Height and mesh size of gill nets to reduce sailfin catfish (*Pterygoplichthys* spp.) population: a case study in Lake Sidenreng, South Sulawesi, Indonesia

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Abstract. The sailfin catfish (*Pterygoplichthys* spp.) is one of the introduced fish species that invaded the waters of Lake Sidenreng, Sidenreng Rappang District, South Sulawesi. Its presence is very disturbing to fish resources in Lake Sidenreng due to predation by sailfin catfish on juveniles and eggs of other fish. Therefore, it is necessary to reduce or control sailfin catfish population. The solution is to create fishing gear that can catch sailfin catfish *en masse*, it is easy to operate at the bottom of the water and is low cost. Gill nets are the first choice, as Lake Sidenreng fishermen are very familiar with them. Fishermen are accustomed to operating surface gill nets with mesh sizes of 2", 2.5", and 3.5". The study aimed to determine: 1) the composition of the gill net catch, 2) the comparison of the number of sailfin catfish caught by 2", 2.5", and 3.5" mesh size gill nets with a primary hanging ratio of 70.07%, 3) the way sailfin catfish are caught in the gill net, and 4) the height and mesh size of the gill net that catches the most sailfin catfish based on the number of sailfin catfish caught. The results showed that the gill net caught three types of fish, namely sailfin catfish (*Pterygoplichthys* spp.), silver barb (*Barbonymus gonionotus*), and tilapia (*Oreochromis niloticus*). Sailfin catfish dominated the catch with 307 fish, or 94% of the total catch, weighing 37.52 kg, followed by 17 silver barbs (5%; 3.63 kg), and 3 tilapias (1%; 0.24 kg). The way the sailfin catfish was caught in the gill net was dominated by entangled with as many as 115 fish, or 40% of all sailfin catfish caught, then gilled (61 fish; 21%), snagged (58 fish; 20%), wedged (34 fish; 12%) and caught by the pectoral fins (20 fish; 7%). The appropriate mesh size for catching sailfin catfish was 2.5" or 3.5" as it caught 127 and 110 fish, respectively, while the 2" mesh size only caught 51 sailfin catfish. The height of the gill net suitable for catching sailfin catfish is 50 cm from the bottom of the water, which was able to catch 267 fish, or 93% of all sailfin catfish caught, while the top 50 to 75 cm caught only 21 fish (7%).
Key Words: construction, design, gill net.

Introduction. The sailfin catfish (*Pterygoplichthys* spp.) originates from South America and is an invasive freshwater fish species in other geographical regions of the world (Sanders 2020). Its characteristics are that they easily breed, grow quickly, have a high tolerance for polluted environments (Tisasari et al 2016), live at the bottom of the water (Sandra & Radityaningrum 2021), and have eating habits that are classified as omnivorous species (Radkhah & Eagderi 2020). Some types of sailfin catfish food consist of protozoa, fish larvae, mollusks, polychaeta, decapods, crustaceans, insects, phytoplankton, algae and fish eggs (Suresh et al 2019).

Sailfin catfish are easily found in many parts of Indonesia. One of them is Lake Sidenreng, Sidenreng Rappang District, South Sulawesi, which is the habitat of various commercial freshwater fish species, such as silver barb (*Barbonymus gonionotus*), goby fish (*Glossogobius giuris*), Nile tilapia (*Oreochromis niloticus)*, snakehead (*Channa striata*), climbing perch (*Anabas testudineus*), and marble goby (*Oxyeleotris marmorata*)

(Oktaviany et al 2023). The population explosion of sailfin catfish that occurred in Lake Sidenreng caused the population of several fish species to decrease (Putri et al 2022). Some of them are silver barb (Rapi & Hidayani 2016), goby fish (Kudsiah et al 2021), and tilapia (Hasrianti et al 2020b).

The continuous decline of fish populations in Lake Sidenreng will eventually lead to the extinction of some fish species. Furthermore, fish diversity and the sustainability of fish resources will also be threatened. Some fish species whose populations are declining are classified as fish that lay their eggs on the bottom of the water, such as marble goby (Fatah & Adjie 2013), silver barb, carp (*Cyprinus carpio*) (Thalathiah & Palanisamy 2004), and pangas catfish (*Pangasius pangasius*) (Poto 2019). The survival of these fish is severely compromised, as most of their eggs are preyed upon by sailfin catfish (Chaichana & Jongphadungkiet 2013).

To conserve fish resources in Lake Sidenreng, it is necessary to reduce or control the sailfin catfish population. One potential solution is the design of efficient, low-cost fishing gear that can be operated at the lake bottom. Bottom gill nets, familiar to local fishermen, are a suitable option. Key factors such as net height, mesh size, and mesh shrinkage ratio must be optimized to effectively catch sailfin catfish of various sizes. This study aims to: 1) analyze the composition of the gill net catch, 2) compare the catch rates of sailfin catfish using gill nets with 2", 2.5", and 3.5" mesh sizes, 3) examine the methods by which sailfin catfish are caught in gill nets, and 4) determine the optimal height and mesh size of gill nets for catching sailfin catfish. The gill net is expected to reduce the sailfin catfish population and their predation on fish eggs and larvae, thereby supporting the sustainability of fish resources in Lake Sidenreng. The research hypothesis is that the height and mesh size of the gill net will significantly affect the catch rates of sailfin catfish.

