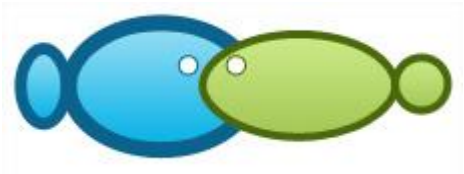

Spawning season and the exploitation status of banana shrimp (*Penaeus merguiensis*) in Cirebon waters, West Java, Indonesia

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Abstract. The banana shrimp (*Penaeus merguiensis*) fishery has contributed to the livelihood of artisanal fishers, to the local community's economy, as raw material for the shrimp processing industry, and as nutritious food in Indonesia. Banana shrimp has been exploited intensively in Cirebon waters as part of the Fisheries Management Area (FMA) 712. To enhance the sustainability of banana shrimp in Cirebon waters, some management tools should be developed by investigating their exploitation status and the spawning season. This research was conducted from January to November 2021, with 3123 shrimp samples. The size of banana shrimps captured by trawl nets ranged from 20 to 64 mm, with a length at first maturity (Lm_{50}) of 36.2 mm. Banana shrimps spawn throughout the year, with peaks in March and October. The overfishing condition has been found for the shrimp fishery in Cirebon waters, with an exploitation ratio of 0.61. This study recommends some management measures by applying the minimum landing size of 36 mm, fishing closure based on the spawning peak in March and October, and controlling the size of the cod end of the trawl net.
Key Words: artisanal fishers, fishing closure, overfishing, *Penaeus merguiensis*.

Introduction. The shrimp resources in Indonesia have been exploited intensively, and their fishery has contributed to various aspects: the livelihoods of the local community, the national foreign exchange as an export commodity, and as a nutritious food source. In addition, apart from the meat liked by the community, the shrimp shell waste can also be used as pellets (Pratiwi 2008). The high protein content of shrimp reaches 21%, having a low cholesterol level (Sulistiyono & Moria 2005). Moreover, this commodity is also a target for exporters. Shrimp resources are in the eighth position in national exports, and the exports increased by 22% from 132.79 thousand tons in 2012 to 207.7 thousand tons in 2019 (Mohani et al 2016).

Various species of shrimp from the *Penaeidae* family were captured from the coastal area, and one of the commercially dominant species is *Penaeus merguiensis*. This species has several trade names in Indonesia, including banana shrimp, 'jerbung', white shrimp, and 'kelong'. The body color is yellowish-white with brown and green spots, and the tips of the tail and legs are red. The antennules are dark red stripes, and the antennae are red. The upper rostrum teeth number 5 to 8 and there are 2-5 at the bottom, but some shrimp have upper rostrum teeth numbering 6-7 and lower 4-5 (Kusrini 2011). Although *P. merguiensis* is found dominantly in shallow coastal areas, they can adapt to the various environmental conditions in the coast and offshore (Tirtadanu et al 2022). *P. merguiensis* in Indonesia is exploited by various fishing gears such as trawls, trammel nets, gill nets, and mini trawlers.

The overfishing condition of *P. merguiensis* has been found in several waters of Indonesia, such as Kota Baru, Tarakan, Sampit, Teluk Cendrawasih, Bengkalis, Tanah Laut and Cilacap (Suman & Umar 2010; Kembaren & Suman 2013; Nurdin & Kembaren 2015;

Kembaren & Ernawati 2015; Pane & Hasanah 2017; Suman et al 2017; Wagiyo et al 2018; Tirtadanu & Chodrijah 2020). Based on the statistical data of the Ministry of Marine Affairs and Fisheries (MMAF 2021), the production of shrimp resources in the Java Sea (Cirebon) increased from 2339.34 tons in 2019 to 3227.91 tons in 2020 indicating intensive fishing of shrimps. Moreover, destructive fishing gear and uncontrolled fishing activities degrade the habitat and threaten the shrimp population in the ecosystem. As part of areas of the Java Sea, shrimp fishing operations in Cirebon waters are conducted using mini trawl nets (arad) and trammel nets.

