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A comparison of diversity and catch composition of mini trawl (*arad*) and lift net (*bagan*) in Cilincing, Jakarta Bay, Indonesia

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Abstract. *Pribadi TDK, Yusfiandayani R, Simbolon D, Patanda M, Caesario R, Sayidina EJ, Violita SR. 2024. A comparison of diversity and catch composition of mini trawl (*arad*) and lift net (*bagan*) in Cilincing, Jakarta Bay, Indonesia. Biodiversitas 25: 265-277.* A*rad* is a traditional fishing gear that is still popular and widely used in Indonesia, including in Cilincing, the bay in the northern part of Jakarta. Even though the Indonesian government has prohibited this fishing gear, the discarded fishing gear is still utilized by many fishers due to its effective result in getting a large volume of fish caught. A study on the diversity and catch composition of *arad* (trawl) and *bagan* (lift net) fishing gear was conducted between January and June 2024 in Cilincing waters to represent active and passive fishing gear. Samples of fish caught from both fishing gears were observed directly, while interviews with the fishers were conducted to get further information on their view. The study showed that in comparison to *bagan*, *arad* caught more species, including reef fish. Both fishing gear caught fin-fish and non-finfish (mollusk, crustacean, jellyfish) in different proportions. The data showed that *arad* caught more species (28) compared to *bagan* (18). *Arad* caught mostly demersal fish (57.14%), while *bagan* mostly caught pelagic fish (53.33%). The value of Total Length (TL) of fish caught by both fishing gears was mostly under the Length of First of Maturity (LM). Referring to the list issued by IUCN, most of the species caught by *arad* and *bagan* were in the Least Concern status of conservation, and neither CITES nor the Indonesian Ministry of Environment and Forestry has issued any information regarding the population status.

Keywords: *Arad*, Cilincing, diversity, lift net, trawl

INTRODUCTION

Amounting to nearly 8% of the global marine capture between 2015 and 2018 (FAO 2020), Indonesia is one of the largest producing countries, only second to China, reaching USD 4.94 billion in 2019 (IISD 2021) due to the growing number of its significant export earnings. Information from statistical and information data center pertaining to fish consumption showed that this potential sector also represents a critical source of animal protein intake as the main source from fish contributing to 55.7% as opposed to meat and milk/egg with only 24.1% and 20.2% respectively. Marine fish including tuna/skipjack with 6.72% kg/capita, and also mackerel with 2.83 kg/capita contributed as the main sources, followed by inland fish such as catfish/snakehead/eel 2.83 kg/capita, and milkfish with 2.46 kg/capita (MMAF 2017).

In general, marine capture fisheries are predominantly small scale, open access, and more concentrated in coastal, inshore waters with depths of less than 100 m (Nguyen et al. 2021). This condition leads to extremely progressive socio-economic development throughout the Indonesian coastal communities, with a large number of households depending on their livelihood on marine fish capture. With the province of Jakarta contributing to 14% amounting to approximately 1.4 million tonnes of the total production across Java Island (MMAF 2022), marine capture fisheries are contributing more than 7 million tonnes in 2022 alone, providing livelihood to roughly 3 million people in coastal areas and related sectors with an estimated number of 217,000 fishers exploring the Java Sea, including Cilincing waters, that are situated in the WPP 572 (national fisheries area) (MMAF 2022).

Cilincing is part of Jakarta Bay, waters which still has fishery activities with significant production and fish supply for both local and national markets in the country. Data from Cilincing Fish Auction shows that fish production in this area reached approximately 15% of the whole Jakarta fish production during 2019-2022 (BPS 2024). Most of the inhabitants in Cilincing fishing village are involved in one way or another in fisheries to a certain extent for their living, using fishing net (local name as *bagan*) and mini trawl (local name as *arad*) as the main fishing gear (Querdiola et al. 2023).

Inseparable from the technological ease, low-investment level, one-day fishing method of catching, and operable in inshore waters (Hapsari et al. 2018), *bagan* is still widely used by numerous small-scale fisheries across Indonesia. With the net tied on a rectangular-shaped bamboo, which is attached to the seabed and firmly floating above the water (Khumaera et al. 2019; Satrya 2020), *bagan* serves as a more preferred passive fishing gear.

Though the use of trawl in fishing has already been restricted in Indonesian waters through government regulation No.2/PERMEN-KP/2015 of Ministry of Marine Affairs and Fisheries (PERMEN-KP/No.2/2015), the use of bottom trawl is still widespread since many claimed to be the most effective fishing gear to reach a huge number of the catch volume regardless of the selectiveness of species target and individual size (Mahendra et al. 2015). With the structure of a cone-shaped bag net which pulled by boat and dragged along the sea bottom in near-shore waters (PERMEN-KP/No.6/2010; Raniwati et al. 2019), trawl is one of the primary pressures on the marine ecosystems, and as such, it directly affects the abundance of the targeted fish species, while also having indirect effects on the fish assemblages by impacting fish habitat through predator-prey interaction, reflecting the relative abundance of both target and non-target species (Foster et al. 2015). These trawl fisheries are characterized by a diverse array of vessel engine power, catching multiple species targets and a wide range of size classes (Nguyen et al. 2021).

With little data available from the government and related agencies regarding *arad* catch, little information is available on its impact on the sustainability of aquatic resources in the northern part of Jakarta. Since *arad* is prohibited due to its massive and non-selective character, any activities related to *arad* trawl fishing are hardly reported to the authorities, thus making the information on *arad* fish catch almost non-existent while any data is no less important for measurable fisheries. In terms of fish stocks and discards of trawl fisheries, rectifying data deficiencies is necessary for the solid basis of a well-informed decisions for sustainable fishery (Soykan et al. 2016). Another study showed that conducting evaluation on the catch composition of the inshore trawl fishery helps develop a more efficient fishing gear design that in turn contributes to long-term and sustainable development in fisheries (Taiwo and Olopade 2017; Nguyen et al. 2021), so it is more than just prerequisite to study diversity and catch composition. By comparing two different characteristics of fishing gear to compare diversity and catch composition, a better understanding is expected to emerge from further investigation of fish populations from the perspective of the ecological dimension.

MATERIALS AND METHODS

Study area

Data samples and interviews of this study took place in the Cilincing area, one of subdistricts of North Jakarta, Indonesia. The fishers who served as respondent were those engaged in fishing activities around Jakarta Bay and landed their catches at the Cilincing Fish Auction Site, located at coordinates 6º05’49”S and 106º56’22”E (Figure 1).

