

Assessing some biological aspects and the stock status of the giant catfish (*Netuma thalassina* Ruppel, 1837) in Gunungkidul waters

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Abstract

The giant catfish (*Netuma thalassina* Ruppel, 1837) fishery in Gunungkidul waters has contributed economically to the local community, and the fishery has intensified since the lobster fishery population has declined. However, there is no information on the biological characteristics and stock status of *N. thalassina* to inform management strategies. This study aimed to assess various biological characteristics and to determine the stock status of *N. thalassina* in Gunungkidul waters. Biological data and stock status of *N. thalassina* were collected from March to December 2023. The results revealed that the majority of the giant catfish caught by bottom longline (63% of the catch) were fish below the length at first maturity. This condition can also be evidenced by the length at first capture ($L_{c50} = 29$ cm), which is smaller than the length at first maturity ($L_{m50} = 37$ cm). The length of *N. thalassina* captured by bottom longline in Gunungkidul waters ranged from 18 to 60 cm, with a mean of 35.44 ± 7.49 cm ($\pm$ SD). The catfish's body weight is optimal, indicated by the relative condition factor (Kn) 1.00 and the coefficient of b 3.15. The diet of *N. thalassina* consists of crabs, stomatopods, shrimps, and fishes, indicating carnivorous feeding habits. Crabs are the dominant prey item, with a preponderance index of 60%. Fecundity was relatively low, with an average of 26 ± 4 eggs ($\pm$ SD). The asymptotic length (L_{∞}) and growth rate (K) were 61.3 cm and 0.22 year^{-1} , respectively. The fishery status of *N. thalassina* is currently fully-exploited, based on three stock assessment methodologies: length-converted catch curve, yield per recruit, and spawning potential ratio analysis. The current fishing mortality of *N. thalassina* ($F_{\text{cur}} = 0.42 \text{ year}^{-1}$) exceeds the target reference point of $F_{40\%}$ (0.28 year^{-1}), indicating recruitment overfishing conditions. Hence, management measures should prioritize protecting immature fish by preventing the capture of individuals under 37 cm to enhance reproductive output.

Keywords: Bottom longline, Fecundity, Growth, Stomach content, Spawning potential ratio

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Introduction

The Gunungkidul waters serve as a habitat for various commercial fish species and have contributed significantly to the economic growth of the local community, particularly for the 2,276 local fishers. The monthly local income for each fisher was about 150 to 300 USD, and most fishers earned only from fishing (Tirtadanu et al., 2024a). One of the commercial fish species in Gunungkidul waters is the giant catfish (*Netuma thalassina*), with production reaching 127 tons in 2023, with an estimated economic value of 121,275 USD (MMAF, 2024).

The giant catfish fishery has grown intensively as lobster production in Gunungkidul waters declines due to over-exploitation (Tirtadanu et al., 2022). The transition from lobster traps to other fishing gears, such as bottom longline and surface gillnet, is linked to the decline of the lobster stocks. Lobster production fell from 63 tons in 2019 to 20 tons in 2023. In contrast, marine catfish production has increased from 13 tonnes in 2019 to 420 tonnes in 2023 (MMAF, 2024). Despite the higher price of lobster than marine catfish, the bottom longline fishery targeting marine catfish has greater profitability than the bottom traps fishery targeting lobster (Tirtadanu et al., 2024a). Increased fishing efforts without proper management may result in population decline and significant economic losses. Moreover, the giant catfish fishery in Gunungkidul waters has contributed economically to a marketing chain that includes intermediaries, traders, restaurants, and processing industries; thus, the risk of population decline will adversely affect various fisheries businesses (Sarwanto et al., 2014). Therefore, the biological aspects and stock status of *N. thalassina* must be investigated as a basis for developing sustainable management measures for catfish fisheries.

Studies on the giant catfish fishery in Indonesia are still limited. Prior studies have reported that *N. thalassina* in the northern waters of Java shows carnivorous traits, prey on other fish, and it has a negative allometry growth pattern with the coefficient of b as 2.79 (Marbun et al., 2017; Taunay et al., 2013). *N. thalassina* has been found in the waters of the Arafura Sea, where the highest density in brackish environments characterized by shallow depths (Tirtadanu et al., 2024b). The reproductive and growth aspects of *N. thalassina* remain unexplored in Indonesia. The overexploited condition of catfish fisheries has been examined in Banyuasin waters through a production and effort approach (Fauziyah et al., 2020). Assessing stock status should incorporate the biological and life history of the target

species to gain insights into its vulnerability to fishing pressure.

The stock assessment method applying production and effort data in Gunungkidul waters is difficult due to the lack of capacity to continuously record various fishing efforts and the risk of unreported production data linked to the dispersed landing sites of fishers in Gunungkidul. A length-based stock assessment is one of the methods that can be applied to the catfish fishery in Gunungkidul waters. This study investigated various biological aspects of *N. thalassina*, including fecundity, stomach contents, selectivity, length at first maturity, length-weight relationship, and growth. The stock status was determined by using multiple methods, including length-converted catch curve (LCC), yield per recruit (YPR), and spawning potential ratio (SPR) analysis (Hordyk et al., 2016; Sparre & Venema, 1992; Thompson & Bell, 1934). The uncertainty on the stock assessment was determined according to various natural mortality approaches. This study provides the first comprehensive assessment of biological characteristics and stock status of *N. thalassina* in the Gunungkidul waters, Indonesia. This study investigated the biological characteristics and stock status of the *N. thalassina* fishery as a basis for developing sustainable management strategies for the catfish fishery.

