillnet gears. To promote conservation and sustainable use of Nile tilapia resources in Batur Lake, fish stocking activities need to be effectively maintained in this lake.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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