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Fishing Dynamic and Stock Status of Endeavour Shrimp (*Metapenaeus ensis* de Haan) in Bombana Waters, South-East Celebes

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Abstract: The high market demand for endeavour shrimp (*Metapenaeus ensis* de Haan) has caused intensive fishing for this resource and tends to threaten their sustainability. Assessment of fishing dynamic and stock status of fisheries resource is the main point to formulate its proper sustainable management in the future. The purpose of this study was to determine the stock status of endeavour shrimp in the Bombana and its surrounding waters. The study was conducted from April to November 2021 using a survey method to analyze the length at first capture (L_c), length at first maturity (L_m), growth rate (K), maximum theoretical carapace length (Loo), and mortality rate such as total mortality rate (Z), fishing mortality rate (F) and natural mortality rate (M). The study results revealed that the endeavour shrimp growth pattern in Bombana was negative allometric and that the ratio of males and females was not balanced. The length at first capture (L_c) was 29.83 mm (carapace length) and the length at first maturity (L_m) was at a total carapace length of 31.67 mm. The growth rate (K) was 1.0 per year and maximum theoretical length (L_∞) was 46.2 mm. The estimate total mortality rate (Z) was 2.52 per year, the fishing mortality rate (F) and natural mortality rate (M) were 0.91 per year and 1.61 per year respectively. The exploitation rate (E) was 0.36 per year, therefore the stock status is not categorized overfishing. In order to ensure the sustainability of the endeavour shrimp, then the effort must be increased by about 28% of the current effort.

Key words: Endeavour shrimp, fishing gear, population dynamic, stock status, Bombana waters, FMA (Fisheries Management Area) 714.

1. Introduction

Endeavour shrimp (*Metapenaeus ensis* de Haan) is one of high economic value of important fisheries commodity in Bombana Waters South East Celebes [1]. This species is Penaeidae family member ordo Decapoda [2]. This shrimp is characterized by straight above rostrum with formula 9/0, brownish until bright pink in color, bright red antenna, striped pink until red leg, and red uropod. The shrimp can reach about 16 cm (female) and 13 cm (male) in length [2], and spread out in both tropical and subtropical waters such as Indo-West Pasific in Indo-Malaysian sub-region, tropical Australia, Sino-Japanese, and Oceania [2]. In Indonesia, the shrimps spread out almost in all coastal waters except in several waters such as Riau, Lampung, Jakarta, Bali, Nusa Tenggara dan north of Sulawesi [3].

Exploitation of endeavour shrimp in Bombana waters has been intensively done due to the increase of market demand year by year which threatened its sustainability and caused depletion of the endeavor shrimp resource in the long term. Latest research data of the endeavour shrimp in Bombana waters including its stock status are needed for management purposes

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in order to maintain stock sustainability in future. Up to now there is no enough peace of research about the endeavor shrimp in Bombana waters. Therefore, this paper will discuss fishing and population dynamics of the endeavor shrimp in Bombana and adjacent waters so that sustainable management of the resource can be properly analyzed.

2. Research Material and Method

This research was done in Bombana waters, South East Sulawesi (Fig. 1) from April 2020 until November 2021 by applying survey method using several enumerators in fishing base around Bombana waters to collect fishing activity data and measure shrimp samples.

Biological aspects to be measured were carapace length, and gonad weight and maturity. Sex identification was inspected through reproduction organoleptic assessment called *petasma* located between couples of first swim leg (male) and *thelycum* located between couples of fifth walking leg (female) [4]. Gonad maturity was assessed based on morphological maturity criteria index namely (1) quiescent/undeveloped, (2) developed, (3) early mature, (4) ripe, and (5) spent [5].

Length weight relationship followed equation $W = aL^b$ [6] where W = weight (g), L = carapace length (mm), a = constant, and b = exponent growth value. Length of first capture (L_c) was obtained through logistic value approach [7]:

$$S_{CL} = \frac{1}{1 + \exp(a - b * CL)}$$

where: S_{CL} = gear selectivity; a and b = constants; CL = carapace length; and value of L_c is obtained from a/b.

