Jurnal Biodjati 7(2):199–211, November 2022

e-ISSN : 2541-4208
p-ISSN : 2548-1606

JURNAL BIODJATI

http://journal.uinsgd.ac.id/index.php/biodjati

Spawning and Reproductive Potential of Blue Swimming Crab (*Portunus pelagicus*) at Spermonde Archipelago, Indonesia

Muh. Saleh Nurdin[1]*, Amanda Pricella Putri[2], Dewi Yanuarita Satari[3], Riris Yuli Valentine[4], Fauziah Azmi[5], Teuku Fadlon Haser[6]

Received: 17 August, 2022
Revise from: 20 August, 2022
Accepted: 20 September, 2022

DOI: 10.15575/biodjati.v7i2.19893

[1]Fisheries and Marine Department, Faculty of Animal Husbandry and Fisheries, Universitas Tadulako Jl. Soekarno Hatta KM. 9, Central Sulawesi, Indonesia, 94148, [2]Center of Excellence for Interdiciplinary and Sustainability Science, Universitas Hasanuddin, Jl. Perintis Kemerdekaan KM. 10, Makassar, Indonesia, 90245, [3]Fisheries Department, Faculty of Marine Science and Fisheries Universitas Hasanuddin, Jl. Perintis Kemerdekaan KM. 10, Makassar 90245, [4]Politeknik Kelautan dan Perikanan, Jl. Kampung Baru Pelabuhan Ferry, East Nusa Tenggara, Indonesia, 85351, [5,6]Department of Aquaculture, Faculty of Agriculture, Universitas Samudra, Jl. Dr. Syarief Lama, Aceh, 24416

e-mail:
*[1]*msalehnurdin@gmail.com*
[2]*amandapriscella.ap@gmail.com*
[3]*dewiyanuarita@gmail.com* ,
[4]*ririssinaga.kkp@gmail.com*
[5]*fazmi@unsam.ac.id*
[6]*teukufadlon@unsam.ac.id*

**Corresponding author*

Abstract. *The problem in the management of blue swimming crab (BSC) fisheries is a decrease in stock that overlaps with an increase in fishing activities. This study aimed to analyze the ratio of spawning potential (SPR), reproductive potential, and reproductive productivity of BSCs taken from the Spermonde Islands. Spawning potential was analyzed using SPR, while reproductive potential analysis used the relative proportion of data between female, berried female and the average fecundity of each class size. The results showed that the BSC in Spermonde were growth overfishing and recruitment overfishing. The SPR of the BSC was estimated to be 7%, below the biological reference point. The highest reproductive potential index of berried females occurred in the group with a carapace width of 111-120 mm which contributed 36.84% of the total egg production. The value of reproductive productivity was 1.35 indicating a productive population. Current legislation allows the capture of BSCs with carapace sizes larger than 100 mm. Based on the data of this study, this size limit has the potential to eliminate 65.92% of the total egg production in the Spermonde Islands. To ensure the sustainability of BSCs in the Spermonde Islands, it is necessary to limit size by capturing BSCs >120 mm to protect the berried female and increase total egg production.*

Keywords: *minimum legal size, overfishing, fishery management*

Citation
Nurdin, M. S., Putri, A. P., Satari, D. Y., Valentine, R. Y., Azmi, F. & Haser, T. F. (2022). Spawning and Reproductive Potential of Blue Swimming Crab (*Portunus pelagicus*) at Spermonde Archipelago, Indonesia. Jurnal Biodjati, 7(2), 199–211.

INTRODUCTION

Blue swimming crabs (*Portunus pelagicus* Linnaeus, 1758) is a renewable fishery resource with high market demand and creates employment opportunities for coastal community (Anand & Soundarapandian, 2011; Watanabe et al., 2014; De La Cruz, 2015; Ihsan et al., 2015; Kembaren et al., 2018). The capture blue swimming crabs (BSC) in Sper-

Copyright © 2022 Jurnal Biodjati
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/)

monde Island occurs throughout the year with a peak in June to September which coincides with dry seasons (Ihsan et al., 2014; Wiyono & Ihsan, 2015; Nurdin et al., 2019). The common fishing gears utilized are gill net and traps although the use of gillnets are rapidly declined because it is less productive (Nurdin et al., 2020).

BSC is the third largest fish commodity exported from Indonesia after tuna and shrimps (Hutapea et al., 2019; Sara et al., 2019), valued at US$ 246.14 million in 2015 (Muawanah et al., 2017). Yet, the largest proportion of the values comes from fishing, resulting in stock declines in several fishing grounds in Indonesia (Ernawati et al., 2014; Sara et al., 2017; Macale & Nieves, 2019) including in Spermonde Islands (Nurdin et al., 2015; Adam et al., 2016). The stock reduction can be resulting in both catch quantity, genetic diversity, and the shifting of fishing ground into the deeper area (Juwana et al., 2009; Susanto et al., 2019; Hidayani et al., 2020).

Management efforts must be established to sustain open-access fishery resources such as BSC (Lai et al., 2010; Muawanah et al., 2017). This entails best scientific data and information in order to depict exploitation level of BSC to support its management. However, the obstacle faced by the BSC fishery in the Spermonde Islands is the unavailability of data and information regarding the spawning potential ratio (SPR) and reproductive potential. This information is fundamental in determining the exploitation status of BSC resources and regulating the minimum legal size (MLS).

