NOTE

Sustainable fishing: a study on barrier traps in Indonesia

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ABSTRACT. Fishermen from Indonesia are uncertain whether the timing and placement of *Belats* (guiding barrier traps) affects their catch. To answer this question and improve the long-term viability and productivity of the *Belat* fishery, this study described the catch composition, productivity, and efficiency of *Belat* in Tanjung Batu Village, Kotabaru Regency, Indonesia. Two *Belats* consisting of a leader net, playground, and chamber net, were used in this study: *Belat*-A was larger than *Belat*-B in both length and breadth. *Belat*-A was deployed at 2 km from the shoreline, while *Belat*-B was installed at 1.5 km away, starting at 10 a.m. over a 24-h and a 48-h period, respectively. Results showed that *Belat*-A outperformed *Belat*-B, capturing twice the number of catch (970 versus 460) and 1.6 times the weight (92.6 kg versus 59.1 kg) across ten fish species between 14-50 cm of total length. However, *Belat*-B achieved similar productivity rates in half the operational time, making it more time-efficient. All fish caught were fresh and marketable, while the method itself was considered environmentally friendly. Several factors that affected the *Belat* catch and recommendation for upcoming *Belat* studies are also discussed.

Key words: *Belat* performance, eco-friendly, productiveness, time-efficient, sustainability.

Pesca sostenible: un estudio sobre las trampas de barrera en Indonesia

RESUMEN. Los pescadores de Indonesia no están seguros de si el momento y la ubicación de los *Belats* (trampas de barrera) afectan sus capturas. Para responder a esta pregunta y mejorar la viabilidad y productividad a largo plazo de la pesquería de *Belats*, este estudio describió la composición de la captura, la productividad y la eficiencia de estos dispositivos en la aldea de Tanjung Batu, Regencia de Kotabaru, Indonesia. En este estudio se utilizaron dos Belats que consisten en una red líder, una red de juegos y una red de cámara: el *Belat*-A era más grande que el *Belat*-B, tanto en longitud como en anchura. El *Belat*-A se desplegó a 2 km de la costa, mientras que el *Belat*-B se instaló a 1,5 km de distancia, comenzando a las 10 a.m. durante un período de 24 h y 48 h, respectivamente. Los resultados mostraron que el *Belat*-A superó al Belat-B, capturando el doble de peces (970 frente a 460) y 1,6 veces el peso (92,6 kg frente a 59,1 kg) de diez especies de peces de entre 14-50 cm de longitud total. Sin embargo, el *Belat*-B logró índices de productividad similares en la mitad del tiempo operativo, lo que lo hizo más eficiente en términos de tiempo. Todos los peces capturados eran frescos y comercializables, mientras que el método en sí se consideró respetuoso con el medio ambiente. También se discuten varios factores que afectaron la captura de los *Belats* y se recomiendan futuros estudios.

Palabras clave: Desempeño del *Balat*, eco-amigable, productividad, eficiente en el tiempo, sustentabilidad.

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Kotabaru Regency, spanning 9,442 km^2, is a prominent marine fishing region in South Kalimantan, Indonesia. Local fishermen utilize 19 diverse fishing gear types, among which is the *Belat*, a passive guiding barrier trap. This eco-friendly method involves permanently positioning the gear in tidal areas that serve as fish migration routes. As the tide rises, fish move towards the shore, and as it recedes, they follow the fence-like structure into the trap (Asmin et al. 2023). This technique, similar to set-net fishing, has minimal environmental impact (Akiyama and Arimoto 2000). The *Belat* is a community-friendly solution, offering low investment cost, profitability, respect for local culture, and compliance with local regulations (Lindawati et al. 2024).

Tanjung Batu, a traditional fishing village in Kotabaru Regency, relies on *Belat* to catch fish. This technique, which involves strategically placing traps in fish-rich areas, has proven effective in a number of regions, including Waetuo and Pallette in Bone Regency, southern Sulawesi Province (Surachmat et al. 2017), and Dakiring in Bangkalan, eastern Java Province (Yunita and Zainuri 2021). Several factors such as gear size, geographical location, fish behavior, moon phase, and fishing time, can affect *Belat* productivity (Milardi et al. 2018; Lindawati et al. 2024). Pinpointing the exact locations for *Belat* can significantly enhance the efficiency and productivity of fishing operations (Hamriani et al. 2021). Siregar et al. (2015) found that night-time *Belat* catches were significantly higher than daytime catches. Fishers are currently uncertain if the timing and location of *Belat* fishing affect their catch. While research might seem counterintuitive to *Belat*-friendly practices, its aim is to enhance the long-term viability and productivity of the *Belat* fishery.