The sex ratio was calculated by comparing the number of male and female and analyzed to know whether the sex ratio is balanced or not by using the Chi-square test [8]. Length at first maturity (L_m) was calculated by plotting carapace length and P_{Lm} logistic function [9] as follow:

$$P_{CLm} = \frac{1}{1 + \exp(aCl + b)}$$

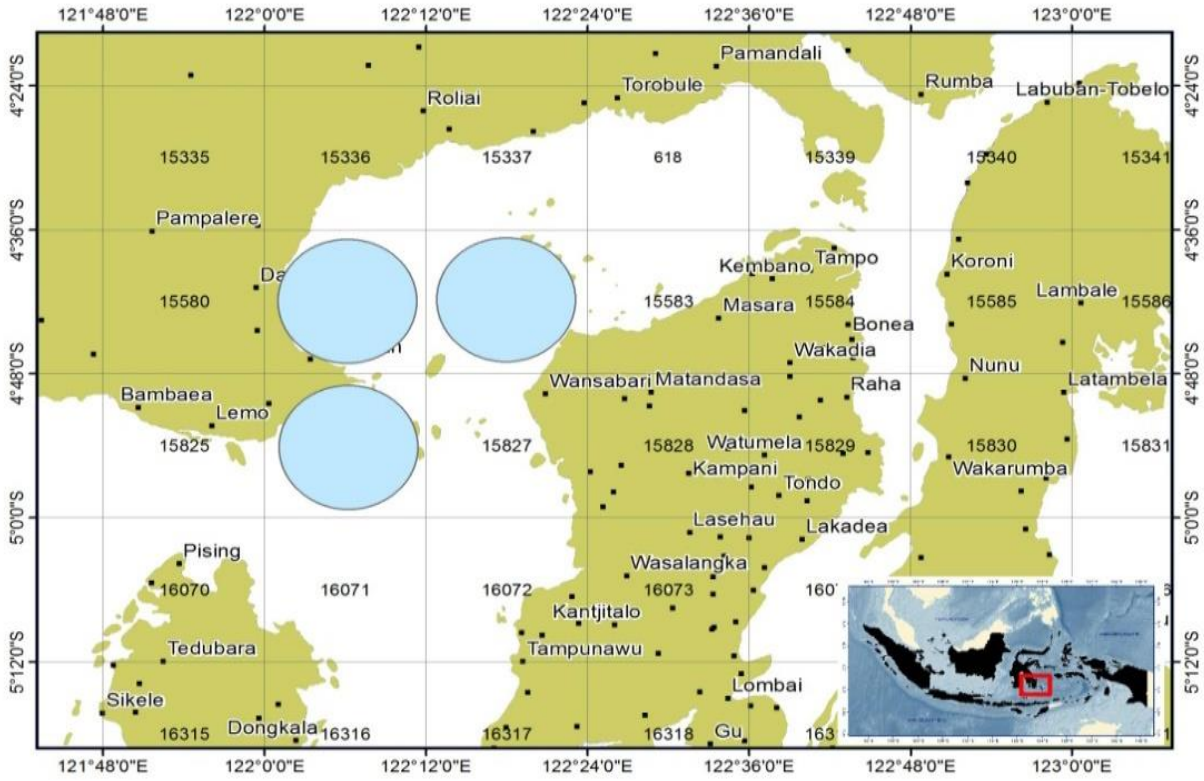

Fig. 1 Endeavour shrimp (*M. ensis* de Haan) fishing ground in Bombana waters.

