Effect of fishing time and mesh size on gill net catches in Lake Sidenreng, Indonesia

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Abstract. Capture fisheries in Lake Sidenreng play a strategic role in providing fish resources for local communities, with gill nets serving as the primary fishing gear. This study aims to evaluate differences in gill net catches by fishing time (day and night) and their association with variations in mesh size. The research was conducted from September to October 2024 using a factorial randomized block design with two factors: fishing time (day and night) and mesh size (2", 2.5", 3", and 3.5"), with 20 replications per treatment combination. The results indicated that fishing time did not significantly affect the total catch ($p = 0.451$), although specific differences were observed in the two major species. Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758), was significantly more abundant during daytime catches ($p = 0.002$), while Silver barb, *Barbonymus gonionotus* (Bleeker, 1850), was more prevalent at night ($p = 0.014$). Catch composition showed that Nile tilapia dominated 66.1% of the daytime catch, whereas Silver barb accounted for 42.6% of the nighttime catch. Mesh size had a significant impact on catch quantity ($p < 0.001$), with 2" mesh nets producing the highest catches (679 individuals), followed by 2.5" (353 individuals), 3" (170 individuals), and 3.5" (85 individuals) mesh sizes. These findings suggest that the use of small mesh-size gill nets enhances catch quantity, while aligning fishing operations with species-specific activity periods may optimize catch efficiency. Implementation of these strategies is recommended to promote sustainable fisheries management and improve the operational efficiency of gill net fisheries in Lake Sidenreng.

Key Words: Gill net selectivity, fishing time, mesh size, sustainable fisheries, Lake Sidenreng.

Introduction. Sidenreng Lake, located in Sidenreng Rappang Regency, South Sulawesi, is a freshwater ecosystem with significant potential, covering approximately 4,753.30 hectares. It serves as an important source of fish for local communities, helping to meet their protein needs, boost fishermen's household incomes, and create job opportunities. In addition to its economic and nutritional value, the lake is also utilized as a tourist destination (Hasrianti et al 2020).

Gill nets are widely used for capture fisheries in Sidenreng Lake due to their operational simplicity and high effectiveness (Hasrianti et al 2024). The principle of gill nets relies on capturing fish based on body size as they attempt to pass through the mesh (Zhang et al 2024). In practice, gill nets are operated continuously throughout the day and night to optimize fish catches.

The dominant species captured in Lake Sidenreng include Silver barb, *Barbonymus gonionotus* (Bleeker, 1850); Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758); Striped snakehead, *Channa striata* (Bloch, 1793); Tank gobi, *Glossogobius giuris* (Hamilton, 1822); Common carp, *Cyprinus carpio* Linnaeus, 1758; *Clarias gariepinus* Burchell, 1822;

Pangasius catfish, *Pangasius pangasius* (Hamilton, 1822); Marble goby, *Oxyeleotris marmorata* (Bleeker, 1852) (Hasrianti et al 2021). These species exhibit distinct diel activity patterns. Diurnal species such as Nile tilapia and Silver barb are predominantly active during daylight hours (Pratiwi et al 2021). Meanwhile, nocturnal species such as Marble Goby, Tank goby, African catfish, and Pangasius catfish are more active at night (Hoese & Allen 2009; Umage et al 2020; Naughton et al 2021; Priyanka & Newton 2023).

Fishermen operate gill nets continuously, using a wide range of mesh sizes varying from 1.5″ to 4″ (3.81 to 10.16 cm) (Rahmat et al 2024; Hasrianti et al 2025). However, mesh size selection is not typically based on targeted fish sizes but rather on the goal of capturing a broad spectrum of fish. According to Klein & McCormick (2023), smaller mesh sizes are more effective for small-to-medium-sized fish, whereas larger meshes target bigger individuals. Mahon & Hunte (2001) emphasize that both the diel activity of fish and the mesh size critically influence the species composition, quantity, and size of catches. Understanding these interactions is fundamental to optimizing fishing efficiency while maintaining ecological sustainability (Jennings et al 2009).

Aligning fishing operation times with appropriate mesh sizes could enhance capture efficiency and minimize ecosystem disruption. Therefore, analyzing catch composition based on both the time of operation and mesh size is crucial to determine optimal fishing practices. The study aims to compare gill net catch compositions between daytime and nighttime operations in Lake Sidenreng and to assess their association with mesh size variations. The findings are expected to provide practical guidelines for fishermen to improve fishing efficiency while supporting sustainable fishery management.

