JIPK. Volume 17 No 3 October 2025
Sinta 1 (Decree No: 158/E/KPT/2021)
e-ISSN:2528-0759; p-ISSN:2085-5842
Available online at https://e-journal.unair.ac.id/JIPK

JIPK
(JURNAL ILMIAH PERIKANAN DAN KELAUTAN)
Scientific Journal of Fisheries and Marine

Research Article

Assessing the Population Parameters of *Karumballichirus karumba* (Poore and Griffin, 1979) from Intertidal Zone of Madura Strait

Abdul Qadir Jailani[1*], Suradi Wijaya Saputra[2], Suryanti[2], and Aninditia Sabdaningsih[2]

[1]Doctoral Program of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Universitas Diponegoro, Semarang. Indonesia
[1]Aquaculture Study Program, Faculty of Agriculture, Tidar University, Magelang. Indonesia
[2]Departement of Aquatic Resources, Faculty of Fisheries and Marine Sciences, Universitas Diponegoro, Semarang. Indonesia

ARTICLE INFO

Received: July 14, 2025
Accepted: August 08, 2025
Published: August 15, 2025
Available online: Sept 27, 2025

*) Corresponding author:
E-mail: abdulqj@untidar.ac.id

Keywords:
Karumballichirus karumba
Growth
Mortality
TropFishR

Abstract

This study provides the first information on the population parameters of *Karumballichirus karumba*. A total of 902 *K. karumba* samples were collected, consisted of 412 males and 490 females. The von Bertalanffy parameters were estimated to have asymptotic length $L\infty$ (mm): male = 44.21, female = 42.8, and pooled = 44, negative allometric condition factor, growth rate K (/years): male = 0.58, female = 0.67, and pooled = 0.9. Growth performance index (ϕ') : male = 3.05, female = 3.08, and pooled = 3.24. The natural mortality rate M (/years): male =0.7, female = 0.8, and pooled = 1, and shrimp mortality rate F (/years): male = 1.57, female = 2.89, and pooled = 3.12. The current exploitation rate is slightly higher than optimal exploitation rate = 0.5, indicating that there is a need to regulate fishing so that it is sustainable. The size of the first time caught is still below (1/2 Linf); thus, the reproductive opportunities of *K. karumba* are guaranteed, and in terms of utilization, fall into the category of sustainable fishing. The estimated life span of *K. karumba* is 4 to 6 years. Reproduction occurs continuously every month, indicated by the discovery of ovigerous females. The highest recruitment occurs in January and November. YPR (yield-per-recruitment) shows that the value of Fcur = 3.12 years^{-1} in the estimated population is lower than Fmax = 5 years^{-1} and above F05 = 1.99 years^{-1} and F01 = 1.8 years^{-1}.

Cite this as: Jailani, A. Q., Saputra, S. W., Suryanti., & Sabdaningsih, A. (2025). Assessing the Population Parameters of *Karumballichirus karumba* (Poore and Griffin, 1979) from Intertidal Zone of Madura Strait. *Jurnal Ilmiah Perikanan dan Kelautan,* 17(3):643-655. https://doi.org/10.20473/jipk.v17i3.75978

1. Introduction

More than 60 million people worldwide depend on fisheries as their source of income and livelihood (FAO, 2018). Global fish production from marine resource captures was estimated at approximately 84.4 million tonnes in 2018 (FAO, 2020). Demand for fish for human consumption has been steadily increasing, reaching 179 million tons in 2018 (FAO, 2018). The majority of people still eat fish, especially those living in low- and middle-income countries (Delgado, 2003; Hassberg *et al.,* 2020). Fish consumption for human consumption is expected to continue to increase from 50% in 2020 to 89% in 2030 (FAO, 2022). Food sourced in aquatic environments is important for the economies, livelihoods, nutritional security, and cultures of people in many nations; they are often nutrient-rich (Golden *et al*., 2021). It may help address problems related to environmental impacts and human health (Crona *et al.,* 2023).

It is widely believed that the majority of marine species are resilient to population reduction and local extinction due to their extensive geographic ranges, high reproductive rates, and great ability to move. Nevertheless, there exist several marine species that do not conform to these generalizations, and extinctions in the ocean can occur more frequently than expected (Carlton *et al.,* 1999; Roberts *et al.,* 1999). Even species that are plentiful and have a wide distribution can have significant decreases in population or even become extinct as a result of habitat loss, changes, and climate change (Ragheb, 2024). However, declines in uncommon or unidentified species may not be observed (Carlton *et al.,* 1999; Roberts *et al*., 1999; Raso and Manjon-Cabeza, 2002). Therefore, the specific environmental conditions that a species needs for its habitat can determine how well it can tolerate disturbances in the environment, even if it is a species that is found in many different locations.

Numerous fisheries encounter significant challenges in maintaining sustainable resource exploitation, including issues such as overexploitation of stocks, the bycatch of juvenile specimens, and shifts in species assemblages (Duarte *et al*., 2020). To address these concerns, fisheries management has adopted strategic interventions, including periodic stock assessments, harvest quotas, regulations on fishing gear specifications (Melnychuk *et al*., 2021; Kennelly and Broadhurst, 2021), and the ecosystem (Clovis and Simon, 2024). Furthermore, the growing necessity for high-resolution fisheries data has driven the expansion of monitoring and surveillance initiatives (Silva *et al*., 2020). This management position highlights the urgent need for conservation strategies to maintain the sustainability of essential benthic habitats.

Madura Strait is the fishing area of ± 92,480 fishermen with more than 9000 fishing boats. The potential of Madura Strait fisheries reached 214,097 tons, and the production has reached 227,427 tons in 2008, indicating that the region has been experiencing overfishing (East Java Fisheries and Marine Service, 2010), even mentioned that over-fishing was detected since 1997 (Hidayah *et al.,* 2020).

K. karumba is commonly found in the intertidal zone of the Madura Strait with varying depths, utilized by fishing communities for consumption or for sale, and thus is feared to endanger the *K. karumba* population. Information on the early development of ghost shrimp in the intertidal zone of the Madura Strait is still lacking. *K. karumba* has considerable ecological and economic significance, playing an important role in nutrient cycling and mineralization of matter. Among benthos, shrimp have significant environmental and economic importance, playing a fundamental role in marine ecosystems as part of food webs and being prey for a variety of species (Mora-Lara, 1973; Willems *et al.,* 2016).

Research has been conducted on morphological identification of *K. karumba* (Poore and Griffin, 1979; Dworschak, 2008; Poore *et al*., 2019; Sakai, 1999), molecular phylogeny (Robles *et al*., 2020), and hepatopancreas organ damage caused by heavy metals (Kristiani, 2016). However, no study has comprehensively observed the entire life history of *K. karumba* population from recruitment to cohort disappearance in the intertidal zone of the Madura Strait. This study aims to assess the growth, mortality and exploitation of *K. karumba* to serve as a baseline for the formulation and implementation of future management measures and plans for the stock.

2. Materials and Methods

2.1 Materials

2.1.1 The equipment

Small hoe; Marina cooler box 18s (capacity 16ltr) Brand : Lion Star size: 37 x 25 x 34,5 cm; analytical scales 50 g ± 0.001 g; Taffware 150 mm Stainless Steel Digital Sigmat Caliper Scales, Brand; Camera Digital Pocket Kyou 44 MP.

