



Biological and Environmental Assessment of Mahseer (*Neolissochilus Soro Valenciennes 1842*) in Sarangan Lake, Indonesia: Implications for Conservation and Invasive Species Management

Budi Nugraha^{1*}, Andri Warsa², Setiya Triharyuni¹, Karsono Wagiyono¹, Andrias Steward Samusamu², Hufiadi¹, Sri Turni Hartati², Ngurah Nyoman Wiadnyana²

¹ Research Center for Fishery, National Research and Innovation Agency, Cibinong 16911, Indonesia

² Research Center for Conservation of Marine and Inland Water Resources, National Research and Innovation Agency, Cibinong 16911, Indonesia

Corresponding Author Email: budi073@brin.go.id

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ABSTRACT

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The mahseer (*Neolissochilus soro*) is widely distributed across Sumatra, Kalimantan, and Java. Currently, there is no information about the biological and environmental aspects of the mahseer in Sarangan Lake. This study aimed to analyze the catch composition, length-weight relationship, and water quality associated with the mahseer in this lake. The research was conducted in August and November 2020. The results revealed that mahseer fish accounted for only 1.57% of the catch. The mahseer fish had a length of 14.1-22.5 cm and a weight of 17-121 g, with a negative allometric growth pattern, $W=0.0216 L^{2.7538}$. Their diet was dominated by plants (80%) and worms as complementary food (20%). Water parameters showed that the temperature ranged from 22.1-25.9°C, pH 7.3-8.2, and dissolved oxygen concentration, 1.2-11.10 mg/L, indicated moderate habitat suitability. Sarangan Lake is classified as mesotrophic, according to the Trophic State Index 42.5-52.6. The presence of invasive species such as *Amphiphilus citrinellus* and *Oreochromis niloticus* is a potential threat due to dietary and spatial competition. Conservation strategies, including habitat protection, population monitoring, and restocking efforts, are recommended.

1. INTRODUCTION

The mahseer (*Neolissochilus soro* Valenciennes, 1842) is an economically important fish of the Cyprinidae family that is still related to the Thai mahseer (*Tor tambroides*) [1]. Previously, the mahseer was described as *Tor soro* species.

However, recently, the *Tor soro* was declared not a member of the *Tor* genus but instead included in *Neolissochilus* and classified as *Neolissochilus soro* [2]. Mahseer is found in Indonesia, including Sumatra, Kalimantan, and Java, but its population has declined due to habitat degradation, overfishing, and competition with invasive species [3, 4]. In different regions of Indonesia, this species is known by various local names (Table 1) [5, 6]. For instance, it is known as Batak fish in North Sumatra, Dewa or Kancra Bodas in West Java, and Soro in parts of East Java [5].

The mahseer has most recently been assessed for the IUCN Red List of Threatened Species in 2020 as Least Concern [7], but in the Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 37 of 2021 concerning Fish Database Structure and Fish Broodstock Data, the mahseer has a status that is not protected or prohibited. However, the population of the mahseer nature is indicated to be rare, and even feared to be extinct [3, 4, 8, 9]. Even the Magetan Regent Regulation Number 23 of 2020 concerning

the Conservation of Fish Resources in the Inland Waters of Sarangan Lake states that the mahseer is a protected fish species under the supervision and management of the conservation of the Sarangan Lake inland waters of Magetan Regency. The results of the study [10] found that the mahseer population in the Asahan River has been over-exploited, with an exploitation rate (E) ranging from 0.5 to 0.82 per year. This status condition is also stated by Hasan et al. [11], who state that the mahseer is rarely found in Javanese waters. The lack of the mahseer in these waters is due to these fish being very vulnerable to anthropogenic change, as they require good water quality and integrity of environmental flow, while Java is an island with a high level of environmental damage [12].

Table 1. Local names of mahseer in Indonesia [5, 6]

Region	Local Name
North Sumatra (Toba, Tarutung, Asahan)	Batak fish
West Java (Kuningan, Majalengka)	Dewa fish, Kancra bodas
Bogor (Cisadane River)	Soro
Blitar (East Java)	Senggaring
Sumatra	Semah
Aceh	Keureling
Borneo (Kalimantan)	Sapaan

Sarangan Lake, also known as Sand Lake, is a natural lake located at an altitude of 1,200 meters above sea level and is located on the slopes of Mount Lawu, Plaosan District, Magetan. Currently utilized as a location for tourism, drinking water, irrigation, and fisheries, with an area of 30 ha and a depth of 28 m. Tourism activities in Sarangan Lake, such as natural beauty tours, speedboats, and horse services used to get around, have an economic impact, namely providing new jobs and increasing income for the community around the lake [13]. While several studies have addressed the lake's tourism economy and plankton ecology [13, 14], no research has assessed the biological and environmental aspects of mahseer in this habitat.