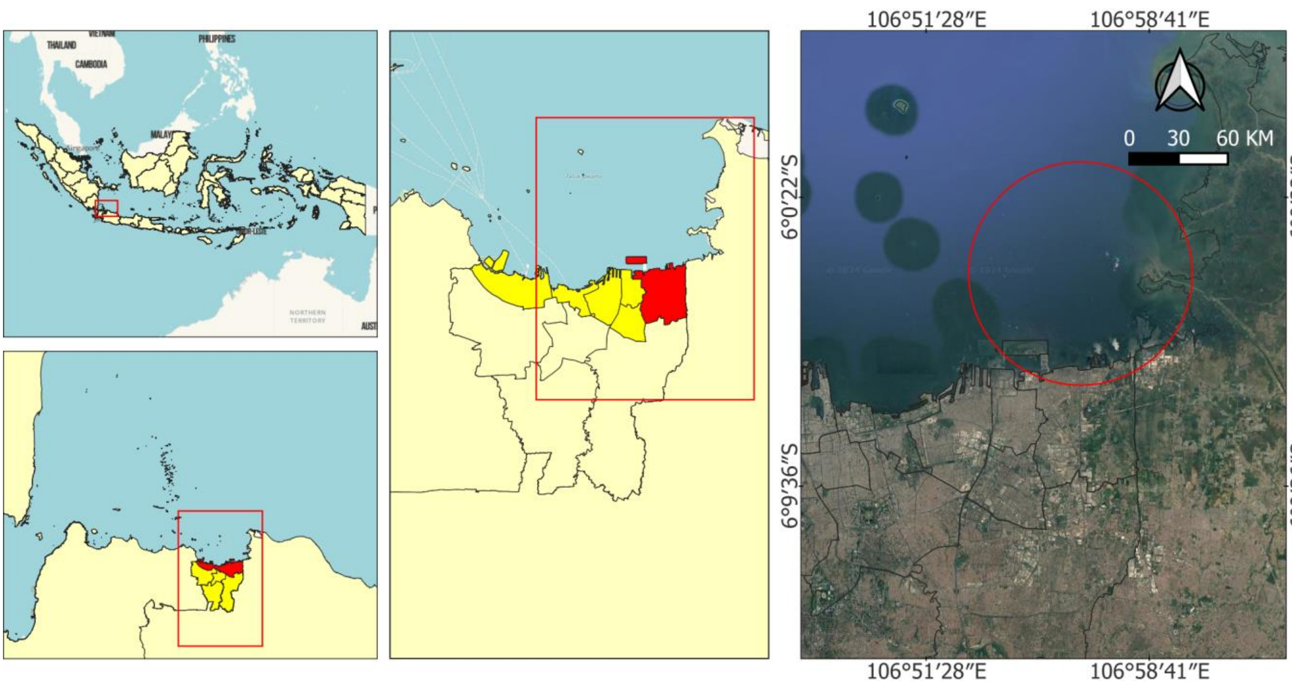


Figure 1. Location of study site for sampling and interview during study period in Cilincing Sub-district, North Jakarta, Jakarta, Indonesia

Procedures

Fish collection

The series of activities in this study was conducted between January and June 2024 in Cilincing waters at Jakarta Bay to gain comparison on the diversity and catch composition of fish catch using active fishing gear represented by trawl (*arad*), and passive one represented by lift net (*bagan*). Fish were collected during the study period, and the interval of fish collection was adjusted to the fishers' fishing time, which depended on weather and wind. With the fish bought at the fish auction right after they arrived from the trip, specimen was directly stored in a cool box prior to analysis. Before the fishers sailed, we asked them to bring along any discard-criteria fish to be observed. The discard-criteria fish was subsampled after separation from the target catch. Specimens were taken to the laboratory to be identified, Total Length (TL) measurements, and to take pictures for documentation.

Questionnaires

During the sampling activities, interviews were also conducted with questionnaires distributed among 45 fishers through fisher's association. The closed-ended questionnaires for the fishers were conducted to collect data of pricing, catch volume per trip, and priority catch groups.

Data analysis

The data gathered from the fish catch were processed for the identification of species and their Total Length, while the fish from the samplings were compared to get the parameters of their richness and individual length. The total measurements of fish length and carapace length of the crustacea (crab and shrimp) were utilized as a maturity level measurement (LM: Length of first Maturity). Measurement of the fish length related to the LM was not carried out in this study, thus the information was obtained from various references to previous research. The LM data was then compared with the results of processed data related to TL. Information on LM, fish groups, and conservation status that were available in a number of literature reviews were used. Fish identification was done by referring the data to an identification book by White et al. (2013) for finfish species and Carpenter and Niem (1998) for non-finfish species.

RESULTS AND DISCUSSION

Diversity and catch composition

32 families and 41 species of both finfish and non-finfish caught by *arad* and *bagan* in total. The result shows that *arad* caught not only more fish in numbers, but also more species compare to the fish caught by *bagan*, with 28 species from 25 families and 18 species from 13 families, respectively. *Arad* also caught broader range of family compare to *bagan*, with 19 families and 9 families, respectively (Figure 2). *Arad* is also illustrated to be more capable of catching more various fish groups compare to *bagan* (Table 1), including reef fish and benthopelagic fish.

The composition of fish catch groups in Figure 3 showed that *arad* caught the most demersal fish. This is inversely proportional to the catch composition by *bagan* with 53.33% of pelagic fish, where *arad* caught more demersal fish than to *bagan*, by 57.14% and 46.67% respectively.

The group of non-finfish caught consisted of 10 species (Table 1), namely *Acetes indicus, Amusium Pleuronectes, Aurelia aurita, Harpiosquilla raphidea, Parapenaeopsis sculptilis, Penaeus merguiensis, Uroteuthis duvaucelii, Podophthalmus vigil, Portunus pelagicus,* and *Sepia* sp. There were four species caught by *bagan* namely *Acetes indicus, Penaeus merguiensis, Uroteuthis duvaucelii,* and *Sepia* sp., and nine species caught by *arad* (Figure 4). In this study, non-finfish caught by *arad* showed more range of class in comparison to *bagan*, as *arad* caught 4 classes (Bivalvia, Cephalopod, Malacostraca, and Scyphozoa), and *bagan* caught 2 classes (Malacostraca and Scyphozoa) (Figure 5).

