Effect of Modified Scoop Net Design and Optimal Fishing Time on Catch Weight and Species Composition in the Morosari River Mouth

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ABSTRACT

Scoop nets are widely used in small-scale fisheries, but their efficiency can be limited by timing and design constraints. To address these limitations, the research aimed to determine the best fishing time for using the scoop net and to demonstrate that adding a pocket to the scoop net can increase the catch weight without affecting the species composition. The construction of a standard scoop net is generally similar to that of a lift net. Its main component consists of a piece of net measuring 4×4 m that can be lowered and lifted in the water. The modified scoop net, however, is equipped with a pocket in the center of the net. In the current study, both types of scoop nets were operated simultaneously at locations approximately 20 m apart. The results showed that the best fishing time for the scoop net was between 12:00 p.m. and 04:00 p.m. (GMT +7), yielding 139.66 kg of fish, or 78.87% of the total catch. The modified scoop net caught five species of fish: spot mullet (*Moolgarda seheli*), barramundi (*Lates calcarifer*), tiger tooth croaker (*Otolithes ruber*), spotted scat fish (*Scatophagus argus*), and long whiskers catfish (*Mystus gulio*). The standard scoop net caught four of the same species, except for barramundi. The additional pocket reduced the drag force of the modified scoop net to 0.973 kgf, which was 75% of the drag force of the standard scoop net (1.296 kgf). Moreover, the additional pocket of the modified scoop net resulted in a total catch of 147.65 kg of catch, which is 5.02 times the catch weight of the standard scoop net (29.42 kg).

Keywords: Drag force, Fishing gear, Lift net, Modification

INTRODUCTION

The scoop net is a traditional fishing gear used by Indonesian fishermen and is classified within the lift net category. It is easy to make and operate, and its cost is relatively low compared to other types of fishing gear. The construction consists of a square-shaped net, with its four corners tied to the ends of two bamboo sticks, which are positioned perpendicularly at the center of the net. These bamboo sticks are suspended from another bamboo pole, enabling the scoop net to be easily lowered and lifted.

To operate the scoop net, it is submerged in the bottom of the water. Lifting is done once a sufficient number of fish have gathered over the net. The targeted species vary depending on where the scoop net is used, such as in wetlands, lakes, or estuaries. Common wetland and lake species include bonylip barb (*Osteochilus vittatus*), Nile tilapia (*Oreochromis niloticus*), striped snakehead (*Channa striata*), and glass fish (*Chela oxygastroides*) (Hermanto *et al*., 2012; Weri and Sucahyo, 2017). In estuarine environments, species like spotted catfish (*Arius maculatus*), speckled tonguesole (*Cynoglossus puncticeps*), goldstripe sardinella

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(*Sardinella gibbose*), slender silver-biddy (*Gerres oblongus*), Russell's snapper (*Lutjanus russelii*), greenback mullet (*Mugil dussumieri*), goatee croaker (*Dendrophysa russelii*), soldier croaker (*Nibea soldado*), and streaked spinefoot (*Siganus javus*) are commonly caught (Hasan *et al*., 2023). According to Sari *et al*. (2017), fishing with scoop nets is generally a side job for fishermen because the catch is relatively small. Fishing is carried out between 8:00 a.m. and 4:00 p.m. despite variations in tidal conditions. The use of bait attractors does not significantly impact the catch, highlighting the need for innovations to determine optimal fishing times and increase the catch.

Field observations revealed that fish above the scoop net often escape when the net is lifted, even if the process is done slowly. The upward drag force created during lifting is substantial. Fish are highly sensitive to environmental disturbances, such as sound or water flow, which they detect through their lateral line. As Bleckmann and Zelick (2009) describe, the lateral line is a sensory system that enables fish to sense water pressure changes. To prevent fish from detecting the movement of the scoop net, it is necessary to reduce drag force through improving the construction of the net.