Material and Method

Study area and period. The study was conducted between September and October 2024 and involved determining the species composition and size structure of fish catches based on the time of fishing operations. The research activities were carried out in Lake Sidenreng, located in Sidenreng Rappang Regency, South Sulawesi Province, Indonesia (3° 58′ 56.02″ S, 119° 51′ 45.04″ E). The study area is shown in Figure 1.

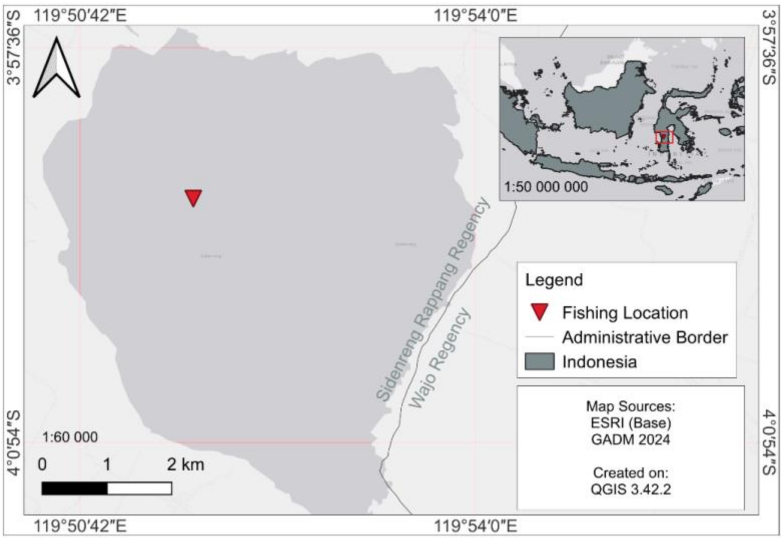


Figure 1. Research location.

Equipment and materials. The primary equipment used was a set of gill nets with four different mesh sizes of 2″, 2.5″, 3″, and 3.5″ (approximately 5.08 cm, 6.35cm, 7.62 cm, and 8.89 cm, respectively). Additional equipment used in the study included small wooden fishing boats powered by 13 HP Honda outboard motors, fish measuring boards (Kenko, Japan) with 30 cm and 50 cm length options marked in centimeters and millimeters, a digital camera (Apple iPhone 15, USA) with a 48 MP wide lens and 12 MP ultra-wide lens, and electronic scales (Camry EK5055, China) with a maximum capacity of 5 kg and an accuracy of 1 g. Fish caught using gill nets were used as the biological material for analysis.

Experimental design. A factorial randomized complete block design was employed, with two main factors: fishing time (t) and mesh size (m). The time of fishing was categorized into two operations, namely daytime (D) (06:00-16:00 UTC +8) and nighttime (N) (18.00-06.00 UTC +8). Each combination of factors (t and m) was tested at randomly determined sites within Lake Sidenreng. The number of replications was determined following the formula proposed by Federer (1963), with the number of treatments t = 8. Thus, a minimum of three replications was required. However, twenty replications were conducted for each treatment combination to increase precision, resulting in a total of 160 experimental units (20 × 8). According to Goulet & Cousineau (2019), increasing the number of replications improves accuracy, reduces experimental error, strengthens statistical power, and stabilizes parameter estimates. The experimental design is presented in Table 1.

Table 1

Experimental design

Replication	*Treatments*								*Total*
	2″ D	*2″N*	*2.5″D*	*2.5″N*	*3″ D*	*3″ N*	*3,5″ D*	*3,5″ N*	
1	Y_{01}	Y_{21}	Y_{41}	Y_{61}	Y_{81}	Y_{101}	Y_{121}	Y_{141}	Y_1
2	Y_{02}	Y_{22}	Y_{42}	Y_{62}	Y_{82}	Y_{102}	Y_{122}	Y_{142}	Y_2
3	Y_{03}	Y_{23}	Y_{43}	Y_{63}	Y_{83}	Y_{103}	Y_{123}	Y_{143}	Y_3
….	…	…	…	…	…	…	…	…	…
20	Y_{20}	Y_{40}	Y_{60}	Y_{80}	Y_{100}	Y_{120}	Y_{140}	Y_{160}	Y_{160}

Legend: Y_n - the response observed in replication number n.

