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Exploitation of striped snakehead (*Channa striata*) in Sempor Reservoir, Central Java, Indonesia: A proposed conservation strategy

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Abstract. *Setyaningrum N, Lestari W, Krismono, Nuryanto A. 2022. Exploitation of striped snakehead (*Channa striata*) in Sempor Reservoir, Central Java, Indonesia: A proposed conservation strategy. Biodiversitas 23: 3584-3592.* Striped snakehead (*Channa striata*) has important economic value in freshwater systems, including Sempor Reservoir in Indonesia, where increases in catch sizes have resulted in a declining population. In this study, we determined its population size based on abundance and distribution of length and assessed the rate of exploitation based on estimated growth and mortality rates to determine a conservation strategy in Sempor Reservoir. The study was undertaken from March to October 2020. The method used was a purposive random sampling survey. Fish samples were taken from five stations with different land uses. The estimated growth, mortality, and exploitation rates were analyzed by Pauly's model using FISAT II. *Channa striata* abundance data were analyzed using a Kruskal-Wallis test. The results showed that the highest abundance of *C. striata* at the KW station was almost three times higher than at the BK station. The average size of the gonads at first maturity was 277.4 mm in females and 284 mm in males. The estimated growth parameters indicated an asymptotic length ($L\infty$) of 409.5 mm. An exploitation rate of 0.74 was classified as overfishing. The proposed conservation strategy is to limit the number of catches by as much as 44% and prohibit the catching of individuals with a length of 230-349 mm. Kedungwringin Station was defined as a reference area with the largest abundance and complete size distribution, namely, the pre-reproduction, reproduction, and post-reproduction stages. Bangkong Station was defined as a spawning ground because there were many fish in the reproductive stage and Sempor River Station was the nursery ground with mostly juvenile fish. These two sites must be protected for sustainable striped snakehead populations in the river and reservoir.

Keywords: Lentic waters, population, preservation, river

INTRODUCTION

Striped snakehead (*Channa striata*) is a freshwater fish with high economic value due to its protein and albumin content, which are beneficial for health (Mustafa et al. 2012; Romadhoni et al. 2016). In Indonesia, the domestic market price for processed snakehead reaches IDR 35,000 to IDR 70,000 per kg (Cia et al. 2018). This has resulted in high market demand and the fish is often the main catch target of fishermen in Asian countries, such as Thailand, Malaysia, India, and Indonesia (Jamaluddin et al. 2011; Boonkusol and Tongbai 2016; Cia et al. 2018; Baisvar et al. 2019; Ansyari et al. 2020). There is no reliable statistical data on demand for snakehead fish, it is assumed that there is an increase in production of 10.2% (3874 kg) per year, which is absorbed by the market due to high economic demand (KKP 2020).

Pressure on fish populations can be estimated from the level of exploitation of a fish species. The exploitation rate of snakehead fish is quite high (more than 0.5), with overfishing (Sparre and Vennama 1999) in several aquatic ecosystems in Indonesia. The results of *C. striata* research in Indonesia have identified overfishing in areas such as the Lubuk Lapam flooded swamp in south Sumatra (0.58: Fahmi et al. 2013), the Musi River flooded swamp (0.67: Nurdawati et al. 2014), the Panggang Lake swamp and Aopa Watumohai swamp waters, Angata District, South Konawe Regency (0.9: Cia et al. 2018). Overfishing results in juvenile fish having insufficient time to mature, leading to a small number of adult fish. One of the causes of overfishing is the widespread use of different fishing gear and intensive fishing (Fahmi et al. 2013; Nurdawati et al. 2014). This fishing pressure can affect the number, size and weight of fish in the population, the ratio of male to female fish, and the composition of juvenile and adult fish in the water (Fahmi et al. 2013; Djidohokpin et al. 2017).

In addition, to catch pressure, the natural snakehead fish population is also influenced by habitat conditions. Ecologically, the main habitat of this species is swamp waters, but the fish can live in various habitats in rivers with calm currents, lakes and reservoirs (Galib et al. 2016; Chan et al. 2017, 2020; Gumiri et al. 2018; Setyaningrum et al. 2020; 2021).

Sempor Reservoir is a standing water body with an area of 43 km^2 that was created by damming the Cingcingguling, Sempor, Mampang, and Kedungwringin rivers. The potential for fishery production is quite large, with both capture fisheries and aquaculture established in the region, and fish production is in the range of 72-236 tons/year (Purnomo et al. 2013). However, the *C. striata* catch in Sempor Reservoir is quite low, being only 0.68% of the 14 species that are fished (Setyaningrum et al. 2020).