Scoop nets are designed with very small mesh sizes, which generate a significant drag force, even when lifted slowly. Reducing the mesh size is not an option, as the scoop net is intended to catch a wide range of fish sizes. The solution in the current study was to add a pocket in the middle of the net. This pocket remains open at the top when the scoop net is lowered and lifted, reducing the overall drag force. The length of the pocket is adjusted to the depth of the water, ensuring that fish trapped in the pocket cannot escape. The pocket is only closed when the bamboo poles attached to the net reach the water surface, by pulling a drawstring. The research objectives were: (1) to determine the optimal fishing time for the scoop net and (2) to demonstrate that the modified scoop net can increase the catch weight without affecting species composition.

MATERIALS AND METHODS

Fish sample collection and preparation

The research was conducted at the Morosari River mouth, located on the north coast of Java Island, Central Java, Indonesia (Figure 1), from November 20^{th} to December 17^{th}, 2022. The water depth at the site was approximately 2 m. The experimental fishing method involved operating two types of scoop nets simultaneously: a standard scoop net (Figure 2a) and a modified scoop net (Figure 2b). The nets were positioned approximately 20 m apart.

Scoop net construction

Both the standard scoop net and the modified scoop net used in this study shared the same design and construction. The main part of each scoop net consisted of a 4×4 (m) monofilament polyamide, square-shaped net, which was knotless, with a thread diameter of 0.0009 m, a mesh size of 2.2 cm, and a hanging ratio of E = 0.71. Two bamboo sticks, each measuring 6×0.02 m (l×Ø), served as the frame. The four ends of the net were tied to the ends of the bamboo sticks, which were positioned crosswise. The intersection of the two bamboo sticks was connected to the end of an additional lifting bamboo, which measured 8×0.025 m (l×Ø).

The key difference between the modified scoop net and the standard scoop net was the additional of a pocket, measuring 2×2×2 m (l×w×h), positioned in the middle of the net. This pocket had a vertical cube–like shape, with its top end left open to reduce net drag force. The bottom end could be opened and closed using a drawstring. The function of the additional pocket was to trap fish that might otherwise escape and to collect the trapped fish efficiently.

Scoop net operating procedures

One standard scoop net and one modified scoop net were operated simultaneously over a period of 28 days. Operations were divided into two time groups: 08:00 a.m. to 12:00 p.m. and 12:00 p.m. to 04:00 p.m. (GMT +7), taking into account the local fishing habits and tidal cycles observed in the area.