2.1.2 The materials

The research location was in the Madura Strait intertidal zone with latitude coordinates at 7°09′34″S, 112°47′32″E (Figure 1). The sampling locations were determined based on the fishing community's habits

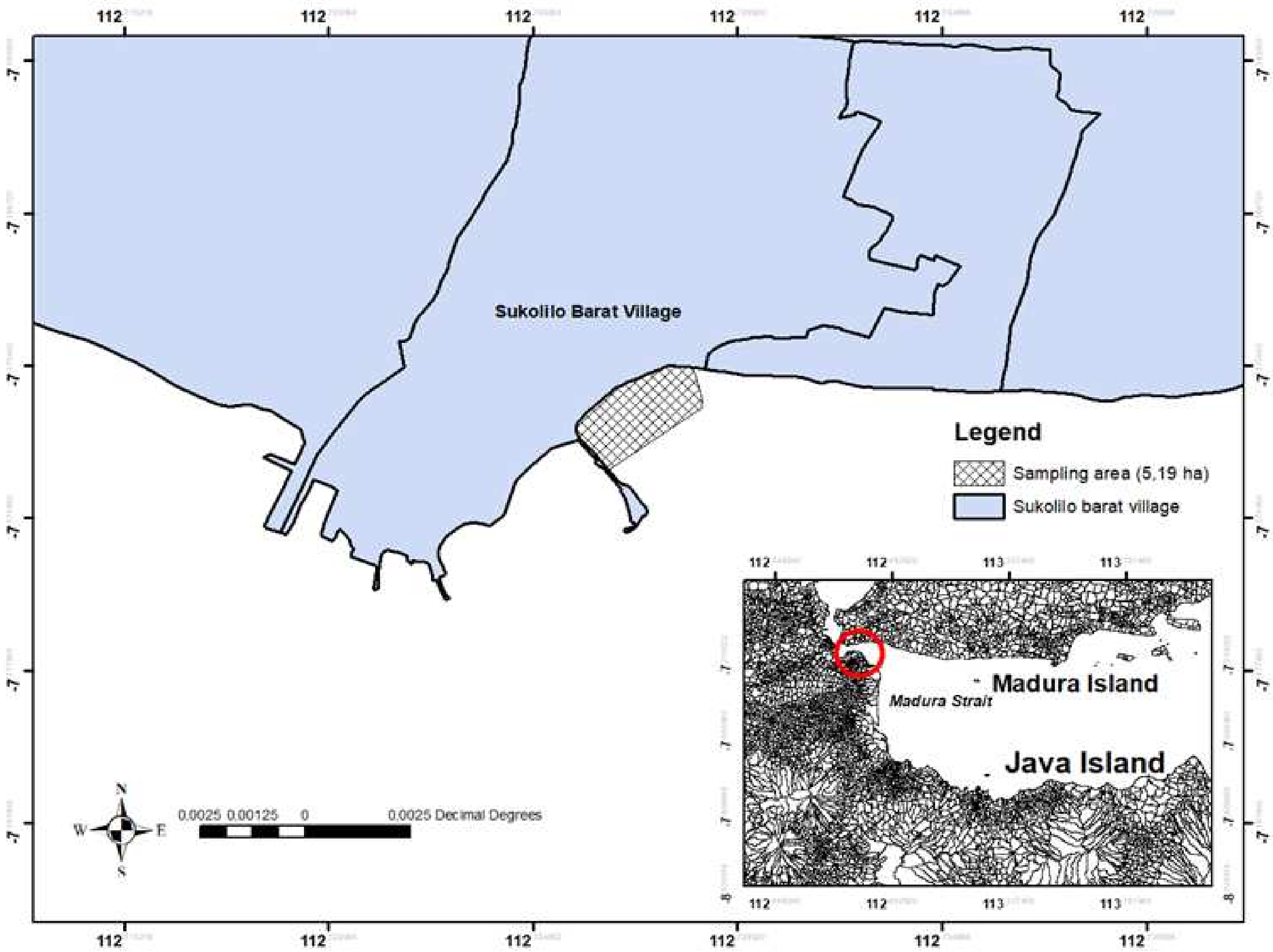


Figure 1. Research location.

in catching ghost shrimp. Sampling was conducted at low tide to assess ghost shrimp burrows, as the species inhabits muddy intertidal zones.

A total of 902 specimens were collected from July 2023 to June 2024. Ghost shrimp were collected monthly from an area of approximately 5.19 ha. Samples were collected and selected based on frequent fishing activity and known ghost shrimp presence, and the patchy spatial distribution of ghost shrimp burrows in the intertidal habitat.

Sampling was conducted at low tide by locating shrimp burrows, identified by light sediment on the surface (Figure 2a). Each burrow was excavated using a traditional digging method to a depth of approximately 10–15 cm, with each burrow typically containing a single shrimp (Figure 2), and one burrow contained a single individual.

2.1.3 Ethical approval

This study does not require ethical approval because it does not use experimental animals.

2.2 Methods

Ghost shrimp samples that have been taken are stored in a coolbox and then weighed and measured based on male and female.

2.2.1 Growth parameters

According to Effendie (1997), length-weight relationship analysis is calculated using the equation:

$W = a L^{b}$ ....(i)

Where:

W = weight (g),

L = carapace length (mm),

a = intercept,

b = constant value a and b is the constant obtained from the regression analysis of length and weight.

Growth parameters following the von Berta

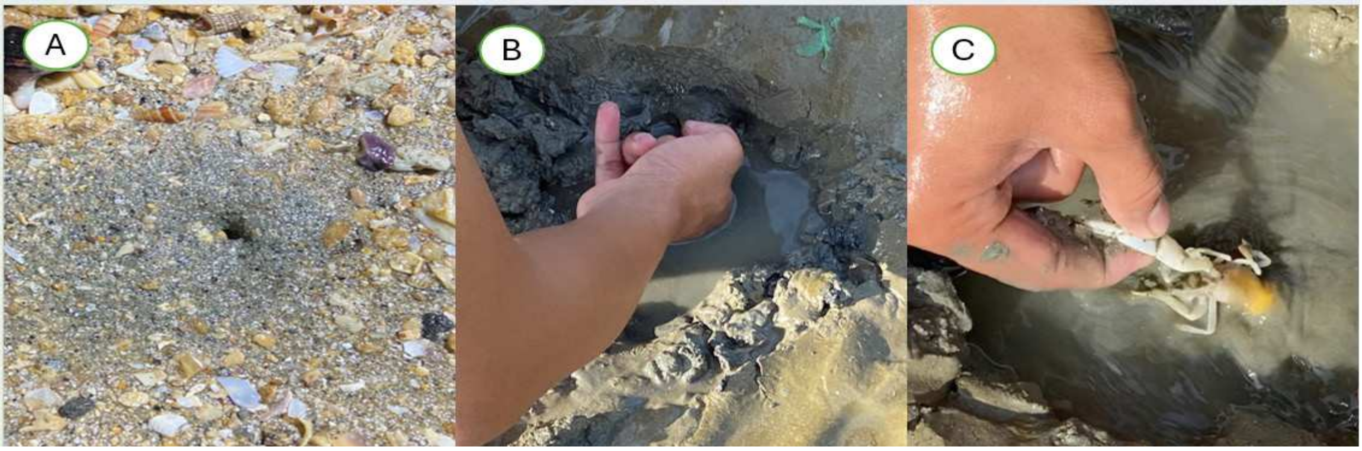


Figure 2. The process of sampling ghost shrimp in the Madura Strait intertidal zone.

lanffy Growth Function (VBGF) including growth rate (K), asymptotic length (L∞) and growth performance index (ϕ') were estimated using the option Simulated annealing (SA) with and without seasonal from Electronic Length Frequency Analysis (ELEFAN) (Taylor and Mildenberger, 2017).

