Species diversity structure of bycatch in blue swimming crab fisheries in Batu Bara Regency, North Sumatra, Indonesia

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Abstract. This study analyzed the composition, abundance, and diversity of bycatch species in the blue swimming crab fishery and examined potential interactions with marine mammals in the coastal waters of Batu Bara Regency. The research was conducted from June to December 2025 in Perupuk Village using direct observations of fishermen's catches during landing activities. Sampling was carried out periodically, 2–4 times per month. Species identification and ecological analyses were performed using the Shannon-Wiener diversity index (H'), Evenness index (E), and Simpson dominance index (C). A total of 9 bycatch species comprising 606 individuals were recorded, dominated by *Johnius belangerii, Cynoglossus lingua*, and *Saurida tumbil* The diversity index (H' = 1.67) indicated moderate diversity, while the evenness index (E = 0.76) and dominance index (C = 0.22) assemblage possesses relatively balanced community structure without dominance by a single species. No marine mammals were identified in the bycatch composition, suggesting minimal or absents interaction with fishing gear. Most bycatch species were classified as Least Concern according to the International Union for Conservation of Nature Red List, although *Eleutheronema tetradactylum* was categorized as Endangered. These findings highlight the importance of ecosystem-based fisheries management to sustain resources and reduce impacts on vulnerable non-target species.

1 Introduction

Indonesia is an archipelagic country with exceptionally high marine biodiversity, supported by its vast ocean area and strategic geographic position between two major oceans. This condition makes fisheries resources one of the key sectors in supporting the livelihoods of coastal communities [1]. One of the fishery commodities of high economic value is the blue swimming crab (Portunus pelagicus), which is widely exploited by small-scale and industrial fishers, particularly in coastal areas of North Sumatra, including Batu Bara Regency. The high demand for blue swimming crab in both domestic and export markets has led to increased fishing intensity, necessitating sustainable management efforts grounded in ecological principles and species diversity [2].

Blue swimming crab fishing activities generally use passive fishing gears such as gillnets and traps. Although relatively simple and cost-effective, these gears tend to have low selectivity, resulting in the capture of non-target organisms, commonly referred to as bycatch. Bycatch consists of organisms that are unintentionally caught during fishing operations, whether they are retained for use or discarded back into the water. The presence of bycatch not only reflects the selectivity level of fishing gear but also represents the community structure of aquatic organisms within an ecosystem [3].

Various studies have shown that the composition of bycatch in blue swimming crab fisheries is highly diverse, including demersal fish, non-target crustaceans, mollusks, and other marine organisms. A study by Abiezer [4] identified at least 19 bycatch species in the waters of Danasari Village, Pemalang. Meanwhile, Mardhan [5] reported 29 bycatch species in the coastal waters of Purirano Beach, Southeast Sulawesi. In a single fishing location, more than 19 bycatch species can be encountered. This high species diversity reflects the complexity of coastal ecosystems and the ecological interactions among their organisms. However, it also indicates that blue swimming crab fishing activities may exert pressure on non-target organisms, ultimately affecting the balance and sustainability of the ecosystem as a whole.

The analysis of bycatch species diversity is therefore a crucial aspect in assessing ecosystem conditions and the level of exploitation of fisheries resources. Furthermore, bycatch can involve interactions with species of high conservation value, such as sharks, rays, sea turtles, and marine mammals (e.g., dolphins and whales). Perupuk Village in Batu Bara Regency, one of the coastal areas in North Sumatra, has relatively intensive blue swimming crab fishing; however, scientific information on the composition and diversity of bycatch species in this area remains limited. Therefore, research on the analysis of bycatch species diversity is essential to provide an overview of local ecosystem conditions and to identify potential

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interactions with protected species. The findings of this study are expected to serve as a basis for formulating sustainable, ecosystem-based, and environmentally friendly management strategies for blue swimming crab fisheries.

2 Methods

2.1 Study area

This study was conducted from June to December 2025 in Perupuk Village, Lima Puluh Pesisir Subdistrict, Batu Bara Regency, North Sumatra. Geographically, the blue swimming crab fishing grounds are located at coordinates 99°32′13.64″ E and 3°17′52.66″ N. The fishing grounds are situated approximately 2–4 miles from the shoreline (Figure 1). The determination of the fishing locations was based on interviews with local fishers in the area.