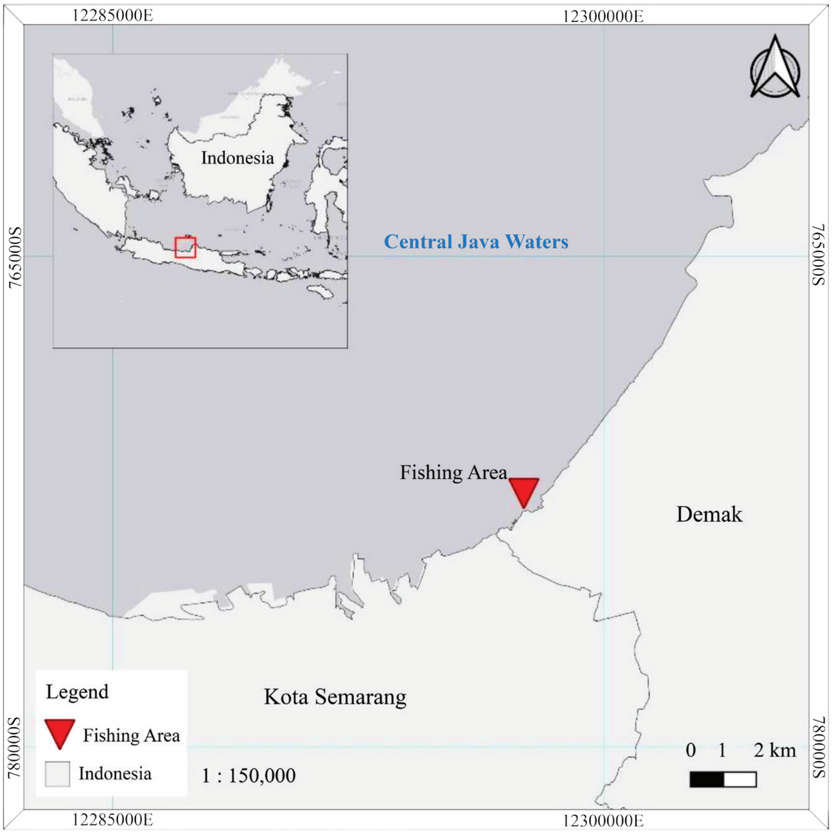

Figure 1. Field research location.

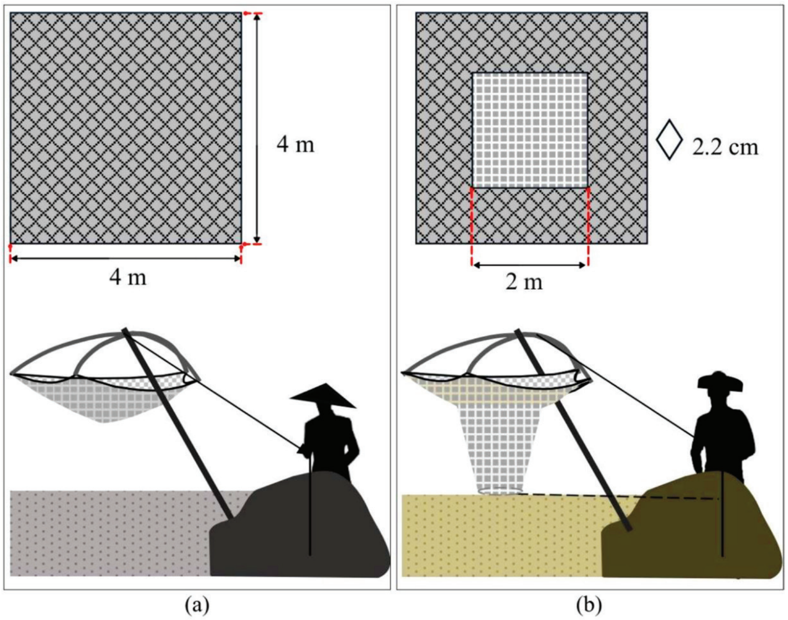

Figure 2. Standard scoop net (a) and modified scoop net (b).

Each scoop net was submerged in the water for 45 min. Lifting the net was done by pulling the lifting rope with a speed of $V = 0.03\ m \cdot s^{-1}$. For the standard scoop net, the fish caught were scooped up and placed into a container. In the case of the modified scoop net, the pocket drawstring was pulled when the four sides of the net began to rise above the water surface. The pocket was then drawn toward the container, and the drawstring was released to collect the trapped fish. The species and weight of the fish were recorded at each capture time for analysis. Each scoop net was operated four times during both time groups.

Data analysis

To calculate drag force, Fridman (1986) equation was used:

$$R_D = 0.5\ C_D\ \rho\ V^2\ A$$

where C_D is the drag coefficient, ρ is water density ($kg \cdot m^{-3}$), V is a pulling speed ($m \cdot s^{-1}$), and A is the cross-sectional area (m^2).

Since the scoop nets were operated in brackish waters, the water density was assumed to be $p = 1,025\ kg \cdot m^{-3}$ (UNESCO, 1981). The pulling speed, $0.03\ m \cdot s^{-1}$, was calculated from direct observations using the formula V=s/t, where s is the estimated water depth and t is the lifting duration. According to Amiry (2013), a thread with a diameter of 0.0009 m moving at a speed of $0.03\ m \cdot s^{-1}$ with an attack angle of 90° results in a drag coefficient of $C_D = 1.44$.

