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Population structure and exploitation rate of striped snakehead (*Channa striata*) in Kawunganten Swamp, Cilacap, Indonesia: Important for fisheries management

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Abstract. *Setyaningrum N, Sugiharto, Susatyo P. 2024. Population structure and exploitation rate of striped snakehead (*Channa striata*) in Kawunganten Swamp, Cilacap, Indonesia: Important for fisheries management. Biodiversitas 25: 3255-3263.* Snakehead (*Channa striata*) is a swamp fish spread in almost all Indonesian waters and has a high economic value. In addition, Bringkeng, Grugu, and Babakan Villages are included in Kawunganten Swamp areas with good fishing potential. Therefore, this study aimed to determine the population structure and the exploitation rate of *Channa striata* in Kawunganten Swamp Cilacap, Indonesia. The survey method with purposive random sampling was used and this study was conducted from April to July 2020. The fish samples were collected from three Bringkeng, Grugu, and Babakan Swamp stations, while the variables examined were abundance and rate of exploitation. The parameters measured included the length of *Channa striata* as well as the growth and mortality rate in each swamp. Abundance was analyzed using the Kruskal-Wallis test, and exploitation rate was assessed with Pauly's model using FAO-ICLARM Stock Assessment Tools II (FISAT II). The results showed that the highest abundance of *Channa striata* was in Bringkeng station, three times higher than in Babakan station. Bringkeng and Babakan stations were considered a fish-rearing swamp due to the dominance of adolescence-sized samples. Grugu was identified as the breeding area because many of the fish present were in the reproductive phase. Estimated growth parameters showed a maximum length ($L\infty$) of 35.18 cm, while exploitation rate of 0.28 was not considered excessive capture. Efforts to manage *Channa striata* were important to preserving biodiversity and ensuring the sustainability of Kawunganten Swamp ecosystem for future generations.

Keywords: Abundance, exploitation, growth, management, mortality, sustainable *Channa striata*, swamp

INTRODUCTION

Channa striata, a commonly called striped snakehead, is found extensively across Indonesian territory and is indigenous to the Sunda Islands including Sumatera, Java, and Kalimantan (Irmawati et al. 2022). The length of *C. striata* can reach around 100 cm, generally a total length of 61 cm, but in several studies the length of snakehead fish is smaller. This small size occurs in the waters of Sempor Reservoir (39-40.9 cm) and Rawa Pening (24.2-64.8 cm) (Kottelat and Whitten 1996; Djumanto et al. 2019; Setyaningrum et al. 2022a). The spawning season for *C. striata* occurs during the rainy season with the peak period occurring from February to April. In floodplain ecosystems, spawning occurs throughout the year, while the peak frequency of spawning occurs in the rainy season. This can be seen from observations of egg diameter which was found to vary each month (Kuan-Chung et al. 2016; Selviana et al. 2020). This species plays an important role in swamp ecosystems as a freshwater fish and holds a high economic value due to its popularity among communities. The meat contains high albumin, which is important for post-operative wound healing (Muflikhah 2007; Boonkusol and Tongbai 2016). This condition has led to increased market demand, causing natural population decline due to high fishing activities (Fahmi et al. 2013). Fishing is very important for the community as a livelihood and as an addition to family nutrition. The lack of catch data information in small-scale fisheries often results in management strategies (Prasad et al. 2012). Information about fish production in several waters is very important, including swamp waters, to assess the rate of exploitation and management. The main threats to the fisheries sector are irresponsible fishing, environmental degradation and pollution which results in a decline in fish populations (Renjithkumar et al. 2016).

Several studies in other regions have proven that snake-head fishing has caused overfishing (Renjithkumar et al. 2011; Nurdawati 2014; Sofarini et al. 2018; Rais and Wulandari 2020), leading to concerns over a potential decline in population (Djidohokpin et al. 2017). However, no study has evaluated the impact of fishing activities on the wild population of striped snakehead in Kawunganten, Cilacap District, Central Java, Indonesia. This shows that there is a need to assess the effects of fishing activities in this area.