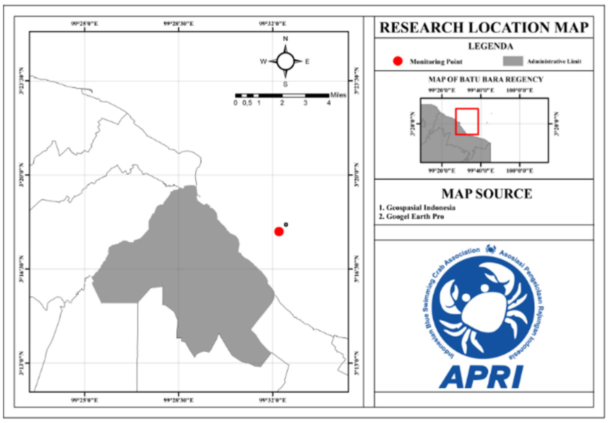

Fig. 1. Research location map.

2.2 Data collection

Primary data were collected through direct observation of blue swimming crab fishers’ catches at the time of landing. Sampling was conducted 2–4 times per month over a 7-month period (June–December 2025). The sampling frequency was adjusted to the enumerators' data collection activities, which primarily focused on blue swimming crab catches, while bycatch data were recorded as supporting information. During the observation period, a total of 606 fish individuals were successfully identified and classified into 9 species. Each bycatch was separated from the main catch (blue swimming crab). Bycatch was then identified to the species level using relevant marine organism identification guides. The parameters recorded included species type, number of individuals, and frequency of occurrence. In addition, semi-structured interviews were conducted with fishers to obtain supplementary information regarding fishing grounds, types of fishing gear used, and fishing operation patterns. Secondary data were obtained from scientific literature, reports from relevant institutions, and publications related to the research topic.

2.3 Data analysis

Species diversity analysis was conducted using three ecological indices: the Diversity Index (H′), Evenness Index (E), and Dominance Index (C). The diversity index was calculated using the Shannon–Wiener formula (H′) [6] as follows:

$$H' = -\sum_{i=1}^{S} (pi \ln pi) \quad (1)$$

where pi is the the proportion of individuals of the i-th bycatch species relative to the total number of bycatch individuals (n_i/N), and S is the total number of bycatch species. The interpretation of the H′ diversity index is as follows: low diversity when H′ < 1, moderate diversity when 1 ≤ H′ ≤ 3, and high diversity when H′ > 3.

The Evenness Index (E) was calculated using the following formula [7]:

$$E = \frac{H'}{\ln S} \quad (2)$$

where H′ is the Shannon–Wiener diversity index and S is the total number of bycatch species. The evenness index is classified into three categories: low evenness (0 < E < 0.4), moderate evenness (0.4 < E < 0.6), and high evenness (0.6 < E < 1).

The dominance index was calculated using Simpson’s formula [8] as follows:

$$C = \sum_{i=1}^{S} p_i^2 \quad (3)$$

where Pi is the proportion of individuals of the i-th bycatch species relative to the total number of bycatch individuals (n_i/N). The dominance index ranges from 0 to 1; higher values of C indicate dominance by one or a few species. The dominance index (C) is classified into three criteria: (1) C ≤ 0.5 indicates no dominant species, (2) 0.5 ≤ C ≤ 0.75 indicates moderate dominance, and (3) 0.75 ≤ C ≤ 1 indicates the presence of dominant bycatch species.

The diversity index was calculated to assess species diversity within the bycatch community. The evenness index was used to describe the distribution of individuals among species, while the dominance index was used to assess whether any species dominates the community. The results of the analysis were then interpreted descriptively to illustrate the condition of bycatch species diversity and its implications for the balance of the coastal ecosystem in the study area.

3 Results and discussion

3.1 Proportion of Target species and bycatch

The catch composition was predominantly blue swimming crab (*Portunus pelagicus*), with a total weight of 810.20 kg, representing 89.31% of the total catch. Non-target species accounted for 97 kg, or 10.69% of the total catch (Table 1). The high proportion of blue swimming crab indicates that the fishing gear used demonstrated effective selectivity for the target species, thereby minimizing bycatch. This outcome suggests that the fishing activity was efficient and may contribute to more sustainable fisheries practices, as the impact on non-target organisms was relatively low.

Table 1. Target species and bycatch in the waters of Perupuk village, Batu Bara Regency, 2025.

