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Feeding ecology study of Asian redtail catfish, *Hemibagrus nemurus* (Teleostei: Bagridae), post-sediment flushing in Jenderal Soedirman Reservoir Central Java, Indonesia

DWI NUGROHO WIBOWO[1,♥], SRI SUKMANINGRUM[1], ANI WIDYASTUTI[1], PETRUS HARY TJAHJA SOEDIBYA[2], NUR LAILA RAHAYU[3]

[1]Faculty of Biology, Universitas Jenderal Soedirman. Jl. DR. Soeparno 63, North Purwokerto, Banyumas 53112, Central Java, Indonesia. Tel.: +62-281-638794, [♥]email: dnwibowo.unsoed@gmail.com

[2]Department of Aquaculture, Fisheries and Marine Science Faculty, Universitas Jenderal Soedirman. Jl. DR. Soeparno, Komplek GOR Soesilo Soedarman, North Purwokerto, Banyumas 53112, Central Java, Indonesia

[3]Program of Biology, Faculty of Sciences and Technology, Universitas Nahdlatul Ulama. Jl. Sultan Agung No. 42, South Purwokerto, Banyumas 53145 Central Java, Indonesia

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Abstract. *Wibowo DN, Sukmaninggrum S, Widyastuti A, Soedibya PHT, Rahayu NL. 2024. Feeding ecology study of Asian redtail catfish,* Hemibagrus nemurus *(Teleostei: Bagridae), post-sediment flushing in Jenderal Soedirman Reservoir Central Java, Indonesia. Biodiversitas 25: 2315-2322. Hemibagrus nemurus* Vallenciennes 1840 is among the valuable fisheries commodities in Banyumas District and led to high exploitation. Research on *H. nemurus* is essential for its conservation, including its feeding ecology**.** Feeding ecology studies of *H. nemurus* have been conducted previously, but the relative examination of this Asian redtail catfish is lacking in Jenderal Soedirman Reservoir, Banjarnegara, Central Java, Indonesia. Therefore, this study aimed to investigate the feeding ecology of *H. nemurus,* focusing on post-sediment flushing in the Jenderal Soedirman Reservoir in 2022. Specimens were collected at nine sampling sites in the reservoir during morning and evening sessions, with observed parameters including mouth position, intestine length ratio, intestine content, and the index of preponderance (IP). The results showed that *H. nemurus* had a subterminal mouth position as well as shorter to slightly longer intestines than the standard body length (SL). Based on the IP value, diets inside the intestine were dominated by animal materials, namely fish compounds. Hence *H. nemurus* seemed to be predatory considering its detected piscivorous habits. The identified mouth position, intestine length, and dominant diets were similar to the reports on the same species from other regions. These feeding ecology data would provide essential information for the fisheries and conservation of *H. nemurus* in Jenderal Soedirman Reservoir.

Keywords: Bagridae, dam, index of preponderance, redtail catfish, subterminal

INTRODUCTION

The Asian redtail catfish, *Hemibagrus nemurus* Valenciennes 1840, a member of the Bagridae family, is geographically distributed across Asia, including Mekong, Chao Phraya, and Xe Bangfai basins, as well as the Malay Peninsula and Indonesia (Froese and Pauly 2023). However, the latest report proved that *H. nemurus* is endemic to Java Island (Ng and Kottelat 2013). This species, locally known as Baung in Indonesia (Nuryanto et al. 2019), inhabits rivers, lakes, and artificial reservoirs in Sumatra, Kalimantan, and Java (Pramono et al. 2018; Suryaningsih et al. 2018; Desrita et al. 2022). Previous studies reported the presence of Baung fish in the Jenderal Soedirman (Mrica or PB Jenderal Soedirman) Reservoir and other sections of the Serayu River (Nuryanto et al. 2019; Suryaningsih et al. 2020).