The sustainability of shrimp resources needs to be a concern, so that management measures can be developed to prevent population decline, which may result in economic loss. Proper management requires scientific studies related to some biological and stock indicators, including the spawning season and the exploitation level. The aim of this study is to provide some recommendations for the management of banana shrimp (*P. merguiensis*) resources in Cirebon waters.

Material and Method

Description of the study sites. This research was conducted in Cirebon waters from January to November 2021, at the landing area in Suranenggala, Cirebon. The shrimp landing area is one of the landing centers for fishermen who use mini trawl (arad) fishing gear. The data collection activities are carried out by researchers who are assisted by enumerators who collect daily data for at least 20 days per month. The fishing grounds of shrimps are presented in Figure 1.

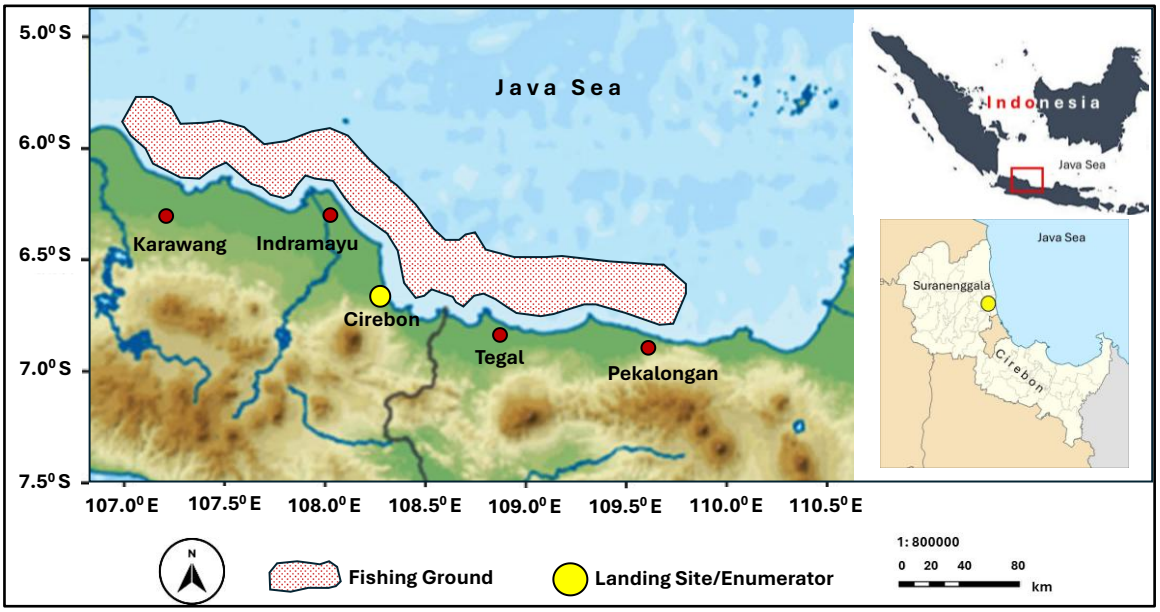

Figure 1. The shrimp fishing grounds in the Cirebon water.

Data collection. Data collection on shrimp samples included measurements of carapace length (CL), body weight, sex, and gonadal maturity stages. 3123 shrimps were sampled. The CL was measured using the calipers with an accuracy of 0.1 mm, while the body weight was determined using a digital scale of 0.01 g. Furthermore, the sex of the shrimp was determined by observing the reproductive organs on the outside of the body, namely the pereopods or walking legs. The male genitalia, called plasma, is located between the first pair of the fifth swimming legs, while the female has a telicum located between the fourth and fifth pairs of walking legs. Determination of the gonad maturity stage was done by visually observing the dorsal part of the female shrimp, which is greenish from head to tail. Gonad maturity is the basis for determining the prediction of the shrimp spawning season in the waters.