Studies from Malaysia and India show that *Tor* is a species that is highly sensitive to environmental changes and requires clean, oxygenated, flowing waters with specific substrate preferences for spawning and feeding [3]. The lack of such environmental flows in artificial or modified lakes like Sarangan might contribute to declining native populations. The existence of the mahseer in Sarangan Lake is a balancer of the ecosystem in the waters and is expected to be an attraction for tourism in Sarangan Lake.

Research on fishing, biology, and environmental aspects, including catch composition, length distribution, weight, length-weight relationship, stomach contents, and natural food and water quality of the mahseer in Sarangan Lake, has never been done. This causes information about the mahseer in Sarangan Lake to be very limited and even tends to be absent. The purpose of this study is to analyse the fishing, biological, and environmental aspects of the mahseer in Sarangan Lake to provide materials and information for sustainable fisheries management.

2. METHODOLOGY

2.1 Data collection

Data collection was conducted in August and November 2020 at Sarangan Lake, Magetan Regency, East Java, Indonesia (Figure 1). The data collected were data on the fishing aspects and biology of the mahseer caught in Sarangan Lake, and the water quality of Sarangan Lake.

Fishing aspect data was collected in the form of data on the composition of fish species caught in Sarangan Lake. Observations of biological aspects include the structure of length, weight, and stomach contents. There were 11 mahseer caught during the study with a length of 14.1-22.5 cm and a weight of 17-121 g.

The data were obtained by conducting fishing trials using gillnet gear that has a mesh size of 1.0, 1.5, 2.0, 2.5, 3.0, and 4.0 inches. Gillnet was installed parallel to the water's edge line at 18:00 pm and lifted at 06:00 am. The fish obtained were then measured in total length (TL) using a measuring board with an accuracy of 0.1 cm and weighed using digital scales with an accuracy of 0.01 g.

Water quality data observed included several physical parameters (water temperature, pH, dissolved oxygen, TDS, electrical conductivity, and redox potential), chemical parameters (nitrate, total phosphates, and chlorophyll a), and phytoplankton and zooplankton identification. Water sampling was conducted using a YSI multi-parameter water quality checker, Kemmerer water sampler, depth sounder, and GPS. The locations of net installation and water quality observations in August 2020 and November 2020 are presented in Table 2 and in Figure 2. Water quality sampling at each location was carried out once at a depth of 0 to 6 m (inlet), 0 to 9 m (middle), and 0 to 9 m (outlet).



Figure 1. Study site

Table 2. Location of net installation and water quality observations in August 2020 and November 2020

Location	Position		Maximum Depth (m)
	S	E	
August 2020			
Net installation	07°40'42.2"	111°12'57.6"	6.3
	Water quality observation		
Inlet	07°40'42.2"	111°12'57.6"	6.3
Middle	07°40'40.7"	111°13'01.8"	21.6
Outlet	07°40'44.4"	111°13'10.2"	9.4
November 2020			
Net installation	07°40'43.1"	111°12'57.4"	
	Water quality observation		
Inlet	07°40'42.7"	111°13'03.3"	
Middle	07°40'42.7"	111°13'15.9"	
Outlet	07°40'43.1"	111°12'57.4"	



Figure 2. Location of net installation and water quality observations inlet (left) and outlet (right)

2.2 Data analysis

The length-weight relationship is one component of the population dynamics of the mahseer that is very important to study. To determine the length-weight relationship of the mahseer, the following equation is used [15]:

$$W = aL^b \quad (1)$$

where,

W = total weight (kg).

L = total length (cm).

a and b = constant.

From this equation, the growth pattern of the observed mahseer can be known. The b value obtained is used to determine the growth pattern with the criteria:

- If $b = 3$, growth is isometric, i.e., length growth is equal to weight growth.
- If $b > 3$, then the growth pattern is positive allometric, i.e., weight gain is faster than length gain.
- If $b < 3$, then the growth pattern is negative allometric, i.e., length growth is faster than weight growth.

To test whether the regression coefficient, $b = 3$, or not, the t-test data analysis was conducted using the following formula:

$$t_{value} = \frac{|b - 3|}{SE_b} \quad (2)$$

SE_b is the standard error of the value of b [16]. The t-test is conducted on the value of b with the hypothesis:

H_0 : $b = 3$, the relationship between length and weight is isometric.

H_1 : $b \neq 3$, the relationship between length and weight is allometric (positive allometric, if $b > 3$, where weight gain is faster than length gain, and negative allometric, if $b < 3$, where length gain is faster than weight gain) [17].

Decision-making is done if the $t_{value} < t_{table}$ then H_0 is

accepted and H_1 is rejected, and vice versa if the $t_{value} > t_{table}$ then H_0 is rejected and H_1 is accepted.

