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RESEARCH ARTICLE

Sustainable Crab Fishing with Rakkang (Stick Dip Nets): Catch Performance and Socio-Economic Evaluation in Tanah Laut, Indonesia

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Abstract: This study aims to evaluate the catch performance and socio-economic relevance of traditional stick dip nets, by comparing two types, *Rakkang*-A in Muara Kintap and *Rakkang*-B in Bawah Layung, Tanah Laut Regency, Indonesia. The fieldworks were conducted between September and October 2024. A total of 580 *Rakkang* were deployed in the mangrove areas, with sample size: *Rakkang*-A (n = 73 lifts, 10.43±0.04) and *Rakkang*-B (n = 71 lifts, 10.14±2.89). The crab catch data on *Scylla serrata* and *S. olivacea* were collected, and statistical analysis was performed to determine significant differences in catch rates. Results showed that the two *Rakkang* types effectively captured both *S. serrata* and *S. olivacea*, but with species-specific preferences. *Rakkang*-A was more effective for *S. olivacea*, while *Rakkang*-B yielded higher catches of *S. serrata*. Catch per unit effort (CPUE) analysis revealed that *Rakkang*-A had a higher CPUE for *S. olivacea* (0.14 ind/trap) compared to *Rakkang*-B (0.05 ind/trap). Conversely, both *Rakkang* types performed equally for *S. serrata* (0.16 ind/trap). Overall, CPUE of *Rakkang*-A (0.30±0.03) was approximately 1.34 times greater than that of *Rakkang*-B (0.22±0.05). The bait selection played a crucial role, with *S. olivacea* being more attracted to fish bait, whereas *S. serrata* preferred crab bait. These findings highlight the importance of selecting the appropriate *Rakkang* type and bait for optimizing crab fishing efficiency. Further research on environmental factors and gear modifications could enhance sustainability and economic viability for local fishers.

Anahtar kelimeler:

Yengeç balıkçılığı
Üretkenlik
Sürdürülebilirlik
Endonezya
Mavi ekonomi

Rakkang (Katlanabilir Sepet) ile Sürdürülebilir Yengeç Balıkçılığı: Endonezya, Tanah Laut'ta Yakalama Performansı ve Sosyo Ekonomik Değerlendirme

Öz: Bu çalışma, Endonezya, Tanah Laut Regency, Muara Kintap'taki Rakkang-A ve Bawah Layung'daki Rakkang-B olmak üzere iki türü karşılaştırarak, geleneksel katlanabilir sepetlerin yakalama performansını ve sosyo-ekonomik önemini değerlendirmeyi amaçlamaktadır. Saha çalışmaları Eylül ve Ekim 2024 arasında yürütülmüştür. Mangrov alanlarına toplam 580 Rakkang konuşlandırılmış olup, örneklem büyüklüğü şu şekildedir: Rakkang-A (n = 73 kaldırma, 10,43 ± 0,04) ve Rakkang-B (n = 71 kaldırma, 10,14 ± 2,89). Scylla serrata ve S. olivacea'da yengeç yakalama verileri toplanmıştır ve yakalama oranlarındaki önemli farklılıkları belirlemek için istatistiksel analiz yapılmıştır. Sonuçlar, iki Rakkang türünün hem *S. serrata*'yı hem de *S. olivacea*'yı etkili bir şekilde yakaladığını, ancak türlere özgü tercihlerin olduğunu göstermiştir. Rakkang-A, *S. olivacea* için daha etkiliyken, Rakkang-B daha fazla *S. Serrata*'yı avlamıştır. Birim çaba başına yakalama (CPUE), Rakkang-A'nın *S. olivacea* için (0,14 ind/tuzak) Rakkang-B'ye (0,05 ind/tuzak) kıyasla daha yüksek bir CPUE'ye sahip olduğunu ortaya koydu. Tersine, her iki Rakkang tipi de *S. serrata* için eşit performans gösterdi (0,16 ind/tuzak). Genel olarak, Rakkang-A'nın CPUE'si (0,30 ± 0,03), Rakkang-B'den (0,22 ± 0,05) yaklaşık 1,34 kat daha fazlaydı. Yem seçimi önemli bir rol oynadı; *S. olivacea* balık yemine daha çok çekilirken, *S. serrata* yengeç yemini tercih etti. Bu bulgular, yengeç avcılığının verimliliğini optimize etmek için uygun Rakkang tipini ve yemini seçmenin önemini vurgulamaktadır. Çevresel faktörler ve ekipman değişiklikleri üzerine daha fazla araştırma yapılması, yerel balıkçılar için sürdürülebilirliği ve ekonomik uygulanabilirliği artırabilir.

Introduction

Rooted in the traditions of a coastal community, *Rakkang* (stick dip net) is a time-honored fishing gear particularly effective for catching crabs. It consists of a circular bamboo frame enclosing a net, anchored to the seabed by a central wooden pole. The *Rakkang* is equipped with bait that releases an odour that stimulates the olfactory senses of crabs, drawing them into the trap. Once inside, the net effectively confines them, enabling fishermen to harvest them without causing physical damage and mortality. It offers a sustainable approach to harvesting the crabs while minimizing environmental impact (Supeni et al., 2020).