Materials and Methods

Data collection

Data were collected from March to October 2023 in Baron landing site, with the coordinate of -8.12877°S and $110.54874^{\circ}\text{E}$. The catfish samples were collected from the catch of longline fishery operating in the southern waters of Gunungkidul, Baron Beach, and nearby coastal areas (Fig. 1). Salinity in the sampling area ranged from 21‰ to 26‰. The longline fishery was characterized by the one day fishing trip, using vessels with the sizes of 3 GT. The mean catch for the catfish by bottom longline was about $25 \text{ kg}^{-1} \text{ vessel trip}^{-1}$. The vessel was motorized with 15 hp (horsepower), and the fishing ground was less than 12 miles from the landing area. Each vessel deployed approximately 800 hooks per set. Bottom longlines were typically set in the afternoon and hauled at night, with a soak time of approximately 4 hours. Fishers typically made 18 to 25 fishing trips per month. A total of 516 catfish were sampled. Biological data collected from each specimen included length (cm), weight (g), sex, gonad maturity stage (using a defined scale), stomach contents (analyzed for prey composition), and fecundity (for mature females).

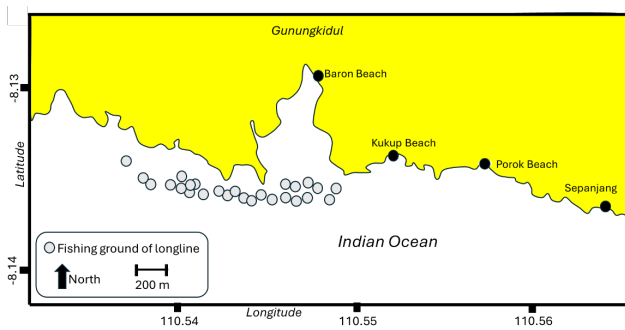


Fig. 1. Fishing ground of bottom longline targeted giant catfish (*Netuma thalassina*) in Gunungkidul waters. Using WGS84 and Google Earth database.

Data analysis

Biological characteristics of *N. thalassina* included size distribution, length at first capture ($L_{C_{50}}$), length at first maturity ($L_{m_{50}}$), stomach contents, fecundity, growth, and mortality parameters. Stock status was explored using the LCC approach, YPR analysis, and SPR.

Length-frequency data were grouped into 2 cm intervals and presented as a histogram to visualize the size structure of the population. Length at first capture and length at first maturity were estimated using a logistic regression (Sparre & Venema, 1992). The length-weight relationship was estimated using the power function (Ricker, 1975):

$$W = aL^b$$

where a is a constant, b is the growth coefficient, L is fork length (cm), and W is the observed weight (g). The growth coefficient of b was calculated using a 95% confidence interval, representing the range within which the true value is likely to fall with 95% probability.

The relative condition factor (K_n) was estimated based on le Cren (1951):

$$K_n = \frac{W}{W'}$$

where K_n is the relative condition factor, W is the observed weight and W' is the calculated weight.

Stomach contents were analyzed using the Index of Preponderance (IP) (Natarajan & Jhingran, 1961) to determine the relative importance of different prey items in the diet.

$$IP_i = \frac{W_i O_i}{\sum W_i O_i} \times 100$$

where IP_i is an index of preponderance, W_i represents the contribution of each prey item to the total weight of stomach contents, while O_i reflects the frequency with which each prey item was observed in the stomachs examined.

Fecundity was determined by direct counts of oocytes from the ovaries of mature female catfish to estimate the reproductive potential of the species. A non-parametric LOESS smoother was used to describe the relationship between fecundity, length, and weight, allowing for visualization of the trend without assuming a specific functional form.

The growth parameters, including asymptotic length (L_∞) and growth rate (K), were estimated using the electronic length frequency analysis with simulated annealing (ELEFAN SA) method within the TropFishR package (version 1.6.4) of the R program (R version 4.4.0) (Mildenberger et al., 2017; R Core Team, 2008; Xiang et al., 2013). A moving average value of 7 was performed to smooth the length frequency data and identify the fish growth over time. The theoretical age at which the fish attains a length of zero (t_0) was calculated using equation (Pauly, 1983):

$$\text{Log}(-t_0) = (-0.3922) - 0.2752 \text{Log}(L_\infty) - 1.038 \text{log}(K)$$

The asymptotic weight (W_∞) was estimated from the cubic equation in the length weight relationship (Ricker, 1975):

$$W_\infty = a(L_\infty)^b$$

where W_∞ is the asymptotic weight (g), L_∞ is asymptotic length (cm), a is the constant and b is the coefficient growth.