Similar values have also been reported in the Nam Theun 2 Reservoir (Lao PDR), where the *C. striata* catch accounts for 0.82% of the 33 species that are fished (Cottet et al. 2016).

The low population of snakehead fish is a result of anthropogenic disturbances such as overfishing, which has caused a population decline and may even ultimately lead to extinction. In addition, the distribution of *C. striata* is more affected by the fish behavior in selecting their habitat. This species prefers aquatic habitats with dense aquatic vegetation, shallow and transparent water. It is necessary to implement a habitat and species conservation strategy for *C. striata* so that its population can be maintained (Biswas et al. 2015; Duong et al. 2019; Setyaningrum et al. 2021). There have been few studies of the exploitation rate of snakehead fish in Java, particularly in reservoir waters. It is therefore necessary to determine the exploitation rate of *C. striata* in Sempor Reservoir.

In this study, we determined the population of *C. striata* based on fish abundance and the distribution of length and assessed the rate of exploitation based on estimated growth and mortality rates. The ultimate aim was to determine a conservation strategy for *C. striata* in Sempor Reservoir. We acquired basic data on the exploitation rate and population of *C. striata*, which will be useful for determining conservation strategies. This includes the identification of reference areas, spawning grounds, and nursery grounds in Sempor Reservoir, ensuring a sustainable population of *C. striata*.

MATERIALS AND METHODS

Study area

The survey was conducted in the Sempor Reservoir, Banjarnegara District, Central Java Province, Indonesia. Five stations were chosen as the representative of the entire reservoir ecosystem based on differences in the surrounding land uses (Table 1). This study also considered inlets, middle, and outlets of the reservoir. There are two river inlets, namely the Kalianget River and the Kedung Wringin River. Therefore, four sampling sites were selected inside the reservoir, namely Kedung Wringin River (KW/inlet), Bangkong Station (BK), Kalianget Station (KA/inlet), and Reservoir Outlet Station (WO). An additional sampling site was also chosen in the downstream areas of the reservoir as the representative of the running water ecosystem. This sampling site was Sempor River Station (KS) which is located downstream of the reservoir. A schematic of the location of fish sampling sites is presented in Figure 1.

Sampling procedures

At each station, purposively random sampling was conducted. Sampling was conducted monthly with eight replications in each location (March to October 2020). The fish samples were collected using fishing rods with hook sizes 6-12 (0.5-1 cm). Fifty fishing rods were installed at each station in the afternoon and they were lifted at night and the following morning to collect fish. Gillnet cannot be used because it cannot be installed in shallow water as a habitat for snakehead fish. Meanwhile, electric fishing is prohibited because of its adverse impact on the fish community. The caught fish were identified by station and then placed into an icebox with ice cubes for transport to the laboratory, where all measurements were conducted.

Fish measurement

Total length was measured using a ruler with a precision of 0.1 cm. Fish sexuality was determined based on their gonad types.

Relative abundance

Relative abundance in each sampling station was determined based on the total number of individuals obtained during sampling.

Body length distribution

Body length distribution was determined to obtain length class. It was determined following the formula from Simanjuntak (2020) as follow:

$$K = 1 + 3.3 \text{ Log } n$$

Where, K: number of length class; n: number of length data.

Length class for each class was determined according to the following formula:

$$C = \frac{a-b}{K}$$

Where, C: length class; K: number of length class; a: maximum length; b: minimum length.

Gonad Maturity Level (GML)

Gonad maturity level (GML) was determined based on gonad morphology. The observed morphology was then compared to gonad morphology of Snakehead from Rawa Pening as summarized in (Table 2).

Table 1. Details of station locations and surrounding land uses

Code	Station	Coordinates	Land use in the area
KW	Sempor Dam Inlet in Kedungwringin	S7°54’15.12” E109°50’65.93”	Agricultural land. The station was located far from the villages around the river
BK	Bangkong	S7°55’05.17” E109°48’49.54”	Teak and pine forests, lots of forest litter, many monkeys, birds and wild boars in the forest
KA	Sempor Dam Inlet in Kalianget River	S7°55’54.75” E109°47’35.74”	On the riverside surrounded by plantation crops (banana and coconut plants) and water shrubs
WO	Sempor Dam outlet	S7°56’51.29” E109°48’39.4”	Close to a dam, with some boat docks and fishing activities
KS	Sempor River	S7°57’45.74” E109°49’26.50”	Village area with garden plants