Spawning potential ratio (SPR) is an estimation used to determine the stock status when data is poor and uncertain, especially for small-scale fisheries such as BSC (Hordyk et al., 2015; Prince et al., 2020). While population reproductive potential index and BSC reproductive productivity are used to determine the minimum legal size (MLS) (Babu et al., 2006; Yoda & Yoneda, 2009; Johnson et al., 2010). Minimum legal size is a very important tool in fishery management. It is required by the FAO standard operation procedure for fishery (Sunarto et al., 2010; Nurdin et al., 2016a; Achmad et al., 2020; Haser et al., 2022). This research aimed to analyze the SPR and reproductive potential of BSC in Spermonde Islands to evaluate current MLS legislation of BSC fishing.

MATERIALS AND METHODS

The research was conducted from February to November 2016 in Spermonde Archipelago (Salemo, Sabangko, Sagara, and Saugi Island) (Figure 1). These four islands are the largest BSC-producing areas in the Spermonde Archipelago. Blue swimming crab (BSC) samplings were done monthly using gillnet, danish seine, and traps. The total samples of BSC collected consisted of 1,195 individuals. Samples obtained from the field were transported to Aquatic Productivity Laboratory, Universitas Hasanuddin. The biological parameters consisted of carapace width, weight, maturity stage, and fecundity. Carapace width was measured using a digital caliper with 0.1 mm accuracy. Body weight and gonadal weight were weighed using a digital scale with 0.001 g accuracy. Each gonad was cut into three sub samples and weighed to obtain partial weight. The sub samples were immersed in Gilson solution for 24 hours to dissolve eggs' outer membranes to allow easier egg counting.

To determine the size of the first maturity of the gonads, the level of gonad maturity was measured at the first hand by observing the BSC gonad sample visually. The carapace was opened starting from the posterior and moved organs that cover the gonads just below the backside. The criteria for the gonad maturity stage (GMS) referred to the modified BSC female GMS classification from Castiglioni & Negreiros-Fransozo (2006): (1) immature phase: the ovary is not yet developed, the gonads are thinly elongated, located to the back on the other side of the feeding canal and completely covered by thin peritoneum, slightly soft pale yellow; (2) the maturation phase: the volume of the ovary is bigger, almost filling the entire chest (cephalothorax) and the color is getting more yellow. The eggs are clearly visible but are still covered by oil glands. The size is wider so that it presses the hepatopancreas; (3) mature phase: the egg granules are getting bigger and are clearly visible in orange color and can easily be separated because the oil layer that surrounds them has been reduced; and (4) spent phase: the ovaries shrink back. There are many eggs on the badomen. There are eggs left around the hepatopancreas that are not released during spawning that look like the maturing phase.

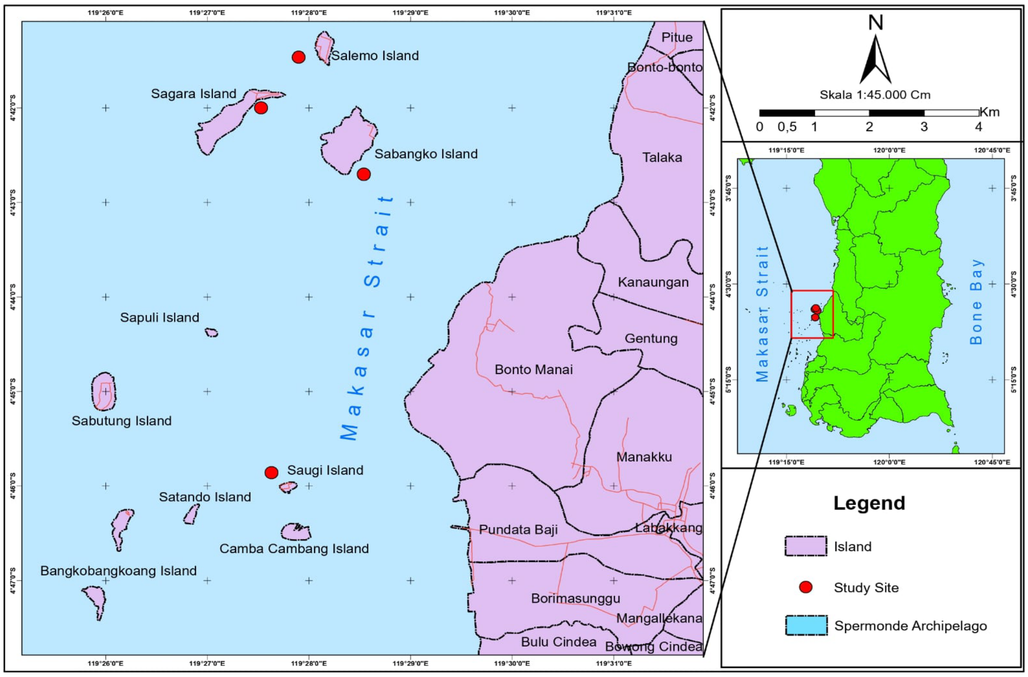

Figure 1. Study site in Spermonde Islands

Data Analysis

Spawning Potential Ratio

In an SPR study, the data required included carapace width and gonadal maturity. Analysis of carapace width will provide information on Bartalanffy growth parameters (K, L∞, t0) and size at first captured. Gonad Maturity Stage (GMS) analysis will produce information on size at first maturity (Lm_{50}) (Hordyk et al., 2015; Kembaren & Ernawati, 2015; Wujdi & Wudianto, 2015; Permatahati et al., 2020; Suman et al., 2020). Previous study has been done by researchers concerning input parameters required for BSC's SPR study in Spermonde Islands using different analysis (Table 1). However, those studies only covered the study area partially. Therefore, here we updated the data by covering more area and employed Response Surface analysis in ELEFAN I which is integrated with FISAT II software

Size at first maturity (Lm_{50}) of BSC was analyzed using logistic function (King, 1995), and the size at first capture (SL_{50}) of BSC was analyzed using the log function as described by Sparre & Venema (1998).

