International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

A Study of Biological Potential and Sustainability of Swimming Crab Population in the Waters of Pangkep Regency South Sulawesi Province

Ihsan[a]*, Eko Sri Wiyono[b], Sugeng Hari Wisudo[c], John Haluan[d]

[a] Student of Study Program of Capture Fishery System and Modeling, Graduate School of IPB
[b, c, d] Department of Fisheries Resource Utilization, Graduate School
Bogor Agricultural University, Bogor -Indonesia
[a] Email : ihsanpsp@yahoo.co.id

Abstract

Swimming crab fishing is greatly potential in the waters of Pangkep Regency and spreads in the districts of the coastal waters and on the islands nearby. The objective of the study was to examine the biological potential and sustainability of swimming crab population in the waters of Pangkep Regency for use as information for the government to regulate the management of swimming crab resource sustainably. The methods used in the study were the measurements of length and weight as well as the collection of data on swimming crab production. The collected data, primary and secondary, were analyzed and described qualitatively and quantitatively with the approach of Surplus Production, where as the length and weight of swimming crab carapace were tabulated into a frequency distribution table using Microsoft Excel, and then analyzed using the ELEFAN program packaged in the software FISAT. The analysis of Equilibrium Schaefer resulted in the Effort of 696,679.48 trips and sustainable production of 1,084,066.54 kg/year, and the analysis with the Fox approach obtained a sustainable production of 1,084,066.54 kg and Effort of 696,679 trips, and swimming crabs are still available without disrupting sustainability. Swimming crab spawning season occurs throughout the year, but the peak season is between the months of May, June, July, August, September and October with the highest spawning season in August each year. It was found that the relationship between the carapace width and the male and female weights was negatively allometric.

----

*Corresponding author
E-mail address: ihsanpsp@yahoo.co.id

The exploitation rate of females was >50%, predicted to be over exploitation and the value of recruitment pattern was 17:45%. The male exploitation rate was <50%, predicted to be under exploitation and the value of recruitment pattern was 20:27%.

Keywords: *potential; sustainable; swimming crab; over exploitation; biology, population.*

1. Introduction

Pangkep is one of the regencies in South Sulawesi, with sea area located on the western coast of the Makassar Strait. The fishery resources in the waters are potentially abundant, such as swimming crab resources that spread in the districts of coastal waters and on the islands nearby in the region of Pangkep regency.

Swimming crab takes the largest market share (41%), and is exported in the form of processed meat with tight requirements. Exported swimming crabs caught from the nature have caused severe pressure on a body of water. The increasing demand for swimming crab each year has also made the increasing capture of swimming crabs in the waters [1].

In Pangkep Regency, people have a high dependency on swimming crab fishing, but there are indications that catches tend to decrease, which is very likely to reduce the income of fishermen. The decrease in the catch by fishermen, while it is likely due to over-exploited potential sustainability, is caused by the many operating units of fishing and the damaged living habitat of swimming crabs from time to time. Catching swimming crabs is carried out by not only the fishermen of Pangkep but also those from neigh boring districts. This happens because the sea is an open territory, making it accessible for anyone using various types of technologies. The damaged habitat is due to the use of environmentally unfriendly fishing gear in Pangkep Regency. To keep the swimming crabs sustainable in the waters, a good and right management is required, one of the bases of which is an assessment of the potential and biological sustainability of the swimming crab population so that it can be determined how many swimming crab can be caught, the number of catching trips made, the crab size is allowed to catch and the number of fishing gear may operate. Accurate data and information can assist policy makers to set up the number of annual capture. At present, limited studies have done on the biological aspects and potential sustainability of crab population. In utilizing swimming crab resources, it is expected not increase the quantity of swimming crab production and captures that exceed the potential sustainability in the waters. If this happens, then great harm will threat the swimming crab resource, i.e., an excessive capture (over-fishing). The formulated problem is what are the potential sustainability and biological aspects of swimming crab population for a sustainable capture of crabs in the waters of Pangkep Regencies.

The objective of the study was to assess the potential and biological sustainability of crab population in the waters of Pangkep Regency. The benefit is this study is a useful information for stakeholders in utilizing crab resources and as reference the government in regulating a sustainable management of swimming crab resources in the waters of Pangkep Regency, South Sulawesi Province.

2. Research Method

This study was conducted in the entire coastal districts and two districts of islands (LiukangTupabbiring and LiukangTupabbiring Utara) in Pangkep Regency. It took six months: from December 2012 until May 2013.