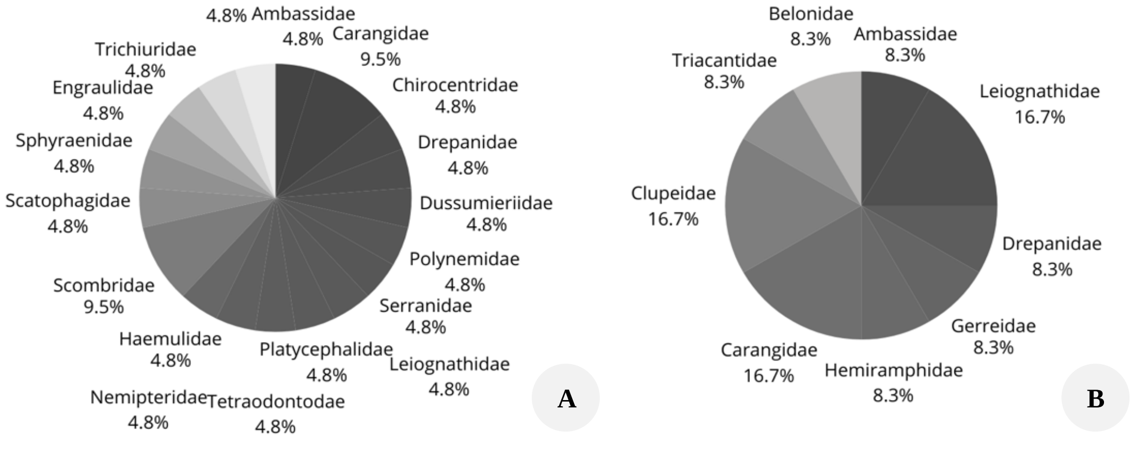


Figure 2. Composition of family in finfish group caught by: A. *arad*; B. *bagan* during observation

Table 1. List of species and groups of fish caught by *arad* and *bagan* during sampling

Family	Species	Local name	Fishing gear		P	BP	R	D
			Bagan	*Arad*				
Finfish								
Ambassidae	*Ambassis nalua* (Hamilton, 1822)	*Sriding*	+	+	v	–	–	–
Belonidae	*Tylosurus crocodilus* (Péron & Lesueur, 1821)	*Kacang-kacang*	+	–	v	–	–	–
Carangidae	*Carangoides malabaricus* (Bloch & Schneider, 1801)	*Kuwe*	–	+	–	–	v	–
	Megalaspis cordyla (Linnaeus, 1758)	*Tetengkek*	+	–	v	–	–	–
	Parastromateus niger (Bloch, 1795)	*Bawal hitam*	–	+	–	–	–	v
	Selaroides leptolepis (Cuvier, 1833)	*Selar*	+	–	–	–	–	v
Chirocentridae	*Chirocentrus dorab* (Forsskål, 1775)	*Golok-golok*	–	+	v	–	–	–
Clupeidae	*Sardinella fimbriata* (Valenciennes, 1847)	*lemuru/ tembang*	+	–	v	–	–	–
	Sardinella gibbosa (Bleeker, 1849)	*lemuru/ tembang*	+	–	v	–	–	–
Drepanidae	*Drepane punctata* (Linnaeus, 1758)	*Tapi-tapi*	+	+	–	–	–	v
Dussumieriidae	*Dussumieria acuta* Valenciennes, 1847	*Japuh*	–	+	v	–	–	–
Engraulidae	*Stolephorus indicus* (van Hasselt, 1823)	*Teri*	–	+	v	–	–	–
Gerreidae	*Gerres shima* (Iwatsuki, Kimura & Yoshino, 2007)	*Kapasan*	+	–	v	–	–	–
Haemulidae	*Pomadasys argyreus* (Valenciennes, 1833)	*Gerot*	–	+	v	–	–	–
Hemiramphidae	*Hemiramphus lutkei* Valenciennes, 1847	*Julung-julung*	+	–	v	–	–	–
Leiognathidae	*Aurigequula fasciata* (Lacepède, 1803)	*Peperek*	+	–	–	–	–	v
	Eubleekeria splendens (Cuvier, 1829)	*Petek*	+	–	–	–	–	v
	Gazza dentex (Valenciennes, 1835)	*Petek*	–	+	–	–	–	v
Monacanthidae	*Aluterus monoceros* (Linnaeus, 1758)	*Ayam-ayam*	–	+	–	–	v	–
Mullidae	*Upeneus sulphureus* Cuvier, 1829	*Kuniran*	–	+	–	–	–	v
Nemipteridae	*Nemipterus japonicus* (Bloch, 1791)	*Kurisi*	–	+	–	–	–	v
Platycephalidae	*Inegocia japonica* (Cuvier, 1829)	*Baji-baji*	–	+	–	–	–	v
Polynemidae	*Eleutheronema tetradactylum* (Shaw, 1804)	*Senangin*	–	+	–	–	–	v
Scatophagidae	*Siganus canaliculatus* (Park, 1797)	*Baronang*	–	+	–	–	–	v
Scombridae	*Rastrelliger kanagurta* (Cuvier, 1816)	*Kembung*	–	+	v	–	–	–
	Scomberomorus guttatus (Bloch & Schneider, 1801)	*Tenggiri*	–	+	v	–	–	–
Serranidae	*Epinephelus fuscoguttatus* (Forrskål, 1775)	*Kerapu macan*	–	+	–	–	v	–
Sphyraenidae	*Sphyraena barracuda* (Edwards,1771)	*Barakuda*	–	+	v	–	–	–
Tetraodontidae	*Lagocephalus spadiceus* (Richardson, 1845)	*Buntal pisang*	–	+	–	–	–	v
Triacantidae	*Triacanthus nieuhofii* (Bleeker, 1852)	*Cupang - cupang*	+	–	–	–	–	v
Trichiuridae	*Trichiurus lepturus* (Linnaeus, 1758)	*Layur*	–	+	–	v	–	–
Non-finfish								
Loliginidae	*Uroteuthis duvaucelii* (A. d'Orbigny, 1835)	*Cumi-cumi*	+	+	–	–	–	v
Pectinidae	*Amusium pleuronectes* (Linnaeus, 1758)	*Kerang simping*	–	+	–	–	–	v
Penaeidae	*Parapenaeopsis sculptilis* (Heller, 1862)	*Udang krosok*	–	+	–	–	–	v
	Penaeus merguiensis (De Man, 1888)	*Udang jerbung flower*	+	+	–	–	–	v
Portunidae	*Podophthalmus vigil* (Fabricius, 1798)	*Rajungan angin*	–	+	–	–	–	v
	Portunus pelagicus (Linnaeus, 1758)	*Rajungan biru*	–	+	–	–	–	v
Sergestidae	*Acetes indicus* (H.Milne Edwards, 1830)	*Udang rebon*	+	–	v	–	–	–
Sepiidae	*Sepia* sp.	*Sotong*	+	+	–	–	–	v
Squillidae	*Harpiosquilla raphidea* (Fabricius, 1798)	*Udang cakrek*	–	+	–	–	–	v
Ulmaridae	*Aurelia aurita* (Linnaeus, 1758)	*Ubur ubur*	–	+	v	–	–	–