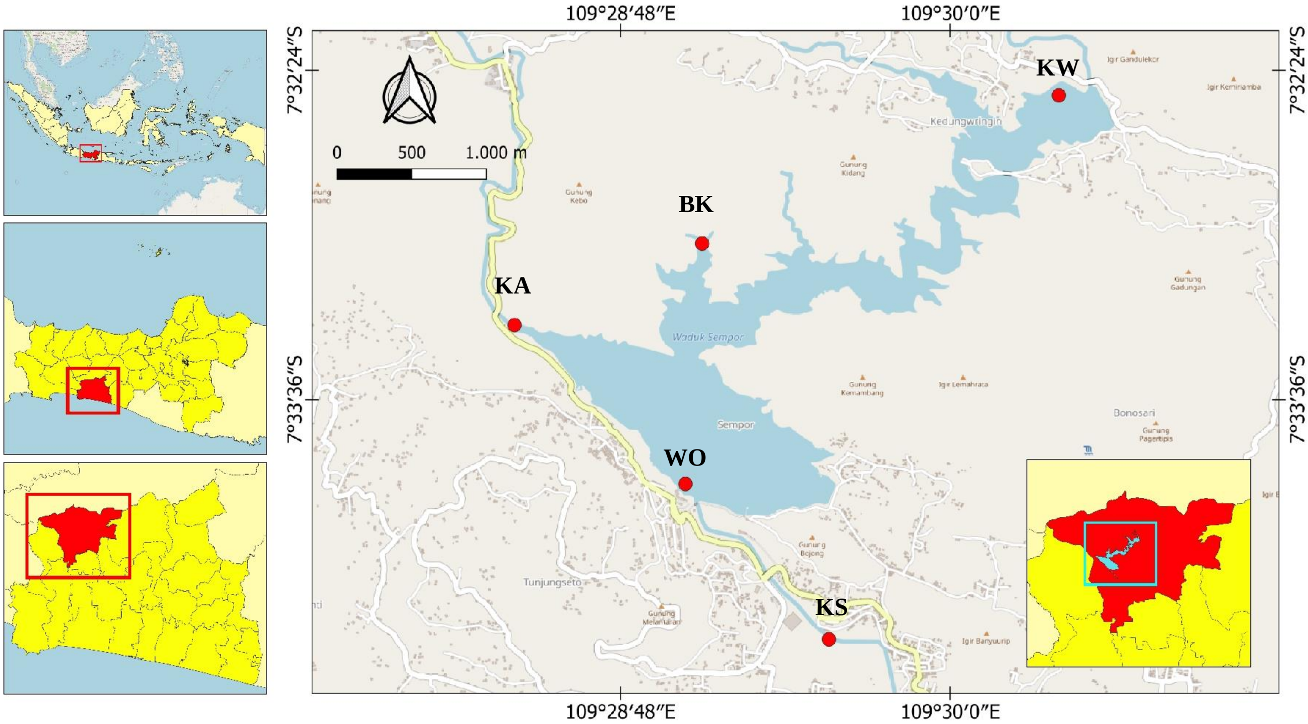

Figure 1. Sampling stations in Sempor Reservoir, Banjarnegara District, Central Java Province, Indonesia. Note: KW: Inlet Kedungwringin; BK: Bangkong; KA: Inlet Kalianget River; WO: Outlet Waduk; KS: Sempor River

Table 2. Gonadal maturity level of *Channa striata* from Lake Rawa Pening (Djumanto et al. 2019)