The species composition in Sarangan Lake can be divided into 2 locations, namely the inlet and outlet. To evaluate whether there is a difference in the species composition between the two water locations, the Chi-Square (χ^2) test was used. This test belongs to the nonparametric category, which is commonly used to test the relationship between two categorical variables, in this case, fishing location and fish species. The null hypothesis (H_0) states that there is no difference in species composition between locations, while the alternative hypothesis (H_1) states that there is a difference in species composition between locations. The Chi-Square formula used is [18]:

$$\chi^2_{i-j} = \frac{(O - E)^2}{E} \quad (3)$$

where,

O = observed value (real frequency).

E = expected value (expected frequency)

Data analysis using Excel software to analyze catch composition and length-weight relationships.

Assessment of the fertility status of Sarangan Lake is also done with the Trophic State Index (TSI) [19]. The estimation of fertility status is based on the brightness of the Secchi Disc (SD), chlorophyll a (CHL-a), and the concentration of total phosphorus (P_{tot}) with the following equations:

$$TSI_{SD} = 10[6 - \frac{\ln(SD)}{\ln 2}] \quad (4)$$

$$TSI_{CHL-a} = 10[6 - \frac{2.04 - 0.86 \ln(CHL - a)}{\ln 2}] \quad (5)$$

$$TSI_{P_{tot}} = 10[6 - \frac{\ln(\frac{48}{P_{tot}})}{\ln 2}] \quad (6)$$

$$TSI = \frac{TSI_{SD} + TSI_{CHL-a} + TSI_{P_{tot}}}{3} \quad (7)$$

Table 3. Classification of fertility status based on TSI values

TSI Values	Fertility Status
<30	Ultraligotrophic
30-40	Oligotrophic
40-50	Mesotrophic
50-60	Mild eutrophic
60-70	Medium eutrophic
70-80	Heavy eutrophic
>80	Hypereutrophic

To determine the status of water fertility, the TSI value is then compared with the fertility status criteria value in Table 3 [20].

Analysis and synthesis of several physical parameters were carried out in situ. While data on biological aspects in the form of stomach contents aimed at knowing the natural food of the mahseer living in Sarangan Lake and water quality in the form of chemical parameters (nitrate, total phosphates, and chlorophyll a), phytoplankton and zooplankton identification were carried out at the Research Institute for Fish Resource Enhancement Laboratory. The analysis methods used are:

- The composition of fish's natural food refers to the

IK.7-2-7 method (qualitative and quantitative).

- Nitrate using the brucine or spectrophotometric method.
- Total phosphates refer to SNI 19-2483-1991.
- Chlorophyll a using the trichometric method, which refers to APHA standard Edition 21 of 2005: 10200H.2.C.
- Phytoplankton and zooplankton refer to APHA standard Edition 22 of 2012:10200F.

3. RESULTS AND DISCUSSION

3.1 Fishing aspects

The species of fish caught in Sarangan Lake using gill nets include the mahseer (*Neolissochilus soro*), spotted barb (*Puntius binotatus*), red devil (*Amphilophus labiatus*), midas cichlid (*A. citrinellus*), three-spot cichlid (*A. trimaculatus*), banded jewel cichlid (*Hemichromis elongatus*), Nile tilapia (*Oreochromis niloticus*), and Java barb (*Barbonymus gonionotus*). Midas cichlid is the dominant species of fish caught, with a proportion of 38.89%, followed by Nile tilapia with a proportion of 28.63%, and banded jewel cichlid with 22.65%. Meanwhile, only 1.57% of the mahseer in Sarangan Lake were caught (Figure 3).

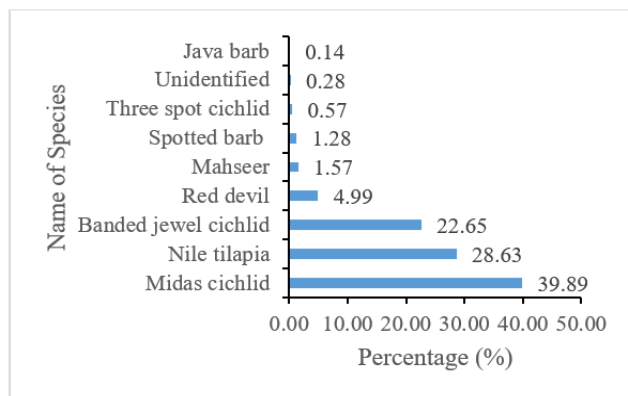


Figure 3. The species composition of fish caught in Sarangan Lake

Midas cichlid is the dominant species of fish caught in Sarangan Lake, with a proportion of 39.89%, followed by Nile tilapia with a proportion of 28.63%, and banded jewel cichlid with 22.65%, meanwhile, the mahseer only 1.57%. Fish caught in Sarangan Lake are dominated by invasive species. This will threaten the native fish of Sarangan Lake, namely the mahseer, to be threatened. Study [21] mentioned that non-native fish species can be a threat to native fish populations. Non-native fish are fish species that originate from outside the waters of Indonesia. The non-native fishes in Indonesian waters can be categorized into two parts: non-native fishes that do not interfere with endemic and native fish populations in an aquatic ecosystem, and non-native fishes that interfere with endemic and native fish populations in an aquatic ecosystem where no non-native fish species were previously present. The disturbing foreign fish category is called invasive species [22].