The cross-sectional area A was calculated as:

$$A = N_l \times N_w \times d_t \times 2 \times m$$

where N_l and N_w are the number of meshes in the length and width of the net, d_t is the thread diameter, and m is the mesh size (Amiry, 2013).

Statistical analyses

The Shapiro-Wilk test was used to assess the normality of the catch data distribution, and it revealed a non-normal distribution of the data. Consequently, a non-parametric test, the Mann-Whitney U test, was used to compare the catch results between the standard and modified scoop nets, and between fishing times. All tests were considered significant at $p<0.05$.

RESULTS

The catch of scoop net during study

The fishing time of the scoop net significantly influenced the weight of the catch. Operations between 12:00 p.m. – 04:00 p.m. produced 139.66±36.38 kg, or 78.87% of the total weight of the catch from both types of scoop nets. The fish weight only reached 37.41±36.38 kg (21.13%) when the scoop net was operated between 08:00 a.m. – 12:00 p.m.

The normality test using the Shapiro-Wilk test showed the catch data were not normally distributed with a p–value = 0.000. Therefore, the relationship between the fishing time and the weight of the catch was analysed using the Mann-Whitney test and followed by the Kruskal-Wallis test.

The statistical tests showed that the fishing time of the scoop net significantly affected the weight of the catch. The operations between 12:00 p.m. – 04:00 p.m. produced high catch with $p<0.005$ ($p = 0.000$) and can be considered as the optimal time to operate the scoop net in the future ($p = 0.000$).

The catch of the standard and modified scoop nets consisted of bluespot mullet (*Moolgarda seheli*), barramundi (*Lates calcarifer*), tigertooth croaker (*Otolithes ruber*), spotted scat (*Scatophagus argus*), and long whiskers catfish (*Mystus gulio*). Bluespot mullet dominated the scoop net catch weighing 101.71 kg or 57% of the total weight of the catch. Barramundi ranked second (52.90 kg; 30%), followed by tigertooth croaker (15.72 kg; 9%), spotted scat (4.44 kg; 3%), and catfish (2.31 kg; 1%). Figure 3 shows the weight of the scoop net catch based on fish species.

The fish species composition caught by the standard scoop net consisted of mullet, tigertooth croaker, spotted scat, and catfish, with a total weight of 29.42±42.92 kg, representing 16.61% of the total catch. The species caught by the modified scoop net were mullet, barramundi, tigertooth croaker, spotted scat, and catfish with a weight of 147.65± 42.92 kg (83.39%). Figure 4 shows the weight of the scoop net catch by species.

The normality test using the Shapiro-Wilk test revealed that the fish weight data of both scoop nets were not normally distributed ($p = 0.000$). Furthermore, the Mann-Whitney U test showed that the modified scoop net produced a higher catch than the standard one. The modification can be considered as a successful effort to increase the catch with $p<0.05$ ($p = 0.000$).

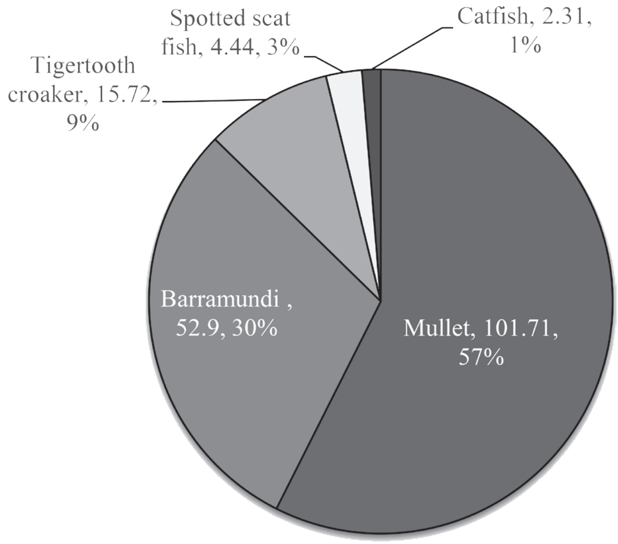

Figure 3. A pie-chart showing catch weight of both types of scoop net by fish species.