Data analysis. Biological analysis of shrimp included the size structure, the relationship between CL and body weight, sex, and gonad maturity stages of female shrimp. The size structure of the shrimp was determined by tabulating the data with a class interval of 2 mm, and it was visualized by using a histogram. The relationship between CL and body weight was analyzed by using the cubic formula, based on Bal & Rao (1984). The sex ratio was measured by comparing male and female shrimp and tested using the chi-square test (Steel & Torrie 1993). The gonad maturity of female shrimp was determined based on Motoh (1981), being divided into five stages (GMS), namely immature, early maturity, advanced maturity, perfect egg maturity, and spent. Analysis of the spawning season was carried out based on the highest proportion of mature shrimps using monthly data on GMS. The shrimp with GMS 3 to 5 were identified as mature.

The length at first capture (Lc_{50}) of *P. merguiensis* by using a bottom trawl was analyzed by determining the cut-off point between the curve of 50% cumulative frequency and the length of shrimps caught by the trawler, and the length at first maturity (Lm_{50}) was determined by the logistic formula (Sparre & Venema 1999; King 2007). Growth parameters (K) and asymptotic carapace length (L_∞) were analyzed using the Electronical Length Frequency Analysis (ELEFAN) packages from FAO ICLARM Fish Stock Assessment Tool (FISAT II) software. The theoretical age of shrimp when the length is equal to zero can be estimated using Pauly's empirical equation (Pauly et al 1984). The natural mortality (M) was determined using Pauly's (1980) empirical formula (Sparre & Venema 1999), using the mean sea surface temperature of 30°C. The total mortality (Z) was estimated by using the catch curve analysis (Sparre & Venema 1999). Furthermore, the fishing mortality (F) is calculated by subtracting the value of total mortality (Z) from natural mortality (M) (F=Z–M). The exploitation rate (E) is calculated by the ratio of fishing mortality (F) to the total mortality (Z) (E=F/Z), with the optimum value of E as 0.5 (Gulland 1971).

Results and Discussion

Biological aspects. The size of banana shrimp in Cirebon waters ranged from 20 to 64 mm with a mode of 30 mm (Figure 2). Female shrimp have a larger size and faster growth than males (Dall et al 1990). Female shrimp in Cirebon waters ranged from 20 to 64 mm, and male shrimp were between 20 to 50 mm (Table 1). The maximum size of *P. merguiensis* in 2021 as 64 mm is smaller than what was reported by Tirtadanu & Ernawati (2016) in the same regions, with a maximum size of 68 mm. In addition, the shrimp found in Aceh waters using mini trawls, ranging from 23.8 to 65.9 mm, were also larger than in the study area (Putra et al 2018). However, some studies reported the smaller size of shrimps in other areas, including in Bengkalis (12-56 mm), East Aceh (16-42 mm), Kota Baru (14-46 mm), Tarakan waters (19-53 mm), Cilacap (11-42 mm), Kaimana (25-49 mm) and Dumai waters (18-60 mm) (Pane & Hasanah 2017; Pane & Widiyastuti 2017; Tirtadanu et al 2017; Chodrijah & Suman 2017; Wagiyo et al 2018; Tirtadanu & Panggabean 2018; Pane & Suman 2020). The variation in the size of shrimps can be influenced by the type of fishing gear, fishing pressure, environmental factors, and food availability, among others (Chodrijah & Suman 2017; Pane & Suman 2020).

The relationship between CL and body weight of both male and female shrimp showed a negative allometric condition, meaning that the length growth was faster than the weight gain (Table 2). Most studies also reported the negative allometry condition for *P. merguiensis* in Indonesia, including Arafura Sea, Bengkalis waters, East Aceh, Cilacap, and Kaimana (Hargiyanto et al 2013; Pane & Hasanah 2017; Pane & Widiyastuti 2017; Wagiyo et al 2018; Tirtadanu & Panggabean 2018). The negative allometric growth pattern indicated that the shrimp was captured at a young age, which required energy for growing. Adult shrimp experience a slowdown in the length growth compared to the body weight (Saputra et al 2013). The relationship between CL and body weight of penaeid shrimp is also related to food availability, generally other crustaceans, detritus, and mollusks (Sentosa et al 2017).