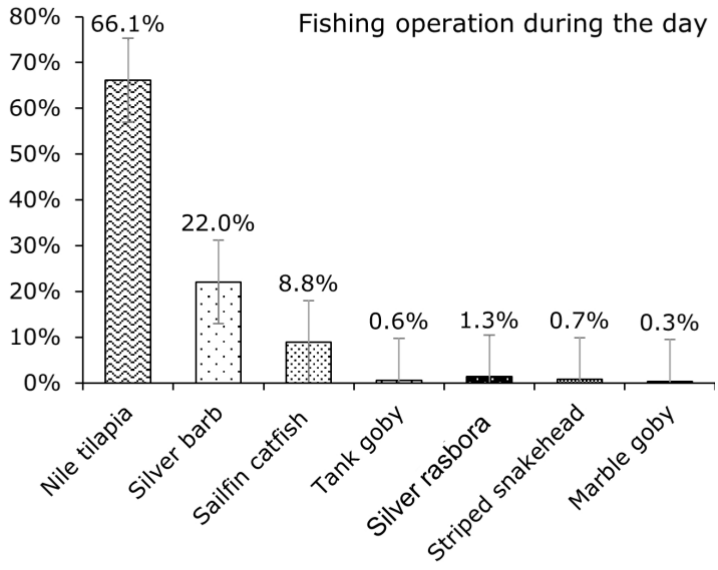
Data collection method. Data collection was performed through experimental fishing trials, utilizing fishermen's gill nets to compare fish catches between daytime and nighttime periods. Gill nets of all mesh sizes were set simultaneously at each predetermined site, consistent with local fishing practices. Nets were deployed twice daily using a boat with ±15-20 knots in speed. After each fishing period, the nets were retrieved, and the fish caught were identified to species level. The number of individuals per species was recorded, and their lengths and weights were measured.

Data analysis

Catch composition analysis. The composition of gill net catches was analyzed descriptively and presented through tables and graphs. Catch composition was assessed based on the number of species (McDonald 2009). Statistical analyses were conducted to evaluate the effect of treatments on catch numbers. The difference in data was tested using nonparametric tests, namely the Mann-Whitney U test and Kruskal-Wallis test, as the assumptions of normality and homogeneity were not met after the data were examined using the Shapiro-Wilk Test and Bartlett's test, respectively (Denis 2021).

Results and Discussion

Species composition of catches. The gill net catches from daytime and nighttime fishing operations in Lake Sidenreng revealed differences in the species composition of the fish caught. During daytime operations, Nile tilapia dominated the catch, followed by Silver barb, Sailfin Catfish (*Pterygoplichthys* spp.), Tank goby, Silver rasbora, *Rasbora argyrotaenia* (Bleeker, 1849), Striped snakehead, Marble goby, Catfish, and Pangasius catfish (Figure 2).



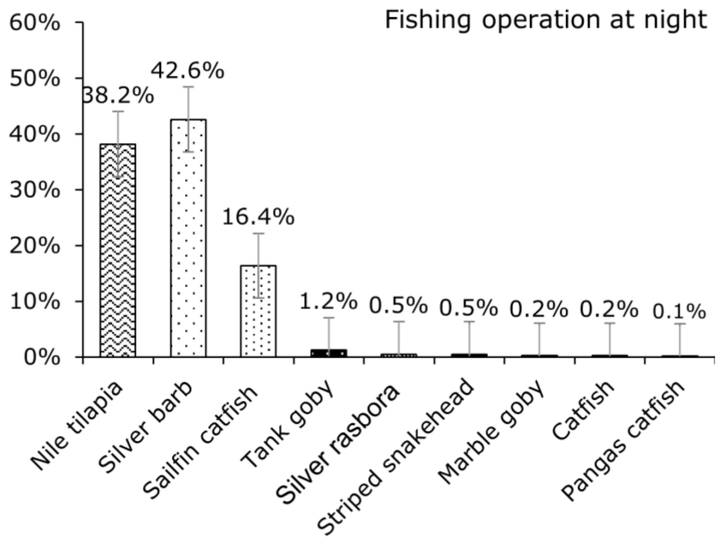


Figure 2. Species composition of gill net catches during daytime and nighttime operations.