Kawunganten Sub-district is about 29 kilometers north of the capital of the Cilacap District. The region is passed by the Cibeureum River, which is a subsidiary of the Citanduy River. This condition creates broad areas of swampy ecosystem, specifically in the Bringkeng, Grugu, and Babakan Villages, which have a high potential for marsh or swampy fishing, specifically in the rainy season. Fishers use various fishing gear, such as fishing rods, traps, and spread nets. The numerous fish species often collected include nile tilapia (*Orechromis niloticus*), climbing perch (*Anabas* *testudineus*), snakeskin gourami (*Trichopodus trichopterus*), silver barb (*Barbonymus gonionotus*), eels (*Anguilla anguilla*), and striped snakehead (*Channa striata*). Fish production, including snakehead, in 2005 amounted to 81,359 kg, and in 2006 increased to 189,779 kg (Wahyudi et al. 2021).

The impact of fishing activities on striped snakehead wild population can be assessed through population structure and exploitation rate study. Population structure may be estimated using the class of body length, sex ratio, and age groups (Setyaningrum et al. 2022b), while exploitation rate is evaluated based on growth rate, recruitment pattern, and mortality (Fahmi et al. 2013; Cottet et al. 2016). Studies of population structure and exploitation rate of snakehead in Kawunganten Swampy areas are important for managing and preserving these fisheries resource.

This study aimed to determine abundance and length of *Channa striata*, evaluate the estimated rate of growth and mortality, as well as assess rate of exploitation for proper management of population in Kawunganten Swamp, Cilacap, Central Java, Indonesia.

MATERIALS AND METHODS

Study area

This study was conducted in Kawunganten Sub-district Cilacap District, Central Java, Indonesia, during the rainy season from April to July 2020, the dry season snakehead fish are not found. *Channa striata* samples were collected purposively from tree villages namely Bringkeng, Grugu, and Babakan (Figure 1). Sampling sites were determined based on their ecological characteristics, specifically aquatic vegetation covers. The geographic position and habitat characteristics of each sampling site are presented in Table 1.

Procedures

Fish sampling

The fish sampling locations were in the villages of Bringkeng, Grugu and Babakan in areas that have vegetation cover such as water hyacinth (*Eichhornia crassipes*) as a suitable habitat for snakehead fish (Djumanto et al. 2019). Fish samples were taken at intervals of 15 days for four months. In the study area fishermen catch snakehead fish using fishing rods, while other types of fish use gill nets or traps. The tools used to catch fish are adjusted to the type and size of fish caught according to research by Ferdous et al. (2023). Fish samples were caught using a fishing rod with a 0.5-1 cm hook size. A total of 50 fishing rods were installed in each sampling site. Each region had nine fishers, and samples were taken randomly from four fishers. Each line was baited with live frogs or earthworms. Frog and earthworm bait are obtained from their territory or other areas, and some fishers use artificial frogs so as not to disturb the population. Installation was conducted in the afternoon and lifted every six hours at night (11.00 pm) and in the morning (05.00 am). The fish were separated according to sampling sites and put into an icebox filled with ice, followed by lab measurements.

Table 1. Geographic position and ecological characteristics of sampling sites in Kawunganten Sub-district Cilacap District, Central Java, Indonesia

Station	Location	Coordinate	Habitat characteristics
I	Bringkeng Village	7°37'18"S-108°55'24"E	It is located near suburbs and settlements. Weeds and grasses cover the water's surface, and the pit is 2 meters wide.
II	Grugu Village	7°38'41"S-108°50'42"E	It is located far from the settlement, water weeds partially cover the water surface, and the breadth of the dam is 6 meters.
III	Babakan Village	7°40'7"S-108°54'37"E	It is located close to rivers and shrubs, the water's surface is only slightly covered with water weeds, and the slope is 6 meters wide.