The study materials and tools were questionnaires, site map, a boat, swimming crab catching tools, digital cameras, Global Positioning System (GPS), stationery, cold boxes, electric scales, sliding rule, filled-in forms for observation, tweezers, labels, and 1 set of surgery equipment. Collected data consisted of primary and secondary data. Primary data include crab production, measurement of length, and width and weight carapace of 1526 swimming crabs. In the biological observation of swimming crab population, the length, carapace width, sex, and gonad maturity were measured. Secondary data was collected through a study of various existing literatures, reports from various agencies and institutions related to the purpose of the study. Techniques of measuring width and length of carapace [2].

The potential sustainability of swimming crabs was estimated by processing analyzing the data of major capture and the number of catching trips for five years from trap gear using traps, gillnet, fishermen and mini trawl operated by fishermen. Biological population data was used to estimate the equation constants of Surplus Production. Of the seven models, the most reliable was taken, which was the best fit of the other approaches. Production Surplus equation approaches were a) Schnute (1977); b) Walter - Hilborn (WH); c) Disequilibrium Schaefer (D); d) Equilibrium Schaefer; e) Gulland; f) Clarke, Yoshimoto, and Pooley (CYP) and g) Fox, [3]; [4]. Calculation of optimum fishing effort was done by using the equation for the fishing effort (Effort)

$$f.opt = \frac{a}{2b}$$

The value of Maximum Sustainable Yield (MSY) of swimming crabs was calculated by the equation, thus the MSY of swimming crabs when:

$$\mathrm{MSY} = \frac{a^2}{4\ b}$$

To analyze the biological aspects of population and the data of swimming crab carapace length and width, tabulation was made in the form of a frequency distribution table by using a Microsoft Excel program. The frequency data of carapace width were then used to estimate the biological population of swimming crabs. Estimated size of the first time sex maturity of swimming crabs was determined with the Spearman-Karber method in [5]. The formulated equation is presented below:

$$m = xk + \frac{x}{2} - (x \sum_{i=1}^{n} pi)$$

where: m = log crab size at the first time of ovarium maturity

X_k = Log crab size when 100% sample swimming crabs are mature

X = log size increment

Pi = proportion of mature swimming crab in groups n-i

The average size of swimming crabs at the first time of gonad maturity was calculated from the value of antilog (m). The balance of sex ratio was tested with chi-square test in [5] by the following equation:

$$x^2 = \sum_{i=1}^{k} \frac{(oi - ei)}{ei}$$

where:

o_i = number of male and female frequency
e_i = number of expected male and female crabs
k = number of groups observed

Swimming crab growth was analyzed using the growth model of [6] with the following equation:

$$Lt = L\,(1 - e^{-K(t-t0)}$$

The width of asymptotic/infinitive carapace (CW^{∞}) and growth coefficient (K) were estimated by using the ELEFAN program packaged in the software FISATII [9]. Theoretical age (t_0) was determined by the empirical equation [7] as follows:

$$\text{Log} - (t_o) = -0{,}3922 - 0{,}2752 \text{ Log } Cw^{\infty} - 1{,}038 \text{ Log } K$$

Age group (cohort) was determined by separating the normal distribution of the frequency data of carapace width by the method of forward motion Battacharya's analysis using the program package FISATII [8]. In [5]; the natural mortality rate (M) was estimated by the empirical equation [7] of annual mean temperature of surface waters as follows:

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

Total mortality (Z) was calculated using a length converted catch curve on FISAT II program package [7]; [9]. Fishing mortality (F) and exploitation rate (E) were calculated by the equation [7]:

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

3. Results and Discussion

3.1. Potential Sustainability of Swimming Crabs

a. Actual Production *(Catch)*

Actual production (catch) of swimming crab for the last five years (2008-2012) shows fluctuations in the catches of swimming crabs. The highest production was in 2010, amounting to 420,335.87 kg, and the lowest in 2009 accounting for 288,088.21 kg. In terms of the three types of swimming crab fishing gear used, the actual production (catch) of swimming crab was the highest for five years with the use of gillnet, followed by traps and mini trawl.