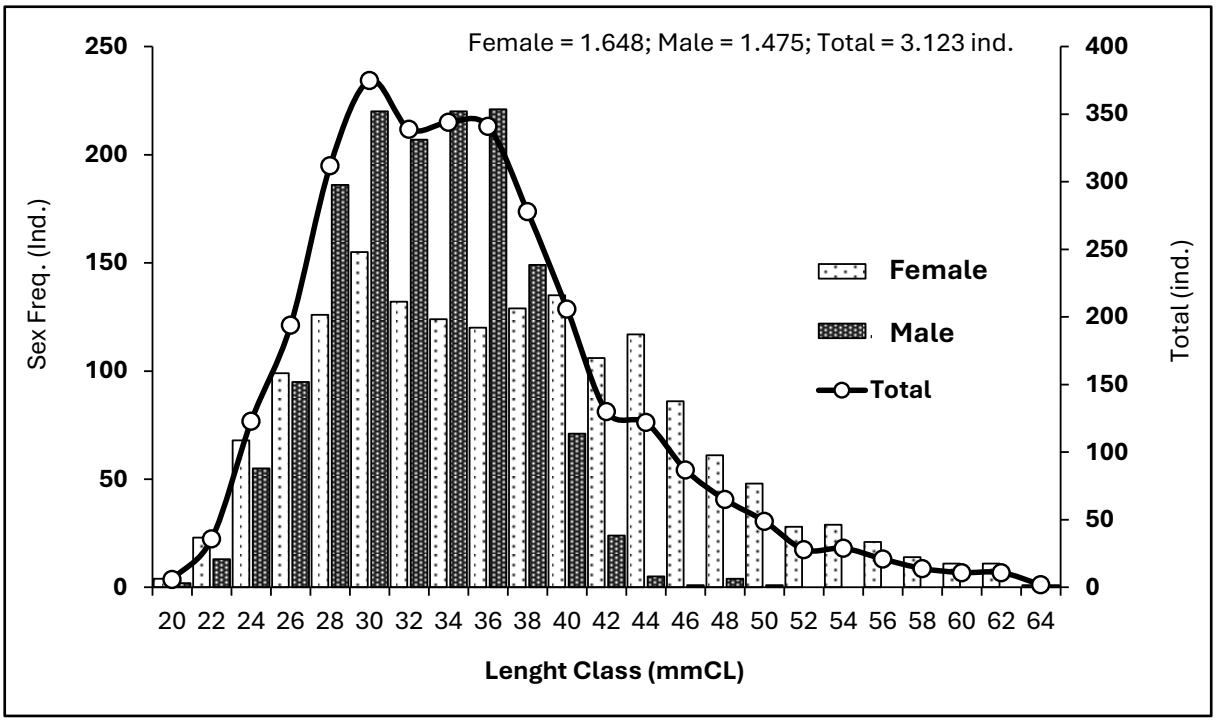

Figure 2. The length frequency of banana shrimp (*Penaeus merguiensis*) in Cirebon waters.

Table 1

The monthly size structure of banana shrimp (*Penaeus merguiensis*) in Cirebon waters

Month	*Female*		*Mode*	*Male*		*Mode*
	Min (mm)	*Max (mm)*	*(mm)*	*Min (mm)*	*Max (mm)*	*(mm)*
January	24	52	28	24	40	32
February	22	50	30	22	48	30
March	28	62	40	30	48	36
April	26	64	44	24	44	34
May	22	62	44	22	50	30
June	20	58	34	22	42	32
July	20	54	30	20	42	28
August	22	62	26	20	42	24
September	24	60	36	26	48	34
October	22	62	38	24	44	32
November	20	62	30	22	42	28
Total	20	64	30	20	50	36

Table 2

Length-weight relationship of banana shrimp (*Penaeus merguiensis*) in Cirebon waters

Sex	*N*	*a*	*b*	R^2	*Growth traits*
Female	1.649	0.0056	2.4715	0.9405	Allometric negative
Male	1.474	0.0064	2.4383	0.8891	Allometric negative
Combination	3.123	0.0061	2.4503	0.9319	Allometric negative