Estimation of the maximum lifespan (T_{max}) of species is performed using this method:

$T_{max} = 3 / K$ (Anato, 1999)

The growth performance index was calculated using the formula:

ϕ› = 2*logL∞ + log K (Pauly and Munro, 1984)

The theoretical age at length zero (t_0) followed the equation:

Log 10 (-t0) = -0.3922 – 0.2752 log 10 L∞ - 1.038log 10 K (Pauly, 1979)

Mortality parameters:

Total mortality (Z) was computed using the Linearized length converted catch curve (Pauly and David, 1981; Spare and Venema, 1992). The natural mortality rate (M) was calculated using the procedure:

M = 4.118K0.73L∞−0.333 (Then *et al.*, 2015)

Fishing mortality (F) was calculated as:

Z – M (Qamar *et al.*, 2016)

The exploitation rate (E) was computed using the equation:

F/Z (Pauly, 1984)

2.2.2 Length at first capture (Lc_{50})

The chance of capture was determined by extrapolating backwards along the falling portion of the length-converted catch curve. A selectivity curve was created by applying linear regression to the ascending data points obtained from a plot of the probability of capture against length. This curve was then used to determine the lengths at which the probabilities of capture were 50%, 75%, and 95% (Pauly, 1987).

2.2.3 Recruitment

The recruitment pattern was estimated using the subprogram of FiSAT, with the asymptotic carapace length (CL), growth constant (K), and age at zero size (t0) being used as input parameters (Gayalino *et al.*, 2005).

2.2.4 Yield per recruit

The Thompson and Bell model was utilized to establish biological reference values, which are essential for determining input control strategies, such as reducing fishing effort. The study obtained the fishing mortality required to determine the yield and biomass trajectories by manipulating the parameter F in the Thompson and Bell model.

2.3 Analysis Data

The TropFishR package in R programming was used to assess the population parameters of *K. karumba* specimens in the intertidal zone of the Madura Strait encountered during the study period (Taylor and Mildenberger, 2017). The script used in analyzing the data is the result of the development of scripts/modules that have been used.

3. Results and Discussion

3.1 Results

3.1.1 Lenght weight relationship

The length-weight relationship (Table 1) analysis of *K. karumba* indicates that growth in length occurs more rapidly than in weight. According to Effendi (1979) a value greater or smaller than 3 fish growth is said to be allometric. The length-weight relationship (Figure 3) equation in male *K. karumba* is 0.5204 $L^{1.121}$, female W = 0.4421 $L^{1.1731}$ and pooled W = 0.4828 $L^{1.145}$. The relationship between carapace length and total weight showed that as total length increased, males weighed more than females. Regression analysis on the transformed data showed a strong and moderately strong relationship between the two sexes (male = 0.72 and female = 0.61). Pooled R^2 value of 0.66, which is predicted because the male sample has differences in the size and shape of the cheliped major, which are larger and wider than those of the female sample. In addition, the males attained a greater size, indicating a size dimorphism.

3.1.2 Length-frequency distribution

The length-frequency distribution of male *K. karumba* (Figure 4a) ranged from 5.95 to 41.95 mm in carapace length range. Females (Figure 4b) ranged from 9.95 to 37.95 mm. For the pooled data (Figure 4c), the carapace length range was 5.95 to 41.95 mm.

The smallest male (4.6 mm) and the smallest female (7.5 mm) were collected in July. The largest male (40.9 mm) and largest female (35.4 mm) were recorded in August. Shrimp were more abundant and showed a wider size range in July and August, suggesting a peak recruitment or activity period.

Based on length-frequency distribution data from 902 *K. karumba* samples, 412 were male and 490 were female. The data show that males generally reach larger sizes than females. According to Saputra *et al.* (2009), a population is considered demographically balanced when males and females occur in approximately equal

Table 1. Table of length weight relationship *K. karumba*

Parameter	Male	Female	Pooled
n	412	490	902
$W = aL^b$	0.5204 $L^{1.121}$	0.4421 $L^{1.1731}$	0.4828 $L^{1.145}$
R^2	0.7212	0.6117	0.6698
Growth pattern	Allometric (-)	Allometric (-)	Allometric (-)
Condition factor	1.02	1.02	1.02

Males and females have the same value condition factor as 1.02. The males had a b value of 1.121, the females had a b value of 1.173, and the pooled value was 1.145. The t test was conducted on males and females, and combined results showed that b ≠ 3 can be concluded to belong in the negative allometric category.

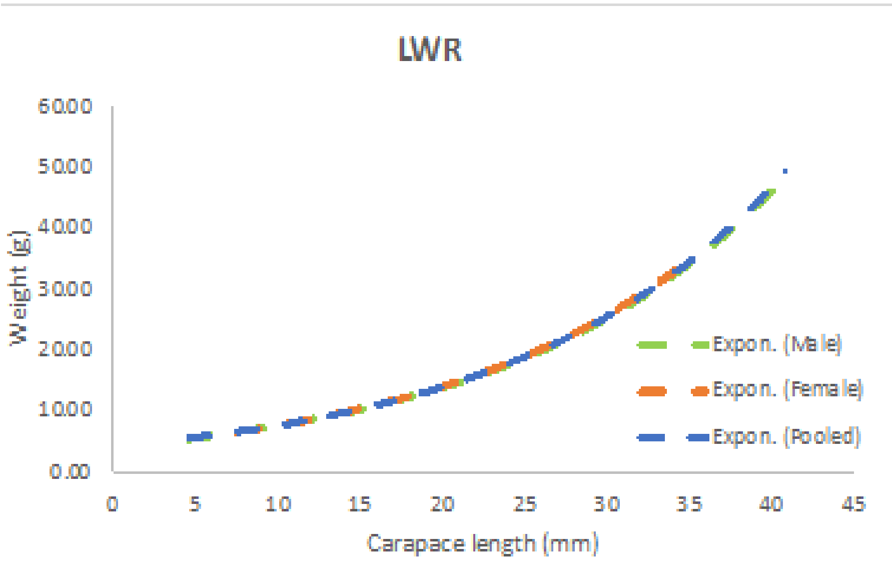


Figure 3. Relationship between carapace length (mm) and W (g) of *K. karumba* in the intertidal zone of the Madura Strait.