Research on the use of gill nets for catching sailfin catfish in Lake Sidenreng is limited, as most studies have focused on marine environments (Khikmawati et al 2017; Gessner & Arndt 2006; Paransa et al 2017). Existing studies on Lake Sidenreng have primarily addressed gill net catch characteristics (Oktaviany et al 2023), feeding habits of sailfin catfish (Dewi et al 2020), nutrient content and heavy metals in sailfin catfish (Hasrianti et al 2022), the impact of restocking on fish production (Mukhlis et al 2021), identification of sailfin catfish species (Hasrianti et al 2021), effects of sailfin catfish on fishermen's catch (Hasrianti et al 2020b), identification of ichthyofauna species (Pindan 2022), population dynamics of goby fish (Kudsiah et al 2021), reproductive aspects of nilem fish (*Osteochilus vittatus*) (Omar 2010), and effects of sailfin catfish on fishermen's income (Hasrianti et al 2020c).

Material and Method. The research was conducted in two stages: the construction of bottom gill nets and their subsequent fishing trials. The gill nets were constructed between December 2023 and January 2024 at the Laboratory of Fishing Equipment Technology, Faculty of Fisheries and Marine Science IPB University. The second stage involved operating the gill nets in Lake Sidenreng, Sidenreng Rappang District, South Sulawesi, from March to May 2024. The research location is illustrated in Figure 1.

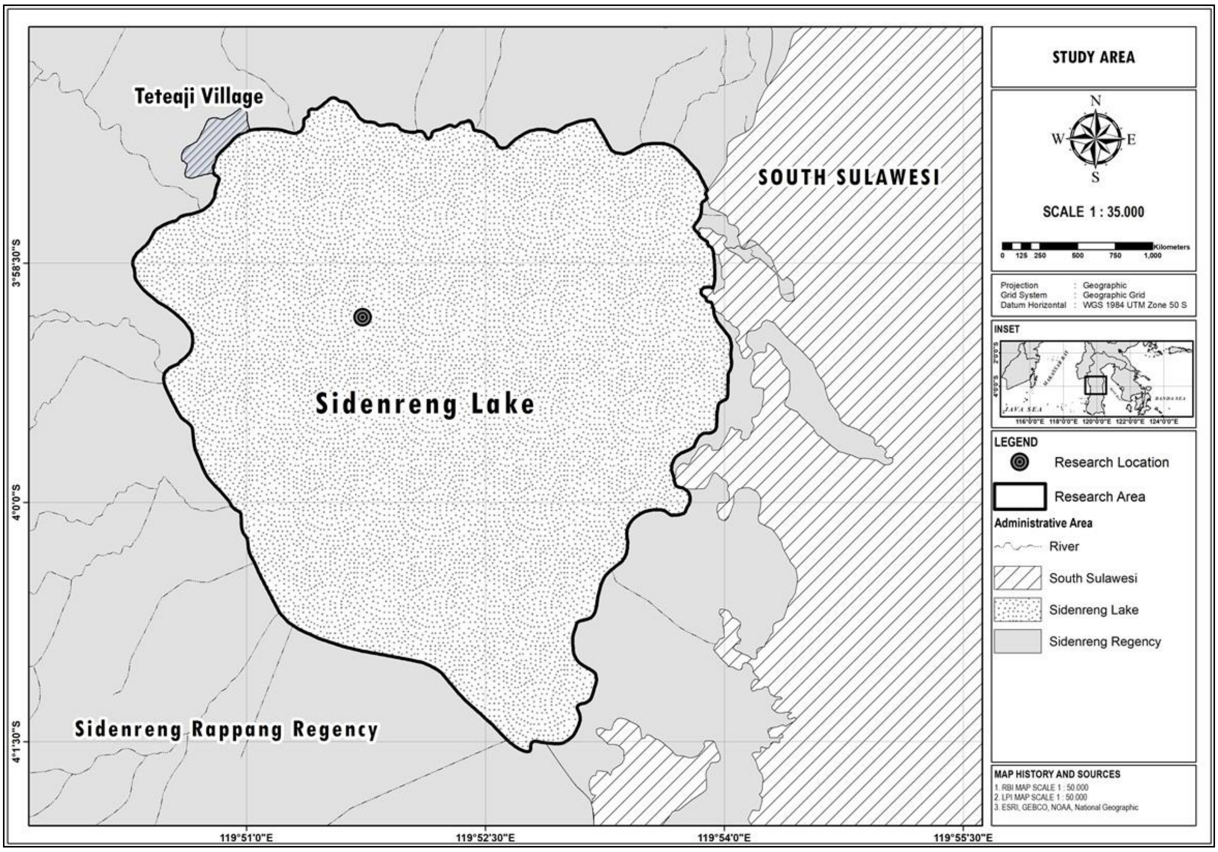

Figure 1. Research location (map generated using ArcGIS 10.8).