The species composition of the gill net differed according to fishing time. Nile tilapia's high number in catch at daytime correspond to its diurnal activity pattern. Although Silver barb is also considered a diurnal species (Pratiwi et al 2021), their higher abundance at night may be attributed to shifts in behavioral patterns, potentially driven by predation pressure, changes in feeding behavior (Payne et al 2013), or environmental factors such as avoidance of heat stress due to increased water temperatures (Brivio et al 2024). Consequently, a shift from diurnal to nocturnal activity is plausible, particularly under competition for food and habitat.

Haroon & Pittman (2008) noted that Silver barb feed on zooplankton, Oedogonium, Cladophora, rotifers, crustaceans, and benthic insects, overlapping significantly with the diet of *Pterygoplichthys* spp. (Tisasari et al 2016; Suresh et al 2019). Studies by Ganguly & Umapathy (2024), Lad (2024), and Sesay et al (2024) have further highlighted that *Pterygoplichthys* spp. exerts substantial ecological pressure by dominating habitats and competing with native fish species. The proportion of Sailfin catfish increased to 16.4% during nighttime operations, indicating a higher nocturnal catch. Hossain et al (2018) explained that juvenile *Pterygoplichthys* spp. are primarily nocturnal, whereas adults are active throughout the day. The species exhibits vertical migration towards the water surface at night, especially under low oxygen conditions near the bottom (Kramer 1987; Da Cruz et al 2013; Sloman 2024).

Other species caught at night included Tank goby (10 individuals; 1.2%), Silver rasbora (4 individuals; 0.5%), Striped snakehead (4 individuals; 0.5%), and Marble goby (2 individuals; 0.2%). Additionally, two catfish (*Clarias* spp.) (0.2%) and one Pangasius catfish (0.1%) were caught exclusively at night. The results signify their nocturnal activity patterns (Naughton et al 2021; Priyanka & Newton 2023).

***Effect of fishing time on catches**.* The influence of fishing time on the number of fish caught is shown in Figure 3. The overall catch numbers were relatively similar between day and night. Mann-Whitney U tests produced a p-value of 0.451, indicating no significant difference in total catch numbers based on fishing time.

Species-specific analyses revealed significant differences. Nile tilapia was more abundant during the day ($p = 0.002$), whereas Silver barb was more abundant at night ($p = 0.014$). Although both species are diurnal (Rodrigues et al 2010; Pratiwi et al 2021), changes in behavioral patterns due to feeding shifts (Payne et al 2013), temperature (Brivio et al 2024), and competition with invasive species such as *Pterygoplichthys* spp. (Quintana et al 2023) could cause these observations.

For other species such as Tank goby, Silver rasbora, Snakehead, Marble goby, catfish, and Pangasius catfish, no significant differences were found ($p > 0.05$), suggesting that fishing time did not affect their capture rates. Potential explanations include mismatches between fishing gear exposure and species morphology, habitat preferences, or broader environmental factors (Sánchez-González & Casals 2022; Moraes et al 2024).

Although fishing time did not significantly affect total catch numbers, it influenced the domination of some species. Tailoring fishing strategies to species activity patterns could enhance fishing efficiency and contribute to fisheries management. Fishermen in Lake Sidenreng could optimize strategies by targeting Nile tilapia during the day and Silver barb at night. For other species, fishing time can be adjusted according to fishermen's preferences, as no significant differences were observed.

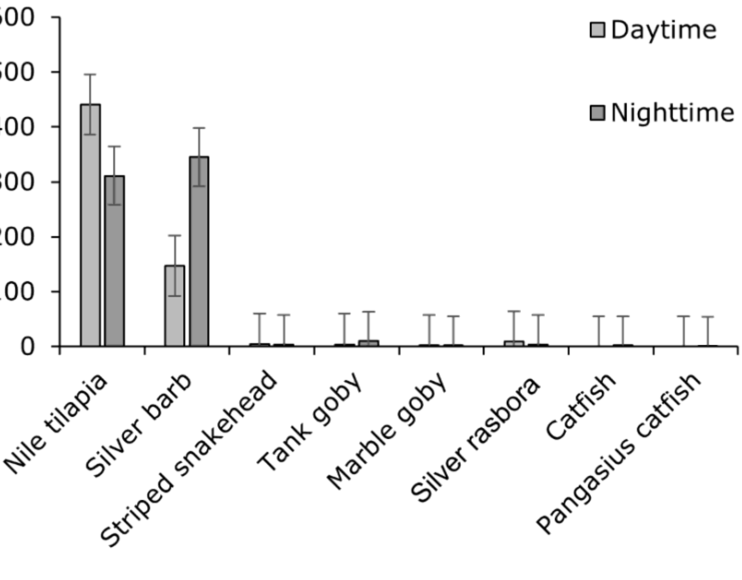


Figure 3. Number of catches at each mesh size (Sailfin catfish were excluded from the figure due to their low economic value).

