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Abstract. The purpose of this research was to determine several population dynamics parameters of a mantis shrimp (*Gonodactylus chiragra*) population including growth, mortality, exploitation rate, and relative yield per recruit. Mantis shrimp were sampled from the waters around Batukalasi, South Sulawesi Indonesia from 16th June to 21st July 2019. Each specimen was measured, weighed and the sex determined. Growth parameters were estimated using the Von Bertalanffy equation. Natural mortality (M) was estimated using Pauly's empirical equation. Total mortality (Z) was estimated using the Beverton and Holt equations. Fishing mortality was calculated from the equation Z = F + M. The exploitation level and relative yield per recruit were estimated using the Beverton and Holt equations. These analyses were conducted in the FAO-ICLARM Fish Stock Assessment Tools II (FISAT II) program. The 707 mantis shrimp samples were collected comprised of 245 females and 462 males. The growth rate coefficient was higher in male than female mantis shrimps, while male mantis shrimps reached their asymptotic length faster than females. For both male and female mantis shrimps, the estimated natural mortality was higher than fishing mortality, indicating the stock is not over-exploited. The relative yield per recruit was below the optimum value for both female and male mantis shrimp (0.035 and 0.046, respectively).

1. Introduction

Mantis shrimps belong to the order of Stomatopod, are benthic marine predator crustaceans live in defendable burrows [1]. Based on the morphology and function of their raptorial appendages, the mantis shrimps *Gonodactylus chiragra* is included in the smasher group. As smasher mantis shrimps, they live in a limited number of pre-existing cavities made of a hard substrate[2]. They kill and forage on hard-shelled prey and have complex communication and agonistic behaviors [3]. The *G. chiragra* is widely distributed in the Indo-Pacific region from French Polynesia to Japan, Australia, and the Indo-Malayan region, including Indonesia [4].

The existence of this mantis shrimp, *G. chiragra*, is still underappreciated and less studied in Indonesia. Several studies related to the population dynamic of mantis shrimp have been done in several countries such as *Squilla mantis* in Amsterdam in the Netherland [5]; *Harpiosquilla harpax* in Peninsular Malaysia [6]; *Harpiosquilla raphidea* in Kuala Tungkal Jambi, Indonesia [7]; *Harpiosquilla harpax and oratosquillina sp*. in the waters of Madura Island, Indonesia [8]. However, information about the mantis shrimps (*G. ciragra*) is still negligible, including their population dynamic. Therefore, the present study

was undertaken on several parameters of population dynamics (growth, mortality, exploitation rate, and relative yield per recruit) to determine the stock status of *G. ciragra* in intertidal waters around Mallusetasi District, Barru Regency, South Sulawesi, Indonesia.

2. Material and Methods

Sampling was conducted at the Batukalasi waters around Pulau Batukalasi mangrove ecosystems, Mallusetasi District, Barru Regency during July 2019. Specimens of Mantis shrimps (*Gonodactylus ciragra*) were collected during low tide using scoop net (2mm in mesh size and 30cm in diameter) from three different sampling sites, namely 1st site: 4°06'40"S, 119°36'23"E; 2nd site: 4°06'44"S, 119°36'19"E and 3rd site: 4°06'41"S ;119°36'13"E (Figure 1).