The bottom gill net was designed to catch a wide range of sailfin catfish (*Pterygoplichthys* spp.) sizes while being selective for other economically important fish (Figure 2). The variable in this study was the mesh size, with three treatments: 2", 2.5", and 3.5", reflecting the mesh sizes commonly used by Lake Sidenreng fishermen. The hanging ratio was set at 70.7%. The considerations for this ratio were: 1) the rhombus-shaped mesh suited the cross-section of the sailfin catfish extending upwards and sideways, and 2) sailfin catfish tend to get entangled and release themselves by breaking the net, thus necessitating net preservation. The total buoyant force, and dimensions of each net with different mesh sizes were standardized to 268.67 gf, and 30×0.75 m² (P×L), respectively. The low net height was based on the sailfin catfish's behavior of being active at the bottom of the water while searching for food attached to the sediment or substrate (Elfidasari et al 2020). The specifications of the sailfin catfish gill net per sheet are presented in Table 1.

Table 1

Bottom gill net specifications for catching sailfin catfish per sheet

No.	*Section*	*Mesh size*		
		2" (5.08 cm)	*2.5" (6.35 cm)*	*3.5" (8.89 cm)*
1.	Float line			
	Length	32 m	32 m	32 m
	Material	PA 210 D/4	PA 210 D/4	PA 210 D/4
	Weight	16.43 g	16.43 g	16.43 g
	Buoyancy force	3 gf	3 gf	3 gf
2.	Net			
	Length × height	30×0.75 m^2	30×0.75 m^2	30×0.75 m^2
	Hanging ratio	70.7%	70.7%	70.7%
	Mesh number			

	Horizontal	836 eyes	668 eyes	477 eyes
	Vertical	21 eyes	17 eyes	12 eyes
	Weight	50.65 g	38.43 g	31.07 g
	Sinking force	11.44 gf	6.21 gf	7.61 gf
3.	Lead line			
	Length	32 m	32 m	32 m
	Materials	PE D/4	PE D/4	PE D/4
	Weight	17.45 g	17.45 g	17.37 g
	Buoyancy force	3.17 gf	3.17 gf	3.17 gf
4.	Float			
	Material	Rubber/EVA	Rubber/EVA	Rubber/EVA
	Shape	Ring Ø 5 cm	Ring Ø 7 cm	Ring Ø 10 cm
	Total	20 pieces	20 pieces	20 pieces
	Weight	50 g	50 g	50 g
	Buoyancy force	265.5 gf	265.5 gf	265.5 gf
	Distance between buoys	77 cm	77 cm	77 cm
5.	Sinker			
	Material	Black tin	Black tin	Black tin
	Shape	Cylinder	Cylinder	Cylinder
	Total	210	210	210
	Weight/piece	32.06 g	32.06 g	32.06 g
	Sinking force	315 gf	315 gf	315 gf
	Distance between weights	15 cm	15 cm	15 cm

The gill net operation began with arranging nets of different mesh sizes intermittently to ensure equal distribution and similar capture opportunities for the target fish. The nets were set at the bottom of the lake at night and left in place for 12 hours. The fishing locations were chosen based on Hoover et al (2014), which indicated that the largest sailfin catfish populations are found along the shores of shallow lakes, rivers, or reservoirs.

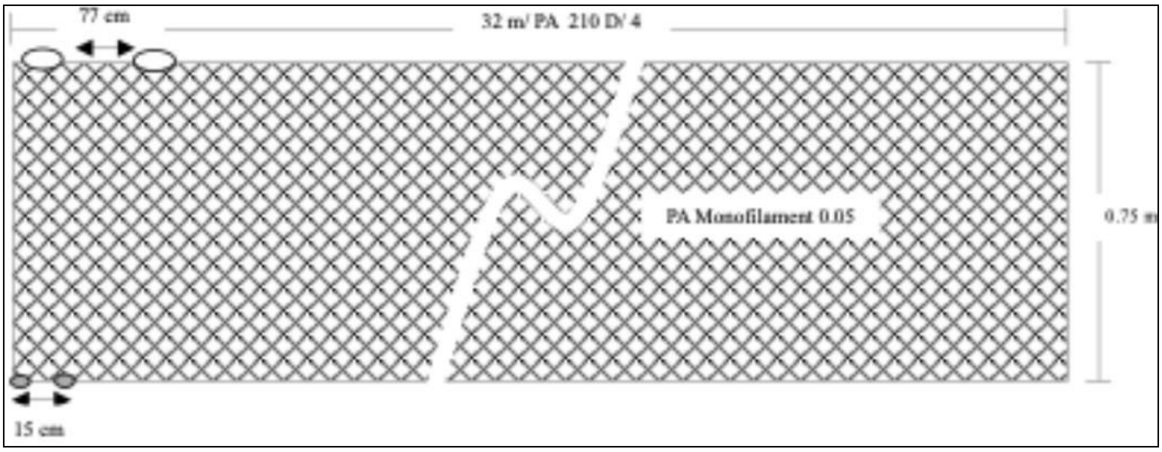

Figure 2. Design of gill net mesh size.