Invasive species are plants, animals, microorganisms, and other organisms that are not part of an ecosystem that can cause damage to ecosystems, the environment, economic losses, and/or have a negative impact on biodiversity and human health (Regulation of the Minister of Environment and

Forestry of the Republic of Indonesia No. P.94/MENLHK/SETJEN/KUM.1/12/2016). One of the invasive species in Sarangan Lake is the midas cichlid. The species are distributed primarily in Nicaragua lakes [23]. The midas cichlid is growing rapidly in Cirata Reservoir, Darna Reservoir, and Kedung Ombo [24], and is one of the most caught fish [25]. If the midas cichlid in Sarangan Lake is not controlled, the fish will grow rapidly and will disrupt the sustainability of the divine fish resources in Sarangan Lake. Invasive species are a common problem in water bodies in South Asia and Southeast Asia, including fish that compete with stocked dewamahseer [3].

Other invasive species in Sarangan Lake are Nile tilapia and red devil. Study [26] stated that Nile tilapia and red devil are invasive species in Kedungombo, Sermo, Jatiluhur, and Situ Panjalu reservoirs. These two fish will also interfere with the sustainability of the mahseer resources in Sarangan Lake because the presence of invasive species will cause disturbances in the mahseer community throughout the trophic network [27], as well as predation and increased competition for resources and niches [28].

Foreign invasive fish dominate in Sarangan Lake due to several factors, especially intentional and unintentional introductions, as well as the high adaptability and reproduction of these fish in a new environment. The introduction of alien species into an ecosystem has a negative impact on the ecosystem if the alien species has become invasive. The invasive alien species grows in competition with local species, which then disturbs local species in the ecosystem, so that changes occur in the ecosystem [29].

The presence of intentionally introduced non-native fish generally has a positive impact on increasing fisheries production [22]. However, some unintentionally introduced and invasive species tend to have a detrimental impact on aquatic ecosystems [30]. Invasive species can threaten biological diversity in various ways, from reducing genetic variation and eroding gene pools, through the extinction of endemic species, and by altering habitat and ecosystem functioning [31].

Based on the fishing location (inlet and outlet), the catch was 45 fish from the inlet and 657 fish from the outlet. Midas cichlid is the dominant species of fish caught, with a proportion of 71.11% in the inlet and 37.75% in the outlet, followed by Nile tilapia with a proportion of 8.89% in the inlet and 29.98% in the outlet. Meanwhile, only 4.44% of the mahseer in the inlet and 1.37% in the outlet were caught (Figure 4).

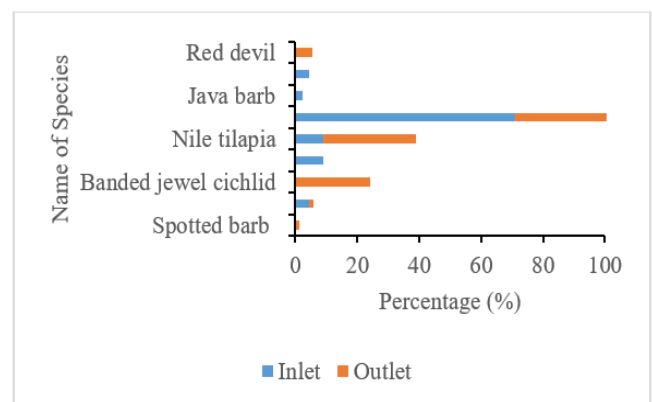


Figure 4. The species composition of fish caught in Sarangan Lake based on location (inlet and outlet)

The results of the analysis showed the Chi-square statistic (χ^2) = 293.69 with a p-value < 0.0001. Because the p-value was much smaller than the significance limit of 0.05, the null hypothesis was rejected. This means that the species composition of fish catch is significantly different between the inlet and outlet locations. This indicates possible differences in habitat, species preferences for the environment, or other ecological factors.

Study [32] explained that the composition and distribution of fish are strongly influenced by physical, chemical, and biological changes. According to study [33], the type of aquatic ecosystem with high current velocity has the greatest variety of fish species. In addition, the availability of aquatic vegetation is quite influential on the diversity of fish species that live in a body of water. Aquatic vegetation will provide food sources and also a place to shelter for fish [34].