Hemibagrus nemurus is a freshwater fish with high economic value (Kusmini et al. 2019) and one of the favorite menus in several specialized restaurants (Nuryanto et al. 2019). This reputation led to its population decline due to overexploitation, which is evident among the Baung fish found in the Klawing River, Purbalingga (Putro 2003). The decline extends to the Serayu River, particularly after the mass death incident experienced in 2022 (personal observation and newspaper) and no scientific studies are available yet. Consequently, a comprehensive investigation into the biology of Baung fish in the Serayu River, including the Jenderal Soedirman Reservoir and downstream river waters, is needed. An essential aspect of this study comprises an exploration of trophic ecology to support conservation efforts both in situ and ex-situ.

Fish are classified as herbivorous, omnivorous, carnivorous, planktivorous, and detritivorous (Henriques et al. 2017; Edem and Opeh 2018), which describes the trophic levels (Henriques et al. 2017) determined through feeding ecology studies by analyzing food habits (Johnson et al. 2012; Day et al. 2014), intestine or stomach length ratio, and mouth type (Faye et al. 2012). The food habits of a fish species are identified from the examination of intestine or stomach contents (Gupta and Banerjee 2014) because the consumption patterns of each vary according to body size (Babut et al. 2017; Edem and Opeh 2018; Jacobson et al. 2018).

Several studies have extensively explored the habits of *H. nemurus* (Fatah and Adjie 2015; Purnamaningtyas et al. 2021). Fatah and Adjie (2015) reported that Baung fish in the Wadas Lintang Reservoir are carnivorous, with a food proportion of 50% fish and 50% crustaceans. However, the trophical ecology of *H. nemurus* has not been investigated in the Jenderal Soedirman Reservoir located in Banjarnegara District, Central Java, Indonesia. The reservoir was constructed in 1988 to primarily function as a hydroelectric power plant and water source for irrigation, with an additional application in aquaculture through floating net cages. This fisheries technique, along with land erosion from upstream areas, has accelerated reservoir sedimentation (Andriyani et al. 2018). To counter the challenges and sustain the reservoir, management has implemented regular sediment flushing (Utomo 2017), with the latest being conducted in April 2022.

Sediment flushing introduces potential environmental changes in the Jenderal Soedirman Reservoir from eutrophic (Piranti et al. 2015) to oligotrophic conditions, affecting food availability and abundance. These conditions may alter the feeding ecology of the fishes inhabiting the reservoir, including *H. nemurus*. According to Thoral et al. (2021), fish feeding habits change based on food availability, which is often influenced by environmental factors (Meng et al. 2017; Wu et al. 2019; Borics et al. 2021). Dinh et al. (2022) stated that feeding habits vary with seasons and habitats, but these features have not been explored among *H. nemurus* population in Jenderal Soedirman Reservoir, specifically after sediment flushing in 2022. Therefore, this study aimed to investigate the feeding ecology of *H. nemurus* in the Jenderal Soedirman Reservoir Central Java, Indonesia, post-sediment flushing in order to promote the conservation and domestication of the examined species.

MATERIALS AND METHODS

Sampling area

The specimens of *H. nemurus* were collected at nine sampling sites in Jenderal Soedirman Reservoir, Banajrnegara Regency, Central Java, Indonesia, as presented in Figure 1. The geographic positions of each sampling site are presented in Table 1.

Table 1. Geographic position of each sampling site in Jenderal Soedirman Reservoir, Banjarnegara, Central Java, Indonesia

Sampling site	Name	Geographic position
1	Spillway (outlet)	-7.387924; 109.604288
2	Middle areas	-7.386783; 109.615103
3	Irrigation outlet areas	-7.377761; 109.612871
4	Power intake areas	-7.389167; 109.624201
5	Fishery (Floating Net Cage) areas	-7.381336; 109.632612
6	Dock (harbour)	-7.373164; 109.627291
7	Lumajang River	-7.374186; 109.643427
8	Merawu River	-7.376910; 109.649263
9	Serayu River	-7.384741; 109.65631