Notes: +: present; –: absent; v: belong to the group of; P: Pelagic; BP: Bentopelagic; R: Reef; D: Demersal

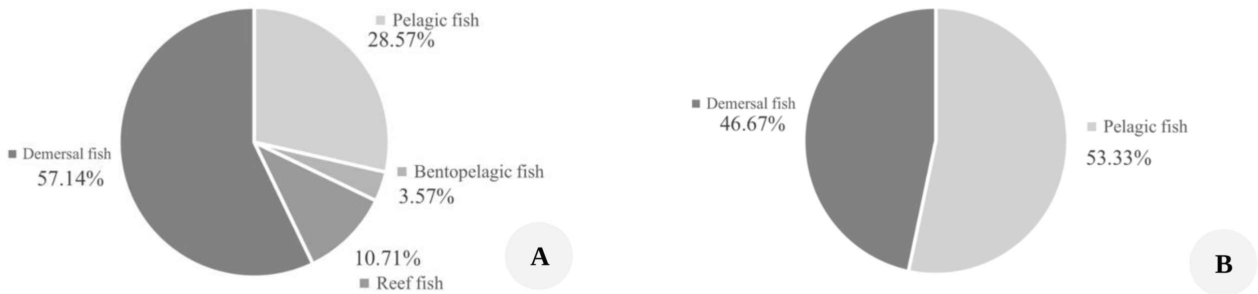
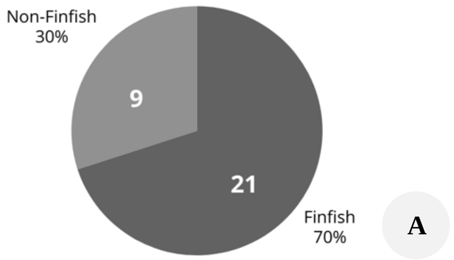


Figure 3. Composition of pelagic/bentopelagic/demersal/reef fish group caught by: A. *Arad*; B. *Bagan* during observation



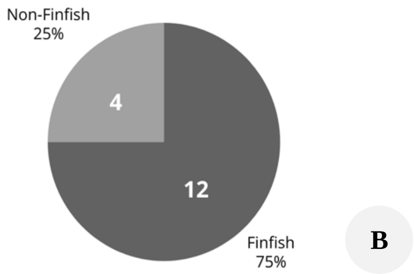
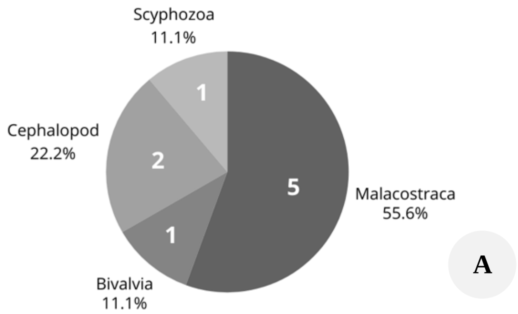


Figure 4. Composition of finfish and non-finfish group caught by: A. *Arad*; B. *Bagan* during observation



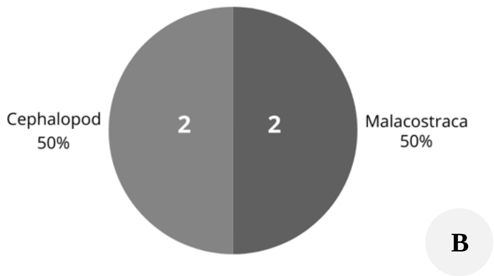


Figure 5. Composition of non-finfish group classes caught by: A. *Arad*; B. *Bagan* during observation

The group of non-finfish caught consisted of 10 species (Table 1), namely *Acetes indicus, Amusium Pleuronectes, Aurelia aurita, Harpiosquilla raphidea, Parapenaeopsis sculptilis, Penaeus merguiensis, Uroteuthis duvaucelii, Podophthalmus vigil, Portunus pelagicus,* and *Sepia* sp. There were four species caught by *bagan* namely *Acetes indicus, Penaeus merguiensis, Uroteuthis duvaucelii*, and *Sepia* sp., and nine species caught by *arad* (Figure 4). In this study, non-finfish caught by *arad* showed more range of classes in comparison to *bagan*, as *arad* caught 4 classes (Bivalvia, Cephalopod, Malacostraca, and Scyphozoa), and *bagan* caught 2 classes (Malacostraca and Scyphozoa) (Figure 5).

Photos of some fish species during analysis in the lab during identification process of finfish (Figure 6) and non-finfish (Figure 7) were documented and presented below to support the study.

Size, price, and catch priority

The comparison of TL and LM from the fish catch groups by *arad* and *bagan* is shown in Table 2, where most of the fish caught by both fishing gear had lower LM than their TL, with 8 out of 28 species amounting to 29% caught by *arad* measured greater than the LM value, and only 4 out of 18 species amounting to 22% caught by *bagan* measured greater than the LM value. The number of these species is much smaller compared to all species being caught by both fishing gear. It can be said that the fish caught by *arad* and *bagan* are dominated by category considered as discard because the length of the fish (TL) was smaller/shorter than LM.

Fish prices generally fluctuate because the influenced by quality in terms of sizes, freshness, supply-demand conditions, and catch season. With fluctuating market prices, most of the fish caught by both fishing gear were shown to be top-grade quality main catch with high economic value reaching more than IDR 10,000/kg. The fish caught by both fishing gear were dominated by target species (main catch), encompassed 30 out of 41 species amounting to 71% (Table 3).

The species classified as by catch was only 2 out of 41 species amounting to 5%, namely *Triacanthus nieuhofii* and *Amusium pleuronectes*. Species categorized as bycatch are the non-target species with an approximate price lower than target species, and in the range of IDR 5,000/kg to IDR 15,000/kg, while the species categorized as discards are also non-target species priced quite considerably low. The species classified as discard category was divided into most discards and always discards, based on price. This group is quite large with 9 out of 41 species amounting to 21% for both *arad* and *bagan*. Other non-target species with a price below IDR 5,000/kg are considered to be the most discards due to the effectivity of ice and space. They usually come with big catch volume and are always present in every catch. Therefore, they are only taken and included in the catch category if the target species (main catch) reachs a small number of amounts with adequate space and ice for storage in the hatch (Table 3). There were 4 out of 41 species that reach the highest catch volume in each trip, namely *Eubleekeria splendens*, *Gazza dentex*, and *Upeneus sulphureus*, which 3 of them were categorized as most discards. Only 1 species was categorized as main catch, namely *Eleutheronema tetradactylum*.