3.2 Biological aspects

3.2.1 Length, weight, and length-weight relationships

Based on the measurement results, the mahseer caught in Sarangan Lake has a length between 14.1-22.5 cmTL, a weight between 17-121 grams, and has a negative allometric growth pattern with the equation $W = 0.0216 L^b$ ($b = 2.7538$), where the increase in length is faster than the increase in weight (Figure 5).

The calculation results on the length-weight relationship of the mahseer fish show that the value of $b = 2.7538$ with a Standard Error (SE_b) of 0.0978. The t-test results show that $t_{value} = 2.518 > t_{table} = 2.110$, H_1 is accepted, which means that the value of b is significantly different from the value of 3, where the growth characteristics of the mahseer fish are negative allometric.

The mahseer caught in Sarangan Lake has a length between 14.1-22.5 cmTL and a weight between 17-121 grams. This show that the mahseer from Sarangan Lake has a slightly larger size than the mahseer from the Aek Godang River, which has a length of 8.2-18.2 cm and weight of 8.4-101.9 grams [35], the Asahan River, North Sumatra which has a length of 7-21 cm and weight 20-205 grams [10] and the Ciliwung River, Wet Java which has a length of 9.83-21.90 cm and weight of 9.49-55.63 grams [36]. The mahseer caught in Sarangan Lake can be categorized as small. Study [37] reported that the mahseer can reach a length of 1.2 m (3.9 ft), but most species are much smaller. In fact, according to study [12], mahseer has a larger body size than the tambra fish, with a length of up to 150 cm and a weight of 22-31 kg.

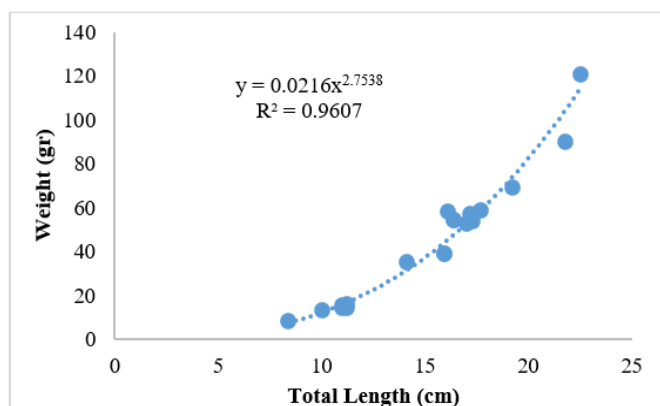


Figure 5. Length-weight relationship of the mahseer in Sarangan Lake

This growth pattern is different from the mahseer from the Aek Godang River which has an isometric growth pattern where length gain is balanced with body weight [35] and the mahseer from the Asahan River which has a positive allometric growth pattern with b values ranging from 3.155-3.164 where research was conducted in December 2016-March 2017 [38] and the mahseer from the Celike River which has a negative allometric growth pattern with b values 2.73 [39]. The difference in b value is thought to be caused by environmental conditions and food availability, age differences, sex, and other factors [40].

3.2.2 Stomach contents (natural food)

The mahseer in Sarangan Lake is an omnivorous fish that utilizes plants (80%) as its main food and worms as complementary food (20%). The natural food of the mahseer is the same as the natural food of Nile tilapia, Java barb, spotted barb, and red devil, which utilize plants as their main food (Table 4).

Table 4. Natural food of some fish species caught in Sarangan Lake

Species	Natural Food (Index of Preponderance)
Mahseer	Plants (80%) and worms (20%)
Spotted barb	Plants (100%)
Java barb	Plants (100%)
Three-spot cichlids	Phytoplankton (1.17%), insects (23.44%), crustacean planktons (61.98%), and zooplanktons (13.41%)
Red devil	Phytoplankton (0.24%), plants (96.61%), molluscs (0.52), insects (1.91%), and crustacean planktons (0.72%)
Nile tilapia	Phytoplankton (7.44%), plants (91.53%), crustacean planktons (0.62%), and zooplanktons (0.41%)

Table 5. Phytoplankton and zooplankton observed in Sarangan Lake

Class	Genus
Phytoplankton	
Bacillariophyceae	<i>Achnanthes</i> sp., <i>Nitzschia</i> sp., <i>Synedra</i> sp.
Chlorophyceae	<i>Chlorella</i> sp, <i>Chrococcus</i> sp.
Cyanophyceae	<i>Merismopedia</i> sp.
Dinophyceae	<i>Peridunium</i> sp.
Euglenophyceae	<i>Trachelomonas</i> sp.
Zooplankton	
Copepoda	<i>Cyclops</i> sp.
Cladocera	<i>Naupilus</i> sp.
Rotifera	<i>Keratella</i> sp.
Protozoa	<i>Cryptomonas</i> sp.

The results of observations of phytoplankton and zooplankton found in Sarangan Lake resulted in 5 classes for phytoplankton and 4 classes for zooplankton. The class and genus names of phytoplankton and zooplankton observed in Sarangan Lake are presented in Table 5.