The estimation of t0 of BSC was calculated using Pauly formula (Pauly, 1980), and natural mortality rate (M) of BSC was estimated using Rickhter and Efanov (Sparre & Venema, 1998). SPR was computed with input parameters which includes M/k and Lm/L∞ (Hordyk et al., 2015; Prince et al., 2020). SPR was considered as the ratio of spawning stock biomass per recruit in the exploited stock ($SSBR_{fished}$) with the spawning stock biomass per recruit in the absence of fishing ($SSBR_{unfished}$) as follows:

$$SPR = \frac{SSBR_{fished}}{SSBR_{unfished}}$$

SPR value was grouped into three categories which are: (1) <20% (over exploited); (2) 20-25% (fully exploited) and; (3) >30-50% (under fishing) (Prince, 2014).

Reproductive Potential

Egg samples were counted under the microscope and fecundity rate was determined following gravimetry method:

$$F = \frac{Bg}{Bs} Fs$$

Where:

F = Fecundity of BSC

Fs = The number of eggs for the subsample

Bg = Gonad weight (g)

Bs = Weight for the sub samples of gonad (g).

The relationship of carapace width, body weight, gonad weight and fecundity was analyzed using multiple linear regression (Zar, 2010) as follows:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3$$

Where:

Y = Total fecundity

X_1 = Carapace width

X_2 = Body weight

X_3 = Gonad weight

$$\text{Egg mass index} = \frac{\text{Average of gonadal weight (g)}}{\text{Average of BSC weight (g)}} \times 100$$

The Index of reproductive potential (IRP) was computed using data on female relative proportion, berried female (BEF) and average fecundity for each class size. IRP computation refers to a method used by Sukumaran & Neelakantan (1997); Johnson et al. (2010); Zairion et al. (2015) as the equation below:

$$IRP = \frac{(A_i \times B_i \times C_i)}{D}$$

Where:

A_i = Proportion of i class size in a group containing all females across size classes that contained BEF;

B_i = Proportion of BEF in i class size

C_i = Average fecundity at i class size and

D = Constant (148.34) at class size 91-100 mm as standard index with the value of 100.

Based on the IRP analysis, female BSC was categorized into less productive (reproductive productivity < 1) and productive (reproductive productivity ≥ 1).

Table 1. Life history parameters of BSC at Spermonde Archipelago as an input for SPR analysis

Parameters	Value	Location	Source
Lm_{50}	98.31 mm	Coral reef (Salemo Island)	Nurdin et al. (2016a)
	83.35 mm	Seagrass (Salemo Island)	Nurdin et al. (2016a)
	94.54 mm	Mangrove (Salemo Island)	Nurdin et al. (2016a)
M	1.31/year^{-1}	Salemo Island	Nurdin et al. (2015)
	0.51/year^{-1}	Saugi Island	Laisow (2013)
	0.26/year^{-1}	Saugi Island	Laisow (2013)
K	0.87/year^{-1}	Coral reef (Salemo Island)	Nurdin et al. (2016b)
	0.96/year^{-1}	Seagrass (Salemo Island)	Nurdin et al. (2016b)
	1.5/year^{-1}	Mangrove (Salemo Island)	Nurdin et al. (2016b)
L∞	222.5 mm	Saugi Island	Laisow (2013)
	143 mm	Coral reef (Salemo Island)	Nurdin et al. (2016b)
	142 mm	Seagrass (Salemo Island)	Nurdin et al. (2016b)
	130 mm	Mangrove (Salemo Island)	Nurdin et al. (2016b)

RESULTS AND DISCUSSION

Spawning Potential Ratio

Coral conditions in Suaka Alam Perairan PData analysis revealed that the size at first capture (SL_{50}) was 80.53 mm, which is smaller than the size at first maturity (Lm_{50}) 103.99 mm (Figure 2). These results indicated that most of BSC captured during the sampling period have not attained sexual maturity. Analysis of growth and mortality parameters results in the value of L∞, K, and M were 159.75 mm, 1.03/year^{-1}, and 0.83/year^{-1} respectively.

The spawning Potential Ratio (SPR) estimation of BSC was calculated to be 7% when ratios of F/M and M/k were 3.43 and 0.81 (Table 2). The value of the SPR was far below the biological limit reference point (20%) (Prince, 2014). Accordingly, the population falls into the overexploitation category. This low SPR estimation owes to the value of SL_{50} which is smaller than Lm_{50} (67% of total BSC captured within the population) that causes growth overfishing. The figure of estimated SPR within this study suggests that only 7% of female BSCs (spawner) can spawn, therefore it also indicates recruitment overfishing.