The capture trial was conducted with 20 replicates. Based on Federer's (1967) formula, the number of replicates r that should be conducted if the number of treatments $t = 3$ is $(t–1)(r–1) \geq 15$, or $(3–1)(r–1) \geq 15$. Thus, $r \geq 8.5$ or rounded up to 9. The establishment of 20 replicates is intended to increase accuracy. According to Harsojuwono et al (2011), the accuracy of estimation becomes higher the more the number of replicates.

Data collected included the type of fish caught, the position of the fish in the net, the way fish are caught, and the size of the fish caught. The vertical position of caught fish was categorized into three net height sections: 0-25 cm (bottom), 25-50 cm (middle), and 50-75 cm (top). Fish were measured for total length, standard length, and weight.

Data analysis involved descriptive and comparative statistical tests. Descriptive statistics were presented using diagrams and histograms. Comparative analysis was conducted using the Kolmogorov-Smirnov test to test data normality and the Kruskal-Wallis test to analyze the effect of different mesh sizes on catch results. The hypotheses were: Ho - the use of 2", 2.5", and 3.5" mesh sizes does not produce significant differences in catch rates, and Ha - the use of different mesh sizes produces significant differences. If the Kruskal-Wallis test at a 5% confidence level results shows $p > 0.05$, Ho is accepted; if $p < 0.05$, Ho is rejected.

Results and Discussion

Catch composition. The gill net catch in Lake Sidenreng consisted of three fish species: sailfin catfish (*Pterygoplichthys* spp.), silver barb (*Barbonymus gonionotus*), and Nile tilapia (*Oreochromis niloticus*). The sailfin catfish species included *Pterygoplichthys pardalis*, *Pterygoplichthys multiradiatus*, and intergrade individuals (Hasrianti et al 2021). A total of 327 fish were caught, weighing 41.39 kg. Sailfin catfish dominated the catch with 307 individuals (94%) weighing 37.52 kg, followed by 17 silver barbs (5%; 3.63 kg), and 3 tilapias (1%; 0.24 kg) (Figure 3).

The dominance of sailfin catfish in the catch is attributed to the bottom-set operation of the gill net, as sailfin catfish are demersal fish (Pound et al 2011; Samat et al 2016; Tran et al 2021). Their peak reproductive season can occur throughout the year (Mendoza Alfaro et al 2009), and they have a relatively long lifespan, reaching up to 5.25 years in public waters (Gibbs et al 2013). Field observations indicate that sailfin catfish caught accidentally by fishermen are often released back into the lake, leading to a population that remains unaffected by fishing pressure and declines only due to natural mortality.

Gill nets aim to reduce the sailfin catfish population, targeting both large and small individuals considered pests by fishermen. Operating gill nets at the lake bottom results in capturing more adult sailfin catfish than juveniles. According to Nico (2010), adult sailfin catfish are active throughout the day, dusk, and night at the lake bottom. The juveniles and sub adults are mostly active at night (Hossain et al 2018). However, the activities of the juveniles and sub adults are mostly carried out at the surface of the water, causing the adults to have a higher chance of being caught compared to the juveniles and sub adults.

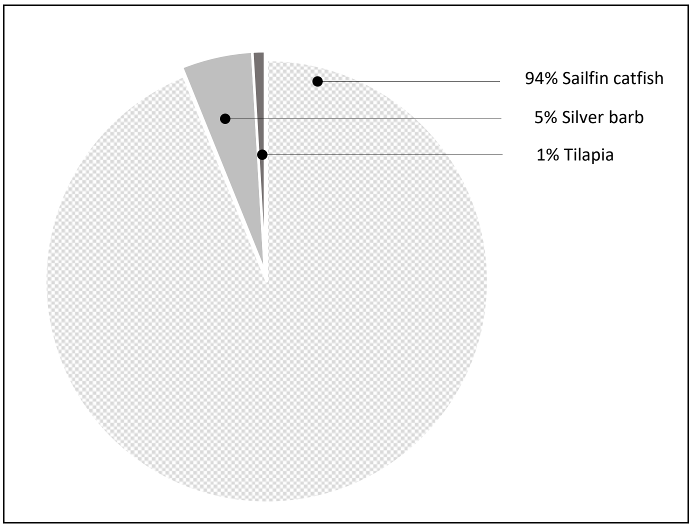

Figure 3. Catch type composition.

Silver barb (*Barbonymus gonionotus*) is one of the most economically important fish species (Triwardani et al 2022). The habitat of silver barbs is in the middle layer to the bottom of the water and corresponds to the location of the gill net operation at the bottom of the water causing silver barbs to be caught. The number of silver barbs caught, which are only 17 fish and relatively low, is more due to the time of capture that is not in accordance with the silver barb fishing season. According to Hamka and Naping (2019), fish populations in lake waters will be abundant during the rainy season. The fishing activities carried out in February were not in accordance with the rainy season in Lake Sidenreng which only begins in May.