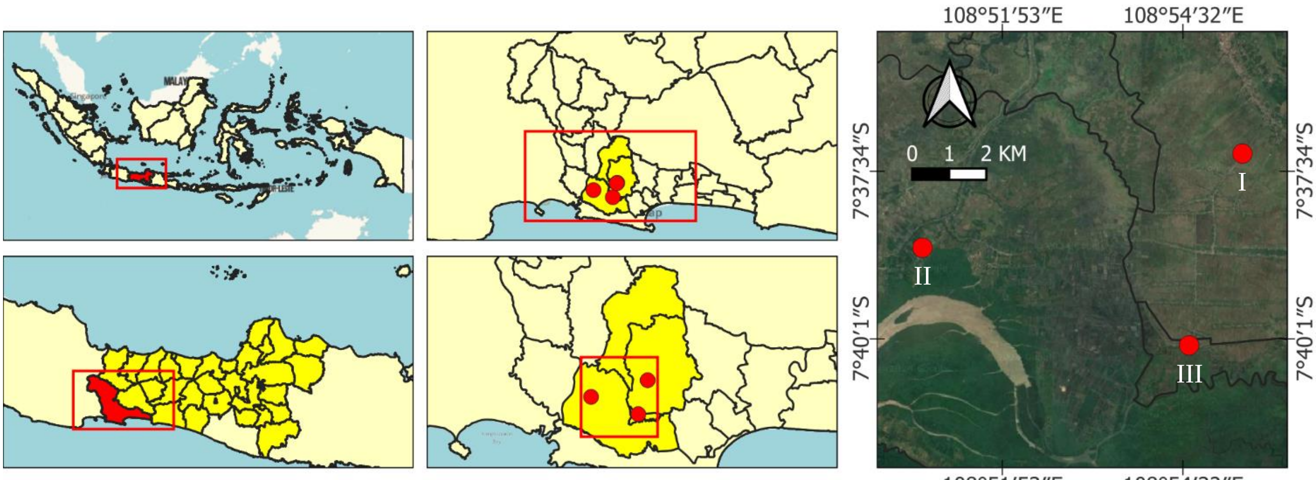

Figure 1. Map of sampling locations in in Kawunganten Sub-district Cilacap District, Central Java, Indonesia

Fish measurement

The total body length was measured using a ruler with a precision of 0.1 cm. Fish sexuality was estimated based on the morphology of male or female gonads observed through dissection. The fish was dissected starting from the anus to the base of the thorax, then from the underside of the thorax, it was cut open to the right and left sides, approaching the operculum without damaging the internal organs. Subsequently, the gonads were taken and observed morphologically, with white signaling mature male snakehead fish, and yellow showing female.

Fish abundance

The number of individuals obtained during the sampling determined abundance of fish at each sampling station. The percentage of fish abundance can be used to determine the status of their availability in waters and based on respondents' opinions, the frequency of their occurrence is categorized into 4 classes. The categories were defined as Abundantly Available (AA): species consistently observed year-round, repeating over 75% of the time; Commonly Available (CA): species frequently seen but in smaller quantities, repeating 51-75% of the time; Moderately Available (MA): species encountered occasionally, with a repetition rate ranging from 26 to 50%; and Rarely Available (RA): species observed infrequently, repeating in small amounts at a repetition rate equal to or less than 25% (Pandit et al. 2020, 2021).

Distribution of body length

The length distribution of the body was determined to obtain the length class, using the formula of Simanjuntak (2020), as follows:

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

Where: K: the number of length classes; n: the amount of long data

The class length for each class was determined by the formula:

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

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

Fish growth and mortality

Estimates of growth rate and mortality are used to determine rate of exploitation, while an analysis of estimated growth rate is required to assess the age of the fish. Based on the long-sized spread by the Bhattacharya method, the composite distribution is a separate normal distribution representing a fish cohort (Sparre and Venema 1999). The asymptotic length (L∞), growth coefficient (K), and theoretical life (t0) were then calculated using Ford-Walford plot analysis (King 2003) derived from Von Bertalanffy's model.

$$Lt = L\infty(1 - e - K^{(t-t0)})$$

Where: Lt: length of the fish at age t; L∞: theoretical maximum length (asymptotic length), K: growth coefficient (per unit time), t0: theoretical life when length is equal to zero

An estimate of exploitation rate was obtained by calculating the mortality rate following the Beverton and Holt equations based on long data (Sparre and Venema 1999). Growth rate, mortality, and exploitation of fish were estimated using FISAT II software.

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

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

Where: Z: total death; L: average length; L': the lower length limit based on the grouping of fish lengths

The natural mortality rate (M) was analyzed using the empirical formula Pauly (1980):

$$\log(M) = -0.0066 - 0.279 \, Log \, L\infty + 0.654 \, Log \, K + 0.4631 \, Log \, T$$

Where: L∞ and K are growth parameters; T: average annual water temperature

Deaths from fishing activities (F) (Pauly 1980) were collected using the formula:

$$Z = F\text{-}M$$

The level of exploitation is:

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

Where: E: the degree of exploitation; F: fishing death; M: natural death

Recruitment patterns were estimated with FISAT II software, by reconstructing time series data from long frequency data. Growth parameter data in the form of L∞, K, and to obtained from the results of length frequency data analysis are then used to reconstruct recruitment patterns (Gayanilo et al. 2005).

Fisheries management

Based on population structure data, fisheries management was developed by identifying reference areas, cultivation sites, and nursery grounds. In addition, through data on growth and mortality rate, exploitation rate and habitat management in Kawunganten Rawa were obtained.