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The traditional use of *Rakkang* reflects global patterns in small-scale fisheries (SSF), which are vital to food security, livelihoods, and sustainable resource use. According to the Illuminating Hidden Harvests (IHH) report (FAO, Duke University & WorldFish, 2023), SSFs contribute over 40% of global fish catches and support 492 million people, especially in developing countries. Yet, despite their importance, practices like *Rakkang* remain under-researched, particularly in terms of catch performance and socio-economic impact. Integrating such traditional practices into the blue economy framework, which emphasizes inclusive, sustainable, and economically viable use of ocean resources, can enhance policy relevance while promoting equitable benefits for coastal communities (Patil et al., 2016).

To support such integration, a clearer understanding of the technical and functional aspects of *Rakkang* is essential. The gear typically consists of a circular frame, a conical net body, and a central anchoring pole. The frame, made of bamboo, rattan, or metal, provides structural support, while the polyethylene (PE) net functions as an effective trap for the target species. A central bamboo pole stabilizes the gear and positions bait hooks near the entrance, keeping the net properly tensioned (Rosalina and Utami, 2021).

Rakkang is an efficient fishing method that requires minimal effort and simple tools. It can be folded, stacked and carried in large numbers when in use. However, successful *Rakkang* fishing requires a deep understanding of several key factors, including strategic trap placement, precise timing that coincides with the target species' behavior, and the selection of highly effective bait (Wijaya et al., 2010; Kabalmay et al., 2017; Diana et al., 2018).

Fishermen must carefully select locations frequented by the target species to maximize their catch (Afriani et al., 2024). *Rakkang* is specifically designed for operation in shallow waters, where it can be easily deployed and retrieved. The traps are usually spaced 15-30 m apart and soaked overnight to maximize efficiency. This makes it a practical tool for small-scale fishing operations (Hanafi et al., 2019). *Rakkang* is typically deployed in mangrove ecosystems with muddy or sandy substrates. These environments provide ideal habitats for mud crabs of the genus Scylla such as *Scylla Serrata*, *S. tranquebarica*, *S. paramamosain*, and *S. olilvaces* (Fazhan et al., 2022). These crabs are highly valued as a food source and play a significant role in the local economy (Abidin et al., 2022).

Understanding the biological behavior of crabs as a target species is crucial in the *Rakkang* fishery (Tahmid et al., 2015). Timing trap deployments to coincide with peak crab feeding activity is paramount (Rosalina and Utami, 2021). This maximizes encounter rates between crabs and the traps, increasing the likelihood of capture. Moreover, selecting the most attractive bait is crucial, as it directly influences crab foraging behavior and ultimately determines the success of the fishing operation (Haqie et al., 2024).

Rakkang exemplifies environmentally friendly fishing practices by utilizing recycled materials and minimizing its impact on the marine ecosystem. This aligns with the increasing recognition of the importance of environmentally responsible fishing practices (Yulisti et al., 2024). Despite adhering to fundamental principles, *Rakkang* designs and construction methods exhibit variations that often reflect the unique needs and preferences of individual fishing communities (Supeni et al., 2020). This study aims to evaluate the catch performance and socio-economic implications of *Rakkang* use, contributing empirical evidence to both national and global discussions on sustainable small-scale fisheries.

Material and Methods

Study site

Two paralel studies were carried out in the fishing villages of Muara Kintap (3°88'62"S, 115°24'33"E) and Bawah Layung (3°67'40"S, 114°62'87"E), located in Tanah Laut Regency, South Kalimantan, Indonesia (Figure 1). These villages, home to diverse ethnic groups including Banjar, Javanese, and Bugis, primarily rely on fishing and fish processing for their livelihoods. The fieldworks were conducted between September and October 2024, and did not encompass a full lunar or monsoon cycle; therefore, potential temporal bias was acknowledged. This study was supported by the Collective business groups, namely KUB Dermaga Bersama in Muara Kintap and KUB Bina Harapan Bersama in Bawah Layung. During the study period, physical oceanographic conditions included water temperature of 28.5-29 °C, water brightness of 45-60 cm, the current speed of 0.05-0.17 m s^{-1}, and salinity level of 5-10 ppt.

Data collection

Two distinct variations of traditional fishing gears: *Rakkang*-A, as practiced in Muara Kintap Village, and *Rakkang*-B, as employed in Bawah Layung Village, were investigated. A detailed summary of the distinctive characteristics of each *Rakkang* types are presented in Table 1. The performance of *Rakkang* itself was visualized in Figure 2, with the following explanations:

Frame Construction

The frames of both *Rakkang* are constructed from bamboo, a sturdy and lightweight material. The upper and bottom parts of the frames differ in size. In Muara Kintap, both the upper and bottom parts measure 510 mm, providing a consistent design. In Bawah Layung, the upper part measures 340 mm, and the bottom part is slightly larger at 410 mm, indicating a variation in structure likely suited to local fishing conditions.