Catch	Weight (Kg)	Proportion (%)
Blue swimming crab (*Portunus pelagicus*)	810,20	89,31
Bycatch / Non-target species	97	10,69

3.2 Composition and abundance of bycatch species in the blue swimming crab fisheries

Based on observations conducted from June to December 2025, a total of 9 bycatch species were identified, consisting of demersal fish and crustaceans, with a total of 606 individuals (Table 2). This composition indicates that blue swimming crab fishing activities interact with non-target organisms inhabiting the bottom (benthic) environments. This phenomenon is common in tropical coastal fisheries, where fishing gears operated near or on the seabed tend to capture various benthic and demersal organisms [9]. The species abundance was dominated by *Johnius belangeri* (205 individuals), *Cynoglossus lingua* (139 individuals), and *Saurida tumbil* (120 individuals), indicating that these species are key components of the demersal community in the study area. This dominance is associated with habitat suitability and their high adaptability to coastal environmental conditions.

According to Siagian [10], these three bycatch species are classified as carnivorous fish that utilize a wide range of natural food sources, such as small fish, shrimp, and organic matter (detritus). These species generally inhabit marine and brackish waters, particularly in coastal and estuarine areas. They are also commonly found in waters with high turbidity, muddy substrates, and lower temperatures than in open waters. In contrast, species such as *Eleutheronema tetradactylum* (2 individuals) and *Megalaspis cordyla* (3 individuals) exhibited low abundance, likely influenced by differences in habitat preferences, mobility, and responses to fishing gear.

Variations in species abundance reflect differences in ecological adaptability, as well as the influence of environmental and fishing operational factors. Species with higher abundance generally have broader environmental tolerances and a greater likelihood of capture, whereas species with lower abundance tend to occupy more specific ecological niches. This indicates that the structure of the bycatch community is shaped by interactions among both biotic and abiotic factors in coastal waters. Overall, the composition and abundance of bycatch indicate the level of selectivity of blue swimming crab fishing gear, which may exert pressure on non-target organisms. Therefore, ecosystem-based fisheries management is required through improving gear selectivity and regulating fishing activities to ensure resource sustainability and maintain the balance of coastal ecosystems [11].

Table 2. Composition and abundance of bycatch species in the waters of Perupuk village, Batu Bara Regency, 2025.

No.	Spesies	Number of Individuals							
		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	*Cynoglossus lingua*	29	26	21	14	16	24	9	139
2	*Johnius belangeri*	52	33	42	22	17	30	9	205
3	*Eleutheronema tetradactylum*	2	0	0	0	0	0	0	2
4	*Saurida tumbil*	15	26	17	14	22	20	6	120
5	*Megalaspis cordyla*	0	0	2	0	0	1	0	3
6	*Upeneus vittatus*	0	0	3	0	0	4	0	7
7	*Hexanematichthys sundaicus*	5	5	8	3	5	6	2	34
8	*Harpiosquilla harpax*	3	4	11	0	9	0	3	30
9	*Charybdis feriatus*	6	4	9	11	11	19	6	66
Total of Individuals		**112**	**98**	**113**	**64**	**80**	**104**	**35**	**606**

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Table 3. Conservation status of bycatch species in the waters of Perupuk village, Batu Bara Regency, 2025.

No	Species	Name		IUCN Red List Status
		Local	Common	
1	*Cynoglossus lingua*	Ikan Lidah	Long Tonguesole	Least Concern
2	*Johnius belangeri*	Ikan Gulama	Belanger's Croaker	
3	*Hexanematichthys sundaicus*	Ikan Kadal	Brazilian Lizardfish	
4	*Saurida tumbil*	Ikan Selar	Torpedo Scad	
5	*Megalaspis cordyla*	Ikan Biji Nangka	Yellowstriped Goatfish	
6	*Upeneus vittatus*	Ikan Kedukang	Widehead Sea Catfish	
7	*Charybdis feriatus*	Kepiting Salib	Charybdis feriata	
8	*Harpiosquilla harpax*	Udang Lipan Putih	Mantis Prawn	Not Evaluated
9	*Eleutheronema tetradactylum*	Ikan Senangin	Fourfinger Threadfin	Endangered

3.3 Conservation status of bycatch species

Based on the identification results of bycatch species, nine species representing various groups of fish, crustaceans, and stomatopods were recorded. Most of the identified species were classified as Least Concern according to the International Union for Conservation of Nature Red List, including *Cynoglossus lingua*, *Johnius belangerii*, *Hexanematichthys sundaicus*, *Saurida tumbil*, *Megalaspis cordyla*, *Upeneus vittatus*, and *Charybdis feriatus* (Table 3).

This conservation status indicates that these species currently face a relatively low risk of extinction and that their populations are considered relatively stable in the wild. Furthermore, the presence of both demersal and pelagic fish species in the catch composition suggests that the fishing ground has relatively high aquatic biodiversity and reflects interactions between the fishing gear and a variety of marine habitats.