Maturity Level	Male	Female
Level 1 (Immature)	Testes were very tiny and translucent, containing many spermatogonia. A few spermatocytes were also thinly scattered macroscopically, the testicles were flat, transparent white and notched. Microscopically, thick testicular walls with primary spermatocytes dominate the peritoneum.	Macroscopically, the ovary was small, thin, transparent, soft texture and blood vessels were not visible yet. Oocytes were not visible through the ovary wall. Histologically, oocytes were located in the germinal epithelium, each with mild eosinophilia cytoplasm to basophilic. Cytoplasmic diameter of 0.05 mm.
Level 2 (Maturing)	Testes at this stage were larger than the immature stage. Spermatocytes and spermatids were more abundant. In the early stages, the testes enlarge, white. Capillary blood vessels were seen in the testicular wall. In the final stage, the testes become more supple and whiter and occupy 1/5 of the abdominal cavity.	Macroscopically the ovary was elongated and only a few oocytes were seen. Blood vessels look unclear. Histological observation of the ovary was the initial stage of yolk oocyte formation from the germinal epithelium; the yolk egg was covered by a simple squamous follicle epithelium. Oocyte size between 0.01 and 0.45 mm.
Level 3 (Mature)	Testes showed the largest volume with a pinkish-white color. A large number of spermatozoa were observed. The testicles were getting bigger and squiggly. Creamy white. Secondary and tertiary spermatocytes were dominant, whereas primary spermatocytes were few.	The ovary size continues to grow bigger. Yellowish oocytes and blood vessels continue to develop well. Round eggs with rough surfaces, no ovulation yet. The blood vessels combine to form larger capillaries on the external surface of the ovarian wall. Oocytes were clearly visible through the reddish-yellow ovary wall, filling half of the abdominal cavity. Histologically, it was the initial stage of vitellogenesis, yolk egg vacuole seen and fat in ooplasm. Oocyte sized between 0.45 to 1.50 mm.
Level 4 (Spent)	Testes were darker, opaque and flaccid. The testicles widened, most of them appeared springy, but some were soft and very squiggly. There were blood vessels and thick, at a gentle pressure, the cement would radiate. Lumen contained spermatozoa. Most spermatozoa migrate towards the periphery of the lobule.	Macroscopically a large ovary with a thin and transparent membrane. Ovaries were larger, yellow or orange, filled the abdominal cavity, oocyte grains were able to separate from each other, peripheral blood vessels and central clear. Microscopically an increase in egg yolk vesicles that fills the entire ooplasm. Oocytes were matured, most oocytes were in the tertiary vitellogenin stage, oocyte diameter 0.50-1.80 mm.

Estimated rate of exploitation

The main parameters measured were the number of fish and their length and weight. Before determining the estimated rate of exploitation, it was necessary to determine the age group by analyzing the estimated growth rate. The distribution of length was determined with the Bhattacharya method, which separated the composite distribution into a separate normal distribution that represented the fish cohorts (Sparre and Vennema 1999), and the pre-spawn, ready to spawn and post-spawn stages were obtained. Then the asymptotic length (L∞), growth coefficient (K) and theoretical age (t0) were calculated using a Ford Walford plot analysis (King 1995) derived from the Von Bertalanffy model. The exploitation rate estimate was obtained by calculating the mortality rate based on the Beverton and Holt equations, which are based on long-term data (Sparre and Venema 1999). To determine the estimated growth rate, the mortality and exploitation rates of fish were determined using the FISAT II software.

Total mortality (Z) in the Beverton and Holt equations was based on length data (Sparre and Venema 1999):

$$Z = K\frac{L\infty - L}{\bar{L} - L'}$$

Where, Z: total mortality; L: average length; and L': Lower limit of length based on fish length grouping.

The natural mortality rate (M) was analysed using Pauly's (1980) empirical formula:

$$Log\,(M) = -0{,}0066 - 0{,}279\,Log\,L\infty + 0{,}654\,Log\,K + 0{,}4631\,Log\,T$$

Where, L∞ and K: growth parameters; T = average annual water temperature.

The mortality rate caused by fishing activity (F) (Pauly 1980) is:

$$F = Z - M$$

The exploitation rate is:

$$E = \frac{F}{Z}$$

Where, E: Exploitation rate; F: Fishing mortality; M= Natural mortality.

Conservation strategy

The conservation strategy was developed by identifying the reference area, spawning ground and nursery ground-based on population data, including abundance and class length. In addition, based on the exploitation rate data in the waters of Sempor Reservoir, the current fishing arrangements could be classified as overfishing or under fishing.

Data analysis

The data were analyzed descriptively by comparison with relevant references and reports. Abundance data were determined from a statistical analysis using the Kruskal-Wallis test.

RESULTS AND DISCUSSION

Population structure of *Channa striata*

There were differences in the relative abundance of *C. striata* among the five stations based on the results of the Kruskal-Wallis statistical test (P: 0.043; P <0.05). The highest relative abundance of *C. striata* was 32.96 at KW station, followed by KS station 28.42, WO 13.65, KA 13.63 and the smallest at BK station were 11.37. At the KW station, the relative abundance was almost three times higher than at the BK, KA, and WO stations (Table 3).