Fieldwork was conducted between May and June 2024 at Tanjung Batu Village (2° 59′ 177″ S, 116° 12′ 640″ E) (Figure 1), Indonesia. Physical oceanographic conditions encompassed water temperature of 29-30 °C, water brightness (Secchi depth) of 34-55 cm, current speed of 0.13-0.15 m s^{-1}, and salinity level of 34-40.

A V-shaped *Belat* structure was constructed with polyethylene netting and sungkai wood to intercept

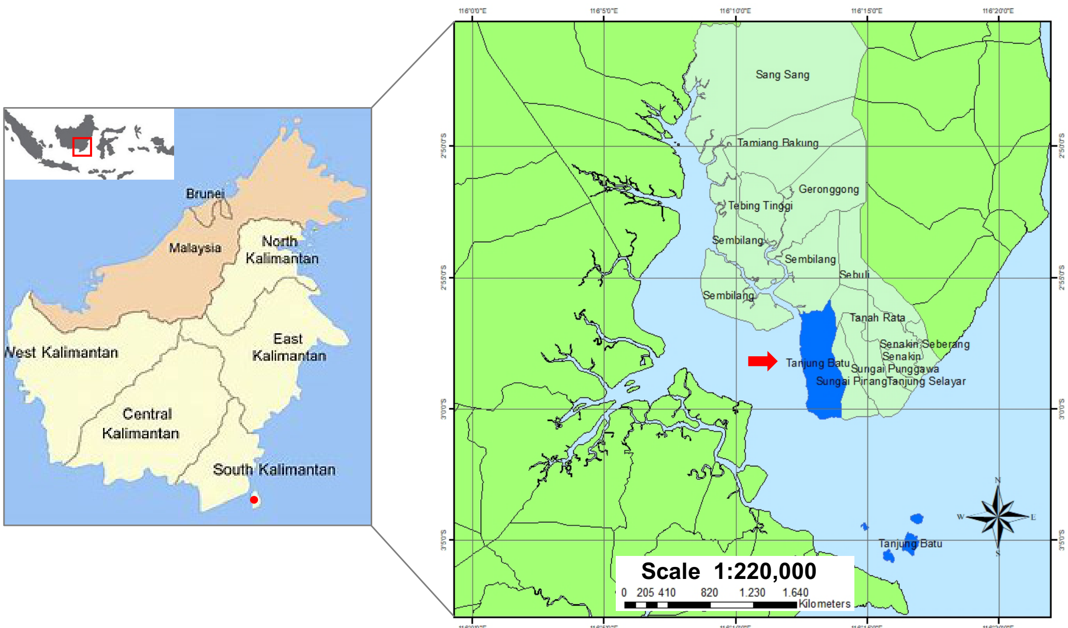

Figure 1. Geographic location of Tanjung Batu Village, Kotabaru Regency, Indonesia, where *Belats* were deployed.

schools of migratory fish and guide them into a chamber net using a seine system (Figure 2). Two different *Belat* sizes were used to compare their productivity rates (Table 1).

The leader net height was adjusted to accommodate the maximum water depth during high tide, ensuring optimal gear performance. Conical playgrounds were situated on both sides of the gear to intercept incoming fish and direct them towards the chamber net. The chamber net was designed with two doors: a primary door of 35 cm in width leading to the main chamber, and a secondary trap door of 15 cm in width leading to a smaller trap chamber. The exterior of the chamber net mesh was covered with bamboo for easier access. *Belat*-A was deployed 2 km from the coast, while *Belat*-B was deployed 1.5 km away, starting at 10 a.m. for a period of 24 and 48 h, respectively. Water depth varied between 4 m and 5 m during high tide and 1 m during low tide. Fishers used a small boat to access these gears. Fish trapped in the chamber net were scooped and transferred to fish boxes, identified, weighted and sorted by species. Subsequently, the proportion of each fish type, both by number and weight, was calculated as a percentage using a standard formula (Simbolon et al. 2011):