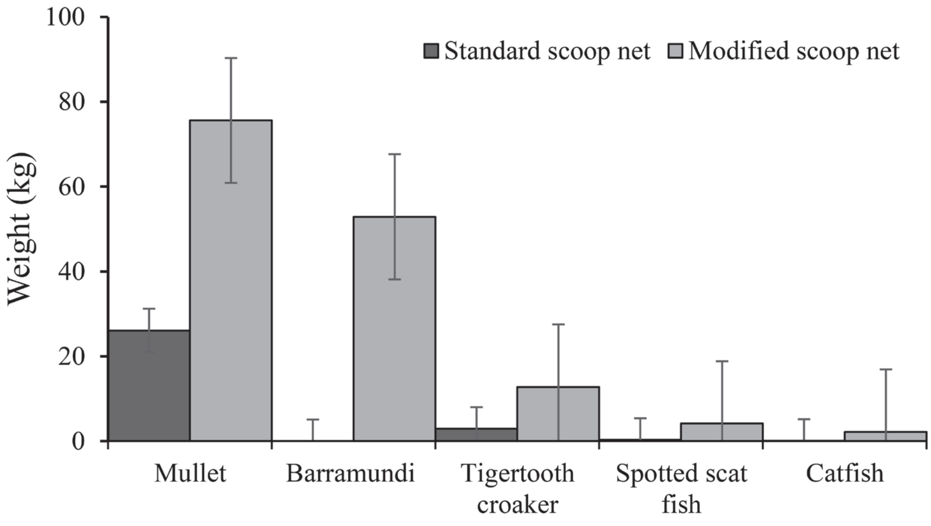

Figure 4. The catch weight of the standard and modified scoop nets based on the species.

Catch per unit effort (CPUE) was calculated to describe the positive influence of the modification of scoop net in increasing the catch. The result was presented in Table 1. It showed that modified scoop net produced the highest value of CPUE with 4.335.

Theoretical considerations of drag force

A scoop net is assumed as a fishing gear that is operated with simple technique. The question is whether it is that simple. The movement of the net to the water surface will cause a drag force R_D (kgf) which will be detected by the fish's lateral line. According to Marenkov (2018), the lateral line can be found at almost all fish, which is a fish seismic sense that is able to receive the low frequency of water vibrations. A high RD value will cause the fish to immediately escape from the top of the net (Bleckmann and Zelick, 2009). Therefore, the probability of successful operation of the scoop net will increase if the R_D value is highly reduced to prevent the fish detecting it.

The R_D value from drag force equation can only be reduced by reducing the V and A values. Nevertheless, the scoop net is designed to have a small mesh size, a small net thread diameter, and its pulling speed is very slow, thus the two variables namely V and A cannot be reduced further. The only way to reduce the R_D value without reducing the effectiveness of the scoop net is to modify the net by adding vertical cuboid-shaped pocket. The top of the pocket will form an opening on the surface of the scoop net. The length of the pocket is adjusted to the depth of the water. Figure 5 illustrates the direction of drag force vertically toward the water surface or in the same direction of the lifting ($\alpha = 0°$) produced by the standard scoop net and modified scoop net.

Table 1. Catch per unit effort (CPUE) of scoop nets during the research.