The abundance of *C. striata* was highest at the KW station and lowest at the BK station due to the location of the KW station in the inlet area of the Kedungwringin River, which resembles a swamp ecosystem. This phenomenon also occurs in Lake Rawa Pening where a large population of snakehead fish is present in shallow habitats covered with water hyacinth and other aquatic plants (Djumanto et al. 2019). The BK station had the lowest abundance due to the absence of the preferred habitat for the fish due to the lack of aquatic plants. This phenomenon has also been observed in Rawa Pening where the number of snakehead fish caught was less in locations where there were not many aquatic plants (Puspaningdiah et al. 2014) and the *Synodontis schall* fish in Tovè River (Southern Benin) (Djidohokpin et al. 2017). In the Batang River, Martapura, the number of snakehead fish caught in a previous study declined at depths of more than 2 m (Ahmadi and Mangkurat 2018).

Table 3. Relatif Abundance of *Channa striata* at five stations in Sempor Reservoir, Banjarnegara District, Central Java, Indonesia

Station	Sampling								Total	Average
	1	2	3	4	5	6	7	8		
KW	0	3.41	6.82	10.23	5.68	0	4.55	2.27	32.96	4.12 ± 3.31
BK	0	2.27	0	3.41	0	0	1.14	4.55	11.37	1.42 ± 1.84
KA	2.27	2.27	2.27	2.27	2.27	1.14	1.14	0	13.63	1.70 ± 0.89
WO	7.95	1.14	1.14	1.14	0	1.14	1.14	0	13.65	1.71 ± 0.56
KS	9.09	4.55	4.55	0	7.95	2.27	0	0	28.41	3.55 ± 3.07

Table 4. Population structure of *Channa striata* by length and sex in Sempor Reservoir, Banjarnegara District, Central Java, Indonesia

Class length (mm)	Station									
	KW		BK		KA		WO		KS	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
110-149	0	0	0	0	0	0	0	0	0	2
150-189	3	1	0	0	0	0	0	0	0	4
190-229	1	0	0	0	1	2	2	4	2	0
230-269	2	6	1	2	1	0	0	2	3	6
270-309	5	3	1	0	1	3	1	1	1	5
310-349	0	2	0	2	0	3	0	1	0	2
350-389	0	2	2	1	0	0	0	1	0	0
390-429	1	3	0	1	0	1	0	0	0	0
Total	12	17	4	6	3	9	3	9	6	19

Table 5. Gonad maturity level (GML) 3 and 4 for different *Channa striata* base class lengths

Male			Female		
Class length (mm)	GML 3	GML 4	Class length (mm)	GML 3	GML 4
110-149	0	0	110-149	0	0
150-189	0	0	150-189	0	0
190-229	0	0	190-229	1	0
230-269	4	0	230-269	1	0
270-309	0	0	270-309	3	0
310-349	1	0	310-349	3	2
350-389	0	1	350-389	0	5
390-429	0	0	390-429	1	1
Total	5	1		8	9

Most male fish were caught at the KW station (12 individuals while female fish tended to be caught at the KS station (19 individuals). The largest male fish were in the size range of 270-309 mm (five individuals) at the KW station, while most female fish were in size range of 230-269 mm (six individuals) (Table 4) (Setyaningrum et al. 2021).

The KW station had the highest number of male and female fish, which varied in size from small to large. This indicates that the area around KW station is a suitable habitat for both the growth and reproduction of snakehead fish, enabling it to maintain its population.

However, in Sempor Reservoir, overall, there were fewer males than females. The larger the size, the fewer fish were caught, and the males that were caught were smaller than the females. The many small males that are caught by fisheries have not yet reached gonad maturity, thus hindering the reproduction process. This has also been observed at Rawa Pening, where the male fish caught were smaller than the female fish (Puspaningdiah 2014). However, the situation was different in a flooded swamp of the Sebangau River, Palangkaraya, where the size distribution was almost balanced and there was even a tendency for male fish to be larger (Selviana et al. 2020). Regulations are required to limit the number of catches and the size of fish caught in Sempor Reservoir. Most fish were caught in the adult, or reproductive stages and some of had reached the age of first gonadal maturity.

The length of the fish at first gonadal maturity is important information in a fish management strategy and is used to determine the level of overfishing or under fishing. This parameter was determined by measuring the length of the fish at gonad maturity Levels (GMLs) 3 and 4 (Table 5).