Growth parameter was predicted by applying von Bertalanffy equation model [7] as follow:

$$L_t = L_\infty\left[1 - e^{-K(t-t_0)}\right]$$

where L_t = carapace length at age t; L_∞ = theoretical maximum carapace length; K = growth rate; and t_0 = theoretical age at zero length. Variables L_∞ and K were counted based on monthly modus of shrimp size structure during 2021 and analyzed by ELEFAN I program in FISAT II [10]. Value of t_0 was predicted using equation as follow [11]:

$$\text{Log}(-t_0) = (-0.3922) - 0.2752\text{log}CL_\infty - 1.038\text{log}K$$

Natural mortality (M) was calculated by using equation which included average water temperature as follow [12]:

$$\text{Log}M = (-0.0066) - 0.279\text{log}CL_\infty + 0.6543\text{log}K + 0.4634\text{log}T$$

Total mortality (Z) was predicted by applying length converted catch curve in FISAT II [10, 11]. In addition, fishing mortality and exploitation rate were analyzed based on equation as follow [7]:

$$F=Z-M \text{ and } E=F/Z$$

3. Result and Discussion

3.1 Result

3.1.1 Fishing Dynamic

Fishing activity to exploit the endeavor shrimp in Bombana waters was conducted by operating mini bottom trawl using small wooden fishing vessel called compreng boat sized of 3-4 GT (Gross Tonnage) with vessel dimension specification of $L \times B \times D$ = 9 ×1.5 ×1.5 m. Each vessel was equipped by 2 boat engines sized 24 and 20 HP (Horse Power) and operated by 1-2 crews. Fishing gear dimension was 21 m each of net length and opened mouth, and 1.5 m of cod end. Mesh size of wing, body, and cod end was 4 inches, 2 inches, and 1 inch respectively. The fishing gear was also equipped by 9 buoys, a sinker with 15 kg in weight, wooden pairs otter board sized 0.9 m in length and 0.5 m in breadth (Fig. 2).