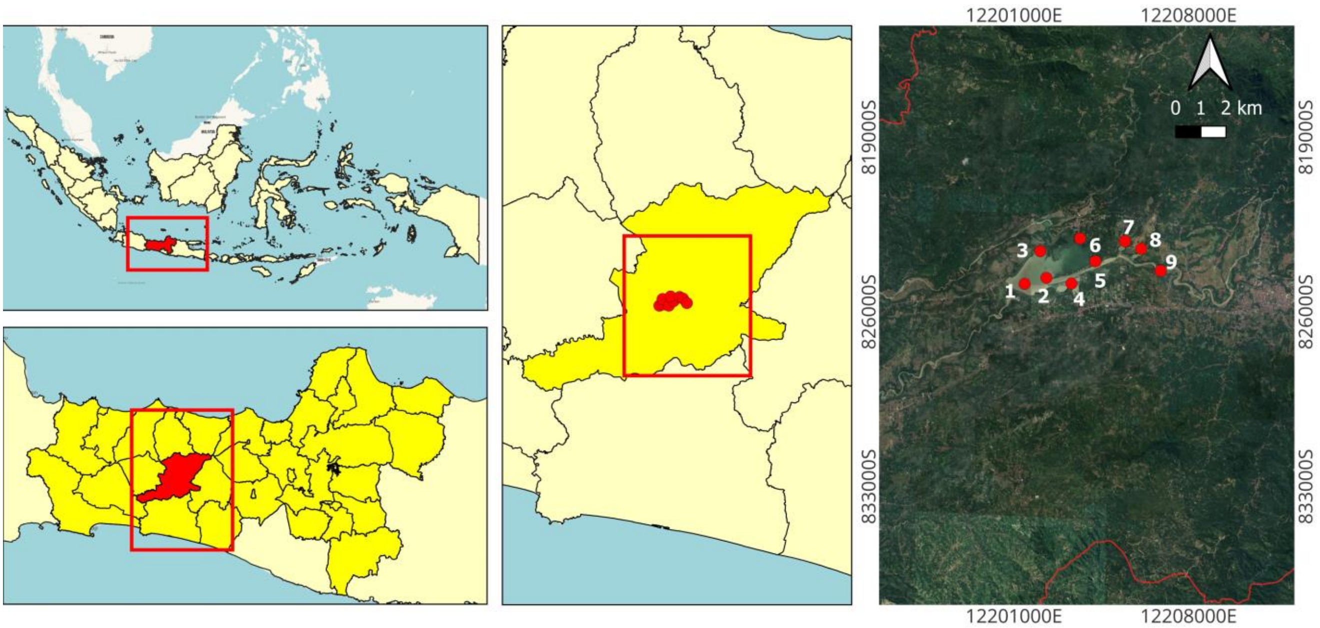

Figure 1. The map of Java Island shows Jenderal Soedirman Reservoir, Banjarnegara, Central Java, Indonesia, with nine sampling sites of *Hemibagrus nemurus*

Procedures

Sample collection and preservation

Sampling efforts were conducted in August, September, October, and November 2023 with the help of fishermen operating in the reservoir. This time duration was determined by considering funding duration and representing dry (August-September) and rainy (October-November) seasons. *Hemibagrus nemurus* specimens were collected in the morning and evening at the predetermined sampling sites in the Jenderal Soedirman Reservoir. Fishing times (morning and evening) were determined to optimize the success of sampling efforts. Fish sampling was using a fishnet with mesh sizes of 0.5, 1, 2, and 3 inches and a total diameter of 6 meters. Different mesh sizes were used to obtain variable individual sizes and expect more comprehensive figures about the feeding behavior of *H. nemurus*. This sampling process was conducted three times with replications at one-month intervals; then the specimens were sorted according to general morphology, preserved in an ice box, and stored in the freezer. A total of 40 fish species were observed during the study (data not presented). This study only focused on the feeding ecology of *H. nemurus* since no scientific information from Jenderal Soedirman Reservoir is available on that species. The number of *H. nemurus* from each sampling site is presented in Table 2.

Fish identification and body size measurement

Fish identification was performed at the Aquatic Laboratory of the Faculty of Biology, Universitas Jenderal Soedirman Purwokerto, Central Java, Indonesia. Due to the importance of accurate information about subjects in ecological investigations, the fish specimens in this study were identified to ensure the correct and valid species were examined. Furthermore, intestine content analysis and plankton identification were conducted at the Aquatic Laboratory. The fish specimen identification process was completed based on morphological characteristics following the procedure of Ng and Kottelat (2013), and scientific name validity was checked by comparing the identification results to those reported by Fricke et al. (2023).