The maximum age ($t_{\max}$) was measured by the equation (Alagaraja, 1984):

$$t_{\max} = \left(-\frac{1}{K} \right) \ln \left(1 - \frac{0.95L_\infty}{L_\infty} \right)$$

where $t_{\max}$ is the maximum age (years), K is the growth rate (year^{-1}), and L_∞ is asymptotic length (cm).

Natural mortality (M) was estimated using multiple empirical models to account for uncertainty in the stock assessment, as M is a critical parameter that is difficult to estimate directly. The five empirical natural mortality methods were selected

based on the suitability of the available data and the life history characteristics of the species. The estimation of natural mortality was assessed using the following equation:

$$M_1 = \frac{3K}{e^{K(0.38t_{\max})} - 1}$$

$$M_2 = -\frac{\ln(0.01)}{t_{\max}}$$

$$M_3 = 1.5(K)$$

$$M_4 = \frac{\beta K}{e^{K(C_i t_{\max} - t_0)} - 1}$$

$$M_5 = 4.188K^{0.73}L_{\infty}^{-0.33}$$

M_1 , M_2 , M_3 , M_4 and M_5 represent the natural mortality (year^{-1}) estimates derived from the methodologies of Alagaraja (1984), Alverson & Carney (1975), Jensen (1997), Then et al. (2015), and Zhang & Megrey (2006), respectively. $t_{\max}$ represents the maximum age (year^{-1}), K denotes the growth rate (year^{-1}), β indicates the coefficient growth derived from the length-weight relationship, C_i is a constant valued at 0.44 that corresponds to demersal fish, t_0 refers to the theoretical age at which *N. thalassina* has zero length (year), and L_{∞} is the asymptotic length (cm).

Total mortality (Z) was estimated using the LCC method as described by Sparre & Venema (1992). Fishing mortality (F) was estimated as the difference between Z and natural mortality (M): $F = Z - M$. This assumes that total mortality is solely due to natural mortality and fishing mortality. The exploitation rate was calculated using the ratio of fishing mortality to total mortality (Gulland, 1983).

Length-based YPR analyses were performed by the Thompson and Bell model through the TropFishR package in the R program (Mildenberger et al., 2017; R Core Team, 2008; Thompson & Bell, 1934). The fishing mortality corresponding to the maximum YPR ($F_{\max}$) was applied as the limit reference point (LRP), while the fishing mortality that produced a YPR of 10% of the initial biomass ($F_{0.1}$) was designated as the target reference point in the YPR analysis (King, 1995).

The SPR was calculated using the ratio of spawning stock biomass per recruit in both exploited and unfished stocks (Goodyear, 1993; Hordyk et al., 2016). The SPR is determined by several input parameters: asymptotic length (L_{∞}), growth rate

(K), lengths at first captured (L_{C50}), length at 95% capture probability ($L_{C95\%}$), length at first maturity (L_{m50}), length at 95% maturity (L_{m95}), natural mortality (M), and current fishing mortality (F). The SPR was illustrated as a function of fishing mortality (F) by using variation of natural mortality to account for uncertainty. Each value from the five natural mortality methods was used as an input parameter to understand the sensitivity of the SPR. The biological reference points utilized in the SPR analysis included fishing mortality corresponding to 20% SPR as the LRP and 40% SPR as the target reference point. A SPR less than 20% indicates a very low percentage of the spawners in nature, potentially disrupting recruitment (Gabriel & Mace, 1999). Moreover, *N. thalassina* inhabit a limited environment and have a low fecundity; the low proportion of spawners will lead to population loss (Parab, 1998; Tirtadanu et al., 2024b). As a conservative metric for population sustainability, the expected SPR is 40% (Clark, 2002). This justifies using 20% SPR as the LRP and 40% SPR as the target reference point.

Results

Length frequency, length at maturity and length at first capture

A total of 516 catfish's length data were collected during March to December 2023. The length of *N. thalassina* captured by bottom longline in Gunungkidul waters ranged from 18 to 60 cm (Fig. 2). The average length was 35.44 ± 7.49 cm ($\pm$ SD). The modal size of the catch was 38 cm. The length at first capture ($L_{C50} = 29$ cm) was smaller than the length at first maturity of *N. thalassina* ($L_{m50} = 37$ cm), indicating that the majority of the fish were captured before reaching gonadal maturity. Approximately 63% of the fish caught were below the length at first maturity, indicating a high proportion of immature individuals in the catch.

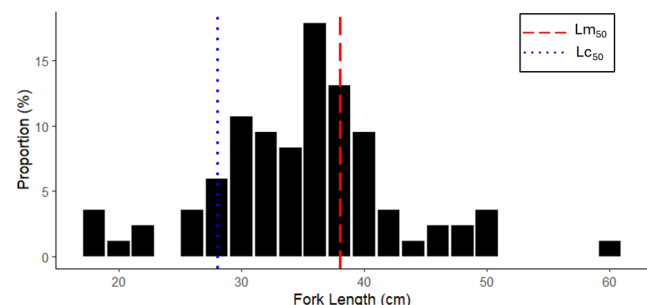


Fig. 2. Length frequency, length at first captured (L_{C50}) and length at first maturity (L_{m50}) of giant catfish (*Netuma thalassina*) in Gunungkidul waters (total sample of 516, collected from March to December 2023).