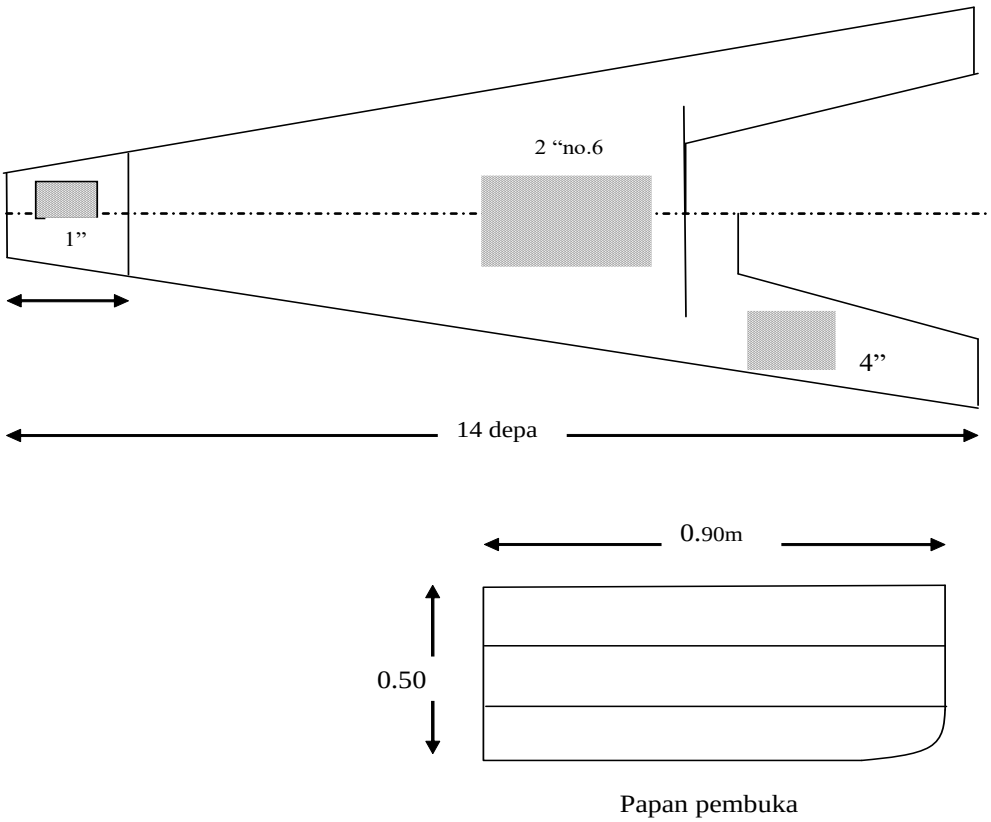

Fig. 2 Design of mini bottom trawl in Bombana waters.

Fishermen applied daily fishing activity during the night for mini bottom trawl in Bombana waters (one day fishing) from 06.00 PM to 06.00 AM with twice setting and hauling each. Fishing activity was conducted in fishing ground about 5-15 m in depth around Bombana waters which was about 10-20 min away and 1-2 miles in distance from fishing base (Fig. 1). Setting was conducted in very short time, about 20 min, and hauling was taken around 4-6 h with 2 knots in speed. Net lifting after hauling was done in off-machine condition during 10-30 min.

Catch composition consisted of 31 fishes, 74% shrimp and 26% demersal fish, and dominated (25%) by endeavour shrimp (*M. ensis*) (Appendix 1).

3.1.2 Population Parameter

(1) Length weight relationship and sex ratio

Length weight relationship analysis resulted in value of *b* as big as 1.75 which indicated that the growth pattern of the endeavor shrimp in Bombana waters was negative allometric. It meant that growth length is faster than that of growth weight.

Chi-square test informed that value of male and female was imbalanced, it was also identified that sex ratio of the endeavour shrimp in Bombana and surrounding waters was found to be 1.0:0.6

(2) The length at first capture (L_c) and the length at first maturity (L_m)

It was found that the length at first capture (L_c) of Endeavour shrimp in Bombana waters was 29.83 mm (Fig. 3).

Another analysis informed that length at first maturity (L_m) was 31.67 mm (Fig. 4). These results illustrated that value of L_c was lower than that of L_m indicating that Endeavour shrimp was caught mostly in immature stage condition.

According to monthly length frequency data, yearly growth rate (*K*) and maximum theoretical carapace length (L_∞) were 1.03 per year and 46.2 mm respectively (Fig. 5). Hence von Bertalanffy equation of Endeavor shrimp in Bombana waters was:

$$L_t=46.2[1-e^{-0.61(t+0.14)}]$$

By plotting these growth parameters (*K* and L_∞) into catch curve, it was found that value of total mortality (*Z*) was 2.52 per year (Fig. 6). While value of natural mortality (*M*), calculated based on Pauly equation (1983) [11], was found as big as 1.61 per year. Hence value of fishing mortality (*F*) was 0.91 per year.