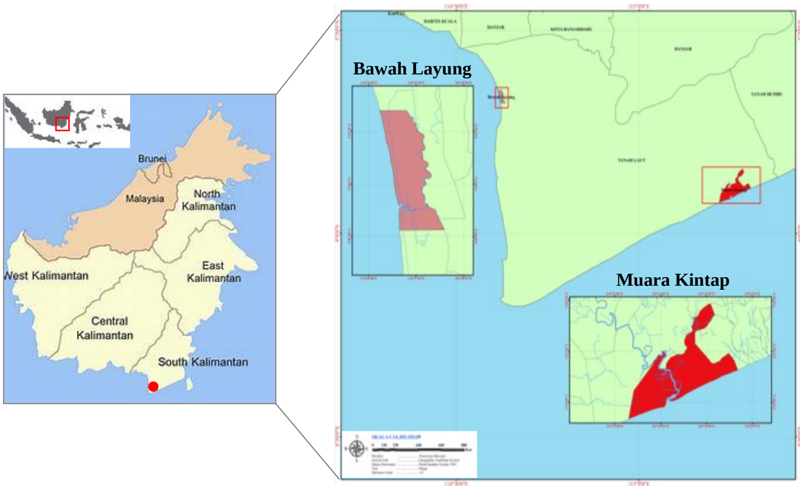

Figure 1. Geographic locations of Muara Kintap and Bawah Layung villages in Tanah Laut Regency, Indonesia, were the *Rakkang* were deployed

Net body

Both *Rakkang* types utilize a PE net body, which is favored for its durability and water resistance. However, they differ in mesh sizes: Muara Kintap uses a 50.8 mm mesh, while Bawah Layung incorporates a larger 63.5 mm mesh.

Entrance

The entrance materials and dimensions differ between the two villages. Muara Kintap uses green mesh with a fine 10 mm mesh size, while Bawah Layung employs PE with a significantly larger 38 mm mesh size. In Muara Kintap, the entrances are wider (240 mm) and taller (115 mm) compared to those in Bawah Layung (220 mm wide and 100 mm high). The slit entrance, which facilitates crab entry, is designed to be slightly narrower in Bawah Layung (70 mm) than in Muara Kintap (80 mm).

Support pole

Both villages utilize bamboo support poles to stabilize the gear and ensure the net opening remains secure. Their lengths and diameters vary slightly. Muara Kintap utilizes longer poles (1550 mm) with a 16 mm diameter, while Bawah Layung employs shorter poles (1450 mm) but with a thicker diameter of 18 mm.

Bait clip

The bait clip in Muara Kintap measures 250 mm in length, while in Bawah Layung, it is slightly shorter at 230 mm. Both locations utilize thin bamboo slices (20 mm) to enhance the bait clip's flexibility and strength.

Binding rope

Binding ropes are crucial for securing the gear components. Both sites use PE ropes, but the lengths vary significantly. Muara Kintap uses 820 mm ropes, while Bawah Layung uses shorter ropes of 540 mm. Both ropes share a consistent diameter of 3 mm, balancing strength and ease of handling.

Support ring

Support rings, made from polyethylene, serve to reinforce the gear structure. In Muara Kintap, the rings measure 25 mm in diameter, whereas those in Bawah Layung are slightly larger at 30 mm.

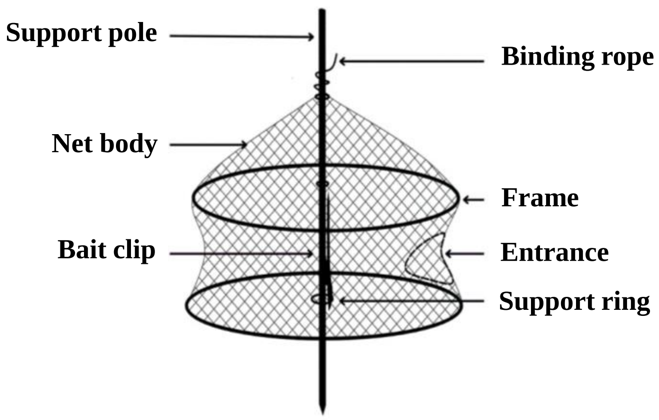

Figure 2. Illustration of the *Rakkang* used in Muara Kintap and Bawah Layung villages

Tabel 1. Technical specification of *Rakkang* used in Muara Kintap and Bawah Layung

No	Gear Construction	Location	
		Muara Kintap	**Bawah Layung**
1	Frame		
	- Material	Bamboo	Bamboo
	- Upper part (mm)	510	340
	- Bottom part (mm)	510	410
2	Net body		
	- Material	Polyethylene	Polyethylene
	- Mesh size (mm)	50.8	63.5
3	Entrance		
	- Material	Green mesh	Polyethylene
	- Mesh size (mm)	10	38
	- Width (mm)	240	220
	- Height (mm)	115	100
	- Slit entrance (mm)	80	70
4	Support pole		
	- Material	Bamboo	Bamboo
	- Length (mm)	1550	1450
	- Diameter (mm)	16	18
5	Bait clip		
	- Material	Bamboo	Bamboo
	- Length (mm)	250	230
	- Thin bamboo slice (mm)	20	20
6	Binding rope		
	- Material	Polyethylene	Polyethylene
	- Length (mm)	820	540
	- Diamter (mm)	3	3
7	Support ring		
	- Material	Polyethylene	Polyethylene
	- Diameter (mm)	25	30