On the other hand, one species, *Eleutheronema tetradactylum*, was classified as Endangered, indicating potential threats to its population sustainability due to exploitation and fishing pressure. Although its occurrence was relatively rare, with only two individuals recorded in June over the seven-month monitoring period, the presence of this species warrants attention within an ecosystem-based fisheries management framework. Mitigation measures may include improving fishing gear selectivity, implementing live-release protocols for accidentally captured individuals (the APRI "5-Minute Release" Program, or called GTK5-minutes), conducting continuous bycatch monitoring through systematic data collection, and identifying critical habitats that require protection. These measures are essential to minimizing potential adverse impacts on vulnerable species while maintaining the sustainability of blue swimming crab fisheries. In addition, *Harpiosquilla harpax* was categorized as Not Evaluated, meaning that its conservation status has not yet been formally assessed. The presence of species with particular conservation statuses within the bycatch highlights the importance of implementing sustainable fisheries management through improved fishing gear selectivity and stricter monitoring of fisheries resource exploitation. Therefore, although the majority of species remain within the low-risk category, conservation measures are still required to prevent population declines in species vulnerable to fishing pressure.

3.4 Species diversity index (H’)

The Shannon–Wiener diversity index (H′) was 1.67, indicating moderate species diversity within the bycatch composition (Table 4). Meanwhile, the medium category indicates that bycatch in blue swimming crab fisheries has sufficient productivity. Also, the ecosystem is well balanced, and ecological pressure remains moderate.

Table 4. Bycatch diversity index in the waters of Perupuk village, Batu Bara Regency, 2025.

No	Ecological index	Value	Limit Standard	Reference	Category	Interpretation
1	Diversity index (H')	1.67	Low (H'<1) Moderate (1 ≤ H′ ≤ 3) High (H'>3)	[8]	Moderate	Indicates that species diversity within the bycatch community is at a moderate level and remains relatively stable
2	Evenness index (E)	0.76	Low (0 < E < 0.4) Moderate (0.4 < E < 0.6) High (0.6 < E < 1)	[23]	High	Indicates that the distribution of individuals among species is relatively even, with no strong dominance
3	Dominance index (C)	0.22	Low (C ≤ 0.5) Moderate (0.5 ≤ C ≤ 0.75) High (0.75 ≤ C ≤ 1)	[9]	Low	Indicates the absence of any species that dominates the community excessively

A moderate level of diversity also suggests that the aquatic ecosystem in Batu Bara Regency still has the capacity to support the survival of various species, despite pressure from fishing activities. Such pressure generally arises from interactions between fishing gear and non-target organisms, which may influence community structure over the long term. However, the H′ value, which is not low, indicates that the disturbances have not yet caused a significant decline in species diversity [12].

This moderate condition suggests that the bycatch's compositional structure is sufficiently productive, though it requires careful management. Moderate diversity is often associated with ecosystems that can still maintain ecological functions but are vulnerable to change if pressures continue to increase. Therefore, sustainable fisheries management is needed to maintain ecosystem balance and prevent future biodiversity degradation.

3.5 Evenness index (E)

The evenness index value of 0.76 indicates that the distribution of individuals among species within the bycatch community is high and relatively uniform (Table 4). A value approaching 1 suggests that there are no striking differences in abundance among species, although some species still have higher individual counts. This is consistent with the statement by White et al. [13], who note that diversity index values approaching 0 indicate a tendency toward dominance by certain species within an ecosystem. Conversely, values approaching 1 indicate that there is a more even distribution of individuals among the existing species.

3.6 Dominance index (C)

The Simpson dominance index (C) value of 0.22 indicates low dominance within the bycatch community (Table 4). Ecologically, this index represents the probability that two individuals randomly selected belong to the same species; thus, a low value indicates minimal dominance and relatively high diversity. Accordingly, no single species dominates excessively, although some species, such as *Johnius belangeri* and *Cynoglossus lingua*, exhibit higher abundance than others. This condition suggests that individuals are still distributed across multiple species within the community. Overall, the low dominance index reflects a relatively stable community structure that is not concentrated on a single species. Communities with low dominance generally exhibit greater ecological resilience to disturbances, as they do not rely heavily on a single dominant species [12].

3.7 Bycatch Diversity and Conservation Considerations in Blue Swimming Crab Fisheries

The potential interaction between marine mammals and fishing activities is an important aspect of sustainable fisheries management. This is due to the biological characteristics of marine mammals, including relatively long lifespans, low reproductive rates, and a strong dependence on environmental stability. Marine mammals, particularly cetaceans, are known to interact with fishing activities both directly and indirectly [14]. Therefore, understanding potential interaction patterns is essential for supporting responsible and sustainable fishing practices.