In all, 23 individuals had a GML of 3 to 4, including 6 males and 17 females. For the female fish, the calculation was based on a length of 277.4 mm, while for male fish, a length of 284 mm was used. Female fish tend to mature more quickly than males.

Based on this parameter, it is recommended that female fish caught should be longer than 277.4, or they should have spawned at least once. This is larger than that of the snakehead fish in the Musi River flooded swamp (Nurdawati et al. 2014) and the Sebangau River flooded swamp, Palangkaraya, but is smaller than in the Rawa Pening (Djumanto et al. 2019). The size of male fish at first gonadal maturity was larger than in the Musi River flooded swamp (Nurdawati et al. 2014) and smaller than in the flooded swamp of the Sebangau River, Palangkaraya (Selviana et al. 2020).

Based on these results and references from other locations, the size of snakehead fish at first gonad maturity varies. This is due to the differences in growth between male and female fish at the age of first gonad maturity. However, at this time point, male and female fish in Sempor Reservoir are still in the same age group (U5), and therefore the reproductive process is not disturbed. Based on age group, most (44.32%) of the snakehead fish were caught in the U3 (190-229 mm) and U4 (230-269 mm) age groups (Table 4). This indicates that the fish caught had immature gonads, and there is no opportunity for these fish to reproduce. The intensity of fishing needs to be limited so that the fish caught are mature or have spawned at least once (King 2003).

Snakehead fish population data were not analyzed monthly because snakehead samples were not obtained in every month. Therefore, this study could not determine the peak of snakehead fish spawning. However, a previous study reported that a snakehead is a fish group that spawns all over the year characterized by having a small Gonado Somato Index (GSI) (Puspaningdiah et al. 2014). It had been found that brood-stock ready spawn was observed monthly and it was estimated that the peak of spawning occurs in the rainy season, the diameter of the eggs varies from 0.65-1.34 mm so that the spawning is partial spawner (Djumanto et al. 2020). The spawning season for snakehead fish takes place in August-October and the peak season was in October (Selviana et al. 2020). So from August to October it can be recommended to ban snakehead fishing as a conservation policy in the Sempor Reservoir.

Estimated exploitation rate of *Channa striata*

From the length distribution of snakehead fish in Sempor Reservoir, it was possible to classify individuals into eight age groups. The KW station had the most variation in age group (from U2 to U8), while the BK, KA and WO stations only had individuals in the U5 to U8 age groups, while the KS station had individuals in the U1 to U6 groups. The age group with the highest frequency in Sempor Reservoir (26.14%) was the U4 age group, with a length of 230-269 mm. This is the pre-reproductive phase and individuals from this class were present at all stations. The lowest frequency (2.27%) was the U1 age group, with a length of 110-149 mm. This is the juvenile stage and individuals from this class were only found at the KS station (Table 6).

The population of snakehead fish at the KW station has varied age groups, which indicates that the good population. The BK, KA and WO stations tended to have more individuals in the reproductive stages ready to spawn. Many of these fish were caught for consumption, thus hampering the reproductive process and production of offspring. The KS station did not contain any U7 and U8 fish. It is possible that the fish did not reach adult size at this location because too many were caught. This result is similar to that reported in the Musi River flooded swamp, where many fish are caught at the reproductive stage in the U3-U6 age group, with an average length of 156-350 mm (Nurdawati et al. 2014).

Based on these results, the population of snakehead fish in the Sempor Reservoir was classified as abnormal because there were few individuals in the age group U1 (juvenile) and the adult age groups U7 and U8. This shows an imbalance in the proportion of age groups, with the recruitment pattern disrupted because many fish that are ready to spawn are caught.

Most individuals in the snakehead fish population in Sempor Reservoir were classified as mature fish that were ready to spawn. The availability of the eight age groups of snakehead fish in Sempor Reservoir was likely related to its ability to spawn throughout the year (Puspaningdiah 2014). This phenomenon also occurs in the population in the Musi River flooded swamp, where eight age groups are also present (Nurdawati et al. 2014) and in Aopa Swamp (Cia et al. 2018). Size can be used as a reference for limiting the number of snakehead fish caught by fishermen.

The growth coefficient value (K) was 2.3/year with an L∞ of 409.5 mm, which was achieved within 25 months with a theoretical age (t0) of -0.0326 years. The equation for the population growth of snakehead fish was as follows: Lt: 409.5 (1-e-2.3(t -0.0326) (Figure 3).