Type of scoop net	Time range	CPUE
Standard scoop net	08:00 a.m. – 12:00 p.m.	0.343
	12:00 p.m. – 04:00 p.m.	0.653
Modified scoop net	08:00 a.m. – 12:00 p.m.	0.994
	12:00 p.m. – 04:00 p.m.	4.335

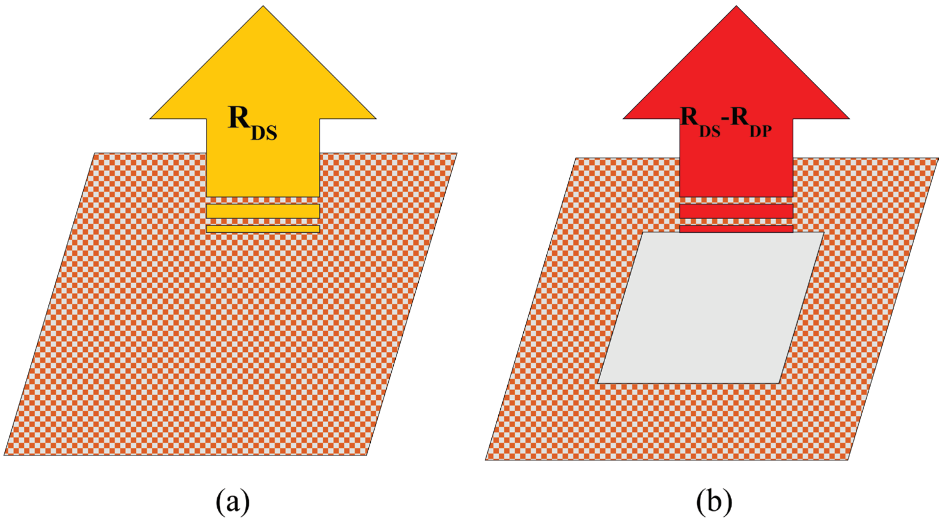

Figure 5. Illustration of drag forces direction on: (a) standard scoop net, and (b) modified scoop net.

Based on Figure 6, the reduction of drag force was caused by the presence of an additional pocket opening with area A_p on the surface of the standard scoop net A_s. The surface area of the pocket gave a value of $R_{DP} = 0$ when the bottom of the pocket had not been completely lifted from the bottom of the water, or the bottom of the pocket had not been closed. Therefore, the drag force generated by the surface of the modified scoop net became:

$$R_{DP} = \frac{1}{2} C_D \rho V^2 (A_S - A_P)$$

The drag force of standard scoop net RDS was:

$$R_{DS} = 0.5 \times 1.44 \times 1025 \text{ (kgf (m}^3)^{-1}) \times 0.03^2 \text{ (m}^2 \cdot \text{s}^{-2}) \times 1.952 \text{ (m}^2) = 1.296 \text{ kgf}$$

The drag force of modified scoop net became:

$$R_{DP} = 0.5 \times 1.44 \times 1025 \text{ (kgf (m}^3)^{-1}) \times 0.03^2 \text{ (m}^2 \cdot \text{s}^{-2}) \times (1.952 – 0.487) \text{ (m}^2) = 0.973 \text{ kgf}$$

The additional pocket reduced the drag force of the modified scoop to 0.973 kgf, or 75% of the drag force of the standard scoop net (1.296 kgf).

Tidal effect toward scoop net catch

The sea surface level in Morosari River mouth were displayed in Figure 6 to describe the tides in the location. The tide cycles in Morosari River mouth were observed and showed several types regarding the time. The daily tidal type