The research steps for *Rakkang* fishing are include (1) Pre-operation: Preparing the bait, attaching the bait to the clip attached to the pole, preparing the boat and loading the *Rakkang* onto the boat. (2) Operation: Assembling the *Rakkang*, anchoring and soaking them in the water, then lifting the catch and detaching the pole from the *Rakkang*. (3) Post-operation: Removing the catch from the *Rakkang*, measuring their sizes, tying each catch individually, cleaning the *Rakkang*, and transporting the catch to the local collector, as well as maintaining the *Rakkang* properly for reuse. According to fishermen, *Rakkang* typically remains functional for two years.

In Muara Kintap, fishermen operated the *Rakkang* using 1 GT wooden boats (L8×B1.2×D0.6 m) powered by Honda GFK engines (diesel/pertalite). In contrast, in Bawah Layung, fishermen employed larger 1.5 GT vessels (L11.5×B1.52×D0.7 m) propelled by Jiang Fa (JF) 26 HP diesel engines. A total of 580 *Rakkangs* (245 units for Muara Kintap and 335 units for Bawah Layung) were deployed in mangrove areas, with depths between 0.40 and 0.65 m, during the period from 4 pm to 7 am. The *rakkang* were hauled in the morning, starting from the first installed to the last. The process begins by lifting and shaking the support sticks in water to remove mud. The equipment is then brought onto the boat, the binding ropes are loosened, and the support sticks are removed. Any remaining bait is discarded. This process is repeated until all *rakkang* are collected.

The daily operational periods for *Rakkang* are outlined in Table 2. Selecting the most attractive bait is crucial.

Two distinct types of bait were selected for crab fishing, namely: *Plicofollis tonggol*, which was used in Muara Kintap, and *Parathelphusa convexa*, was the favored chosen in Bawah Layung. The locations where Scylla crabs were recorded using GPS coordinates, and each crab was measured for carapace width and length. The crabs were then sold to the local market. Prices were initially recorded in Indonesian Rupiah (IDR) and later converted to US Dollars (USD) using the average exchange rate for October 2024, which was approximately IDR 15,690 per 1 USD. Research activities are visualized in Figure 3.

Table 2. The daily operational time periods for *Rakkang* in Muara Kintap and Bawah Layung

Site	Trip	Setting	Soaking	Hauling	Total time (h)
Muara Kintap	1	07:25 - 07:57	07:57 - 13:54	13:54 - 14.23	8
	2	16:10 - 17:24	17:24 - 06:00	06:00 - 07:15	15
	3	16:21 - 17:03	17:03 - 06:07	06:07 - 07:03	15
	4	17:04 - 18:33	18:33 - 06:54	06:54 - 07:59	15
	5	18:49 - 19:51	19:51 - 06:15	06:15 - 07:48	13
	6	16:28 - 17:08	17:08 - 06:03	06:03 - 06:52	14
	7	16:06 - 16:24	16:28 - 06:13	06:13 - 06:32	14
Bawah Layung	1	17.39 - 19.02	19.02 - 05.45	05.45 - 07.22	14
	2	17.05 - 19.25	19.25 - 05.38	05.38 - 07.38	15
	3	17.10 - 19.57	19.57 - 05.44	05.44 - 07.30	14
	4	17.15 - 20.00	20.00 - 06.01	06.01 - 08.02	15
	5	17.12 - 20.05	20.05 - 05.33	05.33 - 07.45	15
	6	17.05 - 19.48	19.48 - 05.33	05.33 - 08.00	15
	7	17.22 - 19.59	19.59 - 05.23	05.23 - 07.45	14

Data analysis

Subsequent to data collection, the proportion of each crab type, expressed as a percentage, was determined using a standardized formula (Anggreini et al., 2017):

$$Pi = \frac{ni}{N} \times 100\ \%$$

where *Pi* denotes the relative abundance of catch (%), *ni* signifies the number of catches for species i (ind.), and *N* represents the total catch (ind.). The productivity of each *Rakkang* was subsequently estimated using the following formula (Dahle, 1989):

$$P = \frac{c}{t}$$

where *P* is the productivity, *C* is total daily catch (ind.), and *t* is effective fishing time (h)

Statistical analysis

Data analysis was performed using Microsoft Excel or SPSS version 18. Descriptive statistics, including mean ± standard error (SE) and percentages, were computed and presented in both graphical and tabular formats. Prior to inferential testing, the Shapiro–Wilk test was applied to assess the normality of continuous data. When data met normality assumptions, independent sample t-tests were used to compare catch number, CPUE, and productivity rate between crab types, and between the two Rakkang designs. Statistical significance was established at the $p<0.05$ level.