Length-weight relationship and relative condition factor

The weight of *N. thalassina* ranged from 96 to 3,980 g, with a mean weight of 808 ± 555 g ($\pm$ SD). The length of *N. thalassina* ranged from 19 to 60 cm, with a mean length of 35.44 ± 7.49 cm. The findings indicated that the length-weight relationship followed the equation $W = 0.09 (L)^{3.1543}$ (Fig. 3). According to the 95% confidence interval of b, the growth coefficient ranged from 3.07 to 3.24, indicating that the growth pattern of *N. thalassina* has a positive allometric pattern. The relative condition factor (K_n) of *N. thalassina* was 1.00 ± 0.09 (Mean $\pm$ SD), indicating that the catfish's body weight is optimal. According to the length-weight equation, the length at first maturity ($L_{m50} = 37$ cm) corresponded to a weight of 818 g, whereas the length at first capture ($L_{c50} = 29$ cm) corresponded to a weight of 379 g.

Stomach contents

The stomach contents of *N. thalassina* in Gunungkidul waters consisted of crabs, stomatopods, shrimps, and fish (Table 1). Among the 21 stomach samples of *N. thalassina*, crabs had the highest occurrence percentage at 57%, followed by stomatopods at 33%. The highest and second highest percentages of food weight and index of preponderance in the stomach contents of *N. thalassina* were found in crabs and stomatopods. The index of preponderance for crabs was 60.11%, while for stomatopods, it was 29.96%. The index of preponderance of shrimps and fishes was below 10%.

Fecundity

Fecundity observations of female *N. thalassina* indicated a low fecundity. The number of eggs ranged from 20 to 32, with an average of 26 ± 4 eggs ($\pm$ SD) (Fig. 4). The findings indicated an absence of a linear correlation between fecundity and the length and weight of *N. thalassina*. The peak fecundity was observed at a length of 44 cm and a weight of 1.359 g.

Growth

The output from TropFish R, based on the monthly length

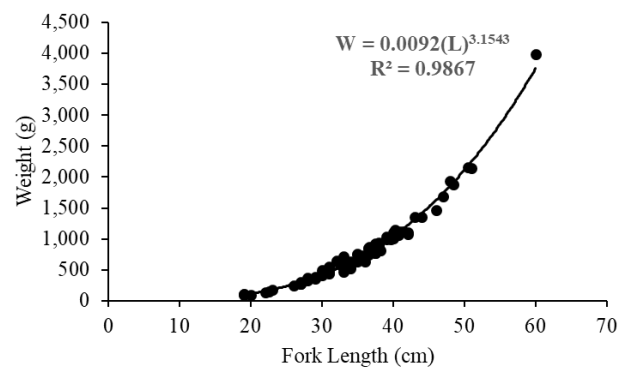


Fig. 3. Length-weight relationship of giant catfish (*Netuma thalassina*) in Gunungkidul waters.

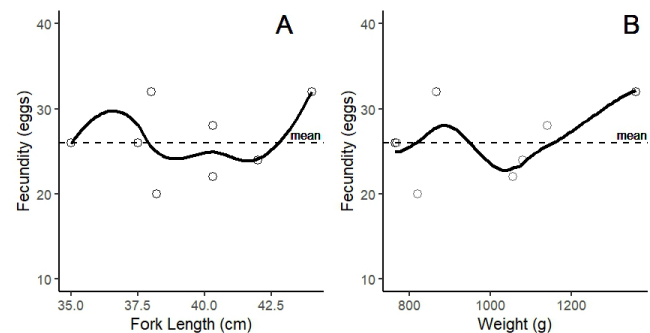


Fig. 4. The fecundity based on the length (A) and weight (B) of the giant catfish (*Netuma thalassina*) in Gunungkidul waters.

frequency data, indicated that the asymptotic length (L_{∞}) of *N. thalassina* was 61.30 cm, with a growth rate (K) of 0.22 year^{-1} and a relative fitness score (R_n) of 0.57 (Fig. 5). The theoretical age of *N. thalassina* at length 0 (t_0) was -0.63 . Therefore, the Von Bertalanffy equation for *N. thalassina* in Gunungkidul waters was represented as:

$$L_t = 61.3[1 - e^{-0.22(t+0.63)}].$$

The asymptotic length (L_{∞}) of *N. thalassina* was 61.30 cm,

Table 1. Stomach content analysis of giant catfish (*Netuma thalassina*) in Gunungkidul waters

Food items	N_i (ind.)	W_i (g)	% Occurance (O_i)	% Weight of food (W_i)	$O_i W_i$	IP_i (%)
Crabs	12	55	57.14	36.18	2,067.67	60.11
Stomatopod	7	47	33.33	30.92	1,030.70	29.96
Shrimps	3	9	14.29	5.92	84.59	2.46
Fishes	2	41	9.52	26.97	256.89	7.47

N_i , number of individuals of each prey; O_i , percentage of occurrence; W_i , percentage of weight; IP_i , index of preponderance.