The female shrimp were more dominant than males, which indicated an unbalanced ratio (Table 3 and Figure 3). A high ratio of females was also found in the waters of Cilacap, Dumai, and Bengkalis (Saputra et al 2013; Pane & Hasanah 2017; Wagiyo et al 2018; Pane & Suman 2020). In contrast, males of *P. merguiensis* were more dominant than

females in Pemangkat (Kembaren 2013). The more dominant female sex ratio can be due to the age of male shrimp, which is relatively shorter than that of females (Saputra et al 2013). The imbalance in the sex ratio can be influenced by various factors, including biological conditions, environmental factors, and fishing gear selectivity (Naamin 1984; Kantun 2011; Effendie 2002). The dominance of females can also be found due to the faster movement of males to avoid the net (Hargiyanto et al 2013).

Table 3

Sex ratio of banana shrimp (*Penaueus merguiensis*) in Cirebon waters

Month	*Sex ratio*	
	Female	*Male*
January	1.40	1
February	1.30	1
March	0.90	1
April	1.50	1
May	1.27	1
June	0.97	1
July	1.14	1
August	1.29	1
September	0.60	1
October	1.12	1
November	1.2	1
Total	1.12	1

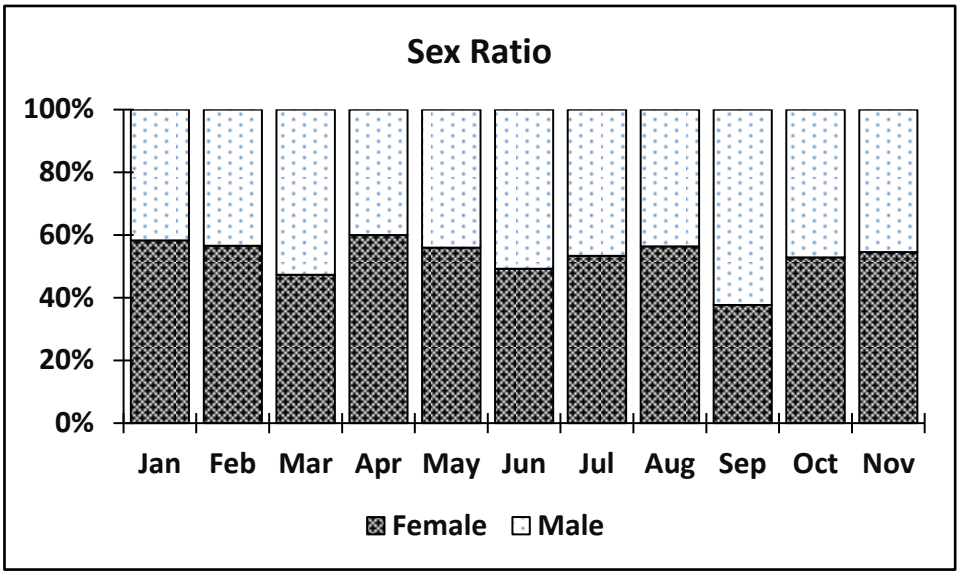

Figure 3. Monthly sex ratio of *Penaeus merguiensis* in Cirebon waters.

The monthly proportion of GMS of *P. merguiensis* in Cirebon waters indicated that the shrimp spawned throughout the year, with the spawning peak in March and October (Table 4). The spawning peak can vary in each area and is influenced by environmental factors, seasons, and rainfall (Kantun 2011; Chodrijah & Suman 2017). Some previous studies have reported the spawning season of *P. merguiensis*: Dumai waters in June and December, Tarakan in March and September, and Sampit in March and September (Kembaren & Suman 2013; Nurdin & Kembaren 2015; Pane & Suman 2020). The spawning season can be a basis for developing time and area closures for shrimp fisheries management to provide opportunities for reproduction and recruitment.