Comparison of catches based on mesh size. According to the results presented in Figure 4, the total number of catches varied between mesh sizes. The mesh with 2″ in size caught more fish than the others. Meanwhile, the mesh with 3.5″ in size produced the lowest number of catches. Statistical tests also confirmed that the smaller the mesh sizes, the higher the catch number. Kruskal-Wallis test generated H equals 58.001, where p-value = 0.00001 ($p < 0.05$).

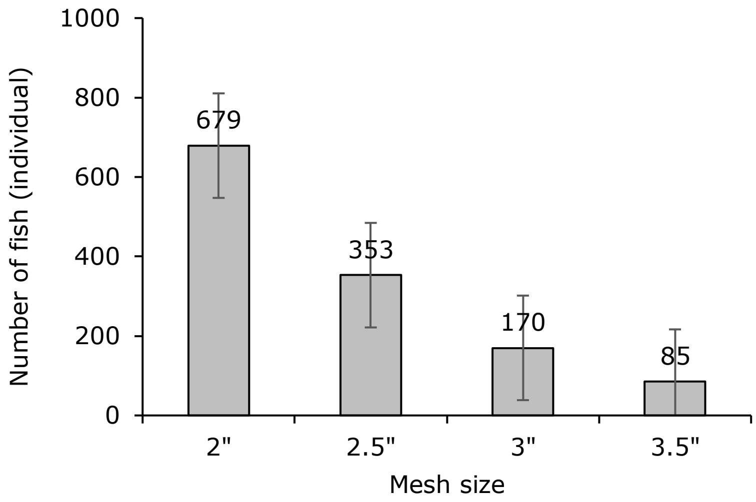


Figure 4. Gill net catches based on mesh size.

Mesh size is a critical factor influencing the effectiveness of gill nets in fish capture. When a fish's body size aligns with the mesh size, it can be caught either by its gills getting entangled or by its body becoming trapped (de Oliveira Lima et al 2023). Sparre & Venema (1998) noted that smaller mesh sizes tend to capture a broader range of fish sizes, including juveniles, whereas larger meshes are more selective for larger fish.

Mesh size can significantly affect the composition of gill net catches. Small meshes are more versatile, capturing fish of various sizes, while large meshes are more selective for large fish. The size distribution of fish caught by each mesh size is illustrated in Figure 5. Ethically, the use of small mesh nets raises concerns regarding overfishing and the fish populations, especially when the fish are caught before they reach maturity and reproductive state. The practice can undermine the sustainability of fisheries and threaten biodiversity. From a policy perspective, regulating minimum mesh size might be essential, but Jennings et al (2009) stated that the mesh tends to be closed as the fishing gear is operated in the waters. Community education, stakeholder engagement, and catch and effort limitations are recommended to balance livelihood needs with conservation objectives (Garcia et al 2003).

Reduced net visibility at night likely contributed to greater entrapment of smaller and more active fish (Vera et al 2009; Fortes-Silva et al 2010; Cooke et al 2017). The domination of Nile tilapia at several mesh sizes during daytime, likely due to the aggressive daytime behavior of larger individuals during territorial and spawning activities (Mrshrigi & Kubo 1978). According to Lisney & Hawryshyn (2010), larger Nile tilapia may have comparatively lower visual acuity than juveniles.

Smaller fish are typically more active at night, which increases their chances of being captured by nets with smaller mesh sizes (Volkoff 2024). In contrast, larger fish tend to be more active during daylight hours. Fish activity patterns are also shaped by environmental factors such as light intensity, water temperature, and the abundance of prey. This is consistent with previous studies emphasizing that differences in fishing time play an important role in determining the effectiveness of catches, as fish exhibit distinct daily activity patterns depending on whether it is nighttime or daytime (Puspito et al 2015; Puspito et al 2017).