Mortality due to fishing occurs more than three folds natural mortality (F/M = 3.43). The high ratio of F/M indicates that the area is under very high fishing pressure (Prince et al., 2020). BSC fishery in Spermonde Islands has been experiencing growth and recruitment overfishing. According to Adam et al. (2016), BSC exploitation in the islands increased from 54.09% to 85% during the period of 2012 – 2014 and it has reached its maximum limit. Fishermen use 400 – 600 bubu (traps) in only one trip while gillnets used in fishing can reach 1,000 – 1,500 m length (Nurdin et al., 2020). This condition is worsened by the low size at first capture and MLS which obstructs recruitment and results in stock declines (Chande & Mgaya, 2004; Johnston et al., 2011).

The BSC's SPR in Spermonde Islands is considerably low compared to other fishing grounds in Indonesia. For example, BSC's SPR in Tanah Laut was reported to be 11.1% (Suman et al., 2020), Kasiputeh 13% (Prince, 2014), and Java Sea 15% (Ernawati et al., 2017). However, it is slightly higher when compared with the SPR in Belitung Island which was only 5% (Ernawati et al., 2015). This condition indicates that BSC's populations in Indonesian waters are over-exploited.

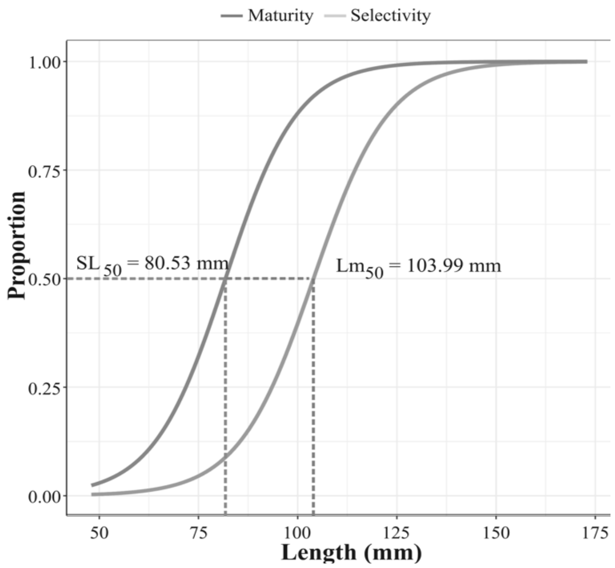

Figure 2. Size of BSC size at first capture (SL_{50}) and first maturity (Lm_{50}) taken from Spermonde

Table 2. Estimated Spawning Potential Ratio

SL_{50}	SL_{95}	F/M	M/K	SPR
80.53	103.7	3.43	0.81	7

Reproductive Potential

Most berried female BSCs were found in the group of class-sized 111-120 mm. Egg mass index was found to be higher as body size bigger, except for those in the class of 111-120 mm (Table 3). Multiple regression analysis describes the relationship between fecundity, carapace width, and gonadal weight following the model below:

$$Y = 28352.211 + 1973.889x_1 + 1734.836x_2 + 47339.950x_3$$

giving medium coefficient determination (R^2= 0.54).

Research results show that BSC fecundity was increasing as gonadal weight increased. It means that gonadal size is proportional to fecundity value (Hamid et al., 2015).

JURNAL BIODJATI

http://journal.uinsgd.ac.id/index.php/biodjati

Still according to Hamid et al. (2015) gonadal weight is the best indicator in fecundity estimation of BSC using linear regression. IRP estimation of the BEF range between 36.39 -795.75. The lowest IRP presents in group class sized 131 – 140 mm and the highest was in the group 111 – 120 mm (IRP = 795.75) (Table 4). This group has the highest number of BEF (36.84%) and it is estimated to produce 38.83% of total egg production with productivity estimation of 1.35.

Size-based management strategies or catch control rules based on Minister Decree No. 1, 2015, Minister Decree No. 56, 2016, and Minister Decree No. 12, 2020 as a reference point (limit reference point) is inadequate to be applied to BSC fisheries in the Spermonde Islands. This reference for MLS potentially removes BEF from group sizes 100 - 110 mm and 111-120 mm which together constitute 57.88% of total BEF and contribute to 65.92% of total egg production in Spermonde Islands. This great proportion of loss will further suppress recruitment to the BSCs stock (Johnson et al., 2010) in Spermonde.

The reproductive productivity value of this research is still within the intervals of other previous studies which ranged from 0.01-2.78 (Table 5). The highest value was found in Mangalore (2.78) (Babu et al., 2006) which occurred to the class size of 110-120 mm which is relatively similar to the class size possessing the highest reproductive productivity in this study. The lowest value was found in East Lampung (0.01) which occurs to the class size of 111-115.99 mm (Zairion et al., 2015).