Tilapia, a high-value species (El-Sayed 2019), can swim at various depths, including surface, water column, and bottom (Muhtadi et al 2022). Therefore, bottom gill net operation captures tilapia, though in small numbers due to the inappropriate timing of fishing. Tilapias are diurnal and active during the day (Masyahoro & Badrussalam 2022), and the study's night fishing was suboptimal. Additionally, fishing was conducted before the spawning season, which runs from March to June (Chandra Roy et al 2018; Muhtadi et al 2022).

Comparison of sailfin catfish catches by mesh size. The catch composition by mesh size is shown in Figure 4. Sailfin catfish dominated across all mesh sizes. The 2.5" mesh size net caught 128 sailfin catfish (44% of the total catch), the 3.5" mesh size caught 110 (38%), and the 2" mesh size net caught 51 (18%). Therefore, the 2.5" and 3.5" mesh sizes were more effective than the 2" mesh size. Wickramaratne et al (2020) also found that 2.5" and 3.5" mesh sizes were more effective for sailfin catfish capture than smaller mesh sizes.

The Kolmogorov-Smirnov test indicated non-normal data distribution ($p < 0.001$). The Kruskal-Wallis test showed significant differences in catch numbers due to mesh size ($p < 0.001$). The 2.5" mesh size net caught more sailfin catfish compared to the 2" and 3.5" nets (Figure 5). Rahantan and Puspito (2012) noted that mesh size significantly affects total catch volume.

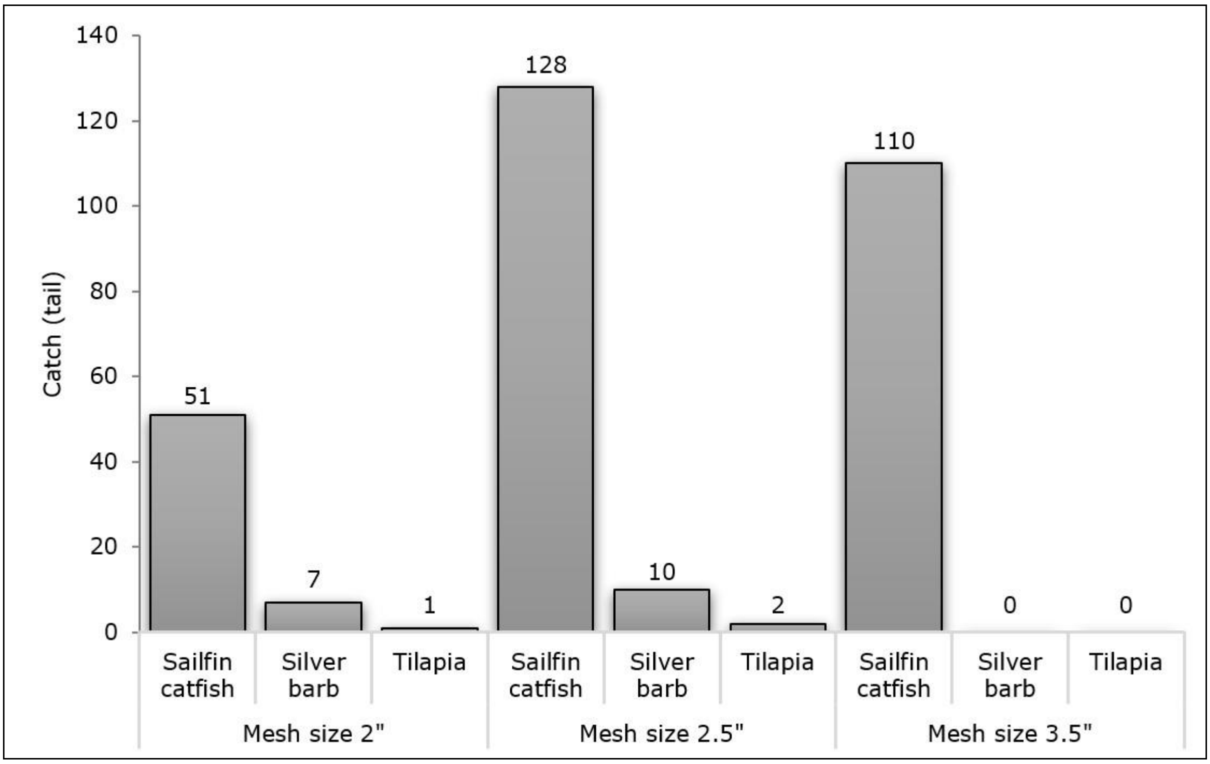

Figure 4. Catch from bottom gill net mesh size of 2", 2.5" and 3.5" per trip.

The sailfin catfish caught by gill nets with a mesh size of 2" had a total length between 17.5 - 30.1 cm (Figure 5). Their sizes were categorized as small and medium-sized. Kasmiati et al (2023) classified sailfin catfishes based on their total length. According to him, sailfin catfish are categorized as small if their total length size is < 20 cm, medium between 20.1 - 30 cm, and large > 30.1 cm. The most common total length of sailfin catfish caught in the 2" net was 19.9 - 22.2 cm (Figure 5).