Data analysis

The data were analyzed descriptively by comparing with relevant articles in the journal. Data abundance were determined from statistical analysis using Kruskal-Walli's test, and rate of exploitation was analyzed with Pauly's model through FISAT II (FAO-ICLARM Stock Assessment Tools) software-ELEFAN I (Electric Length Frequency Analysis) (Bonilla and Perezrul 2003; Setyohadi et al. 2024).

RESULTS AND DISCUSSION

Population structure *Channa striata*

A total of 158 snakehead samples were collected at three stations, consisting of 83 males and 75 females. The number of individuals obtained in this study was higher than those reported from Sempor Reservoir (Setyaningrum et al. 2022a). The difference could be attributed to the variation in the habitat condition. Sempor Reservoir is deeper than swampy areas, while snakehead prefers shallow and muddy habitats. This habitat condition was observed in swampy ecosystem of Kawunganten, resulting in a higher abundance of striped snakehead compared to Sempor Reservoir.

Previous studies in Rawa Pening, a swampy ecosystem (Puspaningdiah et al. 2014; Djumanto et al. 2020), found more of striped snakehead individuals, because the research time was longer (10 months). These results show swamp is the primary habitat. As stated by previous studies, *Channa striata* is a permanent inhabitant of river floodplains, usually swampy areas (Chan et al. 2017; Hossain et al. 2017).

Kruskal-Wallis test proved that striped snakehead abundance significantly differed among sampling sites ($P<0.05$). Bringkeng station had the highest abundance, while the lowest was at Babakan (Table 3). This result is in line with the distribution of snakehead fish availability in Bringkeng 53.81% commonly available, Grugu 29.11% moderately available, Babakan 17.11% rarely available.

The high fish abundance in Bringkeng station was attributed to its status as the most suitable habitat. This sampling station was characterized by shallow depth and mainly covered by aquatic weeds as well as grass. Aquatic habitats with dominant water plant cover are the most preferred for snakehead fish. This phenomenon was observed in the Rawa Pening waters and part of the Sempor Waduk Waters, where population was mostly in shallow waters composed of water hyacinth and other aquatic plants (Djumanto et al. 2020; Setyaningrum et al. 2022a). The Babakan station had the lowest abundance due to the small amount of aquatic plants, and the proximity of the area to the sea, resulting in susceptibility to flooding during waterfall events. The Chanidae, including *Channa striata*, face challenges in surviving saline water and typically thrive in the eastern Himalayan Mountains (Rüber et al. 2020). This pattern is evident in locations such as Rawa Pening (Puspaningdiah et al. 2014), Lubuk Lampam Sumatra (Fahmi et al. 2013), and Rawa Aopa (Cia and Asriyana 2018). The availability of snakehead fish in Bringkeng, Grugu and Babakan reflects the decreasing population in areas close to the sea such as in Babakan. This trend shows that commonly available fish can be distributed in several waters in Kawunganten Sub-district according to their habitat. In line with research by Pandit et al. (2020) that the Gurukchi River shows commonly available fish types (28.07%), moderately available (22.81%), and rarely available (19.30%). Similarly, Pandit et al. (2021) documented 17.4% abundantly available, 27.5% commonly available, 31.9% moderately available, and 23.1% rarely available fish species in the Dhanu River and surrounding areas. *Channa striata* in the rainy season (April and July) based on the statistical test of Kruskal-Wallis showed no difference in abundance ($P>0.05$). The value remained in the same range every month (Table 2).

A similar phenomenon occurred in Rawa Pening, where population of snakehead was almost the same every month (Djumanto et al. 2019). This condition could be attributed to the reproductive process, wherein the fish engage in annual reproduction to preserve population. Snakehead typically initiates spawning early in the rainy season, with harvesting commencing during this period (Nurdawati et al. 2014). During the dry season, the fish use this time for gonadal development, with the melting season spanning from August to October, and reaching its peak in October (Selviana et al. 2020; Sunarni et al. 2021). The 2021 Maturity Stage (MS) in November was dominated by the early gonad maturity in the reovulation process. This stage showed that snakehead was ready for cultivation, and was associated with long-sized spreads

Based on the results, the highest male abundance was found at Bringkeng station (5 individuals), while the highest number of female fish were caught at Grugu (34 indv). The largest male size was 24-27.9 cm (29 indv) at Bringkeng station, and the largest female size was 32-39.9 cm (22 indv) at Grugu (Table 5).