Valid species specimens were subjected to the standard-length measurement, estimated using a millimeter block and ruler with a precision of 0.1 centimeters (cm). During the measurement, the fish head was positioned on the left side, as shown in Figure 2.

Feeding ecology assessment

Several parameters, including mouth position, relative intestine length (RIL), and intestine content, associated with the feeding ecology of *H. nemurus* were estimated. The intestine content analysis was performed to evaluate food type and to calculate the index of preponderance (IP). The mouth position was determined based on its relative position to the snout tip. The RIL was calculated using the formula below (adopted from Al-Hussaini (1947) after Gupta and Banerjee 2014 and Alabssawy et al. 2019).

RIL = intestine length (cm)/standard body length (cm)

Intestine content analysis was conducted by dissecting all *H. nemurus* specimens, starting from the anus to the rear of the operculum, to remove the digestive organ from the abdominal cavity. The dissection was carried out by inserting blunt scissors in the body cavity to avoid damage to the digestive organs. The volume of digestive organs was estimated using a measuring cup filled with a specific volume. Moreover, the volume of the digestive organs varied between the initial and final volume of water after being placed in the measuring cup. The contents of the digestive organs, namely feed, were removed and collected in a labeled sample bottle, then a formalin solution of 4% was added until the entire feed was submerged.

During microscope observation, the intestine content was homogenized, and then a large feed was identified under loops. Small feed was observed using a binocular microscope. Subsequently, a drop of homogenized intestine content was placed on the object glass. Feed observations were conducted at 20 view fields with five replications for each specimen, and identification followed the criteria outlined by Sachlan (1982) and Davis (1955). According to Sachlan (1982) and Davis (1955), natural food mainly composed of plankton was also identified. Fish feeding habits were determined based on the index of preponderance.

Table 2. Number of samples for each sampling site

Month	Number of Sample
August	10
September	0
October	3
November	22

Figure 2. General morphological characteristics of *Hemibagrus nemurus*

The index of preponderance (IP) was calculated using the following formula (Natarajan and Jhingran 1961) after Gupta and Banerjee (2014) and applied to estimate the most dominant diet, as shown in the highest percentage.

$$IP = (Vi \times Oi) / (\Sigma (Vi \times Oi)) \times 100\%$$

Where:
IP : index of preponderance
Vi : percentage of i^{th} food item
Oi : frequency of i^{th} food item

Data analysis

The data regarding mouth position were analyzed descriptively by comparing observation results and the information extracted from previous literature. Similarly, intestine content was also analyzed descriptively based on the food type observed in the intestine and presented in Table. Descriptive determination of feeding habits was conducted based on the dominant food item as shown in IP value and compared to the existing literature.

RESULTS AND DISCUSSION

Taxonomic status

The taxonomic certainty of the specimens was determined based on morphological characteristics. The observed characteristics were 7 rays in the dorsal fin, the tip of the dorsal fin does not reach the base of the adipose fin, the longest barber reaches the origin of the anal fin, and the caudal fin forked (Figure 2). Characteristic of *H. nemurus* according to Ng and Kottelat (2013), includes a flat head, 7 rarely 8 soft rays in the dorsal fin, dorsal fin does not reach the adipose fin, barbel reaching the origin of the anal fin, and caudal fin deeply forked. Based on the characteristics of *H. nemurus*, it can be determined that our samples belong to *H. nemurus*. The presence of *H. nemurus* in Serayu River, including in Jenderal Soedirman Reservoir has been reported by Nuryanto et al. (2019), who identified bagrid sample from Jenderal Soedirman Reservoir using molecular character (cytochrome c oxidase 1) gene.

Feeding ecology

The feeding ecology of targeted species was assessed using various parameters, including mouth position, relative intestine length, intestine content, and index of preponderance. The results are presented as follows.