Gill nets with mesh sizes of 2.5" and 3.5" only caught sailfin catfish in the juvenile and adult categories, or between 20 - 35 cm and 21 - 36.5 cm in total length. The total length of the dominant sailfin catfish caught at each mesh size was different. Mesh size of 2.5" caught the most sailfin catfish in the total length range of 22.3 - 24.6 cm and mesh size 3.5" caught sailfin catfish between 29.5 - 31.8 cm (Figure 5). Based on the size of fish that dominate the catch, Syamsuddin et al (2021) explained that an increase in mesh size will be positively correlated with the size of fish caught.

Silver barb and tilapia caught with 2" and 2.5" mesh sizes, had lengths ranging between 15.6 - 23.9 cm (Figure 4). Silver barbs caught with the 3.5" mesh size were > 25 cm or > 2.5 years old (Aida 2011; Warsa & Tjahjo 2019). The year-round use of small mesh sizes results in the capture of smaller fish, limiting their growth potential (Oktaviany et al 2023). The decline in economic fish catches in Lake Sidenreng is linked to the sailfin catfish population explosion (Hasrianti et al 2020a), which preys on eggs and juveniles at the bottom of the water (Chaichana et al 2013; Chaichana & Jongphadungkiet 2013; Suresh et al 2019).

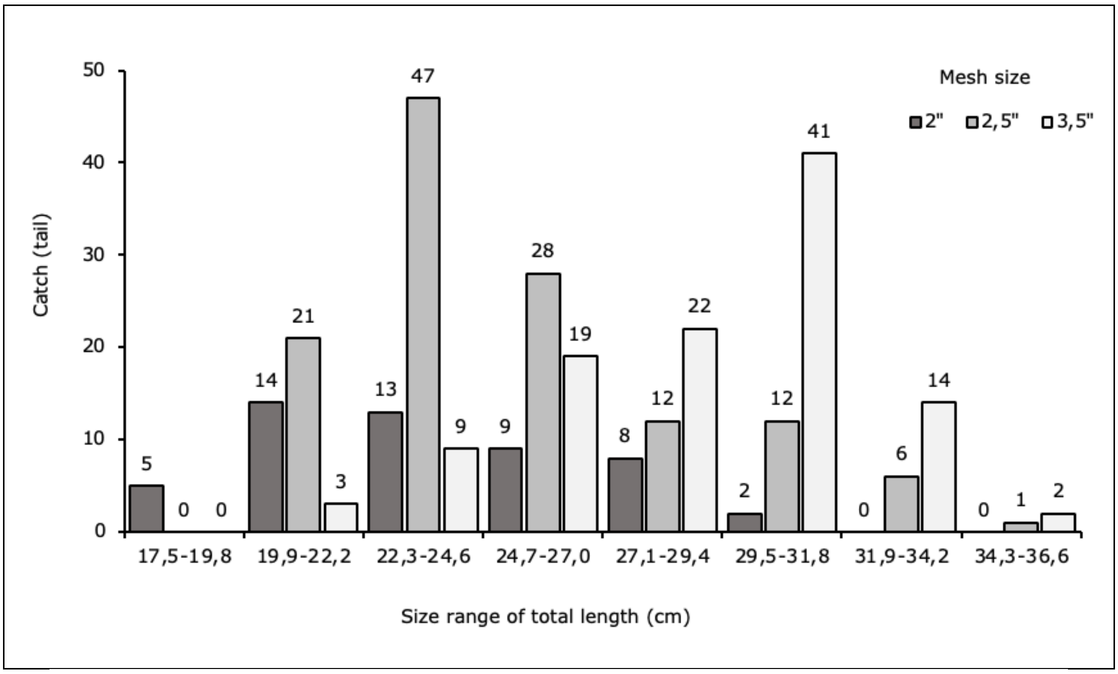

Figure 5. Gill net catches by total length range with mesh sizes of 2", 2.5" and 3.5".

Capture process and position of the sailfin catfish caught by gill nets. Gill nets typically catch fish by entangling around the operculum under the gill cover (Cerbule et al 2022; Savina et al 2022). Fish can be caught by the gills, are snagged, wedged, or entangled (He 2010; Brinkhof et al 2023). In this study, sailfin catfish were caught by the gills, were snagged, wedged, entangled, or caught by the pectoral fins (pectoraled) (Figure 6).