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

where *Pi* represents the relative abundance of catch (%), *ni* is the number of catches for species *i* (fish or kg), and *N* is the total catch (fish or kg). The productivity of each *Belat* was estimated using the following formula (Dahle 1989):

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

where *P* is the productivity, *C* is the total daily catch (kg), and *t* is the effective fishing time (h). Data were analyzed using SPSS version 18 and presented as mean ± standard error (SE) or percentage. Normality homogentiy of the data were tested using the Lilliefors test (Dallal and Wilkinson 1986). A t-test was applied to compare the catch proportion and productivity rate between *Belats*. Statistical significance was determined at $p < 0.05$.

Ten commercial fish species were caught by this fishing method (Table 2). The average daily catch of *Belat*-A and *Belat*-B over a 15-day period was 65 ± 5.0 fish and 31 ± 6.0 fish, respectively. In terms of average daily weight, *Belat*-A caught 6.2 ± 0.6 kg, while *Belat*-B caught 3.9 ± 0.5 kg. All fish caught were fresh and marketable. *Belat* catches were primarily composed of high-value species such as *Siganus javus*, *Lates calcarifer*, *Lutjanus sanguineus*, *L. analis*, and *Epinephelus coioides*, accounting for 50% of the total catch, with an estimated price of USD 2.5-3.0 kg^{-1}. The remaining half consisted of less commercial, more abundant species of lower market demand, priced at USD 1.0-1.5 kg^{-1} (Table 2).

Figure 2. *Belat* installation in Tanjung Batu waters, Kotabaru Regency, Indonesia. A) Leader net. B) Playground. C) Chamber net.

Table 1. Technical specifications of both *Belat* gears used in Tanjung Batu, Kotabaru, Indonesia.

Gear construction	Material	*Belat*-A (m)			*Belat*-B (m)		
		Length	Breadth	Height	Length	Breadth	Height
Leader net	Polyethylene # 2.5-inch	150	-	7	130	-	6
Playground	Polyethylene # 2.5-inch	20	-	-	10	-	
Chamber net	Polyethylene # 1.5-inch	10	-	5	10	-	5

Table 2. *Belat* catch compositions and sell prices at local markets in Tanjung Batu Village, Kotabaru Regency.

Scientific name	Average size (cm)	Total catch (fish)	Total catch (kg)	Price (USD kg^{-1})
Siganus javus	35	25	12.2	2.5
Lates calcarifer	30	17	11.8	3.0
Lutjanus sanguineus	45	4	6.8	3.0
Epinephelus coioides	35	27	19.4	2.5
Sphyraena jello	50	23	5.5	1.0
Lutjanus analis	30	60	30.2	3.0
Alectis ciliaris	19	26	3.3	1.0
Gerres erythrourus	15	1,039	42.4	1.0
Lutjanus fulviflamma	15	155	16.5	1.5
Caranx papuensis	14	32	3.7	1.5

A comparative analysis of catch proportions between *Belat*-A and *Belat*-B revealed significant differences in both catch number and weight ($p < 0.01$) (Tables 3 and 4). *Belat*-A outperformed *Belat*-B, capturing twice the number of fish (970 versus 460) and 1.6 times the weight (92.5 kg versus 59.1 kg) across various fish species. *Gerres erythrourus* was the most abundant species in both methods, accounting for 80.0% and 61.1% of the total catch in *Belat*-A and *Belat*-B, respectively. It also made up the largest portion by weight in *Belat*-A (34.4%), but less pronounced in *Belat*-B (18.0%). *Lutjanus fulviflamma* was the second most numerous species, representing 8.1% and 17.0% of the total catch number in *Belat*-A and *Belat*-B, respectively. It also contributed significantly to the weight, especially in *Belat*-B (14.0%). Meanwhile, *L. analis* and *E. coioides* were substantial contributors to the weight, particularly in *Belat*-A (25.0% and 13.7%, respectively).

Statistical analysis revealed no significant difference in the average daily productivity of *Belat*-A and *Belat*-B, both in terms of catch number and weight ($p > 0.05$). Over a 15-day period, *Belat*-A daily productivity varied between 0.3 and 1.9 fish h^{-1} (1.4 ± 0.1 fish h^{-1}), with an average weight of 0.1 ± 0.0 kg h^{-1} (from 0.1 to 0.2 kg h^{-1})

Table 3. Catch proportions by species and number of catch between *Belat*-A and *Belat*-B.