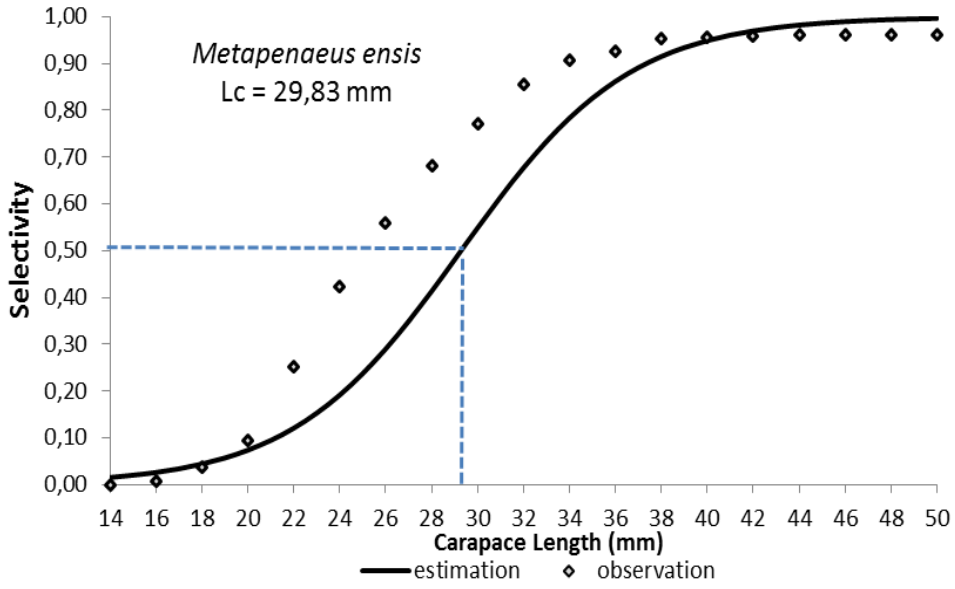

Fig. 3 The length at first capture (L_c) of Endeavour shrimp (*M. ensis* de Haan) in Bombana waters.

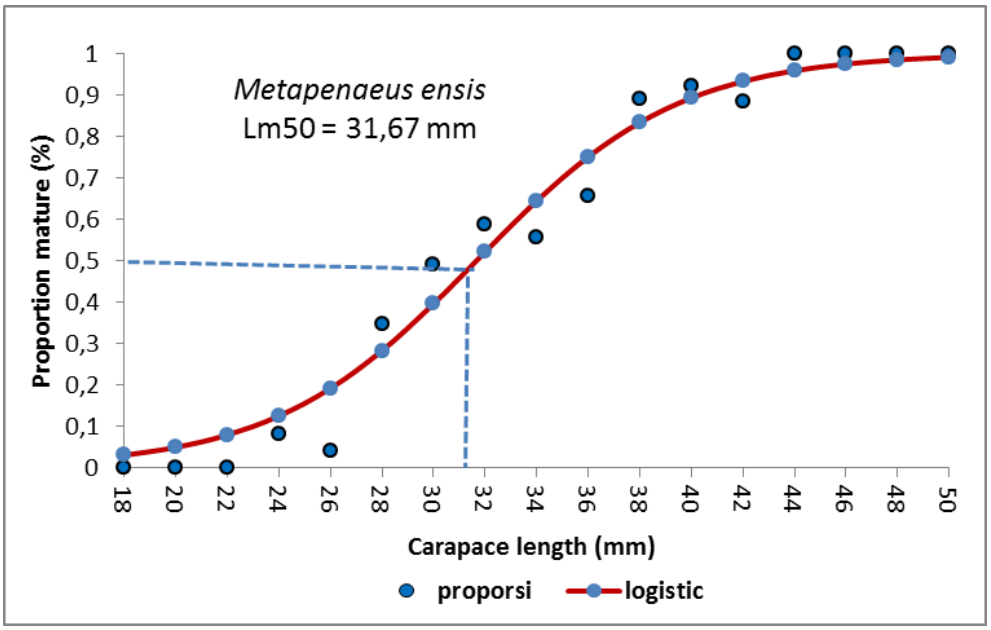

Fig. 4 The length at first maturity (L_m) of endeavour shrimp (*M. ensis*) in Bombana waters.