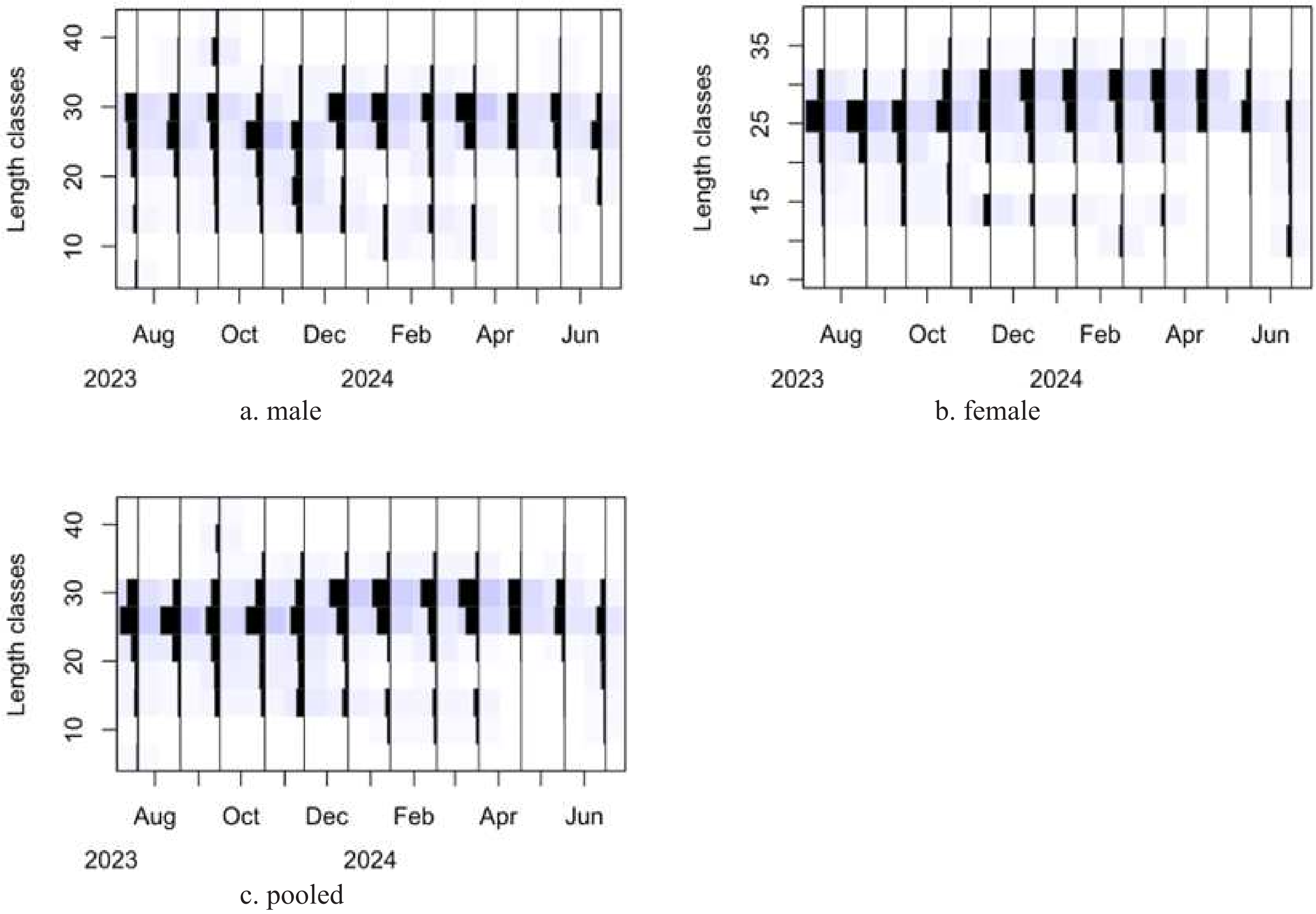


Figure 4. *Karumballichirus karumba* (Pooroe and Griffin, 1979). Monthly length-frequency distributions for males, females, and pooled specimens.

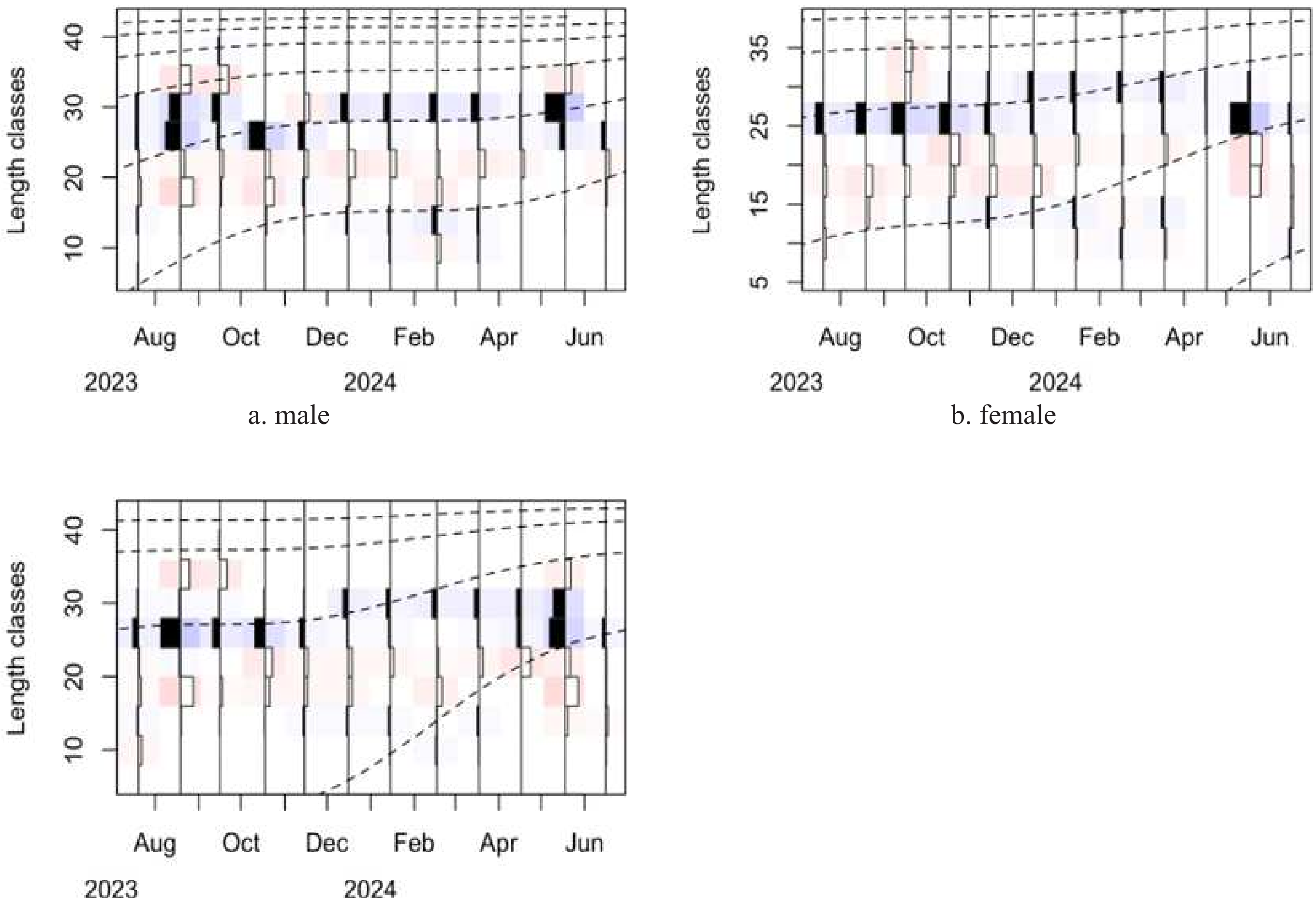
numbers or when females are more abundant, which supports population sustainability. The results of this overall frequency show that the size of shrimp that is often caught in the intertidal zone of the Madura Strait is 20-30 mm, or adult size. This may be due to smaller individuals inhabiting narrower burrows, which are less detectable or accessible using the manual sampling technique employed.