Swimming crab capture is strongly influenced by the change of seasons; from December to April the wind is blowing hard, affecting the number of fishing trips. During the period, the fishermen still go fishing but on limited trips. However, the month of May to November is the season when fishermen effectively catch swimming crabs.

b. Catching Activities *(Effort)*

Swimming crab fishing gears used in Pangkep for the last five years are of three types: 1) folding trap, 2) gillnet and 3) mini trawlers. The increase in effort to catch swimming crabs for five years (2008-2012) can be seen from the number of catching trips using the three catching tools from 2008-2012. The highest number of fishing trip was in 2012 accounting for 145.400 trips, and the lowest was in 2008 with 83.314,54 trips.

c. Catch Per Unit of Effort (CPUE)

Catch per unit of effort (CPUE) in the swimming crab capture in the waters of Pangkep Regency in the period of 5 years indicates that the highest standard was in 2010 amounting to 4.37 kg, and the lowest in 2009 as much as 1.63 kg. The high and low catch was caused by the different number of fishing tools used every year.

The initial increase in the CPUE value resulted from the increased effort but then the value declined because of the increased competition among the fishing gears operated against the limited swimming crab resource capacity, which tends to decrease due to the increasing intensity of capture [10].

d. Swimming Crabs Sustainable Potential Analysis

The result of regression analysis were a = 3,112095512 and b = 0,000002234. The value of effort based on *Equilibrium Schaefer approach was* 696.679,48 trip while MSY was for about 1.084.066,54kg/year or 1.084 ton/year. Percentage of swimming crabs utilization was 54,09 % in 2012. Relationship of catch and effort was presented in Fig 1.

The analysis by the Fox approach resulted in the estimated potential sustainability of swimming crab of 1,084,066.54 kg (1,084 tons) with the effort of 696.679 trips. Based on such values, there is a quite large supply of swimming crabs. The actual catch of swimming crab in 2012 amounted to 586,405.38 kg with the effort of 181,038.18 trips. There is an untapped potential sustainability of 497,661.16 kg/year with the fishing effort of 515,641.30 trips/year. The effort of actual catch of 121,038.18 trips/year is much lower the required efforts for MEY of 526 349,00 trips/year.

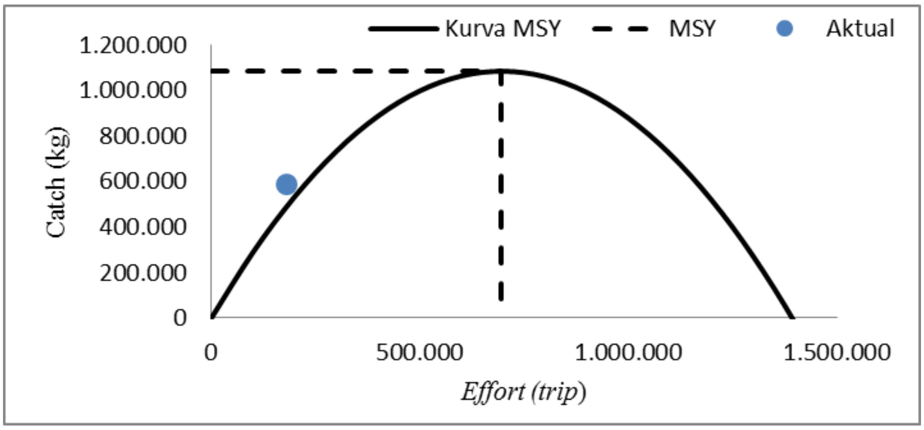

Fig. 1. Relations between catch (kg) and effort (units) in the swimming crab fisheries based on Equilibrium Schaefer Approach

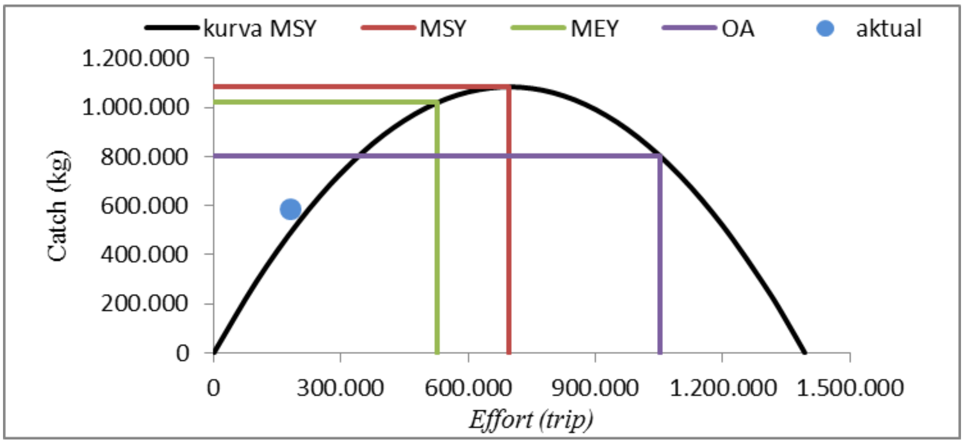

Fig. 2. Relations between catch (kg) and effort (units) in the swimming crab fisheries based on Fox method Approach

3.2. Biological Aspects of Swimming Crab Population

a. First Time of Gonad Maturity

Maturity according to the Oxford Dictionary of Biology, written by Hine and Martin (2004), is defined as a stage in a life cycle that is achieved when an organism develops into an adult form and is capable of reproduction. The size of the first-time gonad maturity becomes an important biological property taken into consideration to determine the patterns of fishery resource reproduction and its management system [11].