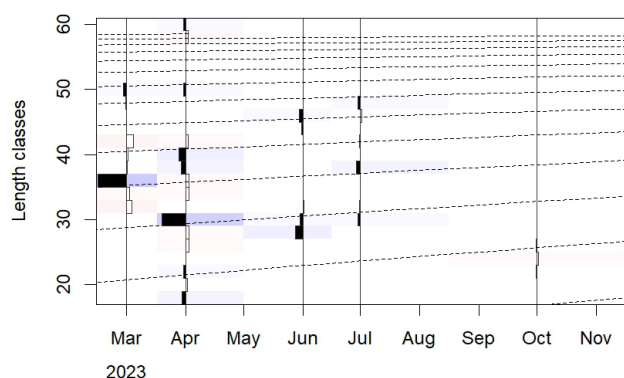


Fig. 5. The monthly length frequency and the growth of the giant catfish (*Netuma thalassina*) in Gunungkidul waters. Data from TropFishR.

corresponding to an asymptotic weight (W_{∞}) of 4,019 g. The maximum age ($t_{\max}$) of *N. thalassina* was 13 years. The length at first maturity ($L_{m_{50}}$) of 37 cm was attained at 3 years of age (Fig. 6). The length at first capture ($L_{c_{50}}$) was approximately 2 years and 4 months of age.

Mortality parameters

The total mortality rate of *N. thalassina* in Gunungkidul waters was 0.77 year^{-1} (Fig. 7). The average natural mortality of *N. thalassina*, varied from five natural mortality approaches, was 0.35 ± 0.09 , which corresponds to a fishing mortality of 0.42 ± 0.09 ($\pm \text{SD}$) (Table 2). The exploitation rates of *N. thalassina* ranged from 0.39 and 0.70. The natural mortality estimation from Then et al. (2015) ($M_{\text{Th}} = 0.47 \text{ year}^{-1}$) led to the lowest exploitation rate of 0.39, whereas the natural mortality from Zhang & Megrey (2006) ($M_{\text{ZM}} = 0.23$) produced the highest ex-

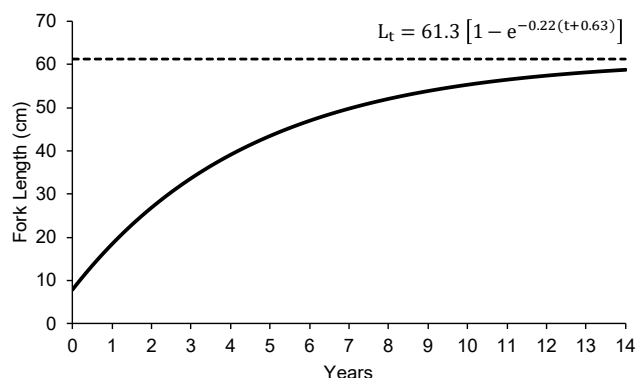


Fig. 6. The Von Bertalanffy growth curve for giant catfish (*Netuma thalassina*) in Gunungkidul waters.

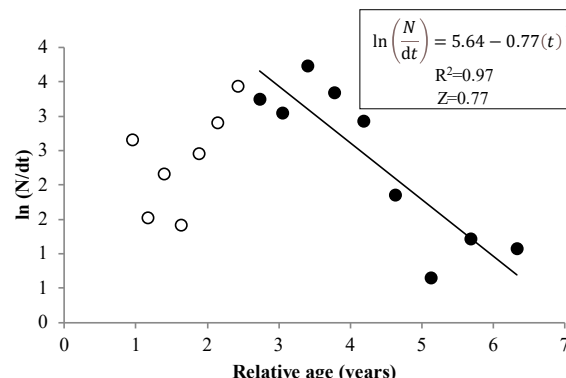


Fig. 7. The length-converted catch curve for giant catfish (*Netuma thalassina*) in Gunungkidul waters.

Table 2. The total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate (E) for giant catfish (*Netuma thalassina*) in Gunungkidul waters

Methods of M	Z (year^{-1})	M (year^{-1})	F (year^{-1})	E (year^{-1})
Alverson & Carney (1975)	0.77	0.34	0.43	0.56
Alagaraja (1984)	0.77	0.35	0.42	0.55
Jensen (1997)	0.77	0.33	0.44	0.57
Zhang & Megrey (2006)	0.77	0.23	0.54	0.70
Then et al. (2015)	0.77	0.47	0.30	0.39
Mean $\pm$ SD	0.77	0.35 ± 0.09	0.42 ± 0.09	0.55 ± 0.11

ploitation rate of 0.70. The average current exploitation rate was 0.55 ± 0.11 , indicating that the current status of giant catfish fishery is in the fully exploited condition.

Yield per recruit analysis

By applying the average fishing mortality rate of 0.42 year^{-1} , the current YPR of *N. thalassina* (YPR_{cur}) is $259.85 \text{ g recruit}^{-1}$ (Fig. 8). The YPR (YPR_{max}) will attain a peak of $268.63 \text{ g recruit}^{-1}$ if fishing mortality rises to a maximum fishing mortality (F_{max}) of 0.64 year^{-1} . However, the current fishing mortality (F_{cur}) has exceeded 26% of the reference point $F_{0.1}$. Reference point $F_{0.1}$ was 0.31 year^{-1} , yielding $247 \text{ grams recruit}^{-1}$. The current fishing mortality lies between the LRP F_{max} and the target reference point $F_{0.1}$, indicating a fully exploited condition.