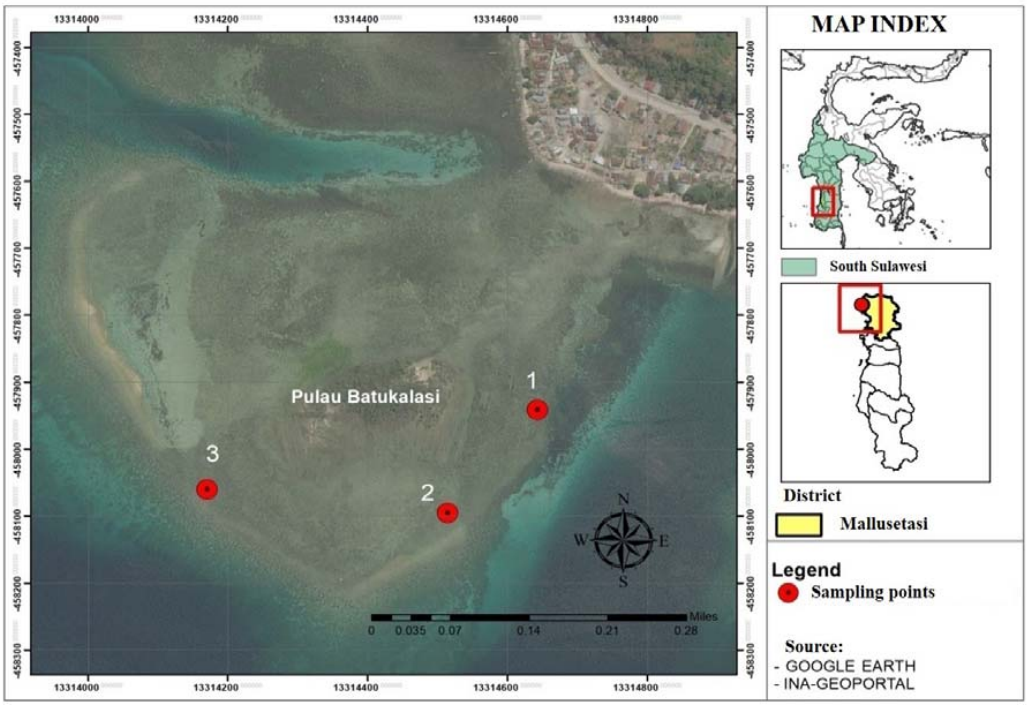

Figure 1. Sampling sites within the study area

The total lengths of each specimen were measured from the tip of the rostrum to the end telson following [9]. The length measurements were done using Vernier digital caliper to the nearest 0.1 mm. The sex determination of the specimens referred to [1,10,11].

2.1. Data Analisis

Growth parameters (the growth coefficient K and the asymptotic length L∞) were determined using ELEFAN (Electronic Length- Frequency Analysis) I in FISAT program (FAO – ICLARM Fish Stock Assessment Tools) II [12]. This is based on von Bertalanffy's growth model (Sparre and Venema 1999): $Lt= L_\infty [1\text{-}e^{-K(t-t_0)}]$, where Lt is the total length of mantis shrimp at the t age (mm), L∞ is the asymptotic length of mantis shrimp (mm), K is the growth rate coefficient (mm month^{-1}), and t_0 is the theoretical age when the length of mantis shrimp is equal to zero, t is the age of mantis shrimp (month). The t_0 was estimated using the empiric Pauly's equation [13]: $\log(-t_0) = -0.3922\ 0 - 0.2752 (\log L_\infty) + 1.038 (\log K)$.

Furthermore, mantis shrimp mortality rates and exploitation levels were analyzed using the length-converted catch curve in the FiSAT II package [12,14,15]. First, the total mortality rate (Z) was estimated

from the estimated K using von Bertalanffy's growth equation. Then, the natural mortality rate (M) was estimated from the relationship between M and L∞, the K and annual mean sea surface temperature T (°C), in compliance with Pauly's empirical equation [13]: Log M = -0.0066 – 0.279 Log L_∞ + 0.6543 Log K - 0.4634 Log T. The mean SST (29°C) in Batukalasi waters taken from the Indonesian Meteorology Climatology and Geophysics Council.

Fishing mortality (F) was calculated by the deduction of natural mortality (M) from the total mortality (Z): F = Z - M. Exploitation level (E) was determined based on [14] as the ratio of the fishing mortality (F) to the total mortality (Z): $E = \frac{F}{Z}$. Finally, relative yield-per-recruit (*Y*/R') was estimated following the Baverton and Holt equation [15] as the following:

$$Y/R' = E.U^{\frac{M}{K}}\left(1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m}\right) \rightarrow U = 1 - \frac{L'}{L\infty};\ m = \frac{1-E}{M/K}$$

, where L' is the mean length of mantis shrimp in the collected sample.