Figure 6. Representative of finfish species caught by *arad* and *bagan* in Cilincing waters, Jakarta, Indonesia: A. *Drepane punctata*; B. *Epinephelus fuscoguttatus*; C. *Gazza dentex*; D. *Gerres shima*; E. *Hemiramphus lutkei*; F. *Lagocephalus spadicus*; G. *Nemipterus japonicus*; H. *Parastromateus niger*; I. *Sardinella fimbriata*; J. *Scomberomorus guttatus*; K. *Siganus canaliculatus*; L. *Sphyraera barracuda*; M. *Stolephorus waitei*; N. *Triacanthus nieuhofii*

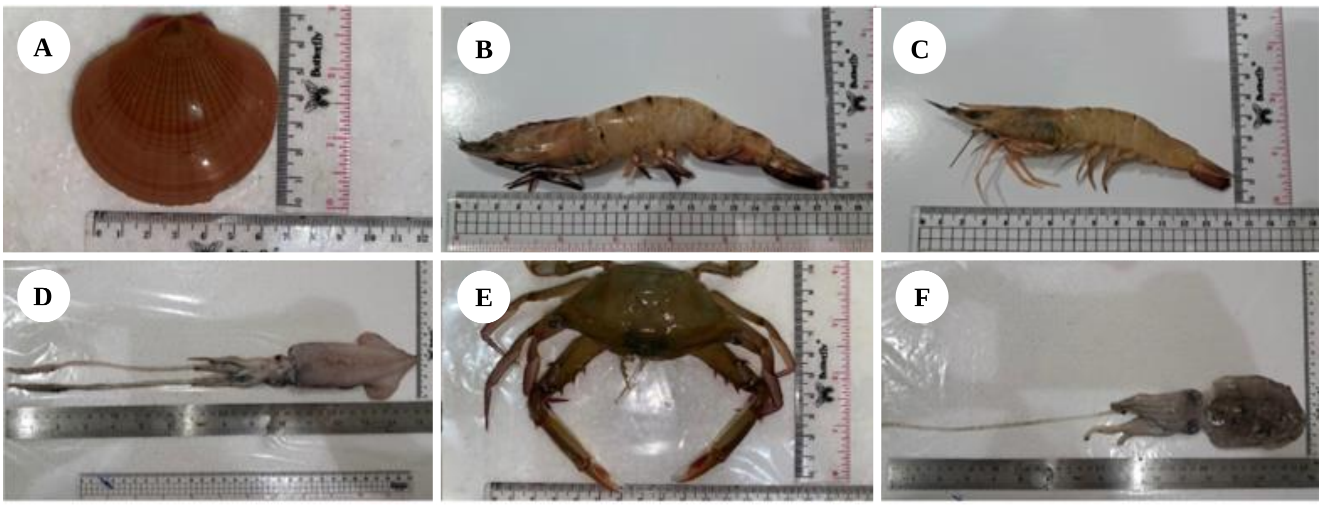


Figure 7. Representative of non-finfish species caught by *arad* and *bagan* in Cilincing waters, Jakarta, Indonesia: A. *Amusium pleuronectes*; B. *Parapenaeopsis sculptilis*; C. *Penaeus merguiensis*; D. *Uroteuthis duvaucelii*; E. *Podophthalmus vigil*; F. *Sepia* sp.

Table 2. Total Length (TL) of fish caught by *arad* and *bagan* during sampling in comparison to Length of First Maturity (LM) from references