Bringkeng station had the most abundant males and females but were small in size. This suggested that the area around Bringkeng station served as a site for *Channa striata* growth. Samples from Grugu station had large male and female body sizes, but the number was few. Therefore, this area was assumed to be a breeding location.

Table 2. Abundance of *Channa striata* based on the moon in Kawunganten Swamp, Cilacap, Central Java, Indonesia

Station	Gender	April	May	June	July
Bringkeng	♂	9	16	15	16
	♀	3	7	14	5
Grugu	♂	1	0	7	4
	♀	10	10	8	6
Babakan	♂	4	1	5	5
	♀	3	0	3	6
	Total	30	34	52	42

Table 3. Abundance of *Channa striata* in Kawunganten Swamp, Cilacap, Central Java, Indonesia

Sampling Station	Repetition				Present status	Number	Average
	1	2	3	4			
Bringkeng	12	23	29	21	CA	85	21.25 ± 7.04^a
Grugu	11	10	15	10	MA	46	11.5 ± 2.38^b
Babakan	7	1	8	11	RA	27	6.75 ± 4.19^c

Note: Different letters in superscript show significant t differences; CA: Commonly Available, MA: Moderately Available, RA: Rarely Available

Table 4. Age group *Channa striata* based on length in Kawunganten Swamp, Cilacap, Central Java, Indonesia

Age group	Class length (cm)	Station			Frequency	Total frequency (%)
		Bringkeng	Grugu	Babakan		
U1	8-11.9	1	0	0	1	0.63
U2	12-15.9	0	0	0	0	0
U3	16-19.9	1	0	0	1	0.63
U4	20-23.9	38	2	3	43	27.22
U5	24-27.9	41	8	14	63	39.87
U6	28-31.9	4	8	5	17	10.76
U7	32-35.9	0	14	1	15	9.49
U8	36-39.9	0	12	4	16	10.13
U9	40-43.9	0	2	0	2	1.27
	Total	85	46	27	158	

Table 5. Size distribution of *Channa striata* by sex in Kawunganten Swamp, Cilacap, Central Java, Indonesia

Class length (cm)	Bringkeng		Grugu		Babakan	
	♂	♀	♂	♀	♂	♀
8-11.9	1	0	0	0	0	0
12-15.9	0	0	0	0	0	0
16-19.9	1	0	0	0	0	0
20-23.9	20	18	1	1	3	0
24-27.9	29	12	3	5	9	5
28-31.9	3	1	4	4	2	3
32-35.9	0	0	3	11	0	1
36-39.9	0	0	1	11	2	2
40-43.9	0	0	0	2	0	0
Total	54	31	12	34	16	11

In general, as observed in Kawunganten Swamp, there were more males than females, but the size of the males was smaller. Many male fish caught had not yet reached gonad maturity, thereby inhibiting reproductive processes. The first ripe gonad male was 28.4 cm, while the female was 27.7 cm (Setyaningrum et al. 2022a) in the Rawa Pening (Djumanto et al. 2019), Merauke Swamp (Sunarni et al. 2021), and Sempor Reservoir (Setyaningrum et al. 2022). However, a different result was obtained in Lake Kilobidan, Agusan Marsh, Philippines (Dumalagan et al. 2017), swamp of Sebangau River whose spread was almost equal in size (Selviana et al. 2020). Regulation is needed to limit the number of catches and the size of fish in Kawunganten Swamp. The majority of the fish caught were small and had not yet matured their gonads, resulting in the inability to reproduce.

The length-size distribution of snakehead in Kawunganten Swamp was grouped into nine age groups. The Grugu station had a more varied age group (U4-U9) but no juvenile size, while the Bringkeng station had individuals in the age group U1-U5 but no adult size, and the Babakan station had a higher prevalence of U4-U8 but no juvenile size. The age group with the highest frequency was U5 (39.87%), with a length of 24-27.9 cm. This group belonged to the pre-reproduction phase and was present at all stations. The lowest age group, namely U1-U3 (0.13%) with a length of 8-19.9 cm was found only at Bringkeng station, while the U2 group had no individuals caught at all stations (Table 4).

