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Measured Catch Blue swimming crab (*Portunus pelagicus*) Based on the Walter-Hilbron Non-Equilibrium Model, Bangkalan Madura Waters

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ABSTRACT

Blue swimming crab (*Portunus pelagicus*) as an export product relies primarily on catches, one of which is in Fishery Management Area 712, where this research was carried out. The frequency of fishing efforts continues to increase because of its high economic value; however, there is not much information about the resource as a basis for following up on Law Number 45 of 2009 concerning measurable fish catches based on control output. A descriptive research method to map crab resources was found on the "Walter-Hilbron Non- Equilibrium Model" The results showed that the maximum catch production (CMSY) was 63,886.114 kg/year with standard Trammel net fishing gear, intrinsic growth was 50.91%/year, the carrying capacity of the waters was 50195,336 Kg/year, dominant species was *Portunus pelagicus*, Optimum effort (Eopt) 6363750 trip/year with a resource potential of 25097.668 kg/year. This information forms the basis for resource mapping to increase inclusive and sustainable economic growth.

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1. Introduction

To realize an independent Indonesia in food, it is necessary to establish sustainable resources with integrated supervision so that it has an impact on improving the welfare of the fishing community. The indicators are that the proportion of catches within safe biological limits of 64% - 80%, as well as the achievement of the strategic target of WPP (Fisheries Management Area), which is a pilot model for strengthening governance in 11 Fishery Management Areas (Minister of Marine Affairs and Fisheries Regulations Number 12/2014) where Rajungan (*Portunus pelagicus*) which is the object of research with the largest catch of one of its catchments is in WPP 712 where the location of this research is carried out.

The problem is that the map of the potential resources of the captured crab (*Portunus pelagicus*) is not yet known, according to Minister of Marine Affairs and Fisheries Regulations Number 70/2016 concerning the prohibition of catching crabs (Portunus spp) in Indonesian waters. There is the Minister of Marine Affairs and Fisheries Regulation Number 17 of 2021 concerning the Management of Lobster, Crab, and Crab in the territory of the Republic of Indonesia to maintain its sustainability and to Minister of Marine Affairs and Fisheries Regulations No. 70/KEPMEN-KP/2016 concerning the crab management plan in WPP RI to create a sustainable crab resource. The condition of the crab resource estimation based on to Minister of Marine Affairs and Fisheries Regulations No. 50/2017 specifically for Fisheries Management Area RI 712, crab potential 23,508 (tons) with JTB 18,806 (tons) utilization rate of 0.65, while crab production in 2020 is 15,923.1 (tons), this catch condition tends to decrease compared to the previous three years, where catch production the highest came from Bangkalan.

The high demand and favorable prices have resulted in the increased exploitation of crab catches, plus the production has come from wild catches. The amount of crab exported to the United States is 89% because the taste is very popular with the local community. Bangkalan Madura is the largest crab producer in Indonesia; its production fluctuates, influenced by the presence and limited stock, recruitment capacity, and high exploitation intensity with shallow coastal to deep-sea catchment areas, while the crab cultivation program has not been maximized. While Portunus trituberculatus is the giant crab in the world, its catch is done commercially worldwide. The largest total catch (95%) occurs in China, including the East China Sea, Yellow Sea, and Bohai Sea (Liu, S., 2013). This condition is different from the catch in the Sinai Peninsula of Egypt, and the research shows that the crab catch is dominated by Portunus pelagicus (85%) and Callinectes sapidus (15%).

The absence of management in utilizing these resources results in the depletion of stocks and affects the fishermen's economy. Information about the resources is limited. Therefore various options for managing stock status are needed. A coastal area is vital for crabs because it is a nursery ground supporting stock recruitment. The Marine Protected Area (MPA) (Botsford LW et al., 2013) states that the fishery refugia area is ideal for managing crab fisheries using an ecosystem approach. The spatial distribution pattern of crabs in the Gulf of Saudi Arabia is mainly near the coast, laying eggs throughout the year, with at least three peaks: winter, late spring-early summer, and autumn (Rabaoui, L., 2021). The female crab (Portunus pelagicus) with dark gray eggs is found in the depth range of 0.35 to 31.0 m, the substrate is sandy to muddy, and the presence of different levels of embryo development indicates an expansive distribution habitat from shallow water to deep water (Bay, L. et al., 2016).