Species	TL (cm)		LM (cm)	References
	Arad	***Bagan***		
Finfish				
Aluterus monoceros (Linnaeus, 1758)	33.85 ± 1.06 *	-	32.2	N'guessan et al. (2017)
Ambassis nalua (Hamilton, 1822)	-	5.35 ± 1.19	12.5	www.fishbase.se
Aurigequula fasciata (Lacepède, 1803)	-	10.5 ± 0.71	21	www.fishbase.se
Carangoides malabaricus (Bloch & Schneider, 1801)	21.25 ± 7.42	-	50	Bubun and Mahmud (2015)
Chirocentrus dorab (Forsskål, 1775)	44.8 ± 5.37	-	48.9	Abdussamad et al. (2011)
Drepane punctata (Linnaeus, 1758)	-	26.2 ± 1.78*	25	www.fishbase.se
Dussumieria acuta (Valenciennes, 1847)	12.75 ± 0.25	-	18.27	Triyono et al. (2021)
Eleutheronema tetradactylum (Shaw, 1804)	20 ± 1.41	-	39.6	Tirtadanu and Chodrijah (2018)
Epinephelus fuscoguttatus (Forrskål, 1775)	21 ± 0.72	-	45.43	Fatma et al. (2022)
Eubleekeria splendens (Cuvier, 1829)	-	9.5 ± 1.06*	7.5	Kanjanarakha et al. (2023)
Gazza dentex (Valenciennes, 1835)	11 ± 1.38 *	-	8.7	Maung et al. (2019)
Gerres shima (Iwatsuki, Kimura & Yoshino, 2007)	-	11.4 ± 0.99	12	www.fishbase.se
Hemiramphus lutkei (Valenciennes, 1847)	-	28.7 ± 1.56*	27.35	Balukh et al. (2021)
Inegocia japonica (Cuvier, 1829)	23.73 ± 9.12	-	35	www.fishbase.se
Lagocephalus spadiceus (Richardson, 1845)	12.4 ± 2.69 *	-	9	Naik and Jalihal (1998)
Megalaspis cordyla (Linnaeus, 1758)	-	13.75 ± 1.71	22	www.fishbase.se
Nemipterus japonicus (Bloch, 1791)	16.55 ± 2.12 *	-	15.1	Rao et al. (2017)
Parastromateus niger (Bloch, 1795)	12.48 ± 0.63	-	27.25	Islam et al. (2021)
Pomadasys argyreus (Valenciennes, 1833)	20.75 ± 0.21 *	-	13.75	Agatha and Kurnia (2019)
Rastrelliger kanagurta (Cuvier, 1816)	18.15 ± 3.09	15 ± 2.81	20	www.fishbase.se
Sardinella fimbriata (Valenciennes, 1847)	-	7.8 ± 1.27	13	www.fishbase.se
Sardinella gibbosa (Bleeker, 1849)	-	10.33 ± 1.29	13.3	www.fishbase.se
Scomberomorus guttatus (Bloch & Schneider, 1801)	22.36 ± 6.02	-	80.4	Noegroho et al. (2018)
Selaroides leptolepis (Cuvier, 1833)	-	12 ± 1.41*	11.9	www.fishbase.se
Siganus canaliculatus (Park, 1797)	23.7 ± 1.22	-	25.9	Rasdam et al. (2023)
Sphyraena barracuda (Edwards,1771)	23.525 ± 3.67	21.5 ± 2.12	68.5	Kadison et al. (2010)
Stolephorus indicus (van Hasselt, 1823)	7.1 ± 1.38	-	8.5	Costa et al. (2020)
Triacanthus nieuhofii (Bleeker, 1852)	-	14.7 ± 2.75	26.3	www.fishbase.se
Trichiurus lepturus (Linnaeus, 1758)	32 ± 3.46	-	39	www.fishbase.se
Tylosurus crocodilus (Péron & Lesueur, 1821)	-	16 ± 1.15	51.7	www.fishbase.se
Upeneus sulphureus (Cuvier, 1829)	9.75 ± 0.21	-	15.3	Yonvitner et al. (2023)
Non-finfish				
Acetes indicus (H.Milne Edwards, 1830)	-	2.97 ± 0.21	3.4	www.fishbase.se
Amusium pleuronectes (Linnaeus, 1758)	7.45 ± 0.66 *	-	6.13	Bobiles and Soliman (2018)
Aurelia aurita (Linnaeus, 1758)	26 ± 4.18	-	-	www.fishbase.se
Harpiosquilla raphidea (Fabricius, 1798)	14.5 ± 1.73	-	23	Mulyono et al. (2017)
Parapenaeopsis sculptilis (Heller, 1862)	17.6 ± 0.28 *	-	9.8	Arshad et al. (2016)
Penaeus merguiensis (De Man, 1888)	14.45 ± 0.21	10 ± 1.83	15.5	Qureshi and Amanat (2014)
Podophthalmus vigil (Fabricius, 1798)	9.45 ± 0.21	-	9.53	Ikhwanuddin et al. (2015)
Portunus pelagicus (Linnaeus, 1758)	10 ± 0.33*	-	9.8	Zairion et al. (2015)
Sepia sp.	9.45 ± 1.63	4.26 ± 0.67	15.3	Sundaram (2014)
Uroteuthis duvaucelii (A. d'Orbigny, 1835)	13.5 ± 6.29	12.81 ± 4.50	17	Bubun and Mahmud (2015)

Note: TL: Total Length; LM: Length of First Maturity; ±: SD; *: over LM

Discussion

Fish diversity

This study showed that basing on the number of species and fish groups caught by *arad*, it can be presumed that *arad* had a higher biodiversity catch capturing various types of fishes with a wide range of groups. On the other hand, the fish catch by *bagan* varied two groups only, demersal and pelagic, exhibiting a narrow range of fish groups and species. This also indicated that *arad* trawl fishing works in a wider range of water columns, which most possibly affects benthic and demersal communities, as well as their food web structure (Preciado et al. 2019).

As shown by the 5 species of fish caught by both *arad* and *bagan*, higher mobility often leads the fish to also have vertical migration in the water column to increase the chance of survival including more food resources, predator avoidance, prey capture and also drift to nursery ground (Afonso et al. 2014). This was most likely the case for pelagic fish species such as *Ambassis nalua* in this study to get caught by *arad* at the bottom, while demersal fish species such as *Drepane punctata* (Linnaeus, 1758) to get caught by life net in the surface layer.

Unlike *Acetes indicus*, which was only found among the catch using *bagan*, the non-finfish group is generally caught by *arad*, presumably due to their planktonic characteristic floating in the surface layer. However, this situation allows them to get caught by fishing gear operating on the surface area (Musel et al. 2019). This result was in line with another study by Krisnafi et al. (2020), which also stated that *A. indicus* was found amongst fish catch using *bagan* in Pangandaran, the southern coast of West Java, dominating up to 87% of the total catch volume.

Table 3. List of species caught by *Arad* and *Bagan* and categorized by price and catch priority

Species	Local name	Target/non-target catches	Selling price (IDR/kg; US $/kg)	Range of catch volume per trip/harvest (kg)
Finfish				
Aluterus monoceros	*Ayam-ayam*	Main catch	45,000; 2.9	3-5
Ambassis dussumieri	*Sriding/beseng*	Most discards	3,000; 0.2	3-5
Aurigequula fasciata	*Peperek*	Most discards	1,500; 0.1	15-20
Carangoides malabaricus	*Kuwe*	Main catch	50,000; 3.2	2-5
Chirocentrus dorab	*Golok-golok*	Main catch	60,000; 3.9	7-10
Drepane punctata	*Tapi-tapi/ketang-ketang*	Main catch	16,000; 1.1	8-10
Dussumieria acuta	*Japuh*	Main catch	25,000; 1.6	3-5
Eleutheronema tetradactylum	*Senangin/sanggeh**	Main catch	17,000; 1.1	7-10
Epinephelus fuscoguttatus	*Kerapu macan*	Main catch	75,000; 4.8	10-15
Eubleekeria splendens	*Petek/pepetek**	Most discards	1,000; 0.1	10-15
Gazza dentex	*Petek/pepetek**	Most discards	1,000; 0.1	10-15
Gerres shima	*Kapasan*	Main catch	28,000; 1.8	7-10
Hemiramphus lutkei	*Julung-julung*	Main catch	45,000; 2.9	7-10
Inegocia japonica	*Baji-baji*	Most discards	3,000; 0.2	25-30
Lagocephalus spadicus	*Buntal pisang*	Most discards	2,000; 0.13	5-10
Megalaspis cordyla	*Tetengkek*	Main catch	20,000; 1.3	10-15
Nemipterus japonicus	*Kurisi/trisi*	Main catch	35,000; 2.2	5-10
Parastromateus niger	*Bawal hitam*	Main catch	45,000; 2.9	2-5
Pomadasys argyreus	*Gerot*	Main catch	40,000; 2.6	5-10
Rastrelliger kanagurta	*Kembung*	Main catch	30,000; 1.9	10-15
Sardinella fimbriata	*Lemuru/tembang*	Main catch	30,000; 1.9	5-10
Sardinella gibbosa	*Lemuru*	Main catch	30,000; 1.9	5-7
Scomberomorus guttatus	*Tenggiri*	Main catch	75,000; 4.8	5-10
Selaroides leptolepis	*Selar*	Main catch	20,000; 1.3	5-10
Siganus canaliculatus	*Baronang*	Main catch	75,000; 4.8	3-5
Sphyraera barracuda	*Barakuda*	Main catch	20,000; 1.3	2-5
Stolephorus indicus	*Teri*	Main catch	25,000; 1.6	30-40
Triacanthus nieuhofii	*Cupang-cupang putih*	Bycatch	7,000; 0.45	10-15
Trichiurus lepturus	*Layur*	Main catch	35,000; 2.2	10-15
Tylosurus crocodilus	*Kacang-kacang*	Main catch	40,000; 2.6	8-10
Upeneus sulphureus	*Kuniran**	Most discards	1,000; 0.1	5-10
Non-finfish				
Acetes indicus	*Udang rebon*	Main catch	40,000; 2.6	7-10
Amusium pleuronectes	*Kerang simping*	Bycatch	5,000; 0.3	2-5
Aurelia aurita	*Ubur-ubur*	Always discards	-	-
Harpioquilla raphidea	*Udang cakrek/ronggeng*	Most discards	2,000; 0.13	5-10
Parapenaeopsis sculptilis	*Udang krosok*	Main catch	60,000; 3.9	10-20
Penaeus merguiensis	*Udang jerbung flower*	Main catch	125,000; 8	10-15
Podophthalmus vigil	*Rajungan angin*	Main catch	30,000; 1.9	3-5
Portunus pelagicus	*Rajungan biru*	Main catch	35,000; 2.2	3-5
Sepia sp.	*Sotong*	Main catch	45,000; 2.9	7-10
Uroteuthis duvaucelii	*Cumi*	Main catch	30,000; 1.9	8-10