From the analysis using the Spearman-Karber approach, it was found that the swimming crab was first mature in gonads or sex for female with the carapace size of 106 mm wide, while the male swimming crabs had the carapace size of 95.5 mm wide.

The analysis with the Spearman-Karber method found that the swimming crab with sex maturity for the first time in the waters of Bone had the carapace width of 71.63 mm, ranging between 69.36 -73.97 mm at the confidence level of 95%. The swimming crab size of first time gonad maturity in Bone was smaller than those found in other waters [5]. In Salemo Island waters of Pangkep Regency, female swimming crabs were of mature gonad the first time with the carapace width of 85 mm [6], in waters of Mayangan, Subang 122.2 mm [12], in the south west waters of India 80-90 mm [13], in the waters of south Australia 82 mm [14].

b. Sex Ratio

Historically, the sex ratio of swimming crab population is used as an indicator of a population's ability to survive through recruitment [15] in [16]. The results of the analysis found that the sex ratio of females to males was 1.2:1; this means that the number of females is more dominant than the male in the sex ratio, so it is predicted to be unbalanced ratio. [11] The sex ratio of male and female swimming crab population in Brebes study showed the ratio of 1.08:1, with the percentage of 51.8% males and 48.1% females.

c. Spawning Ground

The resulted analysis showed that the swimming crab spawning ground in the waters of Pangkep occurs throughout the year, but the peak season is in the months of May, June, July, August, September and October with the highest spawning ground in August every year.

Swimming crab spawning ground can used to observe the female swimming crab gonad maturity [5]. Swimming crab spawning ground is easier to observe that that of fish. It can be seen from the presence of eggs attached to the abdominal folds together with its pleopoda [17].

Swimming crab spawning ground happens throughout the year with the peak in December, March, July and September [17]. In the waters of Bandar Abbas to the north of the Persian Gulf, the peak of swimming crab spawning ground also occurs in December [16]. Mean while in the waters of Mayangan, Subang, West Java, it happens during the period of February-April and September [12], in the coastal waters of Mandalle Pangkep the peak spawning ground is in August [18].

d. Carapace Width

The resulted measurements obtained a sample of 1526 swimming crabs consisting 692 males and 834 females, and the sex types were grouped in the frequency distribution of carapace width for both males and female swith a median value varying from 45.5 to 177.5 mm. The relationship between carapace width and weight of male and female (total) was negatively allometric, meaning that the carapace width grows faster than the weight.

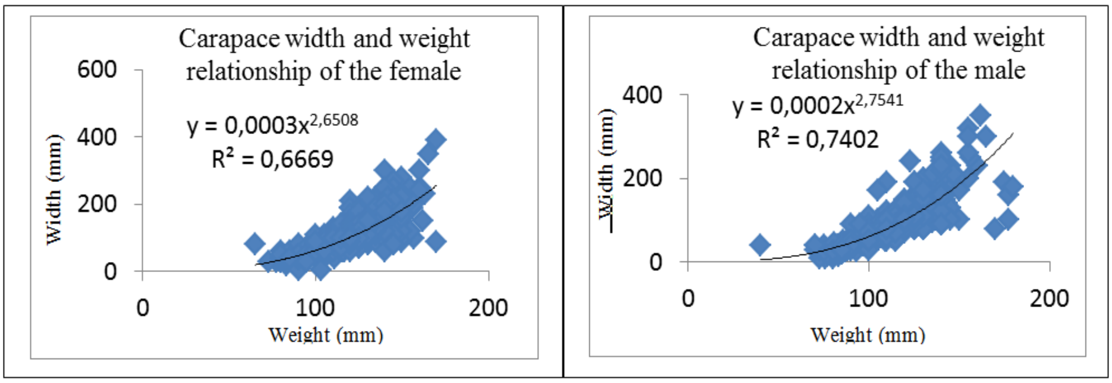

Fig.3.Carapace width and weight relationship of the male and female swimming crabs in waters Pangkep

e. Growth Parameter

The resulted estimation of the swimming crab growth parameter in the waters of Pangkep showed that the width of infinitive carapace (Cw∞) and growth rate (K) of male swimming crabs was larger than that of females. The details are presented in the following table:

Table 1. Growth Parameter of Male and Female swimming crabs in the waters of Pangkep Regency

Sex	Width of Carapace infinitive (Cw∞)	K (year)	T_0 (year)	Growth equation
Male	173,78	1,2	-0,081	CWt =173 (1- e $^{-1,2+0,081}$)
Female	186,38	1,5	-0,063	CWt =186 (1- e $^{-1,5+0,063}$)

Based on the table above, the width of infinitive carapace (CW ∞) and growth rate (K) is larger on the male swimming crab than on the females; the difference in value is due to the difference in the maximum carapace width, i.e., males 186.38 mm and females 173.78 mm. Mean while the growth rate (K) of male swimming crabs is higher than that of the female swimming crab. The K value of male swimming crabs is 1.5/year and the females 1.2/year. The growth rate of swimming crabs in this study is greater than one, which indicates that the swimming crab has a rapid growth rate.

Growth parameters vary within a species. This suggests that growth is dynamic, and so its value varies. The width of infinitive carapace (CW ∞) and growth rate (K) of male swimming crabs is larger than that of the female swimming crab. The difference is due to the difference in the maximum carapace width of male and female swimming crabs: 157.11 mm and 156.80 mm respectively [5].

The resulted study in the waters of Mangalore, India, obtained the CW ∞ value of 211 mm for male swimming crabs and 204 mm for the females, while the K values were of 1.14/year and 0.97/year for males and females respectively [14]. Meanwhile, the study [19] in the waters of Trang, Thailand CW ∞ value was 179 mm for males and 171 mm for females, the K values were of 1.5 / year and 1.6/year for males and females, respectively. In the waters of Mayangan, the CW ∞ value was 161.38 mm for male and 177.17 mm for female swimming crabs, and the K values were 0.97/year and 0.8/year for males and females respectively [12]. These CW ∞ and K values in this study are lower than that obtained in the waters of Mangalore and Trang. However, compared with that of the waters of Mayangan, the CW ∞ value is smaller, but the K value is larger. This difference is caused by the difference in environmental conditions and the catching activities in each location.

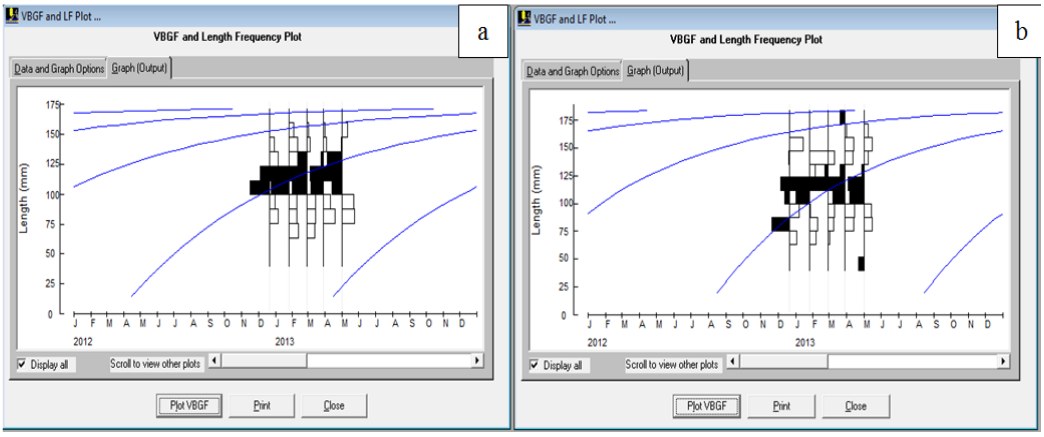

Fig. 4. Graph of Von Bertalanffy of swimming crab females (a), males (b) in Pangkep waters

The analysis of the swimming crab growth resulted in a negative allometric pattern, meaning that the width growth was faster in carapace compared with the weight growth of the swimming crab [20]. The sufficient supply of natural food in the habitat will lead to relatively faster growth of crabs because the need for energy to conduct metabolic processes is met. On the other hand, the high pressure of capture causes the disruption in the swimming crab growth [5].

f. Total Mortality Rate (Z), Natural Mortality (M) and Capture (F)

The total mortality rate of swimming crabs was estimated using the conversion curve of catches with the carapace width packed in the FISAT II program with the values of CW∞, K and t_0 for male and female into the program. The resulted analysis obtained the total mortality rate of 3.22/year for female swimming crabs and 2.53/year for males, and combined rate of 2.53/year for both. Natural mortality was 1.27/year for females, 1.44/year for males, and the combined rate of 1.44/year for both. The mortality rate as a result of capture was 1.95/year for females and 1.09/year for males.