Table 3. Mean of body weight, egg weight, fecundity and egg mass index based on body size class berried female BSC

Carapace width (mm)	Body weight (g)	Gonadal Weight (g)	Fecundity	Egg Mass Index
91-100	60.42±1.08	6.59±2.94	1,371,369±453,278	10.91
101-110	78.88±11.83	10.39±3.48	1,300,914±401,793	13.17
111-120	99.65±8.85	13.90±3.31	1,324,800±405,330	13.95
121-130	113.28±10.06	17.18±5.43	1,335,163±275,434	15.17
131-140	162.22±58.24	26.33±17.10	1,743,750±351.503	16.23

Table 4. Index of reproductive potential and reproductive productivity of berried female

Description	Size Class (mm)				
	91-100	101-110	111-120	121-130	131-140
Proportion of captured females	13.73	30.07	28.76	21.57	5.88
Proportion of berried female	7.89	21.05	**36.84**	28.95	5.26
Average of fecundity potential	13.71	13.01	11.14	13.35	17.44
Index of reproductive potential	100	555.09	795.75	561.96	36.39
Proportion of egg production	4.89	27.09	38.83	27.42	1.78
Reproductive productivity	0.36	0.90	**1.35**	**1.27**	0.30

Table 5. Productivity of blue swimming crab on some waters in the world

Location	Reproductive Productivity	Source
Spermonde Islands, Indonesia	0.30-1.35	Within this study
East Lampung, Indonesia	0.01-1.86	Zairion et al. (2015)
Mangalore, India	0.35-2.78	Babu et al. (2006)
Wallis Lake, Australia	0.32-1.56	Johnson et al. (2010)
Karnataka Waters, India	0.10-2.20	Sukumaran & Neelakantan (1997)

Alternative Management

Small islands constituting Spermonde such as Salemo, Saugi, Sagara, and Sabangko are the central of BSC production in South Sulawesi. BSC fishery started 35 years ago and approximately 80% of local people are BSC fishermen. Additionally, the BSCs meat processing center is also located in this region employing ± 60 people. Fishery-related activities from fishing to BSC meat processing offer the highest contribution to the economic growth of the Islands. In conjunction with market demand growth, exploitation eventually becomes very intense.

According to Musick (1999) criteria, BSCs in Spermonde Islands are highly resilient with annual fecundity >10,000 and K coefficient >0.30. Apart from that, BSC in this region has a productivity value >1 which suggests that female BSCs are particularly productive. In this study, the lowest fecundity is found to be 1,300,914 ± 401,793 and the yearly K coefficient is 1.03/year^{-1}. This high resilience might contribute to BSCs being lasted until the present. However, if exploitation continues without sustainable management and reservation based on the carrying capacity, the population can be at risk (Nurdin et al., 2021).

From the findings, the management strategy that can be applied to the crab fishery in the Spermonde Islands is MLS >120 mm. By this means, BEF which was found to be abundant at class 111-120 will be allowed to reproduce. It can also protect young BSC and improve egg production (Johnson et al., 2010; Zairion et al., 2015; Fujaya et al., 2019). Further, a BSC protection area can also be established in coral reefs and seagrass ecosystems as the BSC spawning grounds. The existence of the BSC protection area in the Spermonde Islands is beneficial for the spill over and export of planktonic eggs and/or larvae from the protected area to the surroundings (Nurdin et al., 2022).

CONCLUSION

BSC stock status in Spermonde is overfishing with an SPR value of 7%. This value is far below the biological reference points. To maintain BSC fisheries in the region, it is important to register a minimum legal size of >120 mm. This allows protection to BSC female berried and improves egg production. In turn, it will contribute to recruitment and resolve overfish.

AUTHOR CONTRIBUTION

The contributions of each author, including conceptualization, methodology, conducted the research, analysis data, and manuscript preparation. M.S.N., A.P.P. and DYS Conceptualization. M.S.N., R.Y.V., T.F.H., and F.A. Methodology. M.S.N., A.P.P. and D.Y.S. Conducted the Research. M.S.N., A.P.P., D.Y.S. and R.Y.V. Analysis Data and Writing Orig-

inal Draft. F.A. and T.F.H. Helped in manuscript preparation.

ACKNOWLEDGMENTS

We acknowledge the contribution of Hermiyanti, Muh. Fuad Affany, Junardiawan Sandi Ode and Nurwahidah for data collections.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

Achmad, D. S., Sudirman, Jompa, J. & Nurdin, M. S. (2020). Estimating the Catchable Size of Orange-spotted Grouper (Epinephelus coioides) in Kwandang Bay, Gorontalo Utara District, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 473, 012133. DOI: 10.1088/1755-1315/473/1/012133.

Adam, A., Firman, F. & Anwar, A. (2016). Model Pengelolaan Perikanan Rajungan dalam Meningkatkan Pendapatan Nelayan di Kabupaten Pangkep. *Jurnal Galung Tropika*, 5(3), 203–209. DOI: 10.31850/jgt.v5i3.190.

Anand, T. & Soundarapandian, P. (2011). Sea Ranching of Commercially Important Blue Swimming Crab Portunus Pelagicus (Linnaeus , 1758) in Parangipettai Coast. *Society for Science and Nature*, 2(2), 215–219.

Babu, K. V. R., Benakappa, S., Mohan, K. C. & Naik, A. T. R. (2006). Breeding biology of Charybdis (Charybdis) feriatus (Linnaeus) from Mangalore. *Indian Journal of Fisheries Fish*, 53(2), 181–184.

Castiglioni, D. D. S. & Negreiros-Fransozo, M. L. (2006). Physiologic Sexual Maturity of the Fiddler crab Uca rapax (Smith, 1870) (crustacea, ocypodidae) from Two Mangroves in Ubatuba, Brazil. *Brazilian Archives of Biology and Technology*, 49(2), 239–248. DOI: 10.1590/S1516-89132006000300009.