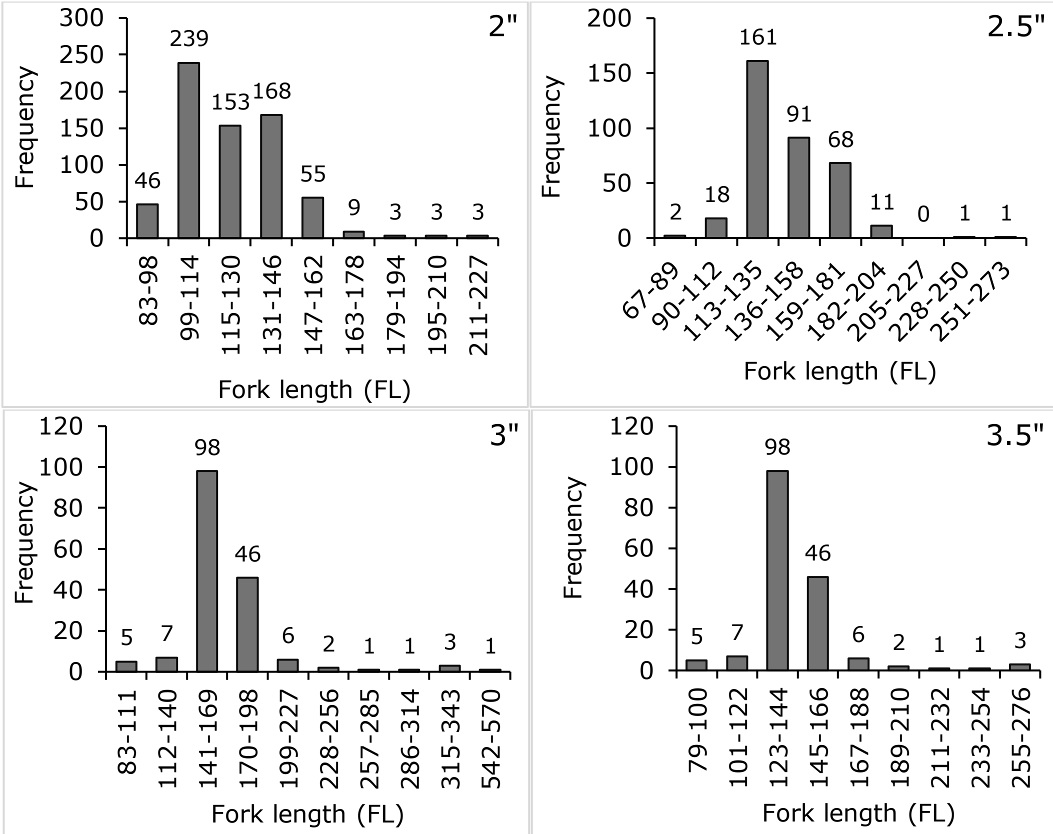


Figure 5. Fish length distribution by mesh size.

Comparison between treatments. The number of catches was displayed in Table 2 and Figure 6 based on the treatments used in the study. Daytime catches were 608 individuals, fewer than nighttime catches (679 individuals). Gill nets with a 2" mesh produced the highest catches both during the day (299 individuals) and at night (380 individuals). In contrast, 3.5" mesh nets recorded the lowest catches, 38 individuals at night and 47 during the day.

Table 2

Gill net catches based on mesh size

Mesh size	*Daytime catches*	*Nighttime catches*	*The difference*	*Percentage of difference*
2"	299	380	81	27.1% more at night
2,5"	165	188	23	13.9% more at night
3"	97	73	24	24.7% more at daytime
3,5"	47	38	9	23.7% more at daytime
Total	608	679	-	-