Spawning potential ratio

By using variations of the four natural mortality methods, the

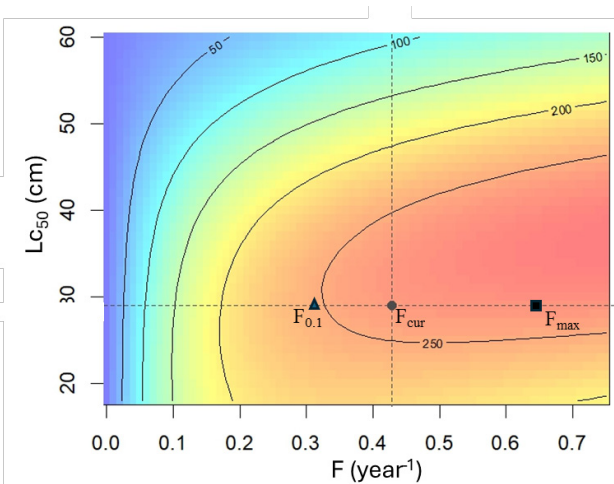


Fig. 8. The isopleth of the yield per recruit analysis as a function of fishing mortality (F) and the length at first capture (L_{c50}) for giant catfish (*Netuma thalassina*) in Gunungkidul waters. The square dot is the fishing mortality that gives the maximum yield per recruit (F_{max}), the circle dot is the current fishing mortality (F_{cur}) and the triangle dot is the fishing mortality at which the slope of yield per recruit is equal to 10% of the initial biomass ($F_{0.1}$).

SPR of *N. thalassina* in Gunungkidul waters ranged from 0.22 to 0.34 (Table 3). The low natural mortality value from Zhang & Megrey (2006) ($M = 0.23$) implies a low SPR estimate of 0.22. In contrast, the largest estimate of SPR of 0.34 was obtained using the largest estimate of natural mortality from Then et al. (2015). However, the variation of the SPR, with an average of 0.28 ± 0.05 , is within the range of the LRP of 20% SPR and the target reference point of 40% SPR, indicating that the spawning stock biomass is in the precautionary condition (Fig. 9). Fishing mortality resulting in a 40% SPR ($F_{40\%}$) is 33% less than current fishing mortality, so a 33% reduction in fishing effort would shift the status to the sustainable condition.

Discussion

Most *N. thalassina* captured in Gunungkidul waters were small or below the length at first maturity ($< L_{m50}$). The study indicated that 63% of the fish population consisted of small fish ($< L_{m50}$). *N. thalassina* captured by bottom longlines in Gunungkidul waters ranged from 18 to 60 cm, close to those from the Oman Sea, which ranged from 17 to 64 cm. However, *N. thalassina* in the current study were smaller than those of *N. thalassina* caught by gillnet in Vietnamese waters, which ranged from 51 to 106 cm (Nguyen, 2024; Vahabnezhad et al., 2021). This condition may be affected by the dominant capture of small-sized fish that cannot reach their maximum size. The length at first capture of *N. thalassina* by the bottom longline

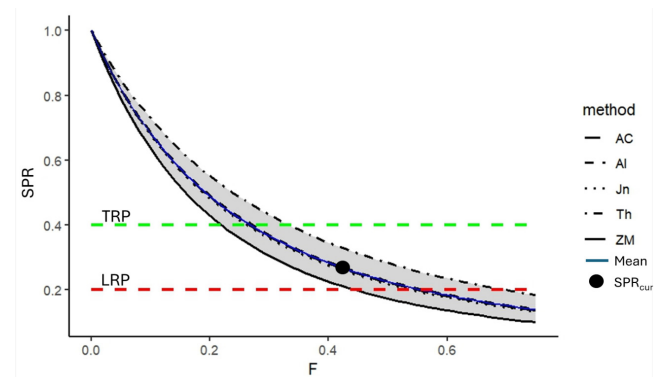


Fig. 9. Spawning potential ratio (SPR) as a function of fishing mortality (F) for giant catfish (*Netuma thalassina*) in Gunungkidul waters. Some variations on the natural mortality from: AI, Alagaraja (1984); AC, Alverson & Carney (1975); Jn, Jensen (1997); Th, Then et al. (2015); ZM, Zhang & Megrey (2006) was performed to visualised the uncertainty of the SPRs. The LRP is the limit reference point as 20% SPR and TRP is the target reference point as 40% SPR.