The restructured length-frequency for *K. karumba* with superimposed growth curves is shown in Figure 5. The asymptotic length (L∞) for *K. karumba* male: 44.21, female: 42.8, and pooled: 44, respectively, with a corresponding growth rate (K) of 0.58 yr^{-1}, 0.67 yr^{-1} and 0.9 yr^{-1}. The growth performance index (Φ′), respectively, for males, females, and pooled data, was 3.05, 3.08, and 3.24, while the age at zero-length (t_0) was -0.249 years, -0.215 years and -0.158 years. Furthermore, the Rn value, respectively, for males, females, and pooled data, were 0.77, 0.71, and 0.52. The longevity (T_{max}) was calculated as approximately 6, 5, and 4 years.

3.1.3 Growth parameters

The restructured length-frequency for *K. karumba* with superimposed growth curves is shown in Figure 5. The asymptotic length (L∞) for *K. karumba* male: 44.21, female: 42.8 and pooled: 44 respectively, with a corresponding growth rate (K) of 0.58 yr^{-1}, 0.67 yr^{-1} and 0.9 yr^{-1}. The growth performance index (Φ′) was 3.05, 3.08, and 3.24 while the age at zero-length (t_0) was -0.249 years, -0.215 years, and -0.158 years. Furthermore, the Rn value were 0.77, 0.71, and 0.52 for males, females, and pooled data, respectively. The longevity (T_{max}) was calculated as approximately 6, 5, and 4 years.

The growth parameters for *K. karumba* (Table 2) have never been reported before. The growth coefficient (K) of *K. karumba* is considered quite slow, between 0.5 and 0.9 per year. This growth value is similar to Mud Shrimp (e.g., *Upogebia* spp. or *Callianassa* spp.): The (K) value generally ranges from 0.3 to 1.0 per year (Kim *et al.,* 2023). The growth of male and female *K. karumba* has a similar pattern, the factors



a. male

b. female

c. pooled

Figure 5. Restructured length-frequency distribution (MA = 5) histograms with the growth curves (dashed lines) obtained through the bootstrapped ELEFAN SA with seasonal analysis for *K. karumba.* The purple shading emphasizes the peaks (black boxes), while the pink shading emphasizes the troughs (white boxes) of the restricted length frequency distribution.

that affect the growth of *K. karumba* are temperature and food supply, the water temperature in the Madura Strait has an average value of 28ºC and the results of the analysis of food habbit in the form of organic materials directly consume deposits in their burrowing habbit. Therefore, fluctuating elements like suspended particles, organic content, and chlorophyll can all be indicators of possible food since satellite remote sensing data on chlorophyll an is frequently utilized as one of the parameters for filter feeder bivalves growth modeling (Radiarta*, et al.,* 2008; Thomas, *et al.,* 2011; Newell *et al.,* 2017). Temperature and the availability of food are the two most significant external factors affecting the growth of marine crustaceans (Hartnoll, 2001). In addition, shrimp growth is influenced by latitudinal distribution. The population growth rate of mud shrimp in East Asia is positively correlated with latitude, as seen by the latitude-specific CL distribution of +1-year-old shrimp following settlement from Russia, Seonjaedo, Jugyo, Tokyo Bay, and Namhae (Kim *et al.,* 2023).

The theoretical maximum lifespan (T_{max}) is the maximum age limit that is theoretically possible for a species to reach, T_{max} of individual *K. karumba*, estimated using the VBGF, was 4 to 6 years (Figure 6). The lifespan of *Upogebia* shrimp is reported to be three to five years in other studies (Kinoshita, 2009). It is challenging to think of the estimated longevity as the average lifespan of the shrimp cohort, even while it can represent an individual's theoretical maximum lifespan. The duration between a cohort's initial identification and eventual disappearance from the samples is commonly used to define the lifespan (Baldwin and Bauer, 2003). The growth of *K. karumba* slows down with age (Figure 4 and 5), some samples were found of varying sizes and individuals that were often found all year had a carapace length of 25 mm or adult size, this is thought to be because

Table 2. Population parameters of the *Karumballichirus karumba* (Pooroe and Griffin, 1979). Von Bertalanffy growth parameter estimation by the ELEFAN analysis of length frequency data for females, males and pooled data

Parameters	Male	Female	Pooled
Lmax (mm)	40.9	37.9	40.9
$L\infty$ (mm)	44.21	42.8	44
K (/years)	0.58	0.67	0.9
t_0 (/years)	-0.24924	-0.21577	-0.15840
ϕ'	3.05	3.08	3.24
Tmax(/years)	6	5	4
Rnmax	0.77	0.71	0.52
Lt	$Lt=44.21(1-e^{-0.58(t+0.24924)})$	$Lt=42.8(1-e^{-0.67(t+0.21577)})$	$Lt=44(1-e^{-0.9(t+0.1584)})$
Z (/years)	2.27	3.69	4.12
M (/years)	0.7	0.8	1
F (/years)	1.57	2.89	3.12
E	0.69	0.78	0.75
E05	0.69	1.03	0.48
Emax	2.19	1.28	1.21
F01 (/years)	1.35	1.69	1.8
F05 (/years)	1.57	3.8	1.99
Fmax (/years)	5	4.79	5
t50 (years)	1.14	1.34	0.75
t75 (years)	1.36	1.55	0.86
t95 (years)	1.72	1.92	1.06
L50 (mm)	24.63	27.87	24.65
L75 (mm)	26.97	29.94	26.62
L95 (mm)	30.28	32.79	29.49
t_anchor	0.44	0.25	0.49
c	0.99	0.79	0.99

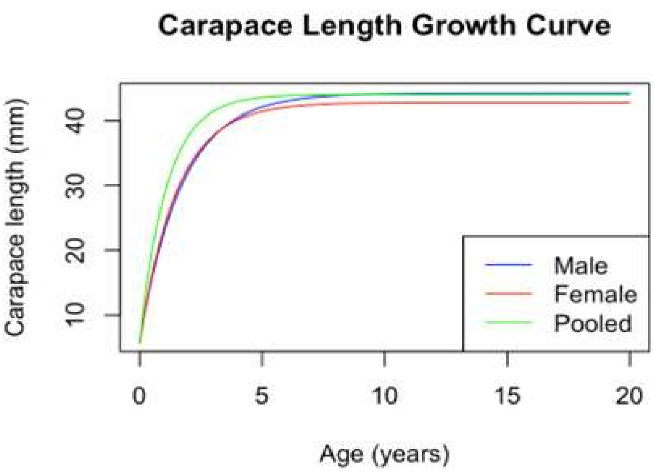


Figure 6. *K. karumba* (Pooroe and Griffin, 1979). Growth curves for male, female, and pooled data based on the length-frequency distributions during the sampling period.

the characteristics of the *K. karumba* population grow quickly to mature, spawn, and live several years with slow growth. The study results by Kinoshita *et al.*, 2003 obtained similar results related to the growth of mud shrimp *Upogebia Major*. Because there are difficulties in applying age determination based on length-frequency data in digger shrimp species, length-frequency-based models require additional data to obtain more precise results (Hartnoll, 2001). Sustainability potential attributes, growth patterns, condition factors, and growth coefficients are the main standards for assessing the suitability and existence of individuals or species (Asrial *et al.*, 2020).