The natural food of the mahseer is the same as the natural food of Nile tilapia, Java barb, spotted barb, and red devil, which utilize plants as their main food. The similarity of the natural food of these fish will cause competition (Figure 6). According to study [41], competition between organisms can occur if they have the same food habits and the available food sources are limited. The fish also occupy the same location as the mahseer, making space competition very likely. The structure of the fish community in these water bodies should

also be a concern, as predatory fish are not dominant [42]. In Jatigede Reservoir, Nile tilapia utilizes plants as their main food, Java barb utilizes detritus as their main food, and midas cichlid utilizes fish as their main food [43]. According to study [44], the diet of tilapia living in Lake Hayq consists of Cyanophyta, Chlorophyta, Bacillariophyta, Euglenophyta, Rotifera, Cladocera, Copepoda, Pisces, Macrophyte shoots, Detritus, and Insect. The phytoplankton genus used as natural food for the mahseer in the Asahan River includes Cladophora, Cymbella, and Vaucheria [39]. The natural food of the

mahseer in Sarangan Lake is different from the mahseer in the Asahan River. The mahseer caught in the Asahan River utilizes phytoplankton, crustaceans, insects, rotifers, and oligochaete as their natural food [10]. The results of study [10], phytoplankton and zooplankton utilized by mahseer in the Asahan River are presented in Table 6. The mahseer can utilize molluscs, aquatic plants, algae, worms, small fish, and insects as their natural food, so the mahseer are classified as omnivorous fish [45].

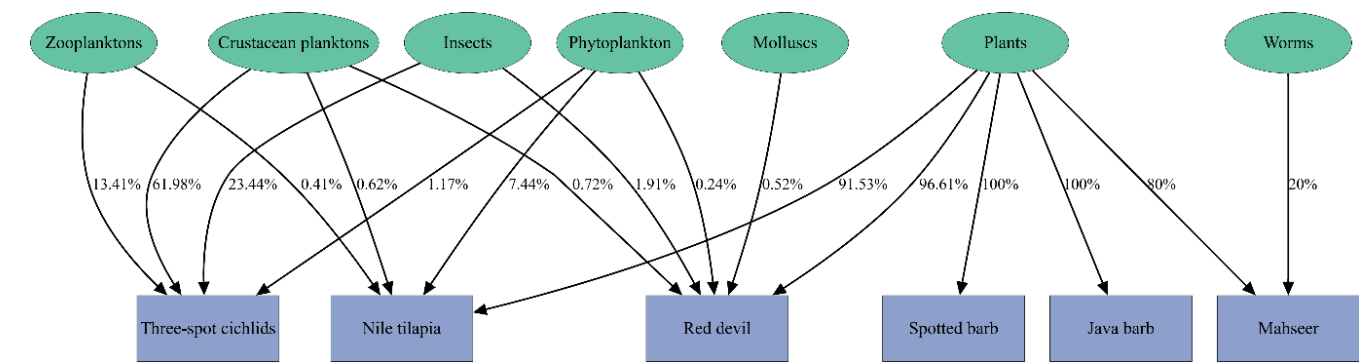


Figure 6. Species competition model diagram

Table 6. Phytoplankton and zooplankton utilized by mahseer in the Asahan River

Class	Genus
Phytoplankton	
Cyanophyceae	Aphanothece sp., Anabaena sp., Chroococcus sp.,
	Dactylococcopsis sp., Gloeotrichia sp.,
	Microcystis sp., Oscillatoria sp.
	Ankistrodesmus sp., Closterium sp., Cosmarium
Chlorophyceae	sp., Gonatozygon sp., Ichthyocercus longispinus,
	Microspora sp., Netrium interruptu, Phytophora
	zelleri, Plantonema sp., Scenedesmus sp.
	Navicula sp., Nitzschia sp., Tabelaria sp.
Bacillariophyceae	Micrasterias sp., Synura sp.
Zooplankton	
Insecta	Halipus sp.
Oligochaeta	Styllaria sp.
Rotifera	Argonotholca sp.
Crustacea	Horsiella sp.

3.3 Environmental aspects

Based on the results of water quality observations with in situ parameters, Sarangan Lake has habitat characteristics that are almost the same as several other mahseer habitats. Water temperature, pH, and dissolved oxygen concentrations in Sarangan Lake range from 22.1-25.9°C, 7.3-8.2, and 1.2-11.10 mg/L, respectively (Table 7).