The lagoon, belonging to the Strait of Messina ecosystem (Fig. 1), is subject to various protection regimes, in the framework of the Natura 2000 network (cod. ITA 030008). It includes two connected but differently featured basins, i.e., Lake Faro, known for its notable depth and a peculiar meromictic regime (Leonardi et al., 2009), and the markedly brackish Lake Ganzirri (Azzaro et al., 2005). On September 22th, 2024, in the morning, during an excursion along Lake Ganzirri, Mrs. Lucrezia Pietramala had the opportunity to observe a sepecimen of *L. surinamensis* in a clam farming area (38°15'29" N; 15°36'38"E).

Figure 3. The photographs of the *Rakkang* used in Muara Kintap and Bawah Layung

Results and Discussion

Rakkang has demonstrated significant effectiveness in capturing both giant mud crab (*S. serrata*) and orange mud crab (*S. olivacea*) within the two villages (Figure 4). In Muara Kintap, *S. serrata* displayed a narrower carapace (102±0.4 mm) than *S. olivacea* (89±1.3 mm), although their caparace lengths were similar. The respective weights of the two species were 247 g and 184 g. In contrast, *S. olivacea* in Bawah Layung had a significantly broader carapace (124±0.5 mm) than *S. serrata* (96.5±1.4 mm). While there was some overlap in carapace length between the two species, *S. olivacea* generally exhibited a slightly longer carapace (81±0.2 mm) compared to *S. serrata* (65±1.1 mm). This trend was also reflected in their weights, with *S. olivacea* and *S. serrata* weighing 300 g and 200 g, respectively.

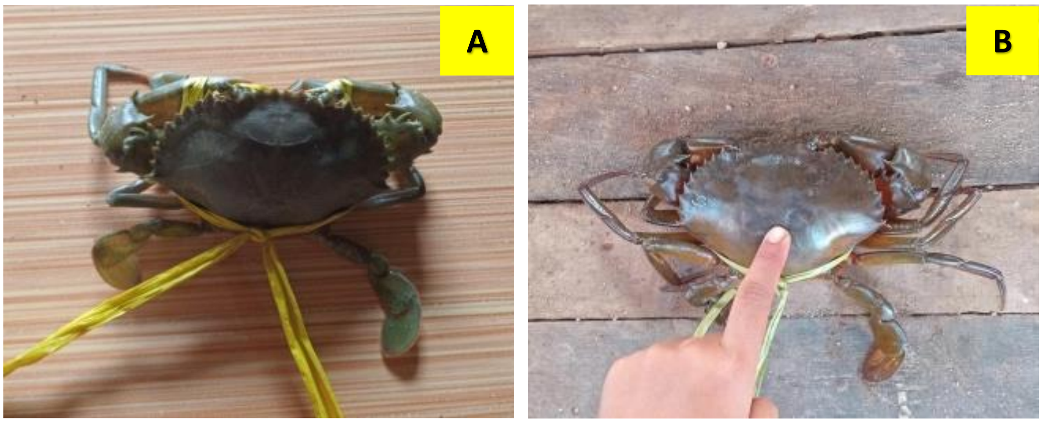

Figure 4. The main catch of *Rakkang*: A. *Scylla serrata*, and B. *Scylla olivacea*
Sample size: *Rakkang*-A (*n* = 73 lifts, 10.43±0.04) and *Rakkang*-B (*n* = 71 lifts, 10.14±2.89)

A more in-depth analysis was performed to investigate the relationship between *Rakkang* usage and daily catch at both sites during the fishing period. While the catch fluctuates, the use of *Rakkang* remains steady in Muara Kintap, unlike in Bawah Layung where it varies (Figure 5). The actual daily catch in both locations consistently falls short of what would be expected based on the number of *Rakkang* employed. This discrepancy suggests that other factors such as environmental conditions or crab abundance, are likely influencing the catch. Moreover, both locations are accessible to both local and outside fishermen. Further investigation is needed to comprehend the dynamics of this relationship fully.

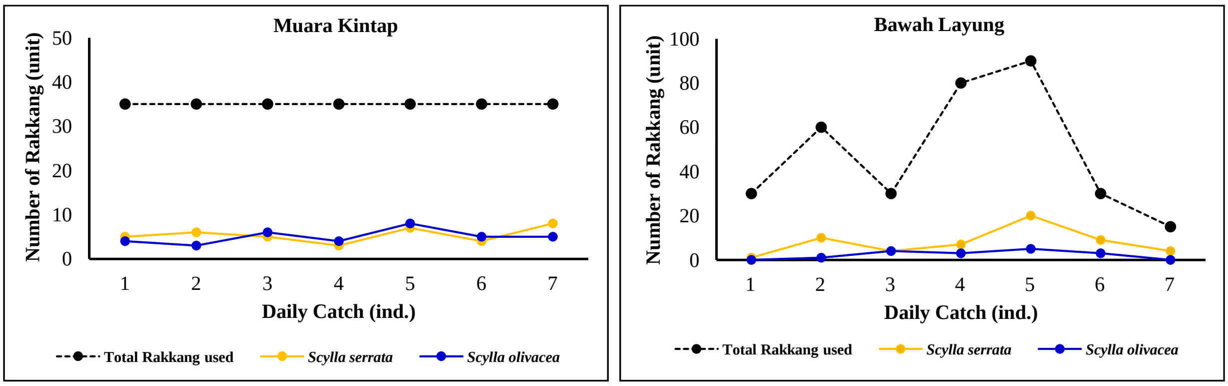

Figure 5. Comparison of *Rakkang* catches in Muara Kintap and Bawah Layung villages