The analysis of female swimming crabs resulted in the width of asymptotic carapace of 173.78 mm (L. Inv), the growth coefficient of 1.2/year, total mortality of 3.22/ year, natural mortality of 1.27/year, fishing mortality value of 1.94/year, exploitation rate of 0.60/year, and the recruitment pattern of 17.45 %. Greater growth coefficient will make growth faster growth, thus this will more quickly achieve L. Inv and so the swimming crab will quickly die.

The analysis of male swimming crab resulted in the width of asymptotic carapace (L. Inv) of 186.38 mm, the growth coefficient of 1.5/year, total mortality rate of 2.53/year, natural mortality rate of 1.44/year, the fishing mortality of 1.08/year, exploitation rate of 0.42/year, and the recruitment pattern of 20.27 %. Greater coefficient of growth means a faster growth, thus more quickly achieving L.inv, and so the swimming crabs will quickly die. Compared with the female swimming crab, the k value of male swimming crabs is greater than that of the females, so the male swimming crabs will reach L.Inv faster and die sooner.

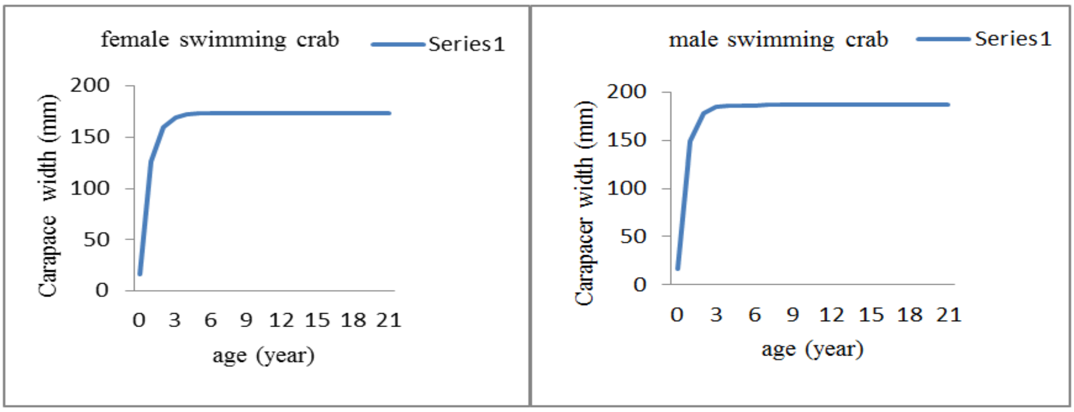

Fig. 5. Swimming crabs growth curve in Pangkep waters

The rates of total mortality, natural mortality and swimming crab catching in the waters of Bone are smaller than those obtained in the waters of Trang, Thailand [5]. Z values for males and females are respectively 9.23 and 8.85, the M value of 1.61 is for both males and females, and the F values are 7.62 and 7.24 for males and females respectively. The mortality rate (M) due to capture varies according to the diversity of annual fishing efforts. Variations in the total mortality rate (Z) from year to year were much influenced by the death rate due to the capture, while the natural death rates were not much different. The natural mortality resulted from a number of factors such as predation, disease, and aging [19].

g. Exploitation Rate

The analysis of exploitation rate resulted in the values of Z and F in the equation E = F/Z. Thus, the results obtained were 0.60 and 0.429889 respectively for the female and male swimming crabs, while the combined rate of males and females was 0.43. The rational rate of sustainable exploitation in the waters is the E value of < 0.5 or the highest value of E = 0.5 [21].

The mortality rate in female swimming crab as a result of fishing is greater than the natural mortality rate, thus more female swimming crabs were caught dead than died naturally. It is also related to the exploitation rate of exceeding 50 %, so it is likely to have been over exploited, without being followed by the percentage value of successful Recruitment Pattern into the stock, namely 17.45 %. Mean while the natural mortality of male swimming crabs is greater than the death rate due to fishing, so the male swimming crab die more naturally. The exploitation rate did not exceed 50 %, so it is likely that male swimming crabs have not suffer from over exploitation or over fishing because they die more naturally than as a result of fishing, and the value of recruitment pattern, the percentage value of successful Recruitment into the stock is 20.27 % .