Table 7. Results of water quality observations in Sarangan Lake

Parameters	August 2020	November 2020
Water temperature (°C)	22.1-23.2	23.5-25.9
pH	7.6-8.2	7.3-8.1
Dissolved oxygen (mg/L)	2.5-11.10	1.2-10.8
TDS (mg/L)	192.4-208.0	194-197
Electrical conductivity (µohm/cm)	281.1-302.3	292.4-307.8
Redox potential (ORP)	-166.7-97.0	-164.5-97.0

The mahseer lives in waters with high dissolved oxygen concentrations, neutral pH, water temperatures tend to be low, and currents with rocky sand bottom waters. 22°C is the ideal temperature for spawning the mahseer [46]. According to study [5], the optimum values of water quality parameters for mahseer to live include water temperature of 22-32°C, dissolved oxygen (DO) > 4 ppm, and pH 6-8. The pH value is very important in determining the use value of water for the life of aquatic organisms. The ideal pH for the life of aquatic biota is in the range of 6.5-8.5. The pH of Sarangan Lake water ranges from 7.3 to 8.2 and is suitable for the life of the mahseer. In general, the pH that is suitable for fish life and fisheries production ranges from 6-9 [47, 48].

The mahseer is a freshwater fish that is usually found in rivers with rocky bottoms, clear water, high oxygen, and fast flowing [49-51]. The mahseer will grow well in locations with sandy-rocky bottoms with fast currents and the availability of natural food [52]. Asahan River is a river with water temperature ranging from 25.1 to 27.6°C and dissolved oxygen concentration ranging from 6 to 7.2 mg/L [53]. The water temperature and dissolved oxygen concentration in the Asahan River are almost the same as in Sarangan Lake, but Sarangan Lake has calm waters and tends not to flow with the bottom of the water in the form of clay. The high concentration of dissolved oxygen illustrates the mild level of pollution in the waters of Sarangan Lake. Pollution causes very low dissolved oxygen content in water [54]. Habitat characteristics of the mahseer in some locations are presented in Table 8.

Chlorophyll a concentration in Sarangan Lake ranged from 5.9-8.2 µg/L⁻¹, with total phosphorus concentration ranging from 6.2-37.9 µg/L⁻¹ and brightness of 1.9-2.3 m. The parameters used in determining the status of water fertility are brightness, total P, and chlorophyll a. Sarangan Lake's fertility status based on the absolute value of brightness is mesoeutrophic, based on chlorophyll a concentration in the mesotrophic to mesoeutrophic category, and based on total P in the mesotrophic-mesoeutrophic category (Table 9).

Table 8. Habitat characteristics of the mahseer in some locations

Parameters	Situ Pemandian Tua [51]	Pond Enlargement Cijeruk, Bogor [5]	Lematang River, South Sumatra [55]	Dolok River, North Sumatra [49]
Water temperature (°C)	20.0-25.0	21.0-25.0	21.7-26.4	18.9-29.0
pH	6.0-7.0	6.5-8.0	6.5-7.0	6.0-8.0
Dissolved oxygen (mg/L)	>5.0	>5.0	5-7-10.65	7.20-8.61
Bottom of the water	Sandy gravel	-	Rocky sand	-
Free CO ₂	-	2.2-4.5	4.4	-
Hardness	-	<12	-	-

Table 9. Fertility status of Sarangan Lake based on the value of brightness, chlorophyll a concentration, and total P

Parameters	Inlet	Centre	Outlet
Brightness	Mesotrophic	Mesotrophic	Mesotrophic
Chlorophyll a	Mesotrophic	Mesotrophic	Mesotrophic
Total P	Mesotrophic-mesoeutrophic	Mesotrophic-mesoeutrophic	Mesotrophic-mesoeutrophic

Habitats with rocky sand bottoms and fast currents, and the availability of natural food are habitats preferred by mahseer [52]. In situ habitat of broodstock mahseer is in clear water at a depth of 3-4 m with sand and gravel substrate. While in rivers in the form of deep holes between 5 and 20 m. Small fish are in rocky waters, moderate current, clear water with sand and gravel substrate. Larval and seed habitats are at the edge of waters that have springs and riverbanks with calm currents, sand substrates, and clear water [5]. According to study [56], the habitat of mahseer is in deep and clear public waters, living in groups of various sizes and moving in the upstream areas of rivers that have clear and swift water flow with rocky bottoms. The habitat conditions for mahseer are clear waters with sandy and rocky substrate types and moderate to strong water currents [11, 57].

Assessment of the fertility status of Sarangan Lake is also done with the Trophic State Index (TSI) [19]. TSI is a simple method that can be used to determine the fertility of waters using three interrelated parameters: brightness, phosphate, and chlorophyll a [20]. The measurement results obtained showed that Sarangan Lake is a water body with a mesotrophic fertility level, with TSI values ranging from 42.5 to 52.6. TSI values at the bottom of the water tend to be lower when compared to the surface and a depth of 4.0 m. The highest TSI value is found at the outlet location, with values ranging from 48.7 to 51.1. [19] said that mesotrophic waters are waters with moderate fertility. According to study [58], mesotrophic has moderate water fertility, moderate water brightness, and increased anoxic changes in the hypolimnetic zone, which is still aesthetically supportive for water sports activities. Mesotrophic status in Sarangan Lake illustrates that the concentration of nutrients in these waters is moderate, and the water ecosystem has good water quality.