The sailfin catfish tended to be caught entangled in gill nets, although a small number were caught by snagging on their pectoral fins. Rahantan and Puspito (2012) explain that the shape of the fish body will affect the way it is caught. Table 2 shows that more sailfin catfish were caught entangled in gill nets with mesh sizes of 2.5" and 3.5" compared to 2". The details are that gill nets with a mesh size of 2.5" caught 60 sailfin catfish that were entangled, or 47% of the catch, followed by mesh size 3.5" (40%; 45 fish), and mesh size 2" (10 fish; 19%). The gill net with a mesh size of 2" caught more by snagging, with 23 fish or 45% of the catch. According to García-González et al (2016) and Hoover et al (2004) the main reasons why sailfin catfish are caught snagged are their hard, rough body structure and long pectoral fins. Another reason is the large head circumference of the sailfin catfish. Thus, a sailfin catfish will be entangled if its head is smaller than the mesh opening. Meanwhile, a sailfin catfish is likely to be caught in an entanglement if its head size is larger than the gillnet mesh opening. Lobyrev and

Hoffman (2018) added that the chance fish will be entangled by the net is significantly influenced by the relationship between the diameter of the gill cover or head and the mesh opening.

Table 2

Capture process of sailfin catfish are caught by nets with mesh sizes of 2", 2.5" and 3.5"

How fish get caught in gill net	*Mesh size*			%
	2"	*2.5"*	*3.5"*	
Gilled	10	29	22	21
Snagged	23	15	20	20
Wedged	-	17	17	12
Entangled	10	60	45	40
Pectoraled	8	6	6	7
Total	51	127	110	100

The number of sailfin catfish caught entangled in all nets was 115, or 40% of the total catch, while gilled were 61 (21%), snagged 58 (20%), and wedged 34 (12%). Fish caught by snagging on the pectoral fins (pectoraled) accounted for only 20 individuals, or 7% of the total catch. Thus, the entangled method was more dominant than the other methods. Research results of Hasrianti et al (2020a) explained that fish that are entangled by the net thread will respond quickly by moving back and forth to escape. Domenici and Hale (2019) added that fish caught by the net will show various escape responses, such as C-start, S-start, single-bend, and double-bend responses. Other responses include maneuvering, turning, or retreating (Domenici & Kapoor 2010). Continuous movement causes the caught sailfin catfish to become increasingly entangled in the net.

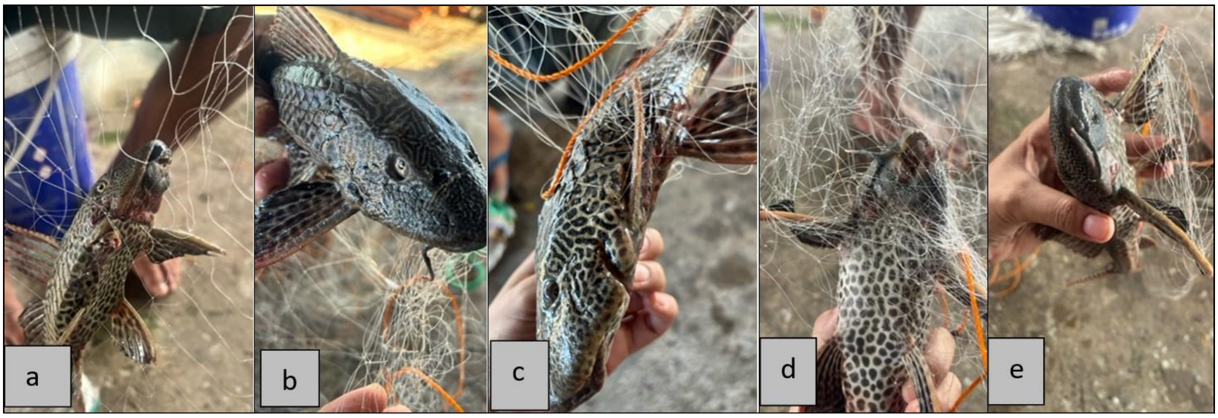

Figure 6. How the sailfin catfish is caught in the net (a) caught in the operculum (gilled), (b) caught by the mouth (snagged), (c) caught by the body (wedged), (d) entangled, and (e) caught by the pectoral fins (pectoraled).

Position of sailfin catfish caught in the net. The position of sailfin catfish in the net was categorized into three heights: bottom, middle, and top. Most sailfin catfish were caught in the middle section of the net (167 individuals; 58%), followed by the bottom (100 individuals; 35%), and the top (21 individuals; 7%) (Figure 7). Sailfin catfish were caught within 0-50 cm from the bottom. Their distribution is influenced by behavior and habitat, favoring the bottom to exploit benthic resources and avoid predators (Blake et al 2007; Agudelo-Zamora et al 2020; Tran et al 2021).