Table 3. Spawning potential ratio (SPR) and some biological reference points for giant catfish (*Netuma thalassina*) in Gunungkidul waters

M Methods	Input					Outputs			
	L_{∞} (cm)	K (year ⁻¹)	M (year ⁻¹)	L_{m50} (cm)	L_{m95} (cm)	SPR_{cur}	F_{cur} (year ⁻¹)	$F_{20\%}$ (year ⁻¹)	$F_{40\%}$ (year ⁻¹)
AC	61.3	0.22	0.34	37	41	0.26	0.43	0.55	0.26
AI	61.3	0.22	0.35	37	41	0.27	0.42	0.57	0.28
Jn	61.3	0.22	0.33	37	41	0.25	0.44	0.54	0.26
ZM	61.3	0.22	0.23	37	41	0.16	0.54	0.44	0.22
Th	61.3	0.22	0.47	37	41	0.43	0.30	0.69	0.34
Mean $\pm$ SD	61.3	0.22	0.35 ± 0.09	37	41	0.28 ± 0.11	0.42 ± 0.09	0.56 ± 0.10	0.28 ± 0.05

AC, AI, Jn, ZM and Th as the natural mortality (M) by Alverson & Carney (1975), Alagaraja (1984), Jensen (1997), Then et al. (2015), Zhang & Megrey (2006).

F_{cur} current fishing mortality; $F_{20\%}$ and $F_{40\%}$ fishing mortality that remained 20% and 40% SPR.

($L_{c50} = 29$ cm) was smaller than the length at first maturity ($L_{m50} = 37$ cm), indicating that the fishery is catching fish before they have had a chance to reproduce, which can have negative consequences for the population. This condition causes a low percentage of spawners in nature, which will lead to population loss. Consequently, it is essential to prevent capturing small fish to facilitate their growth and reproduction. Previous studies indicated that the minimum legal size corresponds to the length at first maturity (Tirtadanu et al., 2023; Widiyastuti & Tirtadanu, 2024). Raising the length at first capture from 29 cm to 37 cm may serve as a management option to conserve *N. thalassina* in Gunungkidul waters. The government can support this initiative by replacing small hook sizes with larger sizes.

The growth pattern of *N. thalassina* in Gunungkidul waters showed positive allometry, characterized by a growth coefficient b of 3.15, which indicated a relatively fat body condition. Moreover, the catfish's body weight condition is good, with the relative condition factor (K_n) of 1.00. A similar condition of growth pattern was observed in the waters of Kuwait, Cilacap-Indonesia and Bangladesh whereas a negative allometric pattern was found for *N. thalassina* in the Vietnam, Pekalongan-Indonesia and Pakistan waters (Table 4). The results indicated that the habitat of Gunungkidul waters remains suitable for the growth of *N. thalassina*, with sufficient food resources.

This study revealed that *N. thalassina* is a carnivore, consuming various food types such as crabs, stomatopods, shrimps, and fish. The primary diet of *N. thalassina* in Gunungkidul waters consists of crabs and stomatopods (mantis shrimps), with a preponderance index proportion of 60.11% and 29.96%, respectively. The primary food source is significantly affected by food availability within its habitat. The predominant components of the stomach contents of *N. thalassina* in Omani waters were bivalves and gastropods, whereas in Semarang waters, the primary dietary component was fish (Taunay et al., 2013;

Vahabnezhad et al., 2021). The optimal fatness condition of *N. thalassina* in Gunungkidul waters indicates abundant preys, such as a population of crabs and stomatopods in the benthic zone of this region.

N. thalassina in Gunungkidul waters has low fecundity, ranging from 20 to 32 eggs. Parab (1998) reported low fecundity of *N. thalassina* in Indian waters, with a fecundity range of 34 to 88 eggs. The fecundity of *N. thalassina* is significantly lower than that of other demersal fisheries commodities, such as *Nemipterus* spp. and *Saurida* spp., which can produce from hundreds to thousands of eggs (İşmen, 2003; Rahman & Samat, 2021). Moreover, *N. thalassina* in Gunungkidul waters has a slow growth rate, with a K value of 0.22 year^{-1} and a maximum lifespan of 13 years. Al-Husaini et al. (2021) reported a slightly faster growth rate of 0.30 year^{-1} for *N. thalassina* in Kuwaiti waters. The lowest growth rate value of *N. thalassina* was found in India, with K value as 0.20 (Table 5). The low fecundity and relatively small growth rate indicated that *N. thalassina* is susceptible to population decline due to overfishing. *N. thalassina* populations must be allowed to grow and reproduce to enhance recruitment levels. *N. thalassina* reached gonad maturity at 3 years, with a maximum lifespan of 13 years, indicating a relatively long reproductive period if smaller individuals were not harvested. Management practices prioritizing a landing size greater than 37 cm are strongly recommended to ensure the sustainability of *N. thalassina* in the waters of Gunungkidul.