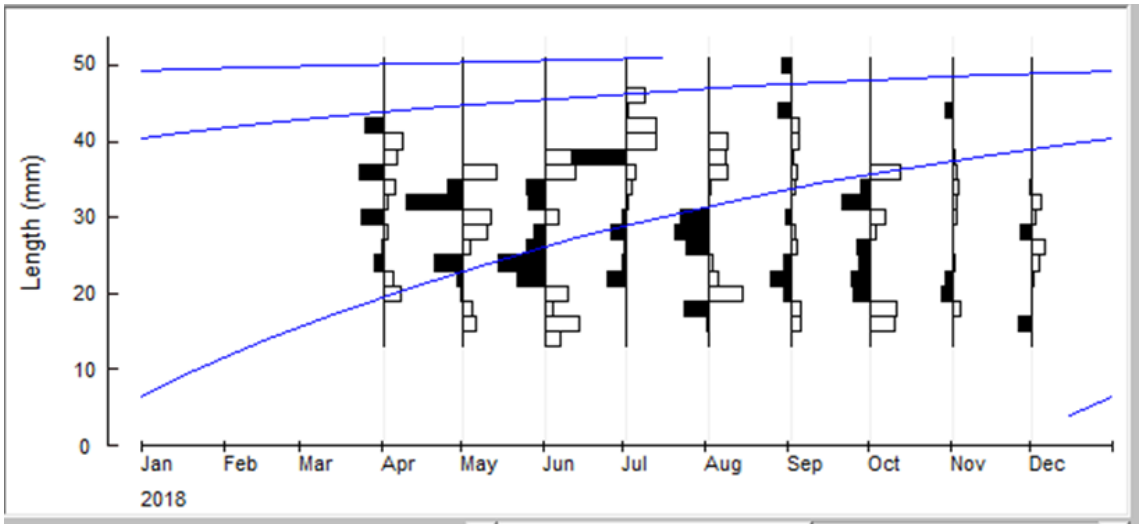

Fig. 5 Von Bertalanffy growth rate of Endeavour shrimp (*M. ensis*) in Bombana waters.

While comparison between fishing mortality (F) and total mortality (Z) informed that value of exploitation rate (E) was 0.36 per year. This variable strongly indicated that stock of Endeavour shrimp resource in Bombana waters was not in overfishing condition.

3.2 Discussion

Recent fishing activity to exploit Endeavour shrimp resource in Bombana waters was conducted by operating mini bottom trawl as the main fishing gear. This fishing gear is made from net like a cone in the shape with wider open in the mouth and getting narrow to the cod end section. The fishing gear is operated by dredging the net in the bottom of sea to catch demersal fish [13, 14]. Mouth of net is able to horizontally open due to the use of otter boards which are attached in both mouth sides. The gear is also able to vertically open due to the use of buoys in head rope and sinker in ground rope [14]. During operation, the fishing gear is able to catch everything in front of the net by keeping the mouth of the gear opened. Hence the

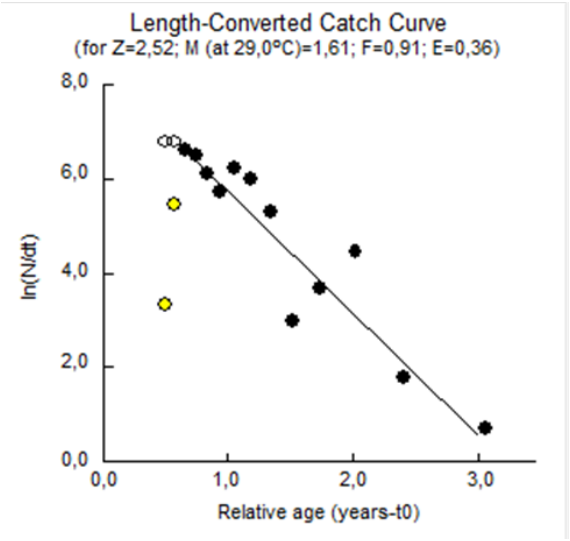

Fig. 6 Catch curve of Endeavour shrimp (*M. ensis*) in Bombana waters.

fishing gear is categorized as less selective fishing gear. This condition informed that ministry decree No. 2/2015 has been applied properly to maintain fisheries resource sustainability. Catch composition of mini bottom trawl in Bombana waters indicated that Endeavour shrimp was as dominant catch with proportion of 74% in average catch of 48.5 kg/trip. Different results of mini bottom trawl catch composition were shown by several previous research. In Arafura Sea, the catch was dominated by demersal fish [15]. Similarly, the catch in Pemalang waters was also dominated by demersal fish with Endeavour shrimp as less dominant catch [16]. Additionally, domination of demersal fish as main catch in north part of Java Sea was almost completed by 90% [17].