The comparative analysis indicates that both *Rakkang* types exhibit similar effectiveness, with only slight variations in catch numbers, productivity, and fishing duration (Table 3). The findings highlight the adaptability of *Rakkang* to different conditions in Muara Kintap and Bawah Layung, offering insights into optimizing gear use for improved efficiency. Overall, there were no significant differences in the catch number and productivity rate between the two *Rakkang* types within the given time period ($p > 0.05$). The proportion of the total catch attributed to each *Rakkang* type shows a near-equal distribution. *Rakkang*-A contributed 48.9% of the total catch, while *Rakkang*-B accounted for 51.1%. This minor difference suggests that both *Rakkang* types are comparably effective, with *Rakkang*-B (0.755 ind/h) was slightly higher productivity compared to *Rakkang*-A (0.723 ind/h).

Table 3. Comparison of *Rakkang* effectiveness based on the productivity rate

Rakkang	Total catch (ind.)	Duration (h)	Productivity (nd/h)	Proportion (%)
A	73	101	0.723	48.9
B	71	94	0.755	51.1
Total	144	195	1.478	100

The comparative analysis of *Rakkang* CPUE based on crab species caught revealed that *Rakkang*-A was significantly more efficient for *S. olivacea*, with a CPUE of 0.14 ind/trap compared to 0.05 ind/trap for *Rakkang*-B, represent 74% of the total *S. olivacea* catch. Dealing with *S. serrata*, both *Rakkang*-A and *Rakkang*-B performed equally, with a CPUE of 0.16 ind/trap, each contributing 50% to the total *S. serrata* catch (Table 4), possibly due to the species' less selective behavior or broader habitat range compared to *S. olivacea*.

Table 4. Comparison of *Rakkang* CPUE and its proportion based on crab species caught

Scylla serrata	Total catch (ind.)	Σ *Rakkang* (trap)	CPUE (ind/trap)	Proportion (%)
Rakkang-A	38	245	0.16	50
Rakkang-B	55	335	0.16	50
Total	93	580	0.32	100
Scylla olivacea				
Rakkang-A	35	245	0.14	74
Rakkang-B	16	335	0.05	26
Total	51	580	0.19	100

The effectiveness of *Rakkang* in catching Scylla crabs in Muara Kintap (*Rakkang*-A) and Bawah Layung (*Rakkang*-B) was presented in Table 5. A total of 93 specimens of *S. serrata* were caught across both sites, with *Rakkang*-B proved to be better than *Rakkang*-A. The productivity rate of *Rakkang*-B for *S. serrata* (0.585 ind/h) was significantly higher than *Rakkang*-A (0.376 ind/h). *Rakkang*-B made up 61% of the total catch, whereas

Rakkang-A accounted for 39%. This responds with the greater number of *Rakkang* employed. Conversely, *Rakkang*-A was more effective in catching *S. Olivacea* than *Rakkang*-B. The productivity rate of *Rakkang*-A (0.347 ind/h) was twice as high as that of *Rakkang*-B (0.170 ind/h). The proportion of total catch also reflects this trend, with *Rakkang*-A contributing 67% and Rakkang-B only 33%. These findings suggested that different *Rakkang* types perform better for different crab species, likely due to variations in their deployment or the selection of bait used.

Regarding the profitability metrics, confidence intervals for net profit per day could not be directly calculated due to incomplete data on operational costs such as fuel, bait, and labor.

Table 5. Comparison of *Rakkang* productivity based on crab species caught

Scylla serrata	**Total catch (ind.)**	**Duration (h)**	**Productivity (ind/h)**	**Proportion (%)**
Rakkang-A	38	101	0.376	39
Rakkang-B	55	94	0.585	61
Total	93	195	0.961	100
Scylla olivacea				
Rakkang-A	35	101	0.347	67
Rakkang-B	16	94	0.170	33
Total	51	195	0.517	100

Discussion

A key advantage of *Rakkang* trap is its minimal impact on the captured crabs. Being a passive method, it reduces stress and physical damage compared to other fishing methods such as trawl net and trammel net. The active use of the *Rakkang* involves lifting and resetting it, as failure to do so increases the risk of crabs escaping. Several factors need to be considered for the success of *Rakkang* fishing operation. First, select the right installation location. The *Rakkang* should be set near crab holes/burrows, in mild weather with sea-to-land winds. Strong winds frequently lead to overnight high tides, drawing crabs out of their burrows in search of food (Rusmilyansari et al., 2021). A crucial element of *Rakkang* is a central wooden pole that anchors the trap to the muddy soil, keeping it stable and upright against currents. Its conical net guides target species towards the center. *Rakkang* should not be set in areas with strong currents, as the bait may be carried away, and the rakkang could shift slightly due to nighttime tides and the soft, muddy soil in the mangrove area. The loss of bait and the shifting are beyond the fishers' expectations.