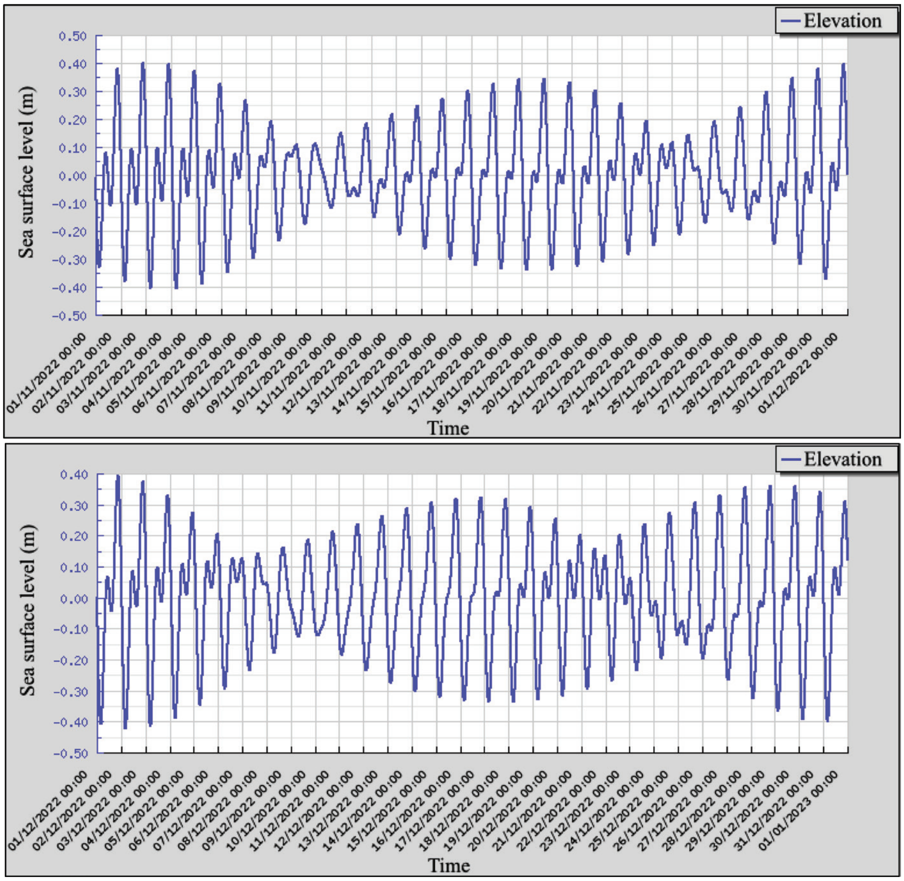

Figure 6. The sea surface level observed at Morosari River mouth during the research period (Ministry of Marine and Fisheries Affairs, 2024).

was mixed semidiurnal from 20th November – 7th December 2022. Flood tides were observed between 08:00 a.m. – 12:00 p.m. and ebb tides between 12:00 p.m. – 04:00 p.m. High tides mostly were observed between 12:00 p.m. – 04:00 p.m. regardless the occurrence of ebb tides. Diurnal tides occurred from 8th December – 17th December 2022 with flood tides were observed between 08:00 a.m. – 04:00 p.m. Spring tides occurred on 18th November, 2nd December, and 16th December 2022. Meanwhile, neap tides occurred on 25th November and 9th December 2022.

DISCUSSION

The research was conducted in an estuary environment, a semi-enclosed coastal area influenced by both marine and freshwater input. Tidal movements, specifically flood and ebb tides, impact fish availability within the estuary by moving water in and out (Naesje *et al*., 2012; Bennett *et al*., 2015). Flood tides, in particular, drive marine fish to swim up the estuary, increasing the potential for fish capture (Stoner, 2004; Pulver, 2017; Milardi *et al*., 2018).

Pahingguan *et al*. (2018) documented the diurnal tide pattern at the Morosari River mouth, where there is one high tide and one low tide, with high tides from 12:00 a.m. – 12:00 p.m. and low tides from 12:00 p.m. to 12:00 a.m. During flood tides, seawater flows into the estuary, bringing fish closer to shore and enhancing catch opportunities. Observations showed peak fishing activity with scoop nets at around 04:00 p.m. Tidal changes also affects the water temperature, which influences fish feeding activity (Yanti *et al*., 2012). High tide temperatures at the Morosari River mouth range from 30.23 to 31.87 ℃, while low tides see temperatures of 28.5 to 29.8 ℃ (Anggraeni *et al*., 2015). Tropical fish feeding peaks at around 30 ℃ (Warman, 2015), enhancing fish catch during high tides.