Length weight relationship analysis was used to identify growth pattern of the endeavor shrimp in Bombana waters. Analysis of *t*-test informed that growth pattern of endeavor shrimp in Bombana waters was negative allometric. It meant that growth length was faster than that of growth weight. This result was quite similar with research in south of Java waters which was also negative allometric [18] which meant that there was imbalance in length and weight growth pattern. The difference in growth pattern was caused by the influence of external factors such as food availability and environment temperature toward individual growth model [19]. Effendie [20] added that besides those external factors, uncontrol internal factors such as inheritance, sex, age, and disease have also influenced length growth development of fish.

There was imbalance in sex ratio of the endeavour shrimp in Bombana waters where male was more dominated than female. This phenomenon also occurred in south of Java waters. In contrast, different result took place in Binuanguen waters in which sex ratio was in a balance condition [21]. Ball and Rao [6] argued that comparison between female and male is 1.0:1.0 in normal condition. The difference in sex ratio can be caused by both fish behavior and fishing activity and migration [4].

The length at first maturity (L_m) is important to be known because exploitation of any fisheries resource needs to lead some adult females which have size bigger than L_m free from fishing in order to keep its sustainability [22]. Size of L_m (31.67 mm) of the endeavour shrimp in Bombana waters was higher than that of L_c (29.83 mm). Fluctuation value of L_m in different waters is influenced by several factors such as food availability, temperature, and salinity. Udupa [23] stated that size of L_m is varied among intra and extra species. Meanwhile variability of L_c value is possibly caused by different habitat and water depth where fishing activity was conducted. Phenomenon about lower value of L_c than that of L_m will disturb stock sustainability in long term. This condition is as illustration that most the stock was exploited in immature stage.

Sparre & Venema [7] stated that the lower the K value, the longer the time needed to reach asymptotic length (L_∞) and vice versa. Endeavour shrimp resource in Bombana waters was categorized as fast growth rate because value of K and L_∞ was 1.0 per year and 46.2 mm respectively. Different phenomenon is shown by research data conducted in Binuangeun waters of West Java where value of K and L_∞ was 1.33 per year and 51.45 mm respectively [21]. While in

south of Java waters, value of K and L_∞ was 0.26 per year and 58.3 mm respectively [24]. Another research done in south of Java waters also gives different result where value of K and L_∞ was 0.4 per year and 45 mm respectively [24]. Different value in growth parameters may be caused by difference in size and length of samples taken and measured and research location [25]. Knaepkens et al. [26] and Effendie [20] added that different value of K and L_∞ can be caused by both internal and external factors such as food availability, water temperature, inheritance, sex, age, and disease.

Total mortality (Z) is a sum of natural mortality (M) and fishing mortality (F) [7]. Endeavour shrimp resource in Bombana waters has greater value of M than F. It meant most of the shrimp resource died due to natural impact rather than fishing activity. By comparing value of F as fishing mortality and Z as total mortality, value of E as exploitation rate can be obtained. It is already noted that value of E of endeavour shrimp resource in Bombana waters was 0.36 per year. According to Pauly et al. [12], optimal exploitation rate is as big as 0.5. It meant that fishing activity of endeavor shrimp resource in Bombana waters has not achieved its optimal exploitation level because exploitation level was only reached about 72% (E = 0.36) of the resource. Therefore, fishing activity to exploit the endeavour shrimp resource in Bombana waters can be continued without jeopardizing the resource. However, fishing effort must be controlled in such level in order to maintain resource sustainability in the future.