3.1.4 Length at capture and mortalitty parameters

The results of the analysis with the length converted catch curve method of *K. karumba* showed the total mortality rate (Z) male = 2.27, female = 3.69, and pooled = 4.12 yr^{-1}, natural mortality (M) male = 0.7, female = 0.8, and pooled = 1 yr^{-1} and mortality due to capture (F) male = 1.57, female = 2.89 and pooled = 3.12 yr^{-1}. The exploitation rate (E) male = 0.69, female = 0.78, and pooled = 0.75 yr^{-1} (Table 2).

The size of the length at capture (L_{50}) obtained in the intertidal zone of the Madura Strait for males = 24. 63 mm, female = 27.87 mm and pooled = 24.65 mm, length at capture values are greater than half of the L∞ values obtained, which are males = 22.1 mm, females = 21.4 mm, and combined = 22 mm. The capture mortality of *K. karumba* is higher than the natural mortality, indicating that the exploitation rate is higher than that suggested by Gulland, 1971, namely, the exploitation rate is said to be optimal if natural mortality and fishing mortality are balanced E_{opt} = 0.5. The exploitation value of *K. karumba* is considered vulnerable at this time, so there is a need for management in terms of capture. Basically, *K. karumba* has a low economic value compared to other types of shrimp, but still must be preserved for ecological benefits. *K. karumba* caught in the Madura Strait is included in the large size. From this situation, it can be concluded that in terms of reproductive opportunities, *K. karumba* is secured, and in terms of its utilization, it is included in the category of sustainable fishing.

3.2 Discussion

3.2.1 Recruitment

Fish growth is an important indicator for assessing the recruitment potential and biomass recovery of fish populations (Yonvitner *et al.,* 2021). The recruitment pattern is obtained by entering the values of L∞, K, and t_0, and these parameters were entered into the TropFishR recruitment estimation function in RStudio to model monthly recruitment. The results of the percentage is obtained in January with a value above 10%. The second and third percentages are in November and April, with a percentage value above 9% and 8%, respectively. The results show that recruitment occurs almost every month. Estimated peak recruitment was concentrated in January and November. Research on the seasonal reproduction of the ghost shrimp *L. bocourti* showed that recruitment, indicated by gonadosomatic index (GSI) and ovigerous females (OF), occurred from March to August and is affected by temperature (Hernaez *et al.,* 2012).

Recruitment patterns of *K. karumba* in the Madura Strait estimated from restructured length-frequency data on a 1 year time scale. The decrease in the percentage of *K. karumba* recruitment value in May was caused by the effects of tides, which reduced the sampling area.

In addition, external factors such as the presence of parasitic infections in the living environment can inhibit or reduce the recruitment of burrowing shrimp, especially female shrimp, another assumption is due to the presence of adult shrimp, and water quality at the study site. another factor is due to the high mortality rate at the benthic juvenile stage due to predation and environmental changes where in May is a transitional season.

The assumption needs to be confirmed by conducting a multi-year study to calculate the recruitment pattern of *K. karumba*. The recruitment pattern shows that *K. karumba* spawns during the year, as seen in the catch of ovigerous females (stage IV) found every month. In *K. karumba* samples, 2 types of parasites from the genus copepoda and from the phylum cestoda were detected. Factors affecting mud shrimp recruitment, including the number of females capable of spawning, are parasitic infections. While most copepods are free-living, there are also many parasitic species (Calbet, 2024). Various factors influence the recruitment of mud shrimp, including a decrease in the number of female shrimp capable of spawning due to parasite diseases (Dumbauld *et al.,* 2011; Repetto and Griffen, 2011; Asson *et al*., 2017), the transport of surface waters (Sarah *et al.,* 2009).

3.2.2 Relative yield per recruitment (YPR)

The length at first capture is an important input in the computation of relative yield-per-recruit and relative biomass-per-recruit. F_{cur} (3.12 yr^{-1}) in the estimated population is lower than F_{max} (5 yr^{-1}) and above F_{05}: (1.99 yr^{-1}) and F_{01} (1.8 yr^{-1}). The observed YPR (7.65 g/r) was lower than the YPR at F_{max} (8.04 g/r). at-age-capture t_c curr (0.74 yr^{-1}) and first time caught size Lc curr (24.65 mm).

The data provide information that the stock condition of *K. karumba* ghost shrimp in the intertidal zone of the Madura Strait is exploited. *K. karumba* fishing activities at the location are not only carried out by fishing communities around the location but also from outside the area. Regulate fishing by reducing intensity to target F01 or F05 and increasing length capture (Lc), as well as providing information to fishing communities about the importance of sustainable fisheries, and empowering fishing communities by involving them in raising awareness about fishery resources, especially the ghost shrimp *K. karumba.* Considering that research on ghost shrimp in the Madura Strait and Indonesia is still very limited, the findings of this study can serve as a suitable benchmark for the formulation of resource management strategies for the fishing resources in this region.

4. Conclusion

K. karumba from the intertidal zone of the Madura Strait had negative allometric growth. *K. karumba* showed signs of slow growth at a rate of 0.5 to 0.9 yr^{-1}. *K. karumba* being "sustainable" despite overfishing (E = 0.75). The size of the length at capture (L_{50}) of *K. karumba* is greater than 1/2 L∞, but the current exploitation level still exceeds optimal levels (Eopt = 0.5). Recruitment occurred throughout the year, with monthly percentages ranging from 8–10%.

Acknowledgement

The authors are grateful to The Indonesian Education Scholarship, Center for Higher Education Funding and Assessment, Ministry of Higher Education, Science, and Technology of Republic Indonesia, Endowment Fund for Education Agency, Ministry of Finance of Republic Indonesia. The authors would like to thank the local fishermen and all those who have helped in supporting the preparation of this work.

Authors' Contributions

Abdul Qadir Jailani and Suradi Wijaya participated in the design of the experiments in this research, software and modification of the article to obtain essential knowledge content. Suryanti, the experimental platform and the equipment required for the experiment. Aninditia Sabdaningsih analyzed and interpreted the final data. The final article was approved by Suradi Wijaya Saputra.

Conflict of Interest

The authors declare that they have no competing interests.

Declaration of Artificial Intelligence (AI)

The author(s) acknowledge the use of ChatGPT for find a script Rstudio programs in preparing this manuscript. All AI-generated content was rigorously reviewed, edited, and validated to ensure accuracy and originality. Full responsibility for the manuscript's final content rests with the author(s). To ensure transparency and support the review process, a comprehensive delineation of the tool's application is furnished in the "Introduction" or "Materials and Methods" section of this manuscript in compliance with the publisher's ethical guidelines.

Funding Information

The Indonesian Education Scholarship, Center for Higher Education Funding and Assessment, Ministry of Higher Education, Science, and Technology of Republic Indonesia, Endowment Fund for Education Agency, Ministry of Finance of Republic Indonesia.

References

Anato, C. B. (1999). Les Sparidae des côtes béninoises: Milieu de vie, pêche, présentation des espèces et biologie de Dentex angolensis Poll et Maul, 1953. Thèse de Doctorat d'Etat es Sciences. Tunisie: Faculté des Sciences de Tunis.

Asrial, E., Rosadi, E., Hamid, Ichsan, M., Khasanah, R. I., Sulystyaningsih, N. D., Sumiwi, A. D., & Khalisah, N. (2020). Growth and population parameters of *Panulirus penicillatus* and *Panulirus homarusin* Labangka Tidal Waters, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 12(2):214-223.