The L∞ was 409.5 mm, in this research, the largest fish caught had a length of 390 mm. This indicates that the fish had almost reached its maximum size and had reached the size of first gonad maturity. However, snakehead fish can still increase in length, the longest snakehead fish ever found measuring 620 mm in Sempor Reservoir (Setyaningrum et al. 2020). The L∞ of snakehead fish in Sempor Reservoir was lower than that of snakehead fish in Rawa Pening (Djumanto et al. 2020), and in the Musi River flooded swamp (Nurdawati et al. 2014). This difference was likely caused by the conditions in Sempor Reservoir, which do not resemble a swamp habitat. Rawa Dizziness and Musi River flooded swamp are stagnant waters that contain many aquatic plants (Saputra et al. 2021).

The equation for the growth rate of snakehead fish was Lt: 409.5(1-e-2.3(t-0.0326)), indicating that the fish in Sempor Reservoir grew relatively quickly, with a growth coefficient of 2.3 mm/year. Fish with a K value of 0.5 typically have a fast growth pattern and the higher the growth coefficient, the faster they reach their L∞ (Sparre and Venema 1999). The fish in the Musi River flooded swamp and Rawa Pening had growth coefficients of 0.173 and 0.923 mm/year, respectively (Nurdawati et al. 2014; Djumanto et al. 2020). The differences in these growth coefficients were because the fish samples obtained in these studies had reached the juvenile stage with a length of 110 mm, and therefore the growth rate from the larval to juvenile stages was not depicted. The growth rates of male and female fish differed. The L∞ of male fish was 402 mm, the growth coefficient was 0.7 mm/year and t0 was -0.054, while the female fish had an L∞ of 410 mm, growth coefficient of 2.0 mm/yr and t0 of -0.038 (Figure 4).

Females grew faster than males. The L∞ of females was reached at 25 months, while males reached the same stage at 61 months. In general, female fish grow faster because they tend to be less-active hunters than males. They also prey on aquatic animals such as crustaceans, which have a higher protein content than typical fish food, while male fish prey on other fish (Mohanty et al. 2017).

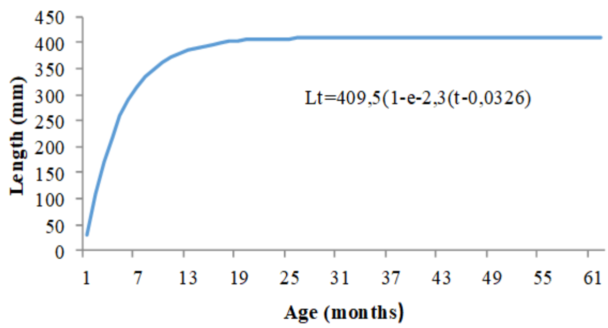

Figure 3. Simulation of the growth rate in length (mm) of *Channa striata* in Sempor Reservoir, Banjarnegara District, Central Java, Indonesia

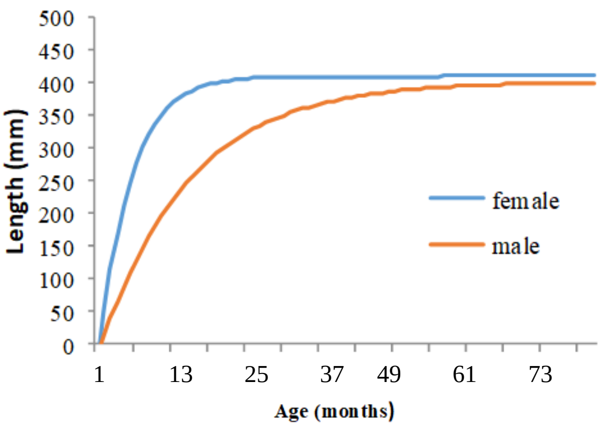

Figure 4. The estimated growth rate of *Channa striata a* for both sexes in Sempor Reservoir, Banjarnegara District, Central Java, Indonesia

Table 6. Age groups based on the frequency distribution of fish lengths in Sempor Reservoir, Central Java, Indonesia

Age group	Class length (mm)	Station/frequency (%)					Total freq. (%)
		KW	BK	KA	WO	KS	
U1	110-149	0	0	0	0	2.27	2.27
U2	150-189	2.27	0	0	0	2.27	4.55
U3	190-229	3.41	0	3.41	6.82	4.55	18.18
U4	230-269	9.10	3.41	1.11	2.27	10.23	26.14
U5	270-309	9.10	1.11	4.55	2.27	6.82	23.86
U6	310-349	2.27	2.27	3.41	1.14	2.27	11.36
U7	350-389	2.27	3.41	0	1.14	0	6.82
U8	390-429	4.55	1.14	1.14	0	0	6.82