4. Conclusion and Suggestion

4.1 Conclusion

Growth pattern of the endeavour shrimp in Bombana waters was negative allometric. It meant that growth length is faster than that of growth weight. The sex ratio was unbalanced that the female was more dominated than male. In order to maintain stock sustainability in the future, fishing effort must be decreased because the L_c value (29.83 mm) was smaller than that of L_m (31.67 mm). The L_c value was smaller than L_m value, this indicates that in long term the exploitation of endeavour shrimp in this area is not sustainable. Management of the endeavour shrimp resource in Bombana waters must be taken carefully because the stock had high growth and mortality rates. Recruitment patterns occurred through the year with a peak in June. Status stock of endeavour shrimp resource in Bombana waters was not in overfishing level.

4.2 Suggestion

Fishing effort of the endeavour shrimp resource in Bombana waters must be increased as big as 28% from existing condition and increase the mesh size of the net in order to maintain stock sustainability in the future.

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Appendix 1. Catch composition of mini bottom trawl in Bombana waters

No.	Species	Number (individul)	Percentage (%)	Weight (kg)	Percentage (%)
	Shrimp and others crustacean				
1	Udang windu (*Penaeus semisulcatus*)	175	10.86	7	14.44
2	Udang (*Penaeus longystilus*)	200	12.41	4	8.25
3	Udang dogol (*Metapenaeus ensis*)	600	37.22	12	24.75
4	Udang (*Metapenaeus dobsoni*)	250	15.51	5	10.31
5	Rajungan (*Portunus pelagicus*)	60	3.72	8	16.50
	Demersal fish				
6	Swanggi (*Priacanthus blochii*)	1	0.06	0.051	0.11
7	Kwee (*Carangoides armatus*)	1	0.06	0.038	0.08
8	Selar hijau (*Atule mate*)	9	0.56	0.257	0.53
9	Kerong-kerong (*Pelates quadrilineatus*)	3	0.19	0.091	0.19
10	Kurisi (*Nemipterus hexodon)*	18	1.12	0.549	1.13
11	Bloso (*Saurida micropectoralis*)	1	0.06	0.246	0.51
12	Kerapu (*Epinephelus sexfasciatus)*	2	0.12	0.194	0.40
13	Selar kuning (*Selaroides leptolepis*)	21	1.30	0.401	0.83
14	Manyung (*Arius sp*)	1	0.06	0.08	0.17
15	Ketang-ketang (*Drepane punctata*)	3	0.19	0.279	0.58
16	Kwee mangmung (*Alectis indica*)	3	0.19	0.143	0.29
17	Petek (*Gazza minuta*)	3	0.19	0.054	0.11
18	Petek (*Eubleekeria jonesi*)	2	0.12	0.089	0.18
19	Petek (*Eubleekeria splendens*)	5	0.31	0.176	0.36
20	Petek (*Secutor indicus*)	1	0.06	0.001	0.00
21	Kuniran merah (*Upeneus cf. margarethae*)	24	1.49	0.692	1.43
22	Selanget (*Nematalosa come*)	15	0.93	0.65	1.34
23	Kuniran kuning (*Upeneus guttatus*)	3	0.19	0.099	0.20
24	Kuniran kuning (*Upeneus sulphureus*)	6	0.37	1.735	3.58
25	*Serinding* (*Jaydia carinatus*)	81	5.02	2.286	4.72
26	Kapasan (*Gerres oyena*)	3	0.19	0.132	0.27
27	Rejung (*Sillago sihama*)	7	0.43	0.155	0.32
28	Kapas-kapas (*Gerres erythrourus*)	1	0.06	0.092	0.19
29	Kapas-kapas (*Gerres filamentosus*)	5	0.31	0.093	0.19
30	Samgeh (*Johnius borneensis*)	84	5.21	3.03	6.25
31	kwee (*Caranx tille*)	24	1.49	0.869	1.79
Total		1,612	100.00	48.482	100.00