Table 4

The gonad maturity stages of banana shrimp (*Penaeus merguiensis*) in Cirebon waters

Month	*Gonad maturity level*					*Gonad maturity percentage*	
	GMS 1	*GMS 2*	*GMS 3*	*GMS 4*	*GMS 5*	*Immature*	*Mature*
January	59	17	7	5	0	86.4	13.6
February	123	8	12	6	20	87.9	12.1
March	56	20	21	20	25	65.0	35.0
April	81	39	0	1	59	99.2	0.8
May	126	22	1	0	19	99.3	0.7
June	97	9	5	0	19	95.5	4.5
July	135	17	1	0	6	95.6	4.4
August	153	9	5	0	3	95.3	4.7
September	74	26	11	1	1	88.5	11.5
October	71	36	26	1	28	66.0	34.0
November	122	25	9	2	8	88.6	11.4

The population dynamics and the exploitation status. The length at first capture of *P. merguiensis* by trawler (Lc_{50}=34.7 mm) was smaller than the length at first maturity (Lm_{50}=36.2 mm), indicating that the young-age shrimp dominated the catch at the immature condition (Table 5). This condition showed that the shrimp had been captured before they could reproduce to enhance the recruitment. If this condition occurs continuously, the shrimp population will decrease, and the shrimp size will be smaller due to lack of recruitment. The non-selective fishing condition in shrimp fisheries (Lc_{50}<Lm_{50}) was also found in some areas in Indonesia, including Tarakan, Arafura Sea, Sampit, East Aceh, Kota Baru and Kaimana waters (Kembaren & Suman 2013; Hargiyatno et al 2015; Nurdin & Kembaren 2015; Pane & Widiyastuti 2017; Tirtadanu et al 2017; Tirtadanu & Panggabean 2018). The size and type of gears mainly influenced the variation in the length at first capture. To increase the recruitment of shrimp and to enhance the sustainability of the shrimp fishery, the mesh size can be increased to adjust the optimal landing size of 36.2 mm.

Table 5

Growth and some population parameters of banana shrimp (*Penaeus merguiensis*) in Cirebon waters

Parameters	*Unit*	*Score*
Length at first capture (Lc_{50})	mm	34.7
Length at first maturity (Lm_{50})	mm	36.2
Asymptotic length (L_∞)	mm	68.3
Growth rate (K)	Year	1.35
Age when the length is equal to zero (t_0)	Year	0.09
Total mortality (Z)	Year	4.57
Natural mortality (M)	Year	1.78
Fishing mortality (F)	Year	2.79
Exploitation rate (E)		0.61

The growth rate (K) of shrimp in Cirebon waters was 1.35 per year, with an asymptotic length (L_∞) of 68.3 mm (Figure 4). The growth rate of shrimps is influenced by various factors, including food availability, environmental conditions, and sex dimorphism (Pane et al 2021). A high growth rate (K) value of *P. merguiensis* indicates that the shrimp is a fast-growing and short-lived species. The growth rate (K) of *P. merguiensis* in this study is also close to some other studies in Indonesia: Tarakan, Teluk Cendrawasih, Tanah Laut, Kaimana, and Cilacap (Kembaren & Suman 2013; Kembaren & Ernawati 2015; Suman et al 2017; Tirtadanu & Panggabean 2018; Tirtadanu & Chodrijah 2020). The rapid growth of species in nature is also in line with the significant value of natural mortality. However,

the population of shrimps would drop rapidly under the overfishing conditions (Suman et al 2017; Tirtadanu & Panggabean 2018).