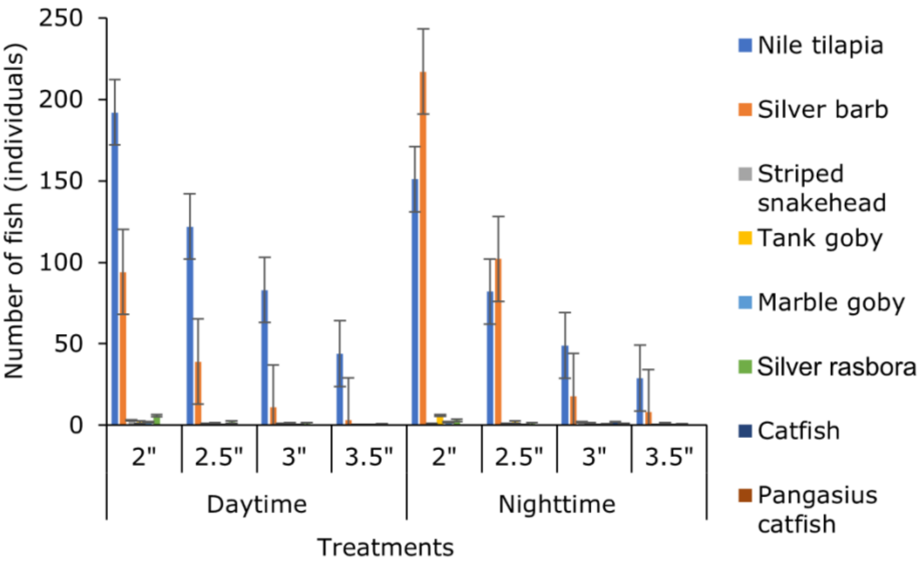


Figure 6. Number of catches based on treatments.

The Kruskal-Wallis test indicated that there is a significant difference in the dependent variable between the different groups, $\chi^2(7) = 93.77$, $p < 0.001$, critical value = 3.8415, with a mean rank score of 127.42 for 2″ D, 97.13 for 2.5″ D, 70.22 for 3″ D, 38.23 for 3.5″ D, 130.35 for 2″ N, 93.28 for 2.5″ N, 55.42 for 3″ N, 31.95 for 3.5″ N. The Post-Hoc Mann-Whitney U test using an alpha of 0.05 indicated that the mean ranks of some pairs are significantly different (Table 3).

Gill nets with 2" and 2.5" meshes showed higher catches at night than during the day, with differences of 27.1% and 13.9%, respectively. Conversely, nets with 3" and 3.5" mesh sizes yielded higher catches during the day (24.7% and 23.7% higher, respectively). Selecting an appropriate mesh size remains essential: 2" nets offer the highest catch rates, whereas 3.5" nets are better suited for targeting larger fish.

Table 3

Multiple statistical comparisons of treatments

Group	*2.5″D*	*3″D*	*3.5″D*	*2″N*	*2.5″N*	*3″N*	*3.5″N*
2″D	6.5	11	13	1.5^{a}	8	12	13
2.5″D	0	4.5	6.5	8	1.5^{a}	5.5	6.5
3"D	4.5	0	2^{a}	12.5	3^{a}	1^{a}	2
3.5"D	6.5	2^{a}	0	14.5	5	1^{a}	0^{a}
2"N	8	12.5	14.5	0	9.5	13.5	14.5
2.5"N	1.5^{a}	3^{a}	5	9.5	0	4	5
3"N	5.5	1^{a}	1^{a}	13.5	4	0	1^{a}

Note: superscript marks indicate pairs are not significantly different.

Gill nets with mesh sizes of 2" and 2.5" are recommended for higher catch efficiency, as they yielded more fish compared to the 3" and 3.5″ mesh sizes. Although total catch did not differ significantly between day and night, species-specific patterns were evident; Nile tilapia were more abundant during the daytime, while Silver barb were more frequently caught at night. Therefore, fishermen can optimize their efforts by selecting fishing times and mesh sizes aligned with their target species, especially those with high economic value. However, such decisions should be made with consideration for sustainability, including maximum sustainable yield or maximum economic yield, and the biological parameters of fish populations. The study is limited to short-term sampling and does not account for seasonal variations or long-term stock assessments. Future research should explore temporal changes across seasons, reproductive cycles, and fishing pressure to better support sustainable management strategies.

Conclusions. The current study concluded that smaller mesh sizes, particularly 2" and 2.5", are more effective for maximizing total catch, with 679 and 353 individuals caught, respectively, compared to significantly lower catches using 3" (170) and 3.5" (85) mesh sizes. While total catch did not significantly vary between day and night fishing, species-specific patterns suggest that fishermen choose their target according to one of the dominant species caught by the gill net. However, to support resource sustainability, regulatory measures should consider limiting the catch based on stock availability to give the fish population time to reproduce.

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

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