3. Results

3.1. Mantis shrimp growth

Overall, there were 707 individuals of mantis shrimp samples collected during the study which consisted of 245 female and 462 male mantis shrimp. Based on the estimation of the mantis shrimp (*Gonodactylus chiragra*) growth, Table 2 showed that the size of female mantis shrimps was bigger than that of the male mantis shrimps.

Figure 2 showed that the *G. ciragra* females reach their asymptotic length (L∞) longer than the males, where the females having a smaller growth coefficient (K = 0.46) than the males (K = 0.51) (Table 2). This is making the females reaching their L∞ slower than the males.

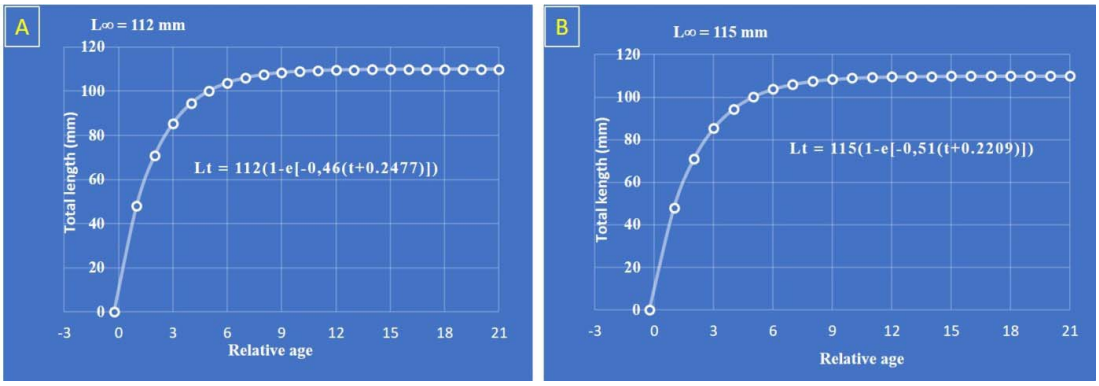

Figure 2. Relationship between the age and total length of female *Gonodactylus chiragra* **(A)** and male *G. chiragra* **(B)** in the waters of Batukalasi, Mallusetasi District, Barru Regency, South Sulawesi, based on the von Bertalanffy's growth equation.

3.2. Mortality rate and exploitation level

The values for total mortality (Z), fishing mortality (F), and natural mortality (M) of mantis shrimps *Gonodactylus chiragra* are shown in Table 1.

Table 1. Mortality rates and exploitation level of mantis shrimps (*Gonodactylus chiragra*) in Batukalasi Waters, Mallusetasi District, Barru Regency, South Sulawesi

Parameter	Estimated rates (per month)	
	Female Mantis Shrimp	Male Mantis Shrimp
Total Mortality Rates (Z)	1.28	1.55
Natural Mortality Rates (M)	0.76	0.80
Fishing Mortality Rates (F)	0.52	0.75
Exsploitation (E)	0.41	0.48

Natural mortality rates (M) of either female or male of *G. ciragra* were higher than the fishing mortality rates. Moreover, the exploitation level (E) of each female and male mantis *G. ciragra*, was comparable i.e 0.41 and 0.48, respectively. These were 18% less for female and 4% less for the male to reach the theoretical optimum level.

3.3. Yield per Recruitment Relative

Figure 3 shows that the estimated Y/R' value of female *G. chiragra* was 0.035 per year with an optimum value of 0.046 per year. Meanwhile, the estimated Y/R' of male *G. chiragra* was 0.051 per year with the optimum value was 0.042 per year. This is considered as the caught with actual exploitation rate as 0.41 for females and 0.48 for males, and the optimum exploitation rate for females and males was 0.80 and 0.85, respectively.