Chande, A. & Mgaya, Y. (2004). The Fishery of Portunus pelagicus and Species Diversity of Portunid Crabs along the Coast of Dar es Salaam, Tanzania. *Western Indian Ocean Journal of Marine Science*, 2(1), 75–84. DOI: 10.4314/wiojms.v2i1.28431.

De La Cruz, J. (2015). The Blue Swimming Crab (Portunus pelagicus) Fishery of Eastern Visayas, Philippines. *Philippine Journal of National Science*, 20(1), 25–45.

Ernawati, T., Boer, M. & Yonvitner, Y. (2014). Biologi Populasi Rajungan (Portunus pelagicus) di Perairan Sekitar Wilayah Pati, Jawa Tengah. *BAWAL Widya Riset Perikanan Tangkap*, 6(1), 31–40. DOI: 10.15578/bawal.6.1.2014.31-40.

Ernawati, T., Kembaren, D. D. & Wagiyo, K. (2015). Penentuan Status Stok Sumberdaya Rajungan (Portunus pelagicus Linnaeus, 1758) dengan Metode Spawning Potential Ratio di Perairan Sekitar Belitung. *Jurnal Penelitian Perikanan Indonesia*, *21*(2), 63–70. DOI: 10.15578/jppi.21.2.2015.63-70.

Ernawati, T., Sumiono, B., & Madduppa, H. (2017). Reproductive Ecology, Spawning Potential, and Breeding Season of Blue Swimming Crab (Portunidae: Portunus pelagicus) in Java Sea, Indonesia. *Biodiversitas*, 18(4), 1705–1713. DOI: 10.13057/biodiv/d180451.

Fujaya, Y., Hidayani, A. A., Dharmawan, D., Alsani, A. & Tahya, A. M. (2019).

Analysis of Genetic Diversity and Reproductive Performance of the Blue Swimming Crab (Portunus pelagicus) from Several waters in Indonesia. *AACL Bioflux*, 12(6), 2157–2166.

Hamid, A., Wardiatno, Y., Lumban Batu, D. T. F., & Riani, E. (2015). Fekunditas dan Tingkat Kematangan Gonad Rajungan (Portunus pelagicus) Betina Mengerami Telur di Teluk Lasongko, Sulawesi Tenggara. *BAWAL Widya Riset Perikanan Tangkap*, 7(1), 43–50. DOI: 10.15578/bawal.7.1.2015.43-50.

Haser, T. F., Nurdin, M. S., Supriyono, E., Radona, D., Azmi, F., Nirmala, K., Widanarni, W., Prihadi, T. H., Budiardi, T. & Valentine, R. Y. (2022). Reproductive Biology of Mahseer (Tor tambroides) from Atu Suasah and Lawe Melang Rivers in Aceh Province to Support Sustainable Fisheries Management. *Pakistan Journal of Zoology*, 54(2), 561–567. DOI: 10.17582/journal.pjz/20200831050805.

Hidayani, A. A., Fujaya, Y., Trijuno, D. D. H., Rukminasari, N. & Alimuddin, A. (2020). Genetic diversity of blue swimming crab (Portunus pelagicus linn 1758) from indonesian waters (sunda and sahul shelf, wallacea region): Phylogenetic approach. *Biodiversitas*, 21(5), 2097–2102. DOI: 10.13057/biodiv/d210537.

Hordyk, A., Ono, K., Valencia, S., Loneragan, N. & Prince, J. (2015). A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. *ICES Journal of Marine Science*, 72(1), 217–231. DOI: 10.4135/9781412953924.n678.

Hutapea, B. K., Nugraha, E., Prayitno, H., Choerudin, H., Suharyanto, S., Sutisna, D. H., Effendy, A. & Bashit, A. (2019). Sustainability of Blue Swimming Crab *Portunus pelagicus* Commodity in Banten Bay, Indonesia. *AACL Bioflux*, 12(3), 777–785.

Ihsan, I., Wiyono, E. S., Wisudo, S. H. & Haluan, J. (2014). Pola Musim dan Daerah Penangkapan Rajungan (Portunus pelagicus) di Perairan Kabupaten Pangkep. *Marine Fisheries : Journal of Marine Fisheries Technology and Management*, 5(2), 193–200. DOI: 10.29244/jmf.5.2.193-200

Ihsan, I., Wiyono, E. S., Wisudo, S. H., & Haluan, J. (2015). Alternatif Pengelolaan Perikanan Rajungan (Portunus pelagicus) di Perairan Kabupaten Pangkep Sulawesi Selatan. *Jurnal Kebijakan Perikanan Indonesia*, 7(1), 25–36. DOI: 10.15578/jkpi.7.1.2015.25-36.

Johnson, D. D., Charles, G. A. & Macbeth, W. G. (2010). Reproductive Biology of Portunus pelagicus in a South-East Australian Estuary. *Journal of Crustacean Biology*, 30(2), 200–205. DOI: 10.1651/08-3076.1.

Johnston, D., Harris, D., Caputi, N. & Thomson, A. (2011). Decline of A Blue Swimmer Cab (Portunus pelagicus) fishery in Western Australia—History, Contributing Factors and Future Management strategy. *Fisheries Research*, 109(1), 119–130. DOI: 10.1016/j.fishres.2011.01.027.