Note: Main catch: target species, price range > IDR 15,000/kg; bycatch: non-target species, price range IDR 5,000 ≤ species ≤ 15,000/kg; most discards: non-target species with low economic value, price range < IDR 5,000/kg; always discards: non-target species with no-economic value; *: the highest catch volume in each trip; 1 US $ equals 15,604 IDR on average exchange rate refers to Bank of Indonesia in October-December 2024

The potential for conflict in the use of pelagic groups is small. This is because the fish target and the layer of water column of *arad* and *bagan* were different due to their characteristic in catching fish. The main catch of *arad* was demersal fish, while *bagan*'s target was pelagic fish. However, the demersal fish that are the target of *arad* are also often caught by *bagan* even though the *bagan* were operated in the pelagic layer. Catching the demersal fish is very possible because some demersal fish can be attracted by the light used in operating the fishing rod (Bubun et al. 2015). *Arad* is more dominant in catching non-finfish groups when compared to *bagan*. This is quite realistic because the habitat of these species non-finfish is generally found in the *arad* operational layer.

Although the catch were mostly non-endangered species where their population was still in abundance, and the size of fish catch may vary regarding the weather conditions (Krisnafi et al. 2020), the TL mostly measured below the value of LM. Only 25% (7 out of 28) and 22% (4 out of 18) of the catch by *arad* and *bagan*, respectively, have their size greater than the LM value. This finding indicates an early sign that the fish caught in the study area with their size decline have been worth observing during the study period. This condition is similar to another research, showing that the catch was dominated by fish that had not yet reached biologically suitable size for catching (Simbolon et al. 2017). Capture fisheries activities that are dominated by fish in the unsuitable size category can cause negative impacts on bio-ecological aspects because the recruitment rate decreases and will further reduce the stock of fish resources in the nature, and disrupt the sustainability of capture fisheries businesses (Simbolon et al. 2020).

The TL value of the fish caught by *arad* showed a broad size range, yet mostly below the value of LM. Even though the fish caught by *bagan* also have a similar pattern regarding the size (with the TL value greater than the value of LM), this catch group comes from a smaller number of species and groups in comparison to the fish caught by *arad*. Thus, *arad* proved to be less selective in catching fish, a factual data of fish size that is also in line with the analyses by Hutubessy and Mosse (2015), showing that broad size range with a high level of diversity indicates a wide trophic level of *arad* catches. Disturbance and negative impacts on a multi-trophic system are consequently also expected (Wootton 1998). This diverse catch composition (of size and species) of *arad* may thus illustrate the ecosystem condition as well and become an important issue in the future. Fish caught in larger sizes usually have a reverse low biomass (Hutubessy and Mosse 2015). Having the effort of targeting larger fish increased will lead to a decreasing number of larger fish, and as a consequence, the remaining smaller fish will form a population with even slower growth development, smaller size, and also other changes that can lower population productivity (Hutubessy and Mosse 2015). The average small size of fish is presumably triggered by the cumulative effect of trawl fishing, which is also supported by another study (Foster et al. 2015), where the fish population's decreasing number of their average size was attributed to the use of trawl leading to a population shift towards smaller fish.

The TL value of the crab caught using *arad* showed a bigger dimension slightly above the legal-size limits for the catch (PERMEN-KP no.56/2016), which is similar to the representation of the LM value. In another study conducted by Azkia et al. (2022), 66% of crabs caught by trawl (*arad*) in Demak, the northern part of central Java had an average size of <10 cm, showing that this condition is the opposite, though the same study also mentioned that crabs with size of >10 cm had been reported to be found in another fishing gear with passive operational method called *bubu* trap. This condition may be attributed to the habitat differences in the bottom layer, influencing the crab distribution where larger crabs were caught in muddy substrates compared to shallow waters with sandy substrates (Asphama et al. 2015). The different type of substrate can give different territorial behavior in swimming crab, including interactions between animals and their environment, which will affect their distribution (Zhu et al. 2022).

Data from the questionnaires also showed that the non-target species (bycatch and most discards) usually have a larger catch volume for each species, compared with the target species. The fact that this non-target species was always present in every catch meets a condition mentioned in another study (Soykan et al. 2016) that is even amounting to 33.2% of the total catch biomass in average. Trawl fishing puts pressure on the marine environment, directly affecting the abundance of target species and at some point, disturbing predator-prey composition (Foster 2015). Trawl fishing also indirectly affects fish assemblages by impacting fish habitat, resulting in a trophic cascade, which can be buffered by natural competitive interaction (Rochet et al. 2013), including predator-prey interaction.