Snakehead fish population at Bringkeng stations with small sizes were included in the juvenile to pre-reproduction phase. This phenomenon occurred in the outlet area of the Sempor reservoir, dominated by the size of 11-26.9 cm (Setyaningrum et al. 2022a). Grugu and Babakan stations tend to have more individuals in the reproductive phase. These fish were caught extensively for consumption, thereby inhibiting the reproductive process to produce offspring. Similar results were found in the Floodplain of the Sebangau River Palangkaraya, where the first signs of gonad maturity in snakehead occurred at a size of 27.72-32.17 cm. (Selviana et al. 2020) and in Sempor Reservoir at 27.7-28.4 cm (Setyaningrum et al. 2022a). This station did not contain a juvenile group, hence, it could be used as a spawning area.

The results showed that snakehead population in Kawunganten Swamp was unusual. The juvenile individual U1-U3 and the adult U9 were not found, resulting in an imbalance between the age groups. This phenomenon caused recruits to be disturbed, as fish that were ready to lay eggs and spawn were caught. Therefore, urgent measures are needed to conserve snakehead fish resources. It is crucial to allow some fish to grow to a size equal to or larger than the first maturity gonads for reproduction without disrupting the proliferation process that could endanger the sustainability of fish resources. This condition was underscored by the research of Nurdawati et al. (2014), which warns that low spawning stock conditions can lead to the inability to produce fry fish (recruitment) in the future, a dangerous situation that could ultimately result in overfishing.

Estimates of growth and mortality

The growth coefficient (K) value was 1.0, with a maximum length ($L\infty$) of 45.18 cm achieved in two years, with a theoretical score of-0.0877. Furthermore, by using the growth equation obtained, a key can be prepared to estimate the relationship between total fish length (cm) and age (years) using several variations of age value (t). Population prediction curve equation is as follows: Lt: $45.18(1\text{-e-}1.0^{(t-0.0877)})$ (Figure 1).

The growth rate of snakehead was relatively fast, in the first year it is very rapid then gradually decreases as the fish older. Based on the result, fish with a K value of 0.5 usually have a rapid growth pattern. The higher the growth coefficient, the shorter the duration to reach maximum length ($L\infty$) because the time required to reach maximum length is short (Sparre and Venema 1999). The maximum length was 45.18 cm, and the largest size was 39.3 cm predicted to be 4 years old. After 4 years of age, the length of the fish grows closer to its maximum length. The fish had entered the gonadal maturity phase, but the catch could still grow up to the maximum length. Java Island, Indonesia, experiences the yearly drought season from May to August, marked by water shortages in the river, stream, or lake area. During the dry season, fish enter the developmental stage and partly into the resting phase (Djumanto et al. 2020; Sunarni et al. 2021).

The maximum length of snakehead in Kawunganten Swamp was more prominent than L∞ snakehead in the Sempor Reservoir. This was because Sempor Waters did not resemble the swamp present in the native habitat. However, the value was lower in Rawa Pening (Djumanto et al. 2020) and Lubuk Lampam Floodplain, South Sumatra (Fahmi et al. 2013). These differences were attributed to variations in the capture device used for sampling, which consequently affected the size of the fish caught and the length of the catch time sampled (Djumanto et al. 2020). This study used a fishing rod capture device with a specific eye size and a spear device. High abundance causes very high intra-and inter-species food competition. The main food of snakehead fish is small fish, insects, worms, macrophytes and crustaceans (Putriani et al. 2023). During the monsoon season, the availability of natural feed was limited, while the rainy season led to the transfer of feed elements from land to water, increased water fertility, and natural feed abundance. This condition occurred in the Lubuk Lampam floodplain (Fahmi et al. 2013) and Rawa Pening (Djumanto et al. 2019). Even though the availability of natural food in Rawa Kawunganten is abundant, competition between individual fish is high, causing the energy from obtaining natural food to be insufficient to support maximum fish body growth, so that the growth in length of the fish also becomes relatively shorter. Insufficient energy intake from natural food will inhibit fish growth, gonad maturity is not simultaneous, the reproductive period is short, maximum length and weight cannot reach a larger size (Djumanto et al. 2014).

The growth rate of male and female fish was different, for males, L∞ was 43.4 cm, while the growth coefficient was 0.5 cm/year and t0-0.4036. On the other hand, females had L∞ 39.3 cm, with a growth coefficient of 0.5 cm/year and t0-0.3371 (Figure 2).

The growth rate of females tended to be higher than that of males, with L∞ reaching 2.5 years and 3.5 years, respectively. The maximum length of males was longer than that of females, but females had faster growth. One important factor that influenced this disparity was the type of feed and the level of activity. The males were more active in hunting prey, while the females dwell under the flocks of goats (Djumanto et al. 2020).