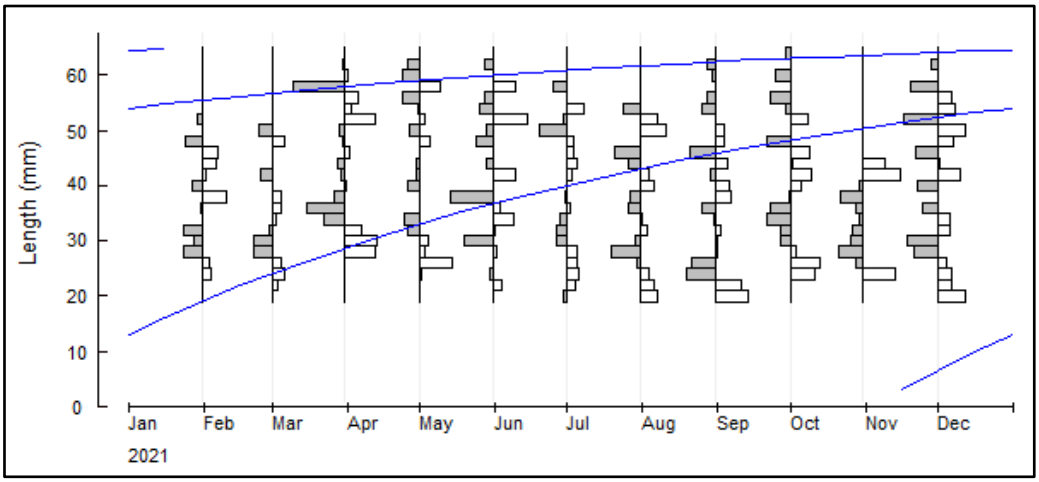

Figure 4. The monthly length frequency and growth of banana shrimp (*Penaeus merguiensis*) in the Cirebon waters.

The natural mortality (M) of *P. merguiensis* in Cirebon waters was lower than the fishing mortality (F), indicating that the banana shrimp is a commercial species that has been exploited intensively. The exploitation rate of *P. merguiensis* was 0.61, indicating that the fishing pressure exceeded 22% of the optimal condition suggested by Gulland (1971), namely 0.50. The overfishing condition of *P. merguiensis* in Cirebon waters was also affected by the use of a trawler, which has low selectivity and threatens the habitat. A reduction in the fishing efforts and the evaluation of the mesh size of the trawlers should be done to enhance the sustainability of the shrimp fishery in Cirebon waters.

Some management measures can be developed by reducing fishing efforts to 22% from the current condition, or by adjusting the mesh size of the trawler to increase the selectivity to 36 mm. Moreover, to increase recruitment, the time and area closure can be applied by considering their spawning area and season. Shrimp resources can be conserved by exploiting them without exceeding the optimal amount. Harvest strategy needs to be developed by all the stakeholders so that the fisheries regulation can be implemented effectively (Pane et al 2021). Ecologically sustainable management must be socially supported and also have an impact on the economy of the surrounding community (Wedjatmiko 2012). Therefore, shrimp resources as a domestic and export commodity should be cooperatively managed by the government, fishers, traders, and other related stakeholders.

Conclusions. Banana shrimp in Cirebon waters was caught at a size of 20 to 64 mm, with a length at first maturity (Lm_{50}) of 36 mm. *P. merguiensis* spawn throughout the year, with the spawning peak in March and October. The growth rate of shrimp (K) was 1.35 per year, with natural mortality (M) lower than the fishing mortality (F). The current fishing pressure exceeded 22% of the optimal condition, so a reduction in fishing efforts is highly recommended. Other recommendations include setting an optimal mesh size to increase the selectivity to 36 mm and implementing fishing closure in March and October at some spawning areas.

Acknowledgements. This article is part of a Study on Fisheries Biological Characteristics, Resources, Habitats, and Potential Productions of Fish Resources in FMA 712 Java Sea in Fiscal Year 2021 by the Research Institute for Marine Fisheries, Jakarta, Indonesia. Researchers are thankful to Mr. Achmad Miftachul Fuad as the enumerator for fish resources in the Cirebon seas, who helped collect the data for this study.

Conflict of Interest. The authors declare no conflict of interest.

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Received: 23 August 2024. Accepted: 14 October 2024. Published online: 31 July 2025.
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How to cite this article:
Amri K., Pane A. R. P., Tirtadanu, Mardjudo A., Yahya F. A., Prihatiningsih, 2025 Spawning season and the exploitation status of banana shrimp (*Penaeus merguiensis*) in Cirebon waters, West Java, Indonesia. AACL Bioflux 18(4):1786-1795.