Based on the results of this study, no marine mammals were found in the bycatch composition of the blue swimming crab fishery. This finding indicates that direct interaction with marine mammals is relatively low or absent. This condition is related to differences in habitat preference and behavior, where marine mammals generally occupy the water column with high mobility, while blue swimming crab fishing activities are conducted in demersal zones. In terms of ecological indices, the diversity index (H′ = 1.67), evenness (E = 0.76), and dominance (C = 0.22) indicate that the bycatch community is relatively stable, with no marine mammals recorded in the catch composition (Table 1). However, the potential for interaction still needs to be anticipated, particularly through indirect pathways such as noise disturbance and changes in prey availability [14]. Therefore, ecosystem-based fisheries management is required through improving gear selectivity, regulating fishing activities, and monitoring the presence of marine mammals around blue swimming crab fishing grounds. These efforts are essential to sustain fisheries resources while protecting high-value marine mammal species.

4 Conclusion

The ecological condition of the bycatch assemblage possesses relatively balanced community structure. The findings also indicate that the blue swimming crab fishing activities interact with bycatch organisms inhabiting coastal waters, demersal fish, highlighting the ecological connectivity between the fishery and the surrounding benthic ecosystem. Although current fishing pressure has no yet led to substantial biodiversity loss, implementation of ecosystem-based fisheries management remains essential to mitigate potential impacts on non-target species and to maintain ecosystem functions. Strengthening fishing gear selectivity, regulating fishing effort, and conducting regular ecological monitoring are important strategies to support the long-term sustainability of blue swimming crab fisheries and the conservation of associated coastal ecosystems in Batu Bara Regency.

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References

1. M.F. Arianto, Potensi wilayah pesisir di negara Indonesia. *J. Geogr.* **10**(1), 204–215 (2020)
2. S. Husni et al., Strategi pengelolaan perikanan rajungan berkelanjutan di kawasan Teluk Ekas Kabupaten Lombok Timur. *AGROTEKSOS* **35**(1), 203–215 (2025)
3. M.A. Firnando, E.W. Setyaningrum, E. Saraswati, Analisis hasil tangkapan sampingan (bycatch) pada alat tangkap jaring insang (gillnet) di Pelabuhan Perikanan Nusantara (PPN) Pengambengan. *J. Fish. Sustain.* **5**(1), 1–11 (2025)
4. Y. Abiezer*, Identifikasi Hasil Tangkapan Sampingan (Bycatch) Nelayan Rajungan di Desa Danasari, Pemalang,* (2023)
5. N.T. Mardhan, L. Sara, A. Asriyana, Analisis hasil tangkapan rajungan (*Portunus pelagicus*) sebagai target utama dan komposisi by-catch alat tangkap gillnet di perairan Pantai Purirano, Sulawesi Tenggara. *J. Biol. Trop.* **19**(2), 205–213 (2019)
6. J.E. Brower, J.H. Zar, C.N. Von Ende, *Field and Laboratory Methods for General Ecology*, Vol. 4 (WCB McGraw-Hill, Boston, 1998)
7. J.A. Ludwig, J.F. Reynold, *Statistical Ecology: A Primer on Methods and Computing* (John Wiley and Sons, New York, 1998)
8. E.H. Simpson, Measurement of diversity. *Nature* **163**(4148), 688–688 (1949)
9. Z. Zairion, I. Purnama, Y. Wardiatno, Keragaman sumberdaya ikan non target perikanan rajungan di Pesisir Lampung Timur. *J. Biol. Trop.* **19**(1), 8–13 (2019)
10. G. Siagian*, Struktur Populasi Ikan Gulamah (Johnius trachycephalus) di Sungai Barumun Kabupaten Labuhan Batu Sumatera Utara*, Universitas Sumatera Utara (2017)
11. A.E. Magurran, Measuring biological diversity. *Curr. Biol.* **31**(19), R1174–R1177 (2021)
12. I. Febrian, E. Nursaadah, B. Karyadi, Analisis indeks keanekaragaman, keragaman, dan dominansi ikan di Sungai Aur Lemau Kabupaten Bengkulu Tengah. *Bioscientist* **10**(2), 600–612 (2022)
13. W.T. White et al., *Market Fishes of Indonesia* (Australian Centre for International Agricultural Research, Canberra, 2013)
14. D.P. Nowacek et al., Responses of cetaceans to anthropogenic noise. *Mammal Rev.* **37**(2), 81–115 (2007)