Secondly, the timing of trap installation should align with the biological cycle or feeding patterns of the target species. Synchronizing trap deployment with the crabs' active feeding periods increases the chances of a successful catch per unit effort (Rosalina and Utami, 2021). Understanding crab behavior helps fishermen target specific areas and times, minimizing the impact on non-target species and the broader ecosystem (Tahmid et al., 2015). Thirdly, selecting the appropriate bait, including its type and freshness, is critical to enhance crab catch efficiency (Gustiawan et al., 2018; Haqie et al., 2024). It is essential to securely attach the bait from end to end to prevent it from being swept away. Also, regularly check the *Rakkang* traps, particularly the netting, for damage that may allow crabs to escape.

Fourth, there is considerable interest in improving catchability by choosing the right materials particularly for trap entrances. In Muara Kintap, slit entrance is made of green mesh, while in Bawah Layung, it is constructed from polyethylene. For trap entrances, green mesh is generally the better choice due to its natural camouflage, flexibility, and cost-effectiveness compared to polyethylene. It helps attract crabs into the trap without deterring them, resulting in maximizing catch efficiency. Polyethylene, while durable, is better suited for structural parts of the trap rather than the entrance. If environmental sustainability is a priority, consider using biodegradable or recyclable polyethylene materials to minimize ecological impact. However, if cost and ease of use are more important, green mesh is a practical and effective option. Additionally, combining the two materials (e.g., using polyethylene for structural strength and green mesh for the trapping area) could offer a balanced solution. A single-entrance trap featuring green netting at the entrance has also proven effective in the swimming crab fishery, as demonstrated by Tran et al. (2020).

The highest catch proportion of *S. serrata* in Bawah Layung is similarly documented in the Central Tapanuli District, North Sumatra (Larosa et al., 2013). In contrast, *S. olivacea* is identified as the dominant species in Muara Kintap, as well as in Terengganu, Malaysia (Fazhan et al., 2022). The average CPUE for crabs in our study (0.16 ind/trap) is relatively lower than the CPUE for Scylla crabs (0.80 ind/trap) in Terengganu, Malaysia

(Fazhan et al., 2022). Regarding bait usage, the results showed that *Rakkang*-A is more effective for targeting *S. olivacea*, while *Rakkang*-B performs slightly better for *S. serrata*. This suggests that *S. olivacea* is more attracted to fish bait, whereas *S. serrata* shows a preference for crab bait. This aligns with Haqie et al. (2024), who highlighted the importance of bait selection in optimizing catch efficiency and reducing ecological impact. While *S. serrata* is associated with dense mangroves, *S. olivacea*, as an intertidal species, is more easily located in mangrove areas because of its limited movement within a specific home range and its habit of returning to the same area after foraging. This behavior is beneficial for trap deployment, enhancing the chances of a successful catch. The movement of mud crabs in mangrove areas, tracked using telemetry systems, is further detailed in studies by Ikhwanuddin et al. (2012) and Fazhan et al. (2022). According to Putri et al. (2022) *S. olivacea* exhibits a greater adaptation rate compared to *S. serrata* within this mangrove ecosystem. While *S. serrata* is prefered species for mud crab farming (Quinitio & Parado-Estepa, 2017).

The use of *rakkang* traps in this study likely had minimal ecosystem impact due to their lightweight design and passive operation. Although some contact with the seabed occurs, these traps are not actively dragged and thus are unlikely to cause significant benthic disturbance. Moreover, the risk of ghost fishing is considered low, as the traps are typically retrieved daily and are constructed with open entryways that reduce continued entrapment of organisms if lost. Similar findings have been reported for other passive gear types, such as crab pots and fish traps, which show limited impact on benthic habitats and low ghost fishing persistence when properly managed (Rijkure et al., 2024). Nevertheless, routine monitoring and lost gear retrieval programs are recommended to minimize potential long-term ecological risks.

The crab prices in Muara Kintap and Bawah Layung vary significantly according to category, sex, weight, and physical condition as outlined in Table 6. These variations reflect the market's valuation of crabs based on their quality, size, and reproductive status. For instance, the egg-bearing female crabs typically command higher prices due to their desirability for breeding or culinary purposes, while crabs with physical defects, such as missing limbs or soft shells, are priced lower. In both locations, the captured crabs weighed between 184 and 300 g, are classified as standard size. This weight range is considered ideal for commercial purposes, as it balances meat yield and market preferences. Crabs within this range are large enough to provide substantial meat but are not overly mature, which can sometimes affect texture and taste. The consistency in weight across both locations suggests stable environmental conditions and effective fishing practices that target crabs within this preferred size range. The sizes of Scylla crab captured in our study align with the requirements of Indonesia's Ministerial Regulation No. 17/2021, which mandates a minimum legal size for domestic consumption or export is 150 g in weight or 120 mm in carapace width.

The outcomes of this study are also directly relevant to the management of lobster, crab, and swimming crab within Indonesia's territory, as regulated under Ministerial Regulation No. 12/2020. This regulation prohibits the capture and trade of egg-bearing females and crabs below a minimum size threshold (≤100 g) to protect reproductive stocks and promote sustainability. However, market observations from this study indicate that undersized crabs and berried females are still frequently harvested and sold, particularly through informal supply chains. This underscores the need for stronger enforcement mechanisms and local stakeholder engagement to ensure compliance. Aligning community-based practices with national regulations could enhance resource sustainability while maintaining livelihoods.