A previous study reported an interesting point that there had been a shift in the abundant species of shrimp, with increasing biomass of the demersal fish and more density of larger-sized shrimp in the middle area of Java Sea two years after the ban of trawl (*arad*) fishing gear had been imposed (Tirtadanu and Suprapto 2017). Another study showed that bottom trawl and dredge fishing have been sustained, where habitats for benthic sedimentary remain in good condition with a well-managed fishing pressure (Hilborn et al. 2023).

Conservation status

The conservation status presented in this study is intended to describe the health of the diversity of the various fish species caught by *arad* and *bagan* in Cilincing waters. Several approaches that can be used to evaluate conservation status include the International Union for Conservation of Nature and Natural Resources (IUCN) and Regulation of the Ministry of Environment and Forestry No. P.106/MENLHK/SETJEN/KUM.1/12/2018.

The conservation status of the fish species caught by *arad* and *bagan* in this study was mostly in LC (Least Concern) category that refers to IUCN (Table 4). As for the conservation status referring to the national regulation by the Indonesian Ministry of Environment and Forestry, whom authorized for conservation status, there is no adequate data and information available pertaining to the population conditions of these species. No species listed in Table 4 are in the threatened category due to excessive fishing activities. The evaluation results did not show any critical criteria such as Critically Endangered (EN), Endangered (EN), Vulnerable (VU), or Near Threatened (NT).

Since most of the caught species were in the least concern status as according to IUCN, it can safely be presumed that their population was mostly still in abundance. The lack of information on the population status referring to the Ministry of Environment and Forestry of the Republic of Indonesia stresses the need for information update as better understanding in fish ecology has been achieved. A number of species caught during the study were important commodities with high economic value such as *Scomberomorus guttatus*, *Sardinella fimbriata*, *Sardinella gibbosa*, and *Rastrelliger kanagurta*. *Sardinella* caught in the samples were genera with LC conservation status, indicating that their population was still in abundance. The same status seems inapplicable to the other *Sardinella* that are found in the Strait of Bali, *Sardinella lemuru* with their IUCN status categorized as NC (Near Threatened) since this species is the main commodity for canned products, triggering for massive catch especially in the Strait of Bali (Pertami et al. 2022).

Table 4. List of fish species caught by *arad* and *bagan* for conservation status from IUCN and Regulation of the Indonesian Ministry of Environment and Forestry

Species	Local name	Conservation status		
		Regulation of the Ministry of Environment and Forestry	IUCN	
Finfish				
Aluterus monoceros	*Ayam-ayam*	-	LC	Matsuura et al. (2015)
Ambassis dussumieri	*Sriding*	-	-	-
Aurigequula fasciata	*Peperek*	-	-	-
Carangoides malabaricus	*Kuwe*	-	LC	Smith and Williams (2016a)
Chirocentrus dorab	*Golok-golok*	-	LC	Santos et al. (2017)
Drepane punctata	*Tapi-tapi/ketang ketang*	-	LC	Bucol et al. (2024)
Dussumieria acuta	*Japuh*	-	LC	Hata (2021)
Eleutheronema tetradactylum	*Senangin*	-	-	-
Epinephelus fuscoguttatus	*Kerapu macan*	-	-	-
Eubleekeria splendens	*Petek/pepetek*	-	LC	Larson (2012)
Gazza dentex	*Petek/pepetek*	-	-	-
Gerres shima	*Kapasan*	-	-	-
Hemiramphus lutkei	*Julung-julung*	-	-	-
Inegocia japonica	*Baji-baji*	-	LC	Motomura and Matsuura (2016)
Lagocephalus spadicus	*Buntal pisang*	-	-	-
Megalaspis cordyla	*Tetengkek*	-	-	-
Nemipterus japonicus	*Kurisi*	-	LC	Al Buwaiqi et al. (2019)
Parastromateus niger	*Bawal hitam*	-	LC	Smith et al. (2018)
Pomadasys argyreus	*Gerot*	-	LC	Al Abdali et al. (2019)
Rastrelliger kanagurta	*Kembung*	-	LC	Collette and Pollard (2023a)
Sardinella fimbriata	*Lemuru/ tembang*	-	LC	Munroe (2018)
Sardinella gibbosa	*Lemuru*	-	LC	Santos et al. (2018)
Scomberomorus guttatus	*Tenggiri*	-	DD	Collette and Pollard (2023b)
Selaroides leptolepis	*Selar*	-	LC	Smith and Williams (2016c)
Siganus canaliculatus	*Baronang*	-	LC	Carpenter et al. (2016)
Sphyraera barracuda	*Barakuda*	-	-	-
Stolephorus indicus	*Teri*	-	LC	Santos et al. (2017)
Triacanthus nieuhofii	*Cupang-cupang putih*	-	-	-
Tylosurus crocodilus	*Kacang-kacang*	-	-	-
Trichiurus lepturus	*Layur*	-	LC	Collete et al. (2015)
Upeneus sulphureus	*Kuniran*	-	LC	Smith and Williams (2016b)
Non-finfish				
Acetes indicus	*Udang rebon*	-	-	-
Amusium pleuronectes	*Kerang simping*	-	-	-
Aurelia aurita	*Ubur-ubur*	-	-	-
Harpiosquilla raphidea	*Udang cakrek/ronggeng*	-	-	-
Parapenaeopsis sculptilis	*Udang krosok*	-	-	-
Penaeus merguiensis	*Udang jerbung flower*	-	-	-
Podophthalmus vigil	*Rajungan angin*	-	-	-
Portunus pelagicus	*Rajungan biru*	-	-	-
Sepia sp.	*Sotong*	-	-	-
Uroteuthis duvaucelii	*Cumi-cumi*	-	DD	Allcock et al. (2019)

Notes: LC: Least Concern; DD: Data Deficient; -: no data; IUCN: International Union for the Conservation of Nature and Natural Resources; Regulation of the Ministry of Environment and Forestry No. P.106/MENLHK/SETJEN/KUM.1/12/2018

In conclusion, the use of *arad* in Cilincing waters showed un-selective and wide range of catches in relation to the size and diversity of species compared to *bagan*. Although no species caught were endangered, the catch composition indicates an imbalanced proportion of both target and non-target species (by catch and mostly discards). The trend of the fish caught with smaller sizes during the study period also leads to another concern, where the abundance of non-target species and smaller fish in size may reflect the disturbance in their ecosystem and consequently lead to population issues in the future. As an outlook, a further study on environmental impacts of *arad* fishing is necessary in particular with the focus on gear and size selectivity, and also modifications to improve fishing gear such as nets, in order to enhance selectivity and sustainability as part of the *arad* management.

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