Mouth position

According to Figure 3, visual observation showed that the mouth of *H. nemurus* is slightly positioned below the snout tip as indicated by the position of the mouth angle (red box) which is below the median line (red line) of the body. Subterminal mouth position is also showed by slightly shorter lower jaw than upper jaw (red box) as shown in Figure 3.

Based on the results, the subterminal mouth position was identified in *H. nemurus*. The mouth position of fish can be classified as inferior, subterminal, terminal, or superior (Oliveira et al. 2018). Moreover, the subterminal mouth position is among catfish characteristics (Wright and Bailey 2012; Wibowo et al. 2022), including other members of Siluriformes (Marceniuk et al. 2017), consisting mainly of carnivore species (Chattopadhyay et al. 2015). The discovered subterminal mouth of *H. nemurus* as a member of catfish from Siluriformes suggested the species to be predatory or carnivorous. This characteristic has been reported by Chattopadhyay et al. (2015) as a general characteristic of Siluriformes, which includes the Bagridae family.

Relative intestine length (RIL)

This study showed that *H. nemurus* specimens had a standard body length (SL) ranging from 12.8 cm to 35.0 cm, while the intestine length spanned between 11.5 cm and 27.2 cm (Table 3). Additionally, the RIL ranged from 0.56 to 1.66 (Table 3), and these values showed a shorter to slightly longer intestine than the SL of *H. nemurus*. The comparison between the intestine and body length of specimens from Jenderal Soedirman Reservoir is presented in Figure 4.

Fish trophic levels are not only determined based on the mouth position but require several additional parameters, such as the ratio of intestinal length to standard length. According to the intestine ratio, fish can be divided into three trophic levels, including herbivorous, omnivorous, and carnivorous (Henriques et al. 2017; Edem and Opeh 2018). Herbivorous fish have lengthy intestines with a ratio ranging from 3.0 to 6.0, omnivorous possess medium intestines with a ratio of 1.3 and 4.3, while the carnivorous contain a ratio varying from 0.5 to 2.4 (Gupta and Banerjee 2014; dos Santos et al. 2015). The observed ratio ranged between 0.56 and 1.6, indicating a short intestine. Therefore, *H. nemurus* can be categorized as a carnivore species because the intestine ratio values fell in a range of 0.5 to 2.4, as proposed by Gupta and Banerjee (2014) and Idrus et al. (2021). The observed RIL ratio supported the categorization of *H. nemurus* as a carnivorous species based on its mouth position.

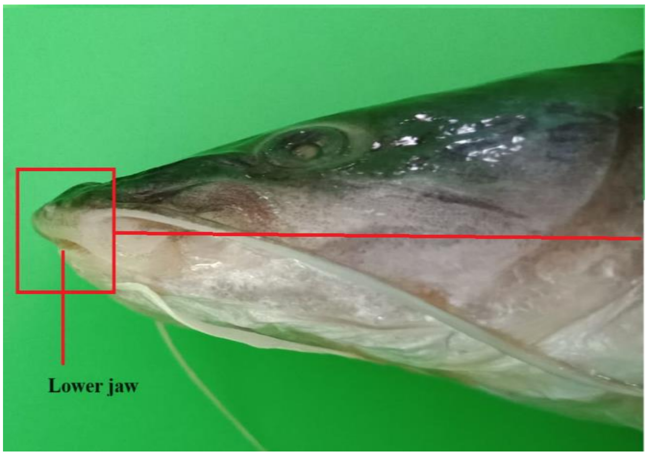

Figure 3. The head of *Hemibagrus nemurus* shows a subterminal mouth position

Intestine content

After dissection, the intestine of 22 out of 35 *H. nemurus* specimens was found to contain food, while the remaining individuals had an empty stomach. The food items observed inside the stomach were phytoplankton and animal compounds, as presented in Table 4. Some of the planktons are shown in Figure 5.