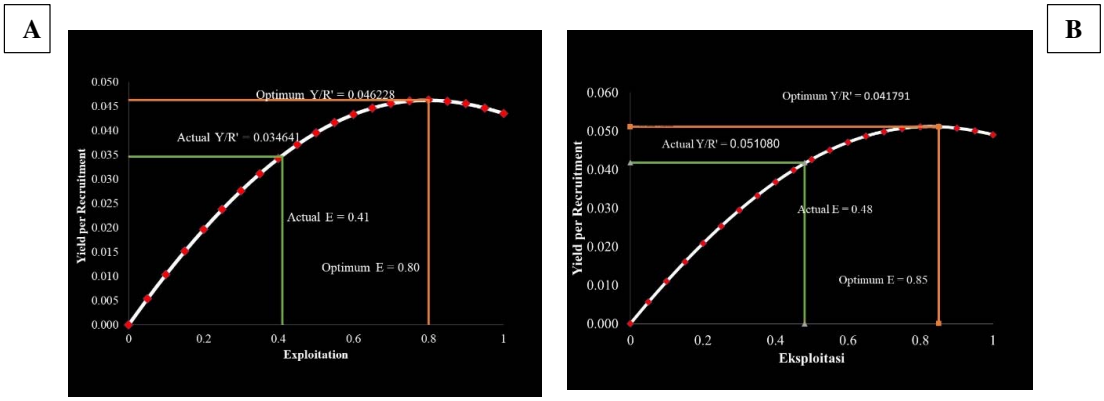

Figure 3. Relationship between *Yield* per *recruitment* (Y/R') with exploitation rate (E) of mantis shrimps (*Gonodactylus chiragra* Fabricius, 1781); female (A) and male (B) in Batukalasi waters, Mallusetasi District, Barru Regency, South Sulawesi.

4. Discussions

Females of *G. ciragra* slower to reach the asymptotic length (L∞) compare to the male might be due to the female G. ciragra more prioritize to their gonadal development than their growth. It is supported by [16] that when the mantis shrimps are approaching adulthood, their growth can be affected by the gonads development and the available food among the mantis shrimp population and other biotas.

The higher mortality rate of *G. ciragra* (female and male) than the fishing mortality rate (Table 3) indicating that their mortality was probably caused by several natural factors such as predation, including cannibalism, disease, stress during the spawning period, hunger, and old age. According to [17] that if the optimum exploitation rate (E) of fishery resources is equal to 0.5, it means that the natural mortality rate must be the same as the fishing mortality. Therefore, if the E value higher than 0.5 suggests overexploitation

of particular fishery resources. The E value of female (0.41) and male (0.48) of *G. ciragra* lower than 0.5 indicates that the mantis shrimps *G. ciragra* in Batukalasi waters was still under-exploited. Based on the yield per recruitment showed in Figure 3, the actual exploitation was lower than the optimum exploitation level. This strengthens the indication that the mantis shrimps *G. ciragra* have not experienced overexploitation yet.

Although lower than the optimum exploitation level, the E value of mantis shrimp *G. ciragra* almost reaches the optimum value. This might be because the mantis shrimp *G. ciragra* in Batukalasi waters was only as bycatch and they are discarded. They were not utilized as commercial fisheries catch. The discarded bycatch of the *G. ciragra* could contribute to the fisheries problem as [18] explained that the bycatch wasted in fisheries is a serious problem on a local to a global scale. However, due to limited data, this suggestion still needs to be strengthened by a more detailed study with more adequate data

5. Conclusion

This study found that mantis shrimp *Gonodactylus ciragra* in Batukalasi waters, in Barru Regency, South Sulawesi, Indonesia are underexploited and their mortality mostly caused by natural factors instead of fishing.

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