Josileen, J. (2013). Fecundity of the Blue Swimmer Crab, *Portunus pelagicus* (Linnaeus, 1758) (Decapoda, Brachyura, Portunidae) Along the Coast of Mandapam, Tamil Nadu, India. *Crustaceana*, 86(1), 48–55. DOI: 10.1163/15685403-00003139.

Juwana, S., A., A. & Ruyitno. (2009). Evaluasi Potensi Ekonomis Pemacuan Stok

Rajungan di Perairan Teluk Klabat, Pulau Bangka. *Oseanologi dan Limnologi di Indonesia*, 35(2), 107–128.

Kembaren, D. D. & Ernawati, T. (2015). Dinamika Populasi dan Estimasi Rasio Potensi Pemijahan Udang Jerbung (Penaeus merguiensis deMan, 1907) di Perairan Teluk Cenderawasih dan Sekitarnya, Papua. *Jurnal Penelitian Perikanan Indonesia*, 21(3), 201–210. DOI: 10.15578/jppi.21.3.2015.201-210.

Kembaren, D. D., Zairion, Z., Kamal, M. M. & Y, W. (2018). Abundance and Spatial Distribution of Blue Swimming Crab (Portunus pelagicus) Larvae During East Monsoon in the East Lampung waters, Indonesia. *Biodiversitas*, 19(4), 1326–1333. DOI: 10.13057/biodiv/d190420.

King, M. (1995). *Fisheries Biology, Assessment and Management: Second edition* (Second). Blackwell Publishing

Lai, J. C. Y., Ng, P. K. L. & Davie, P. J. F. (2010). A revision of the P*ortunus pelagicus* (Linnaeus, 1758) species complex (Crustacea: Brachyura: Portunidae), with the Recognition of Four Species. *Raffles Bulletin of Zoology*, 58(2), 199–237.

Laisow, H. N. H. (2013). *Pendugaan Beberapa Parameter Dinamika Populasi Kepiting Rajungan Portunus pelagicus (Linnaeus, 1758) di Perairan Sekitar Pulau Saugi, Kabupaten Pangkajene dan Kepulauan*. Hasanuddin University.

Macale, A. M. B. & Nieves, P. M. (2019). Stakeholders' Perception on the Status of Blue Swimming Crabs P*ortunus pelagicus* (Linnaeus, 1758) and Performance of Lying-in Hatchery Concept in San Miguel Bay, Philippines. *AACL Bioflux*, 12(2), 413–416.

Muawanah, U., Huda, H. M., Koeshendrajana, S., Nugroho, D., Anna, Z., Mira, M. & Ghofar, A. (2017). Keberlanjutan Perikanan Rajungan Indonesia : Pendekatan Model Bioekonomi Sustainability of Indonesian Blue Swimming Crabs : the Bioeconomic Model Approach. *Jurnal Kebijakan Perikanan Indonesia*, 9(2), 71–83. DOI: 10.15578/jkpi.9.2.2017.71-83.

Musick, J. A. (1999). Criteria to Define Extinction Risk in Marine Fishes: The American Fisheries Society Initiative. *Fisheries*, *24*(12), 6–14. DOI:10.1577/1548-8446(1999)024<0006:ctderi>2.0.co;2.

Nurdin, M. S., Ali, S. A. & Satari, D. Y. (2015). Mortalitas dan Laju Eksploitasi Rajungan (Portunus pelagicus) di Perairan Pulau Salemo Kabupaten Pangkajene Kepulauan. *Jurnal Ipteks Pemanfaatan Sumberdaya Perikanan*, 2(4), 316–321. DOI: 10.20956/jipsp.v2i4.1901.

Nurdin, M. S., Ali, S. A. & Satari, D. Y. (2016a). Sex Ratio And Size At First Maturity Of Blue Swimming Crab (Portunus pelagicus) Salemo Island Pangkep Regency. *ILMU KELAUTAN: Indonesian Journal of Marine Sciences*, 21(1), 17–22. DOI: 10.14710/ik.ijms.21.1.17-22.

Nurdin, M. S., Ali, S. A., & Satari, D. Y. (2016b). Distribusi Ukuran dan Pola Pertumbuhan Rajungan (Portunus pelagicus) di Pulau Salemo Kabupaten Pangkajene Kepulauan. *Simposium Nasional Kelautan dan Perikanan*, 315–322.

Nurdin, M. S., Azmi, F., & Haser, T. F. (2021). Gonad Maturity and Gonadal Somatic Index of Blue Swimming Crab *Portunus pelagicus* Harvested from Spermonde Archipelago, South Sulawesi, Indonesia. *Aceh Journal of Animal Science*, 6(1), 23–26. DOI: 10.13170/ajas.5.2.19187.

Nurdin, M. S., Azmi, F. & Haser, T. F. (2022).

A Marine Protected Area Design to Protect the Blue Swimming Crab Population in Salemo Island, Spermonde Archipelago. *Indonesian Fisheries Research Journal*, 28(1), 41–51. DOI: 10.15578/ifrj.28.1.2022.41-51.

Nurdin, M. S., Bakri, E., Haser, T. F. & Hasanah, N. (2020). The Relationship Between Blue Swimming Crab (Portunus pelagicus) Abundance and Environmental Parameters in Spermonde Archipelago. *Tomini Journal of Aquatic Science*, 1(1), 8–15. DOI: 10.37905/tjas.v1i1.5917.