Exploitation rate

The mortality rate of *Channa striata* was calculated to determine the level of exploitation using Beverton and Holt analysis based on long-term data. From the calculation, total (Z) deaths were 1.90/year, natural (M) mortality was 1.70/year, and fishing deaths (F) were 0.20/year (Figure 3), showing that natural fish deaths were higher than those caused by capture. Natural mortality rate is classified as expected when the ratio to growth rate ranges from 1.5 to 2.5. (Beverton and Holt 1957; Djumanto et al. 2014; Asrial et al. 2021). In this study, the ratio of the natural mortality to the growth rate was 1.0, hence, the natural mortality rate was considered abnormal.

Natural mortality can be caused by poor water quality, specifically dissolved oxygen, which potentially affects the health conditions of snakehead fish (Fahmi et al. 2013). Dissolved oxygen in Kawunganten Swamp falls below 5 ml/L (PP 2021). Low soluble oxygen levels can cause stress and susceptibility to disease, increasing the risk of natural mortality (Anggana and Susanti 2020; Waltham and Schaffer 2021).

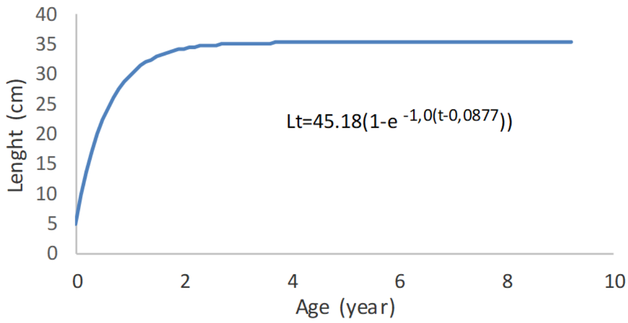

Figure 1. Growth of *Channa striata* in Kawunganten Swamp, Cilacap, Central Java, Indonesia

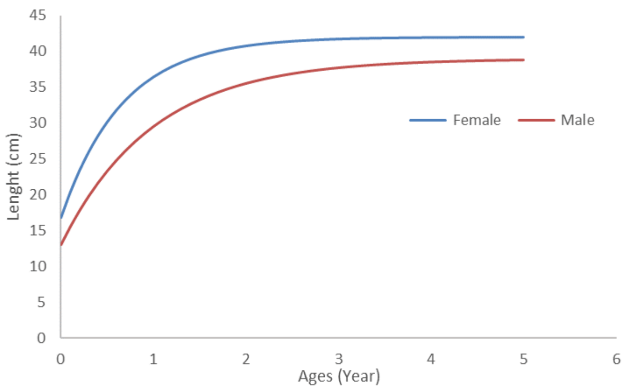

Figure 2. Growth of males and females in Kawunganten Swamp, Cilacap, Central Java, Indonesia

Fishing mortality is caused by the activities of fishermen and anglers. The rate of snakehead fish catching by anglers is very high because it has a high selling value compared to other types of swamp fish such as climbing perch (*Anabas testudineus*), nile tilapia and snakeskin gourami (*Trichopodus trichopterus*). Snakehead fish exploitation rate in Kawunganten Swamp, denoted by E: 0,11, was below 0.5, showing that overfishing was not a concern. Fishing in Kawunganten Swamp for commercial purposes is relatively small and remains under low exploitation pressure. This condition was consistent with the fact that part-time fishermen mainly carry out fishing activities in the field. The estimate of the E value obtained was relative, but it could be a rough representation of exploitation.

The estimation pattern of recruitment presented in Figure 4 showed a single refinance in a year. Recruitment patterns were estimated with the help of FISAT II software, by reconstructing time series data from length frequency data, growth parameters in the form of L∞, K, and to. Snakehead fish populations in Kawunganten Swamp reached peak recruitment, beginning at the peak of the rainy season, which was highest in August and September. Recruitment decreased with the commencement of the end rainy season as shown in Figure 4.

The results of growth parameter analysis show the movement of the fish's length frequency mode. The growth curve moves from March. Snakehead fish gonads are thought to experience egg maturation in June-July, then the eggs continue to develop until ovulation occurs during spawning in August. Fertilized eggs will hatch into larvae. Three months after hatching, the fish larvae have developed into young fish which gradually enter the fishing area as new recruits. Recruitment of young fish continues to increase until it reaches its peak in the dry season (Djumanto et al. 2014).