Asson, D., Chapman, J., & Dumbauld, B. (2017). No evidence that the introduced parasite *Orthione griffenis* Markham, 2004 causes sex change or differential mortality in the native mud shrimp, *Upogebia pugettensis* (Dana, 1852). *Aquatic Invasions*, 12(2):213-224.

Baldwin, A. P., & Bauer, R. T. (2002). Growth, survivorship, life-span, and sex change in the hermaphroditic shrimp *Lysmata wurdemanni* (Decapoda: Caridea: Hippolytidae). *Marine Biology,* 143(1):157-166.

Calbet, A. (2024). The wonders of marine plankton. Springer Cham. ISBN 978-3-031-50765-6. ISBN 978-3-031-50766-3 (eBook).

Carlton, J. T., Geller, J. B., Reaka-Kudla, M. L., & Norse, E. A. (1999). Historical extinctions in the sea. *Annual Review of Ecology and Systematics,* 30(1):515-538.

Clovis, H. I. A., & Simon, A. M. (2024). Understanding overfishing: A literature review. *Asian Journal of Fisheries and Aquatic Research,* 26(1):61-71.

Crona, B. I., Wassenius, E., Jonell, M., Koehn, J. Z., Short, R., Tigchelaar, M., Daw, T. M., Golden, C. D., Gephart, J. A., Allison, E. H., Bush, S. R., Cao, L., Cheung, W. W. L, DeClerck, F., Fanzo, J., Gelcich, S., Kishore, A., Halpern,

B. S., Hicks, C. C., Leape, J. P., Little, D. C., Micheli, F., Naylor, R. L., Phillips, M., Selig, E. R., Springmann, M., Sumaila, U. R., Troell, M., Thilsted, S. H., & Wabnitz, C. C. C. (2023). Four ways blue foods can help achieve food system ambitions across nations. *Nature,* 616(1):104-112.

Delgado, L. C., Wada, N., Rosegrant, W. M., Meijer, S. & Ahmed, M. (2003). Fish to 2020: Supply and demand in changing global markets. Washington, DC: International Food Policy Research Institute and Penang, Malaysia: WorldFish Center.

Duarte, C. M., Agustí, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J. P., Fulweiler, R. W., Hughes, T. P., Knowlton, N., Lovelock, C. E., Lotze, H. K., Predragovic, M., Poloczanska, E., Roberts, C., & Worm, B. (2020). Rebuilding marine life. *Nature,* 580(1):39-51.

Dumbauld, B. R., Chapman, J. W., & Torchin, M. E. (2011). Is the collapse of mud shrimp (*Upogebia pugettensis*) populations along the Pacific Coast of North America caused by outbreaks of a previously unknown bopyrid isopod parasite (*Orthione griffenis*)? *Estuaries and Coasts,* 34(1):336-350.

Dworschak, P. C. (2008). *Neocallichirus kempi* Sakai, 1999, a junior synonym of *Callianassa karumba* Poore & Griffin, 1979 (Decapoda: Callianassidae). *The Raffles Bulletin of Zoology,* 56(1):75-84.

East Java Province Marine and Fisheries Service. (2010). East Java capture fisheries statistics.

East Java Province Marine and Fisheries Service. (2016). East Java capture fisheries statistics.

Effendie, I. M. (1979). Fisheries biology. Bogor: Faculty of Fisheries, Bogor Agricultural University.

Effendie, I. M. (1997). Fisheries biology. Jakarta: Yayasan Pustaka Nusatama.

FAO. (2018). The state of world fisheries and aquaculture 2018 – Meeting the sustainable development goals. Rome: FAO.

FAO. (2020). The state of world fisheries and aquaculture 2020. Sustainability in action. Rome: FAO.

FAO. (2022). The state of world fisheries and aquaculture 2022. Towards blue transformation. Rome: FAO.

Gayanilo, F. C. Jr., P. Sparre & D. Pauly. (2005). FAO-ICLARM stock assessment tools II (FiSAT II). Revised version. User's guide. FAO Computerized Information Series (Fisheries). No. 8, Revised version. Rome: FAO.

Golden, C. D., Koehn, J. Z., Shepon, A., Passarelli, S., Free, C. M., Viana, D. F., Matthey, H., Eurich, J. G., Gephart, J. A.,Chouinard, E. F., Nyboer, E. A., Lynch, A. J., Kjellevold, M., Bromage, S., Charlebois, P., Barange, M., Vannuccini, L. C., Kleisner, K. M., Rimm, E. B., Danaei, G., DeSisto, C., Kelahan, H., Fiorella, K. J., Little, D. C., Allison, E. H., Fanzo, J., & Thilsted, S. H. (2021). Aquatic foods to nourish nations. *Nature,* 598(1):315-320.

Gulland, J. A. (1971). The fish resources of the ocean. West Byfleet, Surrey, England: Fishing News (Books) Ltd.

Hartnoll, R. G. (2001). Growth in crustacea – twenty years on. *Hydrobiologia,* 449(1):111-122.

Hasselberg, A. E., Aakre, I., Scholtens, J., Overå, R., Kolding, J., Bank, M. S., Atter, A. & Kjellevold, M. (2020). Fish for food and nutrition security in Ghana: Challenges and opportunities. *Global Food Security*, 26(3):1-10.

Hernáez, H., Jiménez, E. V., Rojas, F. V., & Wehrtmann, I. S. (2012) Reproductive biology of the ghost shrimp *Lepidophthalmus bocourti* (A. Milne-Edwards, 1870) (Decapoda: Axiidea: Callianassidae): A tropical species with a seasonal reproduction, *Marine Biology Research,* 8(7):635-643.

Hidayah, Z., Nuzula, N. I., & Wiyanto, D. B. (2020). Analysis of the sustainability of fisheries resource management in the waters of the Madura Strait, East Java. *Jurnal Perikanan*, 22(2):101-111.

Kim, S. T., Cheol, Y., Chae-Lin, L., Sukhyun N., & Jae-Sang, H. (2023). Population characteristics of the mud shrimp *Upogebia major* (De Haan, 1841) (Decapoda: Gebiidea: *Upogebiidae*) on Korean Tidal Flats in the Eastern Yellow Sea. *Journal of Marine Science and Engineering,* 11(12):1-26.

Kinoshita, K. (2009). Burrow structure and life-history characteristics of the mud shrimp, *Upogebia major* (Decapoda: Thallasinidea: Upogebiidea). *Journal of Crustacean Biology*, 22:474-480. Nagasaki University: Nagasaki, Japan,; Volume 24, pp. 7–13.

Kinoshita, K., Nakayama, S., & Furota, T. (2003). Life cycle characteristics of the deep-burrowing mud shrimp *Upogebia major* (Thalassinidea: *Upoge-*

biidae) on a tidal flat along the Northern Coast of Tokyo Bay. *Journal of Crustacean. Biology,* 23(2):318-327.

Kennelly, S. J., & Broadhurst, M. K. (2021). A review of bycatch reduction in demersal fish trawls. *Reviews Fish Biology and Fisheries* 31(1):289-18.

Kristiani, Herawati E. Y, & Yahuhar U. (2016). The analysis of hepatopancreas histologycal damage in *Neocallichirus karumba* (Poore and Griffin) shrimp caused by heavy metal Pb exposure in Madura Strait. *The Journal of Experimental Life Science,* 6(1):1-6.