3.4 The ecotourism economic value

The role of mahseer fish in Sarangan Lake is currently still in the development stage, and its direct economic impact on

tourism revenue is not yet significant. The economic benefits of the mahseer fish if managed as a direct tourist attraction in Sarangan Lake are potentially quite large, especially if managed with an educational, conservative, and special interest tourism approach. However, this has not been regulated by the Magetan Regency Government in the Magetan Regency Regional Regulation No. 8/2016 concerning the Master Plan for Tourism Development of Magetan Regency 2015-2025.

The mahseer, including iconic species, holds significant potential as a tourist resource at Sarangan Lake. The potential benefits of mahseer, if managed properly as part of ecotourism, conservation tourism, or adventure tourism in Sarangan Lake, include catch-and-release fishing or recreational fishing and educational tours that feed mahseer while learning the importance of mahseer conservation and its habitat. Mahseer is used in fishing tours in India by involving local people as guides [59, 60]. Recreational fishing is being considered an intrinsic part of eco-tourism, which involves exploring scenic locations and experiencing the local cuisine, culture, and heritage [60]. Revenue from tourism supports mahseer conservation and community livelihoods. Educational tours of feeding mahseer while learning the importance of conserving mahseer fish and their habitat can be done by giving visitors the opportunity to feed mahseer fish using feed provided by the tour manager. This tour also provides information about mahseer fish, their life cycle, and conservation efforts that can be done.

3.5 Protection of mahseer

The existence of mahseer fish is expected to be an attraction for tourism in Sarangan Lake, so it is necessary to conserve these fish resources so that the balance of ecosystems and habitats is maintained and prevent the extinction of mahseer fish in Sarangan Lake caused by habitat destruction and uncontrolled fishing. As an effort to protect the mahseer, several conservation measures need to be taken. Habitat protection, restocking, and population monitoring, especially for invasive species, are some of the suggested techniques. The creation of a fishery sanctuary (intermediate culture) specifically for mahseer to minimize competition with other fish in the lake, so that mahseer can grow and develop well. The fishery sanctuary is in the form of semi-confined waters, in which hatchery-reared mahseer fish seeds are stocked with mahseer parents who are gonadally mature or ready to spawn. With the hope that the mahseer fish reproduced in the lake can survive and compete with other fish in the lake.

As an effort to conserve mahseer fish in Sarangan Lake, the Regional Government of Magetan Regency has issued Regent Regulation Number 23 of 2020 concerning the Conservation of Fish Resources in the Mainland Public Waters of Sarangan Lake. In this regulation, the mahseer fish is included in the protected, supervised, and conserved fish species. In addition, one of the efforts to conserve mahseer fish in Sarangan Lake, the Ministry of Maritime Affairs and Fisheries, together with the Magetan Regency Government, which stocked mahseer fish. According to study [52], stocking, regulation of fishing, and fishery sanctuaries are successful conservation efforts of mahseer fish resources in Baba Dhansar, Gambhir, and Anji.

In addition, to support sustainable conservation policy, more research over a longer period and with larger sample sizes is required. However, these rescue and conservation efforts will not succeed if there is no participation from the

community. The government provides guidance to the community by conducting counselling on the importance of conserving god fish resources and their habitat. The government, together with the community, supervises the conservation of mahseer fish in the field. The community can participate in the implementation of supervision individually, in groups, customary institutions, and or non-governmental organizations.

3.6 The limitations of the mahseer study

A key limitation of this study is that field sampling was conducted only in 2020. Supplemental sampling in 2024 would have been necessary to verify whether the findings remain valid and to evaluate population trends over time. However, due to budget constraints and limited research time to study the biological and environmental assessment of mahseer in Sarangan Lake, such additional sampling was not possible within the current study. We therefore strongly recommend that future research prioritize follow-up sampling over a longer period and with larger sample sizes.

4. CONCLUSIONS

The mahseer is one of the endemic fish species in Sarangan Lake, which is currently threatened because of invasive species. The catch proportion of mahseer fish is only 1.57% of the total catch, indicating population limitation. Mahseer has a negative allometric growth pattern ($b = 2.75$) and the main food of plants (80%) and worms (20%). The water quality showed that levels up to 11.1 mg/L and temperatures between 22.1-25.9°C were favourable for mahseer habitat, but the presence of invasive species triggered competition for food and space. With a mesotrophic state, conservation activities are necessary. Habitat protection, restocking, and population monitoring, especially for invasive species, are some of the suggested techniques. To support sustainable conservation policy, more research over a longer period and with larger sample sizes is required.

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