The exploitation rate of swimming crabs in the waters of Bone has already exceeded the rational value or potential sustainability, or it can be said to be overexploited. Therefore, good care must be taken in the management of swimming crab resource in these waters. The exploitation rate in this study is also lower than that in the waters of Trang, Thailand, amounting to 0.83 and 0.82 respectively for males and females. This is due to the different fishing pressure in both aquatic environments [6].

4. Conclusion and Suggestions

4.1. Conclusion

Based on the analysis and discussion that has been done in deduce a few things are as follows:

a. Swimming crab catch fluctuates annually and is strongly associated with the fishing season catch in 2012 was 231,540 kg, with a monthly average of 19,295 kg. Catch of traps, gillnet and minis trawl was the highest in 2012, while the lowest occurred in 2008 for traps, in 2009 for gillnet and in 2010 for mini trawls.
b. Total catching trips using traps, gillnet and mini trawls were the highest in 2012 and the lowest number of trips in 2009. The swimming crab catch per unit of effort for the period of 5 years shows the highest standard in 2010 amounting to 4.37 kg, and the lowest in 2009 accounting for 1.63 kg.
c. The analysis of Equilibrium Schaefer approach results in the Effort of 696,679.48 trips with the sustainable production of 1,084,066.54 kg/year or 1,084 tons/year and the Fox approach analysis indicates the production of sustainable swimming crab 1,084,066.54 kg with the effort of 696,679 trips, meaning that a maximum sustainable production is still available for use.
d. The relationship between the carapace width and the weight of females and males is negatively allometric, meaning the carapace width grows faster than the weight of the swimming crab. Sex ratio of females to males is 1.2:1, which means that the number of females is more dominant than that of the males, thus the sex ratio of swimming crab is predicted to be unbalanced.
e. The mortality of female swimming crab as a result of fishing is greater than the natural mortality, thus many female swimming crabs are caught dead than die naturally. The exploitation rate exceeds 50 % in female crabs, thus considered to be over exploited because it is not accompanied by the percentage value of successful Recruitment Pattern into the stock, namely 17.45 %. Male exploitation rate does not exceed 50 %, hence not suffering from over exploitation because death happens more naturally than because of capture, and the percentage value of successful Recruitment into the stock of 20.27 %.

4.2. Suggestions

Based on the discussion and conclusion, further studies are recommended on the potential sustainability and biological aspect of swimming crab population using monthly catch data for several years, and measurement of length, width, and weight for a year for the analysis of the biological aspects of swimming crab population.

References

[1] [KKP] Kementerian Kelautan dan Perikanan, 2008. Rajungan Terus Berjuang. Warta pasar ikan. Rajungan *(Portunus sp).*

[2] Jafar L. 2011. Perikanan Rajungan di Desa Mattiro Bombang (Pulau Salemo, Sabangko dan Sagara) Kabupaten Pangkep. *Skripsi*. Program Studi Manajemen Sumberdaya Perairan Jurusan Perikanan Fakultas Ilmu Kelautan dan Perikanan Universitas Hasanuddin. Makassar 2011.

[3] Ihsan, 2000. Kajian Model Pengelolaan Sumberdaya Perikanan Laut secara optimal di Perairan Kabupaten Pinrang Sulawesi Selatan. Tesis. Sekolah Pascasarjana Institut Pertanian Bogor. Bogor.

[4] Gigentika., S. 2012. Optimasi Pengembangan Perikanan Cakalang di Kabupaten Lombok Timur Provinsi Nusa Tenggara Barat. Tesis. Sekolah Pascasarjana Institut Pertanian Bogor. Bogor 2012.

[5] Kembaren D.D., Ernawati. T. dan Suprapto, 2012.Biologidan parameter populasi rajungan (*Portunus pelagicus*) di perairan Bone dan sekitarnya. Jurnal Penelitian Perikanan Indonesia. Diterbitkan oleh Pusat Penelitian Pengelolaan Perikanan dan Konservasi Sumber Daya Ikan-Badan Penelitian dan Pengembangan Kelautan dan Perikanan Kementerian Kelautan dan Perikanan Republik Indonesia.

[6] Sparre P and Venema S.C. 1999. Introduksi Pengkajian Stok Ikan Tropis. Diterbitkan Berdasarkan Kerjasama dengan Organisasi Pangan dan Pertanian Perserikatan Bangsa-Bangsa, Oleh: Pusat Penelitian dan Pengembangan Perikanan, Badan Penelitiandan Pengembangan Pertanian, Jakarta, Indonesia.