Melnychuk, M. C., Kurota, H., Mace, P. M., Pons, M., Minto, C., Osio, G. C., Jensen, O. P., de Moor, C. L., Parma, A. M., Little, L. R., Hively, D. Ashbrook, C. E., Baker, N., Amoroso, R. O., Branch, T. A., Anderson, C. M., Szuwalski, C. S., Baum, J. K., McClanahan, T. R., Ye, Y., Ligas, A., Bensbai, J., Thompson, G. G., Devore, J., Magnusson, A., Bogstad, B., Wort, E., Rice, J., & Hilborn, R. (2021). Identifying management actions that promote sustainable fisheries. *Nature Sustainability,* 4(1):440-449.

Mora-Lara, C. O. (1973). Biology and fishery of the 'titi' shrimp *Xiphopenaeus riveti* on the Pacific Coast of Colombia, South America (Doctoral dissertation) Memorial University of Newfoundland.

Newell, C. R., Hawkins, A. J. S., Morris, K., Boss, E., Thomas, A. C., Kiffney, T. J., & Brady, D. C. (2021). Using high-resolution remote sensing to characterize suspended particulate organic matter as bivalve food for aquaculture site selection. *Journal of Shellfish Research,* 40(1):113-118.

Pauly, D. (1979). Theory and management of tropical multi-species stocks. A review, with emphasis on the Southeast Asian demersal fisheries. Manila, Philippines: ICLARM, International Center for Living Aquatic Resources Management.

Pauly, D. (1984). Some simple methods for the assessment of tropical fish stock, Rome: FAO.

Pauly, D. (1987). A review of the ELEFAN system for analysis of length-frequency data in fish and aquatic invertebrates. In D. Pauly, and G. R. Morgan (Eds.), Length-based methods in fisheries research. (pp. 7-34). Manila, Philippines: ICLARM Conference Proceedings 13, International Center for Living Aquatic Resources Management.

Pauly, D., & David, W. (1981). ELEFAN 1, Basic program for the objective extraction of growth parameters from length- frequency data. *Report on Marine Science*, 28(4):205-211.

Pauly, D., & Munro, J. L. (1984). Once more on the comparison of growth in fish and invertebrates. *ICLARM Fishbyte*, 2(1):1-21.

Poore, G. C. B., Dworschak, P. C., Robles, R., Mantelatto, F., & Felder, D. L. (2019). A new classification of Callianassidae and related families (Crustacea: Decapoda: Axiidea) derived from a molecular phylogeny with morphological support. *Memoirs of Museum Victoria,* 78(1):73-146.

Poore, G. C. B. & Griffin, D. J. G. (1979). The thalassinidea (Crustacea: Decapoda) of Australia. *Records of the Australian Museum*, 32(6):217-321.

Qamar, N., Panhwar, S. K., & Brower, S. (2016). Population characteristics and biological reference point estimates for two carangid fishes *Megalaspiscordyla* and *Scomberoides tol* in the northern Arabian Sea, coast of Pakistan. *Pakistan Journal of Zoology*, 48(3):869-874.

Radiarta, I. N., Saitoh, S. I., & Miyazono, A. (2008). GIS-based multi-criteria evaluation models for identifying suitable sites for japanese scallop (*Mizuhopecten yessoensis*) aquaculture in Funka Bay, Southwestern Hokkaido, Japan. *Aquaculture*, 284(1):127-135.

Ragheb, E. (2024). A view on climate change and its impact on the Mediterranean fisheries. *Blue Economy*, 2(1):53-64.

Repetto, M., & Griffen, B. D. (2011). Physiological consequences of parasite infection in the burrowing mud shrimp, *Upogebia pugettensis*, a widespread ecosystem engineer. *Marine and Freshwater. Research*, 63(1):60-67.

Raso, J. E. G., & Manjón-Cabeza, M. E. (2002). A new record of *Galathea capillata* for Europe and Spain, and notes on *Philocheras bispinosus* (Decapoda). *Crustaceana*, 75(3):383-393.

Roberts, C. M., Hawkins, J. P., Van'T Hof, T., De Meyer, K., Tratalos, J. & Aldam, C. (1999) Effects of recreational scuba diving on Caribbean coral and fish communities. *Conservation Biology*, 13(4):888-897.

Robles, R., Dworschak, P. C., Felder, D. L., Poore, G. C. B., & Mantelatto, F. L. (2020). A molecular phylogeny of Callianassidae and related families (Crustacea : Decapoda : Axiidea) with morphological support, *Invertebrate*

Systematics, 34(2):113-132.

Sakai, K. (1999). Synopsis of the family Callianassidae, with keys to subfamilies, genera and species, and the description of new taxa (Crustacea: Decapoda: Thalassinidea). *Zoologische Verhandelingen*, 326(1):1-152.

Saputra, S. W., Soedarsono, P., & Sulistyawati, G. A. (2009). Biological aspects of goatfish (*Upeneus* spp.) on Demak Waters. *Jurnal Saintek Perikanan.* 5(1):1-6.

Sarah, E. D., Brian, A. Grantham., Anthony, R. K., Bruce, A. M., Jane, L., & John, A. B. (2009). Current reversals as determinants of intertidal recruitment on the central Oregon Coast. *ICES Journal of Marine Science*, 66(2):396-407.

Silva, O. L. L., Macedo, A. R. G., Nunes, E. S. C. L., Campos, K. D., Araujo, L. C. C., Tiburco, X., Pinto, A. S. O., Joele, M. R. S. P., Ferreira, M. S., Silva, A. C. R., Raices, R. S. L., Cruz, A. G., Juen, L., & Rocha, R. M. (2020). Effect of environmental factors on the fatty acid profiles and physicochemical composition of oysters (*Crassostrea gasar*) in Amazon estuarine farming. *Aquaculture Research*. 51(1):2336-2348.

Sparre, P. & Venema, S. C. (1992). Introduction to tropical fish stock assessment. Part 1. Manual, FAO Fisheries Technical Paper, 306. No. 1, Review 1, Rome: FAO.

Taylor, M., & Mildenberger, T. K. (2017). Extending electronic length frequency analysis. *Fisheries Management and Ecology*, 24(4):330-338.

Then, A. Y., Hoenig, J. M., Hall, N. G., & Hewitt, D. A. (2015). Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. *ICES Journal of Marine Science*, 72(1):82-92.

Thomas, Y., Mazurié, J., Alunno-Bruscia, M., Bacher, C., Bouget, J. F., Gohin, F., Pouvreau, S., & Struski, C. (2011). Modelling spatio-temporal variability of *Mytilus edulis* (L.) growth by forcing a dynamic energy budget model with satellite-derived environmental data. *Journal of Sea Research*, 66(4):308-317.

Willems, T., De Backer, A., Kerkhove, T., Dakriet, N. N., De Troch, M., Vincx, M., & Hostens, K. (2016). Trophic ecology of Atlantic seabob shrimp *Xiphopenaeus kroyeri*: Intertidal benthic microalgae support the subtidal food web off Suriname. *Estuarine, Coastal and Shelf Science*, 182(15):146-157.

Yonvitner, Boer, M., & Kurnia. R. (2021). Spawning potential ratio (SPR) approach as a management measure of skipjack sustainability record from Cilacap fishing port, Central Java, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 13(2):199-207.