Scientific name	*Belat*-A		*Belat*-B	
	Fish	Percentage	Fish	Percentage
Siganus javus	9	1.0	16	3.5
Lates calcarifer	8	0.8	9	2.0
Lutjanus sanguineus	1	0.1	3	0.7
Epinephelus coioides	16	1.7	11	2.4
Sphyraena jello	5	0.5	18	3.9
Lutjanus analis	44	4.6	16	3.5
Alectis ciliaris	10	1.1	16	3.5
Gerres erythrourus	758	80.0	281	61.1
Lutjanus fulviflamma	77	8.1	78	17.0
Caranx papuensis	20	2.1	12	2.6
Total	970	100	460	100

Table 4. Catch proportions by species and weight between *Belat*-A and *Belat*-B.

Scientific name	*Belat*-A		*Belat*-B	
	kg	Percentage	kg	Percentage
Siganus javus	5.6	6.1	6.55	11.1
Lates calcarifer	5.5	5.9	6.25	10.6
Lutjanus sanguineus	1.2	1.3	5.6	9.5
Epinephelus coioides	12.65	13.7	6.7	11.3
Sphyraena jello	0.7	0.8	4.8	8.1
Lutjanus analis	23.1	25.0	7.1	12.0
Alectis ciliaris	1.4	1.5	1.9	3.2
Gerres erythrourus	31.8	34.4	10.6	17.9
Lutjanus fulviflamma	8.2	8.9	8.3	14.0
Caranx papuensis	2.4	2.6	1.3	2.2
Total	92.55	100	59.1	100

(Figure 3). Similarly, the daily productivity of *Belat*-B varied between 0.3 and 3.0 fish h^{-1} (1.3 ± 0.3 fish h^{-1}), with an average weight of 0.2 ± 0.1 kg h^{-1} (from 0.1 to 0.3 kg h^{-1}) (Figure 4).

Overall, *Belat*-A caught 970 fish and 92.6 kg over a 48-h period, corresponding to productivity rates of 20,208 fish h^{-1} and 1,928 kg h^{-1}, respectively. Although *Belat*-B captured fewer fish (460) and less weight (59.1 kg) in a 24-h period, its productivity rates (19,167 fish h^{-1} and 2,463 kg h^{-1}) were not significantly different from those of *Belat*-A ($p > 0.05$). This suggests that *Belat*-B is more time-efficient, requiring only half the operational time to achieve comparable productivity levels (Table 5). Fishermen expected that the longer the fishing time, the higher the abundance of fish. However, this is not necessarily true. While it is possible that longer fishing time could lead to higher catches, especially if fish are abundant, other factors can also influence the relationship between fishing time and catch, such as fish behavior, water depth, weather condition and fishing techniques. Therefore, more detailed studies conducted in different coastal areas are needed to understand factors that affect catch.

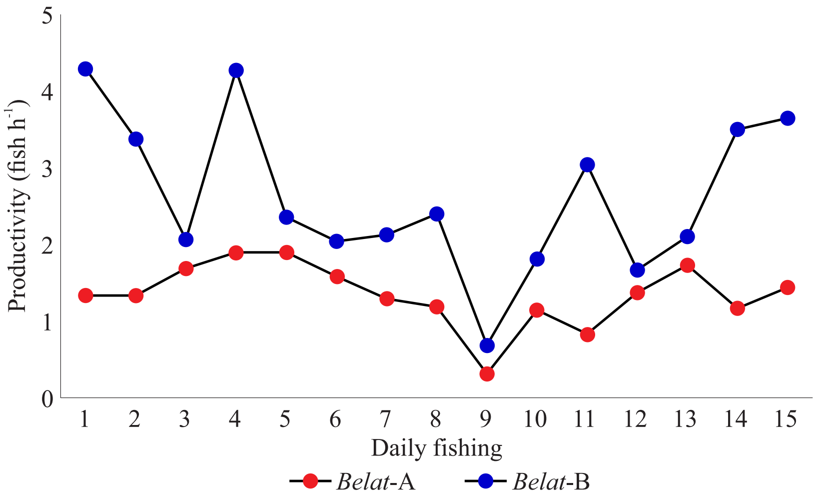

Figure 3. Daily productivity rates of *Belat*-A and *Belat*-B based on catch number.