[7] Pauly, D. 1983. Some Simple Methods for the Assessment of Tropical Fish Stocks. *FAO Fisheries Technical Paper* (254): 52 p.

[8] King, M. 1995. *Fisheries Biology: Assessment and Management.* Fishing News Books. Oxford, England: 341 p.

[9] Gayanilo, F. C. Jr., P. Sparre and D. Pauly. 2005. *FAO-ICLARM Stock Assessment Tools II (FiSATII).* Revisedversi on. User's guide. FAO Computerized Information Series (Fisheries). No. 8, Revised version. *FAO Rome.*168 p.

[10] Gulland JA. 1983. *Fish Stock Assessment* : A manual of basic metods. FAO.John Willey and Sons Inc. London. 21 – 46.

[11] Sunarto, 2012. Karakteristik Bioekologi Rajungan (*Portunus pelagicus*) di Perairan Laut Kabupaten Brebes. Disertasi. Sekolah Pascasarjana Institut Pertanian Bogor.

[12] Hermanto, D.T. 2004. Studi pertumbuhan dan beberapa aspek reproduksi rajungan *(Portunus pelagicus)* di perairan Mayangan, Kabupaten Subang, Jawa Barat. *Skripsi*. Institut Pertanian Bogor.64 p.

[13] Sukumaran, K.K. & B. Neelakantan. 1997. Age and growth in two marine portunid crabs, *Portunus sanguinolentus* (Herbst) and *Portunus pelagicus* (Linnaeus) along the southwest coast of India. *Indian J. Fish.*, 44 (2) : 111-131.

[14] Clarke, K and Ryan, S., 2004. Ecological assessment of the Queensland blue swimmer crab fishery biology and distribution of the blue swimmer crab (*Portunus pelagicus*) in South Australia waters. *SARDI Research Report Series*. No. 47, 10 p.

[15] Ault., J.S. and N.M. Ehrhardt, 1991. Correction to the Beverton and Holt Z-estimator for truncated catch length-frequency distributions. ICLARM Fishbyte, 9(1);37-39.

[16] Kamrani, E., A.N. Sabili, M. Yahyavi. 2010. Stock assessment and reproductive biology of the blue swimming crab, *Portunus pelagicus* in Badar Abbas coastal waters, northern Persian Gulf. *Journal of Persian Gulf (Marine Science)*. 1 (2): p. 11-22

[17] Romimohtarto, K. 1977. Hasil Penelitian Pendahuluan tentang Biologi Budidaya Rajungan, *Portunus pelagicus* (L), dari Teluk Jakarta dan Pulau Pari (Pulau-pulau Seribu). *Prosiding Seminar Biologi V dan Kongres III Biologi Indonesia.* p. 199-216.

[18] Anisah. 1998. Studi beberapa aspek biologi produksi rajungan (*Portunus pelagicus*, Linnaeus) di perairan pantai Mandalle Kabupaten Pangkep Sulawesi Selatan. *Skripsi*. Universitas Hasanuddin. 37 p.

[19] Sawusdee, A. & A. Songrak. 2009. Population Dynamics and Stock Assessment of Blue Swimming Crab (*Portunus pelagicus*Linnaeus, 1758) in the Coastal Area of Trang Province, Thailand. *Walailak J Sci& Tech 2009; 6 (2): 189-202.*

[20] Bertalanffy, L. Von, 1934. Untersuchungenuber die Gezetzlichkeiten des Wachstum. I. Algemeine Grundlagen der Teorie. Roux Arch. Entwicklungsmech. Org., 131;613-653.

[21] Pauly, D.1984. Fish Population Dynamics in Tropical Waters: A Manual for Use with Programmable Calculators. ICLARM Studies and Reviews 8. International Center for Living Aquatic Resources Management. Manila. Philipina.325 p.

[22] Kangas, M.I. 2000. Synopsis of the biology and exploitation of the blue swimmer crab, *Portunus pelagicus* Linnaeus, in Western Australia. Fisheries Research Report no. 121, 2000. Fisheries Western Australia. http://www.fish.wa.gov.au.

[23] Susanto, 2006**.** Kajian Bioekonomi Sumberdaya Kepiting Rajungan (*Portunus pelagicus* L) di Perairan Kabupaten Maros, Sulawesi Selatan. *Jurnal Agrisistem, Desember 2006, Vol 2 No. 2.ISSN 1858-4330.*