The mortality rate of *C. striata* was calculated to determine the rate of exploitation using a Beverton and Holt analysis based on length data. The calculation obtained total mortality (Z) of 5.8/year, natural mortality (M) of 1.51/year and mortality due to fishing (F) of 4.29/year. Thus, mortality due to fishing is higher than natural mortality. The high fishing mortality and low natural mortality indicate that growth overfishing has occurred (Ahmad et al. 2018; Cia et al. 2018). This results in a decrease in the population of snakehead fish in the age group U4 to U6 with a size of 230-349 mm (Table 1), which had reached gonad maturity for the first time. This size of snakehead fish was most commonly caught by fishermen, resulting in very few snakehead fish in the U1 group (110-149 mm) at the tiller stage (two individuals).

The exploitation rate of snakehead fish in Sempor Reservoir was E: 0.74, which was classified as overfishing because it exceeded the 0.5 limits. This is higher than the exploitation rate in the Musi River flooded swamp (E: 0.67; Nurdawati et al. 2014) and Lubuk Lampam flooded swamp (E: 0.58; Fahmi et al. 2013). Market demand is largely met by the snakehead fish caught in nature, and therefore the exploitation rate has increased over time (Fahmi et al. 2013). The snakehead fish catch increased from 7327 tons to 16,528 tons during 2000 to 2004 (FAO 2005) and from 6490 tons to 21,987 tons during 2015 to 2019 (KKP 2020). Similar results have been observed for the economically important fish *Siganus canaliculatus* in Ambon Bay, which can reach maturity at the age of six months and has high mortality and exploitation rates (Latuconsina et al. 2020, 2022), as well as in tilapia in Siombak Tropical Coastal Lake, North Sumatra, Indonesia (Muhtadi et al. 2022). High exploitation rate is the cause of low genetic variation in *C. striata*, as happened between central west Peninsular Malaysia and Malaysian Borneo populations implied anthropogenic activities (Tan et al. 2012).

The exploitation rate of snakehead fish in Sempor Reservoir was enhanced by the use of fishing gear that is not environmentally sustainable. The fishermen there use fishing rods with varying hook sizes (0.1-1 cm), and therefore various sizes of fish are caught, with some having reached the stage of first gonadal development. In Sempor Reservoir, it would be advisable to catch fish at the adult stage (size of 300 mm). The intensity of fishing needs to be limited to ensure that it does not lead to recruitment overfishing in both reservoirs and rivers (Phomikong et al. 2014; Cia et al. 2018; Rusmilyansari et al. 2021).

Conservation efforts need integrated management strategies so that the ecological and economic functions of these natural resources can be preserved to support the lives of future generations. An important strategy in the management of Sempor Reservoir is to take into account the carrying capacity of the environment, which will ensure that there will be a balance between capture and conservation that remains sustainable. The conservation measures that need to be conducted are limiting the number of catches; limiting the size of fish caught related to the age of the fish (i.e., the prohibition of catching fish measuring 230-349 mm); limiting the timing of the catch, particularly in the dry season; and restricting the size and type of fishing gear. In addition, efforts should be made to domesticate snakehead fish, enabling them to remain sustainable in the future, particularly in Java. Domestication efforts have been carried out on snakehead (*C. strita*) in Cambodia based on the high genetic diversity in the Mekong Basin (Duong et al. 2019) and development of seed mass production of snakehead in the Sunda Plate (Sumatra, Java, and Kalimantan) (Saputra et al. 2021).

This study found a healthy population of *C. striata* at the KW station, but in the reservoir overall, the population was relatively unhealthy in terms of abundance, age, size and weight. The exploitation rate of *C. striata* in Sempor Reservoir was 0.74, which indicates overfishing, and the decrease in the population could eventually lead to extinction. A conservation strategy is proposed that limits the catch by 44% and prohibits the catching of individuals with a length of 230-349 mm. Conservation strategies are based on abundance and size distribution. The KW station is recommended as a reference area because it had the largest abundance with a complete size distribution, namely, the pre-reproduction, reproduction and post-reproduction stages. The BK station was the spawning ground with many fish in the reproductive stage and the KS station had the most juvenile fish (pre-reproductive stages) and was therefore considered a nursery.

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