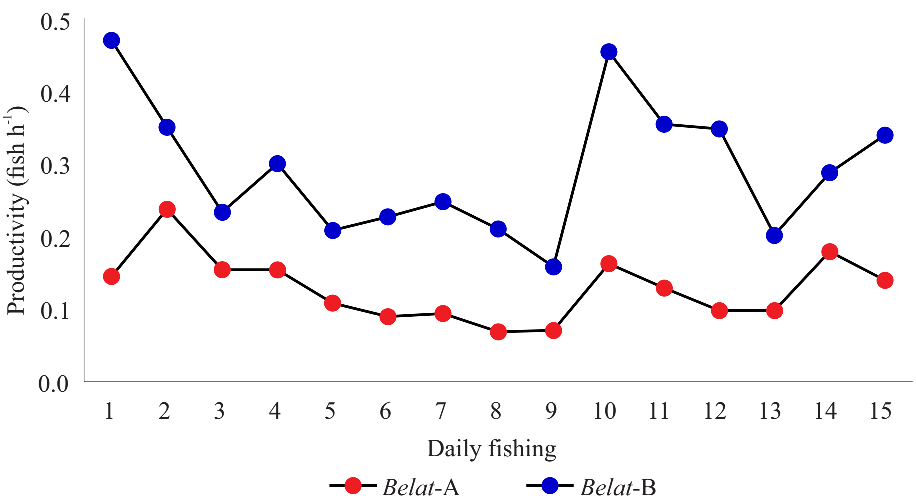

Figure 4. Daily productivity rates of *Belat*-A and *Belat*-B based on catch weight.

Table 5. Comparison analysis of *Belat* effectiveness based on catch numbers and weight.

Belat	Total catch (ind.)	Duration (h)	Productivity (ind. h^{-1})	Percentage
A	970	48	20,208	51.3
B	460	24	19,167	48.7
Total	1,430	72	39,375	100
Belat	Total catch (kg)	Duration (h)	Productivity (kg h^{-1})	Percentage
A	92.55	48	1,928	43.9
B	59.10	24	2,463	56.1
Total	151.65	72	4,391	100

In addition to food availability and fish behavior, tidal patterns also play an important role in the success of *Belat* fishing. The rising and falling tides create currents that push fish towards the shoreline (Milardi et al. 2018). When the tide recedes, the fish swim back to the sea, guided by the barrier, making them easier targets for the *Belat*, resulting in increased catches compared to low tide periods, and the results aligned with the previous investigations. Yunita and Zainuri (2021) found that large tidal ranges correlated with increased catch in terms of weight, species diversity, and individual numbers. Likewise, smaller tidal ranges lead to decreased catch. The largest (spring) tides typically occurr during the full moon, driven by the stronger gravitational pull of the moon. Numerous empirical studies have demonstrated that the rhythmic patterns of tides and lunar phases directly influence fish behavior and the supply of natural nutrients in aquatic ecosystems (Zhang et al. 2021; Li et al. 2024). Lindawati et al. (2024) found that lunar phases of the new moon and the second quarter resulted in the highest productivity rates. Although Hamriani et al. (2021) emphasized the significant influence of water temperature and current velocity on the *Belat* catch, no evidence of a relationship with water depth was observed. Conversely, Asmin et al. (2023) found that *Belat* productivity was higher at 5 m depth than 3 m in areas closer to productive coral reefs and seaweed farms that attract larger numbers of pelagic fish.

Further studies will be needed to assess catch and productivity of *Belats* as well as their impact on local livelihoods. Expanding the spatial scope to different seasons and coastal areas, monitoring times with varying environmental conditions to optimize catch and minimize environmental impact, and utilizing underwater cameras and acoustic telemetry to monitor fish behavior and trap efficiency in real-time are all research activities that will be required.

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Conflict of interest

The authors declare that there is no conflict of interest and that the research meets the required ethical guidelines.

Author contributions

Ahmadi: conceptualization; data curation; formal analysis; investigation; writing-original draft. Iriansyah: methodology; writing-review and editing. Cahyani Lestiani: data collection; writing-review and editing; documentation.

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