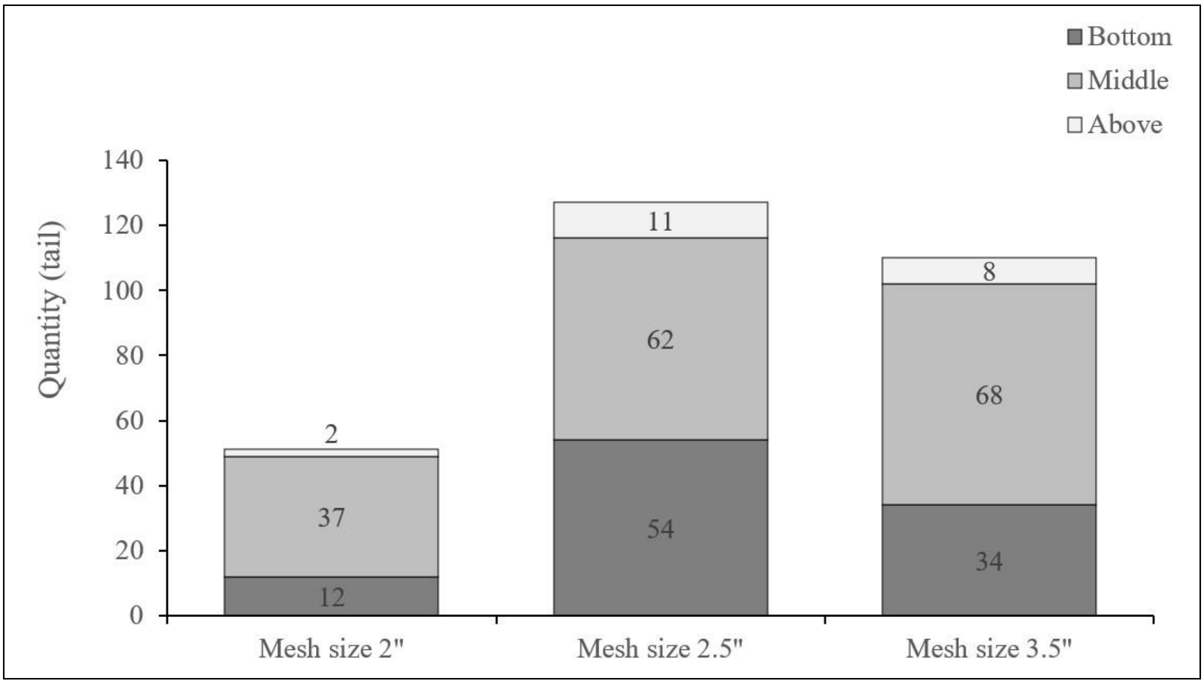

Figure 7. Position of sailfin catfish caught in the mesh.

The size categories of sailfin catfish based on their position in the net are shown in Table 3. Small sailfin catfish were caught in the 2" mesh at all positions, bottom, middle and top of the net. Medium sized fish were caught at all mesh sizes and positions. Large fish were caught in all positions at mesh sizes of 2.5" and 3.5". The 2" mesh size net only caught large fish at the bottom position.

The vertical spread of sailfin catfish is influenced by the physiological condition of its body, which experiences hypoxia when dissolved oxygen levels at the bottom of the water are low (Gibbs et al 2021). Kramer (1987) mentioned that sailfin catfish show a response when experiencing a lack of oxygen, namely by increasing oxygen uptake activity in surface waters, and also a response to vertical or horizontal habitat changes.

Table 3

Position of entangled sailfin catfish based on fish size criteria

Position	*Mesh size 2"*			*Mesh size 2.5"*			*Mesh size 3.5"*		
	Small	*Medium*	*Large*	*Small*	*Medium*	*Large*	*Small*	*Medium*	*Large*
Above	1	1	0	0	10	1	0	7	1
Middle	3	34	0	0	62	3	0	48	20
Bottom	1	10	1	0	44	7	0	22	12

Large sailfin catfish can be caught in the 2" net because of the way it is caught on the pectoral fins. No small sailfin catfish were caught in the 2.5" and 3.5" nets due to the smaller diameter of the head and body compared to the mesh size. Each size category of sailfin catfish has the opportunity to be caught at the top, middle and bottom of the water. However, medium size fish were more likely to be caught at 50 cm, compared to small and large sailfin catfish.

Conclusions. The conclusions drawn from the research are as follows:

1. The gill net catch in Lake Sidenreng consisted of three fish species: sailfin catfish (*Pterygoplichthys* spp.), silver barb (*Barbonymus gonionotus*), and Nile tilapia (*Oreochromis niloticus*). Sailfin catfish dominated the catch, with 307 fish (94% of the total catch) weighing 37.52 kg, followed by 17 silver barbs (5%; 3.63 kg) and 3 tilapias (1%; 0.24 kg).

2. Gill nets with a 2.5" mesh size captured the most sailfin catfish, with 128 individuals, followed by the 3.5" mesh size (110 individuals) and the 2" mesh size (51 individuals).
3. The predominant capture method for sailfin catfish in the gill net was entangling, accounting for 115 individuals (40% of the sailfin catfish caught), followed by gilled (61 individual; 21%), snagged (58 individual; 20%), wedged (34 individual; 12%), and pectoraled (20 individual; 7%).
4. The optimal gill net height for catching sailfin catfish is 50 cm of the water bottom which was able to catch 267 individuals (93% of the sailfin catfish caught), while in the upper section from 50 to 75 cm caught only 21 individuals (7%). The effective mesh sizes were 2.5" and 3.5", which caught 127 and 110 individuals, respectively, compared to 51 fish caught by the 2" mesh size.

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Conflict of interest. The authors declare that there is no conflict of interest.

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