Additional data used to classify fish trophic levels is the diet type contained in the intestine. The diets presented in Table 4 showed a broader food spectrum for *H. nemurus* in Jenderal Soedirman Reservoir compared to those reported in *H. nemurus* from Wadaslintang Reservoir (Fatah and Adjie 2015). This study found fish, shrimp, and twelve phytoplankton species in the intestine of specimens from Jenderal Soedirman Reservoir. Similarly, Fatah and Adjie (2015) only reported fish and shrimp as the diets of *H. nemurus* from the Wadaslintang Reservoir. This observed difference could be due to variations in the food availability of both reservoirs. Water flushing in April 2022 in Jenderal Soedirman Reservoir might limit the availability of fish and shrimp as feed sources for *H. nemurus*. Previous studies stated that fish food availability is often influenced by environmental factors (Meng et al. 2017; Wu et al. 2019; Borics et al. 2021). In 2022, food (especially fish and shrimp) was washed away by an extreme water current during flushing in Jenderal Soedirman Reservoir, leading to the expansion of *H. nemurus* food spectrum to meet nutritional needs. According to Thoral et al. (2021), availability tended to affect food selection and nutritional shifts of fish species. The alterations of nutrition patterns in *H. nemurus* initiated by seasonal changes due to food availability were reported by Purnamaningtyas et al. (2021) in Lindung Pangelang Lake, Kapuas Hulu District, Kalimantan. During the dry season, the diets included fish and plant compounds, changing to 100% fish during the transition season and finally incorporating fish and insects in the rainy (flooding) season, with insects being the dominant content (Purnamaningtyas et al. 2021). Moreover, Dinh et al. (2022) stated that season and habitat alterations might change fish feeding habits. Therefore, it was reasonable that this study found a different food spectrum in *H. nemurus* in Jenderal Soedirman Reservoir than those reported by previous studies in other areas (Purnamaningtyas et al. 2021; Dinh et al. 2022).

Table 3. Standard body length (SL), intestine length (IL), and relative intestine length (RIL)

Standard body length (cm)	Intestine length (cm)	Relative intestine length	Trophic level	Standard*
19.8	19.6	0.99	Carnivorous	Herbivorous:
14.4	17.7	1.23	Carnivorous	3.0-6.0
14.8	12.8	0.84	Carnivorous	Omnivorous:
17.2	9.6	**0.56**	Carnivorous	1.3-4.3
14.3	11.5	0.80	Carnivorous	Carnivorous:
35	26.6	0.76	Carnivorous	0.5-2.4
17.3	28.8	**1.66**	Carnivorous tend to Omnivorous	
14.3	12.6	0.88	Carnivorous	
20.7	27.2	1.31	Carnivorous	
15.4	18.7	1.21	Carnivorous	
18	15	0.83	Carnivorous	
20.4	26.3	1.29	Carnivorous	
12.8	15	1.17	Carnivorous	
17.3	15.3	0.88	Carnivorous	
18	19	1.06	Carnivorous	
14.2	14.7	1.04	Carnivorous	
18.3	22	1.20	Carnivorous	
19.8	22.6	1.14	Carnivorous	
19	22.2	1.17	Carnivorous	
21.3	27	1.27	Carnivorous	

Notes: *Gupta and Banerjee (2014); dos Santos et al. (2015)