The stock assessment of the *N. thalassina* fishery should consider a precautionary approach due to its status as a commercial commodity characterized by low fecundity and relatively slow growth rate, which increases its vulnerability to stock decline. This study presented fisheries stock assessment using multiple methods: LCC, YPR, and SPR analysis. The LCC method indicated variations in several natural mortality calculation approaches, resulting in exploitation rates (E) from 0.39 to 0.70, with a mean

Table 4. Length weight relationship of marine catfish in some areas

Species	Length-weight relationship		Areas	Source
	a	b		
<i>Netuma bilineata</i>	0.0051	3.16	Kuwaiti Waters	Al-Husaini et al. (2021)
<i>Netuma thalassina</i>	0.032	2.76	Vietnam	Nguyen (2024)
<i>Netuma thalassina</i>	0.0158	3.05	Cilacap Waters	Anggawansa & Faizah (2020)
<i>Netuma thalassina</i>	0.00003	2.79	Pekalongan Waters	Marbun et al. (2017)
<i>Netuma thalassina</i>	0.011	2.89	Arabian Coast, Pakistan	Farooq et al. (2017)
<i>Netuma thalassina</i>	0.004	3.29	Bay of Bengal, Bangladesh	Sultana et al. (2019)
<i>Netuma thalassina</i>	0.0092	3.15	Gunungkidul waters, Indonesia	Present study

Table 5. Asymptotic length (L_{∞}), growth rate (K) and natural mortality (M) of marine catfish in some areas

Species	L_{∞} (cm)	K (year ⁻¹)	M (year ⁻¹)	Areas	Sources
<i>Netuma bilineata</i>	46.5 ^a	0.35	-	Kuwaiti waters	Al-Husaini et al. (2021)
<i>Netuma thalassina</i>	91.6 ^a	0.30	-	Kuwaiti waters	Al-Husaini et al. (2021)
<i>Netuma thalassina</i>	97.6 ^a	0.33	0.62	Bengal Coast, Bangladesh	Sultana et al. (2019)
<i>Netuma thalassina</i>	84.8 ^a	0.20	-	Mandapam Waters, India	Menon (1986)
<i>Netuma thalassina</i>	68.0 ^b	0.45	0.84	Brunei Darussalam	Silvestre & Garces (2004)
<i>Netuma thalassina</i>	61.3 ^b	0.22	0.35	Gunungkidul waters, Indonesia	Present study

^a the total length, ^b the fork length.

of 0.55 ± 0.11 . The average exploitation rate of *N. thalassina* in Gunungkidul waters is classified as fully exploited (yellow zone), aligning with the optimal exploitation rate of 0.5 proposed by Gulland (1983). This status resembles the results of the YPR and SPR analysis, finding that the current fishing mortality lies between the LRP $F_{\max}$ and the target reference point $F_{0.1}$. Based on the length-based SPR, the current fishing mortality lies between the LRP of 20% SPR and the target reference point of 40% SPR.

Applying several approaches for assessing stock status is important for comprehending uncertainty and informing policy decisions by fisheries managers. Using the natural mortality approach from Then et al. (2015) resulted in a more optimistic assessment of the *N. thalassina* fishery in Gunungkidul waters, impacting a lower exploitation rate and a higher SPR. In contrast, the natural mortality method from Zhang & Megrey (2006) provided a more conservative estimate, leading to a higher exploitation rate and a low SPR. By understanding the biological characteristics of *N. thalassina*, decision-making should focus on achieving the target reference point. A SPR of 40% for *N. thalassina* is recommended due to its dominant small-size capture (63% below length at first maturity), low fecundity, and slow growth rate. The fishing mortality rate of *N. thalassina* currently surpasses 33% of the target reference point $F_{40\%}$. Therefore, a 33% reduction in fishing efforts is strongly advised to ensure the sustainability of the *N. thalassina* fishery in Gunungkidul waters. Fishing effort reduction can be achieved through the socialization of optimal hook-size fishing gear and government-supported hook-size modifications. Enhancing the SPR can improve the reproduction and recruitment of *N. thalassina* in natural environments, leading to the sustainability of the *N. thalassina* fishery.

Conclusion

The findings indicated that the majority of giant catfish (*N.*

thalassina captured by longline in Gunungkidul were small-size fish, as evidenced by the length at first capture ($L_c = 29$ cm), which is below the length at first maturity ($L_{m50} = 37$ cm). *N. thalassina* has a relatively fat body shape and is carnivorous, consuming various food items, including crabs, stomatopods, shrimps, and fish. Crabs constituted the primary diet, indicating from a high preponderance index of 60%. Fecundity was low, with a mean of 26 ± 4 eggs ($\pm$ SD). The asymptotic length (L_{∞}) and growth rate (K) were 61.3 cm and 0.22 years⁻¹, respectively. The status of the *N. thalassina* fishery is classified as fully exploited. The fishing mortality of *N. thalassina* currently surpasses 33% of target reference point $F_{40\%}$. Therefore, a 33% reduction in effort is strongly recommended to ensure the sustainability of *N. thalassina* fishery in Gunungkidul waters. Effort reduction can be achieved through the socialization of optimal hook-size fishing gear and government-supported changes in hook-size. Raising the SPR is recommended to improve the reproduction and recruitment of *N. thalassina* in natural environments, thereby influencing the future viability of the *N. thalassina* fishery.

Competing interests

No potential conflict of interest relevant to this article was reported.

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Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Ethics approval and consent to participate

The samples are commercial fish that was obtained directly from the bottom longline fishers in the Gunungkidul waters, and the samples are used for biological assessment. We certify that this research followed all the applicable guidelines for the care and use of fish.

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