Nurdin, M. S., Haser, T. F., Azmi, F. & Hasanah, N. (2019). Penetapan Strategi Pengelolaan Penangkapan Berdasarkan Studi Distribusi Spasial dan Temporal Ukuran Rajungan Betina yang Mengerami telur. *Jurnal Ilmiah Samudra Akuatika*, 3(2), 14–20.

Pauly, D. (1980). On the Interrelationships Between Natural Mortality, Growth Parameters, and Mean Environmental Temperature in 175 Fish Stocks. *ICES Journal of Marine Science*, 39(2), 175–192. DOI: 10.1093/icesjms/39.2.175.

Permatahati, Y. I., Bugis, N. N., Sara, L., & Hasuba, T. F. (2020). Stock Status of Blue Swimming Crab (Portunus pelagicus Linnaeus, 1758) in Tiworo Strait waters, Southeast Sulawesi, Indonesia. *Ilmu Kelautan: Indonesian Journal of Marine Sciences*, 25(2), 85–90. DOI: 10.14710/ik.ijms.25.2.85-90.

Prince, J. (2014). *A Technical Report on an SPR@Size assessment of the Blue Swimmer Crab fishery in Southeast Sulawesi*. Retrived from http://www.committedtocrab.org.

Prince, J., Creech, S., Madduppa, H., & Hordyk, A. (2020). Length based assessment of spawning potential ratio in data-poor fisheries for blue swimming crab (Portunus spp.) in Sri Lanka and Indonesia: Implications for sustainable management. *Regional Studies in Marine Science*, 36, 101309.DOI: 10.1016/j.rsma.2020.101309.

Sara, L., Astuti, O., Muzuni, & Safilu. (2019). Status of blue swimming crab (Portunus pelagicus) population in southeast sulawesi waters, Indonesia. *AACL Bioflux*, 12(5), 1909–1917.

Sara, L., Muskita, W. H., Astuti, O., & Safilu. (2017). Some population parameters of blue swimming crab (Portunus pelagicus) in Southeast Sulawesi waters, Indonesia. *AACL Bioflux*, 10(3), 587–601.

Sparre, P., & Venema, S. C. (1998). Introduction to tropical fish stock assessment - Part 1: Manual. In *FAO*.

Sukumaran, K. K., & Neelakantan, B. (1997). Sex ratio, fecundity and reproductive potential in two marine portunid crabs, Portunus (Portunus) sanguinolentus (Herbst) and Portunus (Portunus) pelagicus (Linnaeus) along the Karnataka coast. *Indian Journal of Marine Sciences*, 26(1), 43–48. DOI: 10.1016/S0967-0653(98)80678-9.

Suman, A., Hasanah, A., Pane, A. R. P., & Lestari, P. (2020). Stock status of blue swimming crab (Portunus pelagicus) in Tanah Laut, South Kalimantan, and its adjacent waters. *Indonesian Fisheries Research Journal*, 26(1), 51–60. DOI: 10.15578/ifrj.26.1.2020.51-60.

Sunarto, S., Dedi, S., Riani, E., & Martasuganda, S. (2010). Performa Pertumbuhan dan Reproduksi Rajungan (Portunus pelagicus) di Perairan Pantai Kabupaten Brebes. *Omni-Akuatika*, 9(11), 70–77. DOI: 10.1177/030751335404000106.

Susanto, A., Irnawati, R., Mustahal, Nurdin, H. S., Marliana, Y., Kurniasih, A., Widowati, N., Murniasih, T. R., & Affandi, N. (2019). Meta analisis pengaruh tekanan penangkapan terhadap ukuran rajungan (Portunus pelagicus) di Teluk Banten. *Marine Fisheries*, 10(2), 153–163. DOI: 10.29244/jmf.v10i2.29483.

Watanabe, T. T., Sant'Anna, B. S., Hattori, G. Y., & Zara, F. J. (2014). Population biology and distribution of the portunid crab Callinectes ornatus (Decapoda: Brachyura) in an estuary-bay complex of southern Brazil. *Zoologia*, 31(4), 329–336. DOI: 10.1590/S1984-46702014000400004.

Wiyono, E. S., & Ihsan, I. (2015). The dynamic of landing blue swimming crab (Portunus pelagicus) catches in Pangkajene Kepulauan, South Sulawesi, Indonesia. *AACL Bioflux*, 8(2), 134–141.

Wujdi, A., & Wudianto. (2015). Status Stok Sumberdaya Ikan Lemuru (Sardinella lemuru Bleeker, 1853) di Perairan Selat Bali. *Jurnal Penelitian Perikanan Indonesia*, 21(4), 253–260. DOI: 10.15578/jppi.21.4.2015.253-260.

Yoda, M., & Yoneda, M. (2009). Assessment of reproductive potential in multiple-spawning fish with indeterminate fecundity: A case study of yellow sea bream Dentex hypselosomus in the East China Sea. *Journal of Fish Biology*, 74(10), 2338–2354. DOI: 10.1111/j.1095-8649.2009.02246.x.

Zairion, Z., Wardiatno, Y., Boer, M., & Fahrudin, A. (2015). Reproductive biology of the blue swimming crab portunus pelagicus (Brachyura: Portunidae) in east Lampung waters, Indonesia: Fecundity and reproductive potential. *Tropical Life Sciences Research*, 26(1), 67–85.

Zar, J. H. (2010). *Biostatistical analysis*. USA: Prentice Hall.