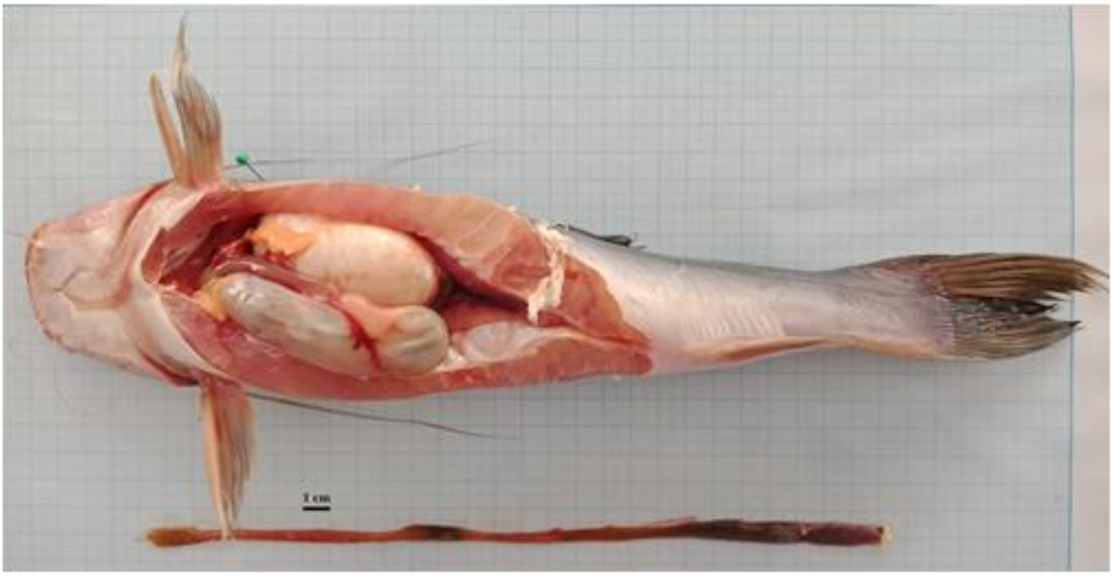

Figure 4. The ratio between intestine and body length of *Hemibagrus nemurus*

Index of preponderance (IP)

Based on the primary food component observed inside the intestines of 22 fish individuals, *H. nemurus* had a similar IP value during the sampling periods. The IP values of the animal compound were 54.25%, while that of plant materials was 45.75%. The detailed IP data for each food item is presented in Table 5.

Hemibagrus nemurus from Jenderal Soedirman Reservoir had a broad food spectrum, yet fish and shrimp were the dominant components of the diets, as shown by a higher IP of animal compounds (54.25%) compared to the plant compounds (45.75%). These data suggested that *H. nemurus* could be categorized as a carnivorous species. Previous studies stated that fish with dominant food components from animal materials could be classified as carnivorous (Gupta and Banerjee 2014; Chattopadhyay et al. 2015; Alabssawy et al. 2019). Moreover, Purnamaningtyas et al. (2021) reported *H. nemurus* to be a predator, suggesting this species is carnivorous. The identified animal component only consisted of fish and shrimp materials, with the fish compound being dominant. This phenomenon proved the existence of piscivorous potential in *H. nemurus*. The current results were similar to those previously reported by Purnamaningtyas et al. (2021), describing *H. nemurus* as a piscivorous species.

This study found that IP for fish was 37.55% and for shrimp was 16.21%, while a previous study in Wadaslintang Reservoir (Fatah and Adjie 2015) reported the IP for the fish compound was 50% and 50% for shrimp compounds and no plant materials were reported. The comparison proved that *H. nemurus* in Jenderal Soedirman Reservoir had altered its food habits and showed to be a carnivore but with an omnivore tendency. This assumption was supported by a high IP for plant materials, i.e. 45.75%, which was almost similar to the animal compounds (54.25%). This finding strengthens the argument that fish might alter their food preference when food availability and environments are changed. The phenomenon has been reported by Purnamaningtyas et al. (2021) in *Hemibagrus* population in Kapuas River, which showed dynamic food preference in different seasons and also proved that *Hemibagrus* might consume plant (phytoplankton) when the availability of fish and shrimp are limited. Comparison to Purnamaningtyas et al. (2021) was not completely congruent due to the study being conducted in different species. However, since this and Purnamaningtyas et al. (2021) work on the same genus, therefore the comparison is reasonable.

Table 4. Food items found in the intestine of *Hemibagrus nemurus*

Group	Food item
Animal	Shrimp compound and fish compound
Plant	Phytoplankton (*Lyngbya*, *Oscillatoria*, *Melosira varians*, *Synedra ulna*, *Synedra affinis*, *Synedra tabulata*, *Synedra acus*, *Navicula* sp., *Navicula placentula*, *Diatoma elongatum*, *Cyclotella* sp., *Gyrozigma* sp., *Gyrozigma acuminatum*, *Neidium affine*)