An understanding of local market conditions and crab biological traits proved crucial in assessing the economic contributions of the crab fishery. The classification of crabs into categories based on weight, sex, and physical condition not only helps fishermen maximize their profits but also ensures that collectors/buyers receive the crabs that meet specific quality standards. Furthermore, the consistent capture of crabs within the 184-300 g range indicates sustainable fishing practices, as it avoids overharvesting juvenile crabs, which are critical for population replenishment, and overly mature crabs, which may have lower market value. The prices of mud crabs fluctuate depending on marketing channels, seasonal variations, and the interplay of supply and demand (Manzano et al., 2023).

While this study provides insights into the economic returns of crab fishing, confidence intervals for daily net profit could not be directly determined due to limitations in collecting comprehensive cost data (e.g., fuel, bait, labor). This limitation should be considered when interpreting the profitability results. Nevertheless, the observed variability in crab selling prices (USD/kg) across different categories and study sites is provided as a proxy to reflect potential fluctuations in revenue streams. After all, maintaining market transparency and ensuring fair pricing in small-scale crab fisheries is essential to prevent conflicts of interest and promote equitable practices.

Although sex-specific catch data were not recorded in this study, price classifications based on sex and reproductive condition (e.g., egg-bearing females) suggest a significant presence of females in the catch. Monitoring sex ratios is essential in crustacean fisheries management, as overharvesting of females, particularly gravid individuals, can negatively impact reproductive output and stock sustainability (FAO, 2015). Future research should incorporate sex ratio assessments to inform more targeted and ecologically sound management interventions.

While this study focused on the income generated by crab harvesting activities, it is important to acknowledge the role of women in the post-harvest segment of the crab value chain. In both Muara Kintap and Bawah Layung, women are actively involved in tasks such as sorting, cleaning, boiling, and selling crabs in local markets. These roles, although often informal and underrecognized, are essential in maintaining product quality and ensuring access to market. Women's participation in these stages contributes to household income and food security, and therefore should be considered in the design of equitable fisheries management and value chain interventions (Harper et al., 2013).

Table 6. Crab marketing prices in Muara Kintap and Bawah Layung at the collector level.

Muara Kintap			Bawah Layung		
Category	**Weight (g)**	**Price (USD/kg)**	**Category**	**Weight (g)**	**Price (USD/kg)**
Egg-bearing female [1,2]	410	14	Egg-bearing female [1]	400	25
	300	11		300	19
	250	10		<300	13
Super	455-500	10	Large male	300-400	6
Large male	300-450	5	Egg-bearing female [2]	400	27
Medium male	190-220	4		300	20
Black large male	300-450	5		<300	14
Black medium male	190-220	3	Large male	300-400	6
Missing 1 claw	190-220	3	Standard large male	>300	2
Missing 2 claws	150-180	2	Standard large female	<300	4
Small crab for			Missing 1 claw	<300	1
seedlings	100-150	1	Missing 2 claws/small	100-150	1

Note: [1] *S. serrata*. [2] *S. olivacea*

To support a sustainable *Rakkang* fishery in Muara Kintap and Bawah Layung, the following recommendations can be implemented: (1) Harvest only crabs that meet the legal size requirements and refrain from capturing the egg-bearing females to protect juvenile crabs and sustain breeding stocks. Restrict fishing access during breeding seasons to allow crab reproduction and population growth. (2) Replace non-biodegradable materials with biodegradable alternatives like green mesh to reduce environmental impact. Modify *Rakkang* to improve selectivity for target species and minimize bycatch rate. (3) Restore degraded mangrove areas to provide essential habitats for crab breeding and growth. Prevent illegal fishing or habitat destruction to ensure compliance with regulations. (4) Engage local fishers in decision-making to encourage collective responsibility for sustainable crab fishery. Establish fair pricing based on crab size, sex, and condition to discourage the capture of undersized or egg-bearing crabs. Incentivize sustainable practices with certifications or eco-labels. (5) Perform regular stock assessment to monitor crab population growth, condition factor, and utilization trends to inform adaptive management strategies.

Conclusion

Rakkang is an eco-friendly and highly selective fishing gear that maintains catch quality, minimize bycatch, and promotes sustainability, making it a favored choice among fishermen. *Rakkang*-A was more effective for catching *S. olivacea*, while *Rakkang*-B proved to be better for catching *S. serrata*. Furthermore, *S. olivacea* is more attracted to fish bait, whereas *S. serrata* shows a preference for crab bait. By optimizing trap placement, timing, and bait selection, *Rakkang* enhances catch efficiency in mangrove environments. This study also provides a basis for future inclusion of local crab fisheries in Fishery Improvement Projects (FIPs), helping to improve sustainability and market access.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

Author Contributions

The author conceived, designed, analyzed, and prepared this manuscript.

Ethics Approval

No ethics committee approval is required for this study.

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