Fish catch composition

The largest catch proportion came from mullet which is a commercial fish with high economic value (Nita and Nenciu, 2020; Sawestri *et al*., 2021). Its habitat is in coastal waters, such as lagoons and estuaries (Arinç *et al*., 2000). Adult mullets migrate to the sea to spawn, while the larvae will be carried by the currents into shallow coastal waters (Sukumaran *et al*., 2022) and juveniles return to estuarine waters to feed on plankton and detritus (Peng *et al*., 2017). Spawning occurs once a year between August to February, with peak spawning between October and November (Moorthy *et al*., 2002), which align with the high catch period from September to December, when scoop net operations were conducted.

Barramundi comprised the second largest catch following mullets. Baramundi is known as one of commercial and valuable demersal fish in Indonesia and other Southeast Asian countries (Paulangan *et al*., 2020; Shah *et al*., 2020; Patangngari *et al*., 2022; Amir *et al*., 2022). As a catadromous, euryhaline species (Grey, 1987; Pethiyagoda *et al*., 2013; Amir *et al*., 2022; Nazir *et al*., 2023), it feeds mainly on shrimp, with small fish and worms as supplementary prey (Mushahida-Al-Noor *et al*., 2012; Ridho and Patriono, 2016). The juveniles migrate upstream and return to spawning habitat namely estuaries or the sea as adults or subadults (De, 1971; Ghosh, 1973; Blaber *et al*., 2008; Roberts *et al*., 2024). Baramundi mature as males by age 2–3 years and as females by age 4–6 (Guppy *et al*., 2022). Catches from current study was relatively high in number because the fishing was conducted during the fishing season which took place between May–February (Paulangan *et al*., 2020).

The catch numbers for croaker, scat fish, and catfish were lower than those for mullet and barramundi, primarily because their peak fishing seasons (April–June for croaker, August for scat fish, and April–July for catfish) did not align with the study period (Barry and Fast, 1992; Mitu, 2017).

Effect of additional pockets

The difference in fish weight caught by the standard and modified scoop nets can be attributed to variations in net construction. The standard scoop net is a 4×4 m square-shaped net, while the modified scoop net is smaller at 2×2 m and features a central opening. When lifted, the standard scoop net experiences a higher drag force (1.296 kgf) compared to the modified scoop net's drag force of 0.973 kgf. This 25% reduction in drag force (0.324 kgf) in the modified net decreased water vibrations, which is detected by the lateral line of the fish, allowing fish to escape less readily.

Fish detect drag forces through their lateral line, a hydrodynamic receptor system that enables them to sense water movement (Kalmijn, 1988). This system consists of hair cell receptors that respond to relative movements between the fish's body and the surrounding water (Coombs *et al*., 1992; Montgomery *et al*., 1995; Xu and Mohseni, 2016). The ability to sense water flow is particularly important for fish behaviour, especially in low-visibility conditions, such as at night, in murky waters, caves, or deep sea (Pohlmann *et al*., 2004; Windsor and McHenry, 2009). Therefore, adding an extra pocket to the net reduces the surface area exposed to water, thereby lowering the drag force. This reduction in drag force makes it harder for fish to detect water pressure changes, increasing the likelihood of capture by the scoop net. Furthermore, the probability of capture rises further if the fish is positioned directly above the top end of the additional pocket. At this point, the fish cannot detect any water flow, as the net at the bottom of the pocket remains open and unlifted, resulting in a drag force (R_{DP}) of 0 kgf.

CONCLUSIONS

The study found that fishing time with the modified scoop net between 12:00 p.m. – 04:00 p.m. yielded 139.66 kg of fish, or 78.87% of the total catch. The modified scoop net captured five fish species, namely bluespot mullet, barramundi, tigertooth croaker, spotted scat, and long whiskers catfish. The standard scoop net caught all these species except barramundi. The additional pocket feature of the modified scoop net increased the total catch weight to 147.65 kg, approximately 5.02 times greater than the standard scoop net catch weight (29.42 kg).

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