Table 5. IP of each food item observed in the intestine of *Hemibagrus nemurus*

Food items	IP (%)
Animal compounds	54.25
Fish	37.55
Shrimp	16.21
Plant compounds	45.75
Lyngbya sp.	16.93
Oscillatoria	1.96
Melosira varians	0.49
Synedra ulna	7.36
Synedra affinis	1.96
Synedra tabulata	0.49
Synedra acus	0.49
Navicula sp.	4.05
Navicula placentula	4.41
Diatoma elongatum	4.41
Cyclotella sp.	0.49
Gyrozigma sp.	0.49
Gyrozigma acuminatum	1.72
Neidium affine	0.49

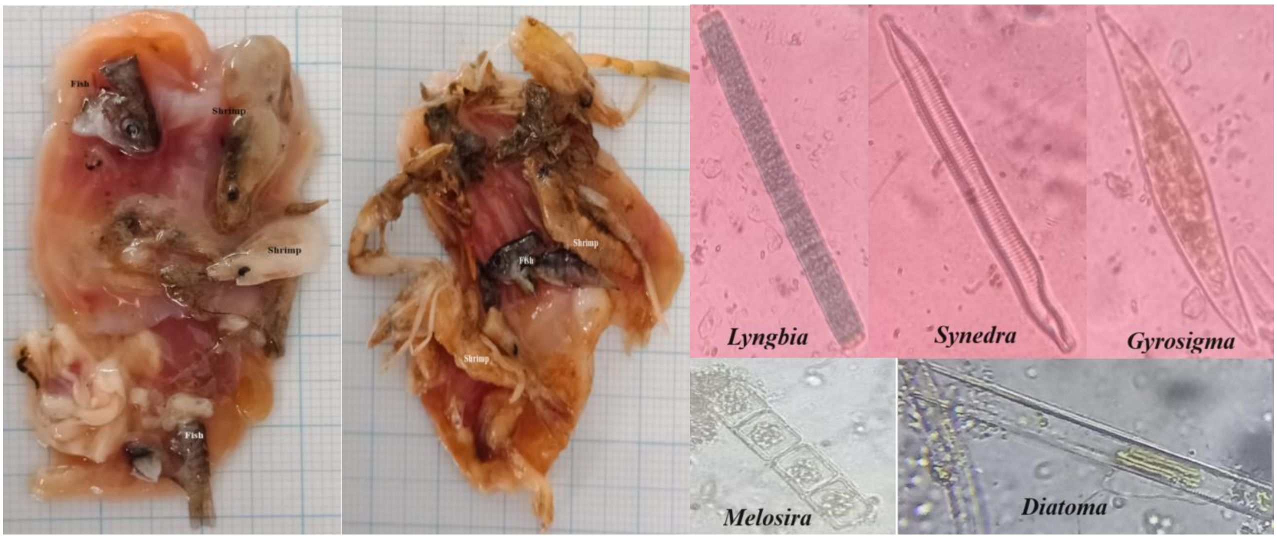

Figure 5. Some of the phytoplankton examples found in the *Hemibagrus nemurus* intestine

A previous study stated that *H. nemurus* is obligate carnivorous (Fatah and Adjie 2015). However, this study observed that *H. nemurus* in Jenderal Soedirman was tend to be omnivorous as show by almost the IP value between animal and plant compounds. The alteration could be due to food availability changes. The assumption was also supported by previous studies which proved that food preferences of fish species might alter due to environmental factors and food availability (Thoral et al. 2021; Dinh et al. 2022).

Our result is important to support the conservation effort on *H. nemurus* in Jenderal Soedirman Reservoir Banjarnegara, Central Java, Indonesia because it provides information that shows that *H. nemurus* can alter its feeding habits to adjust to food availability due to environmental changes, such as water flushing. It has been reported that *H. nemurus* is an obligate carnivorous (Fatah and Adjie 2015), but it can change to almost omnivorous, as indicated in this study. Moreover, fish can alter their food habits due to environmental changes (Thoral et al. 2021).

Mouth position, relative intestine length, food composition, and food habits of *H. nemurus* suggested this Bagridae (Siluriformes) family from Jenderal Soedirman Reservoir Central Java, Indonesia, to be carnivore with omnivorous tendency. Additionally, fish components were dominant in the examined intestine, comprising the highest index of preponderance.

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