Adopting a sustainable management strategy is vital to preserve snakehead fish populations in Kawunganten Swamp. This strategy includes setting capture quotas, protecting swamps habitats by reducing the accumulation in the waters, monitoring destructive human activity, and developing appropriate conservation policies. Proper conservation and management efforts are important to preserve biodiversity and ensure the sustainability of Kawunganten Swamp ecosystem for future generations. Establishing a fish reserve to conserve snakehead fish in the Kawunganten Swamp with a community-based management approach is necessary. The impact of fish reserves on the status of species availability and diversity index in Bangladesh's Ratargul Swamp Forest (RSF) is an increase in fish populations (Kunda et al. 2022). Haque (2013) also found an increasing trend in the abundance of native fish species (e.g., *Ompok bimaculatus*, *Puntius alatus*, *Nandus nandus*, *Labeo gonius*, and *Chitala chitala*) after the establishment of a fish reserve in Baikka Beel. The results show that the creation of improved and protected local habitats in the sanctuary area influences the abundance of fish there. Pandit et al. (2015) also revealed that fish reserves create better habitats for their survival and help increase the size and abundance of their populations.

The study found that populations at Bringkeng station were healthier than those at Grugu and Babakan based on abundance, length, and age groups, with relatively fast growth rate (K:1.0). Fish mortality in Kawunganten Swamp was still dominated by natural mortality (M>F) caused by poor water quality. Although rate of fishing has yet to reach its optimum, increased fishing activity needs to be monitored to avoid overfishing. To achieve sustainable management of snakehead, a breeding area at the Grugu station was recommended. There were many fish in the breeding phase at the Bringkeng station, while others were in the pre-breeding stage.

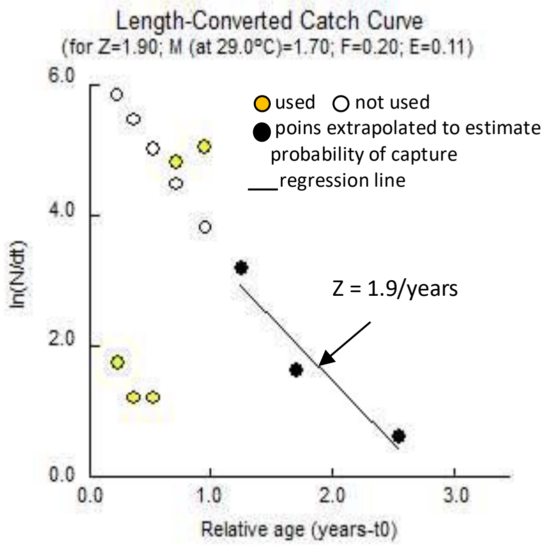

Figure 3. Linearized catch curve for Z: 1.90; M (temperature 29°C): 1.70; F: 0.20; E: 0.11

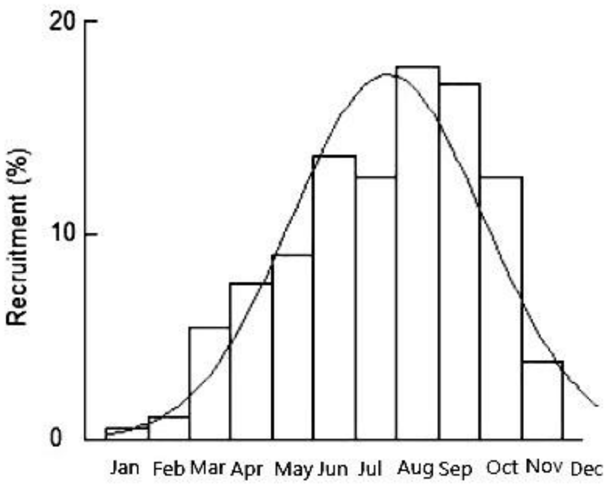

Figure 4. Recruitment patterns of snakehead fish in the Kawunganten Swamp, Cilacap, Central Java, Indonesia

The snakehead fish population in the Kawunganten swamp can still be sustainable, with the high number of fish in the reproductive phase and the snakehead fish spawning throughout the year. The population, with an average recruitment of 8.5% per year based on the results of FISAT II calculations and a natural mortality and capture of 1.9% per year, is predicted to reach 480 individuals/year, indicating a sustainable trend. To maintain this, a size limit of 24-28 cm and the establishment of a fish reserve are recommended. Importantly, a community-based management approach is crucial for the conservation of snakehead fish in the Kawunganten swamp areas.

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