Meanwhile, natural mortality and catch will reduce the amount of stock (King, M., 1995), fishing gear that can affect ecosystem fertility (Tran P.D. et al., 2020), and even research on environmental factors in general additive models in Taiwanese waters. , stated that the concentration of chlorophyll-a (Chl-a) and demersal temperature affected the catch rate of the crab (Portunus pelagicus) (Naimullah, M. et al.; (2020). However, changes in environmental conditions in Western Australian waters affect two determinants of CPUE, including fishing power (q) and abundance (N) (Johnston, D. J., et al., (2021), a similar study with an ecosystem component approach based on participatory multi-criteria analysis (MCDA) in New South Wales (NSW) Australia conducted by (Fowler, A. M., et al., (2021). Even in the rainy season (low salinity), the concentration of metal content in the crab organ (Portunus pelagicus) is higher than in the non-monsoon season. Therefore in the future, microcosm experiments are needed to test the effect of salinity fluctuations (Karar S. et al., 2019). Research in crab cultivation (Portunus pelagicus) uses a temperature difference variable before molting with different acclimatization temperatures. It turns out that temperature tolerance affects the locomotor activity of the crab (Portunus pelagicus) (Azra, M. N. et al., 2019). Meanwhile, the management of crab fisheries based on the spatial zoning of the Pangkep waters of South Sulawesi was carried out by (Ihsan., et al., 2019), stating that the critical period occurred in vase zoea, megalopa, and juveniles from May to October with peak spawning in August. Research on the Persian Gulf's crab stock conditions (Portunus pelagicus) was conducted (Giraldies,

B. W. et al., 2016). It turned out that taxonomic and ecological descriptions influenced crab stock management.

Therefore the information on biological, ecological, and taxonomic factors was comprehensively used as the basis of strategies for managing this species in the Arabian Gulf. Even in Cockburn Sound, Western Australia, there has been a significant decline in stocks since 2000. This condition resulted in the closure of the catchment area for three years to provide spawning opportunities at least once to increase nursery stocks (Johnston D. et al., 2011). Different researchers regarding the use of capture technology in East China Sea waters using a trap model and the number of escape ventilation with the aim that the size of the crab (Portunus pelagicus) caught meets legal standards, the results are not significant on the size selectivity between the two types of traps (Zhang, T. et al., 2021). The problem is sustaining the current Rajungan resources regarding existing resource stocks, utilization level maps, types of standard fishing gear, and fishing methods based on resource criteria. This study combines population dynamics and technical management of capture management. This initial information is needed primarily as a legal basis for following up on Minister of Marine Affairs and Fisheries Regulations No. 70/KEPMEN-KP/2016 concerning the crab management plan in WPP RI to create a sustainable crab resource. The research objective is to map crab resources using the "Non-Equilibrium Walter-Hilbron Model."

2. Material and methods

This research was conducted using a descriptive method, and the sampling technique was carried out by purposive sampling of the fishermen's catches. The fishermen in question were crab fishermen with fishing gear and several fisherman community leaders and personnel/officers working at the Marine and Fisheries Service. This follows the research objective: to analyze and map sustainable crab fishing resources based on the "Non-Equilibrium Walter-Hilbron" model, which includes the following variables: maximum catch, exploitation efforts, potential reserves of resources, and standard crab fishing gear and their catching capabilities. This study used primary and secondary data, primary data obtained from interviews and direct observations in the field, including crab fishermen (initial survey of fishing gear used, clitic nets, fixed gillnets, traps, trammel nets, and several other fishing gears). In contrast, secondary data is the production of crab catch, the effort to catch for the last 14 (ten years) years. The research chart and its stages are shown in Figure 1.

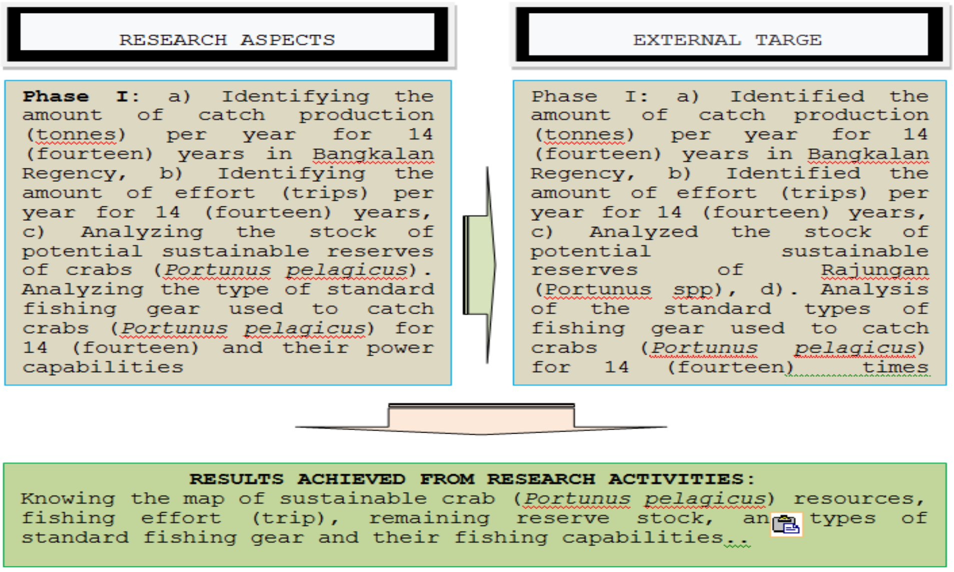

Figure 1. Research stage

This study focused on mapping the limits of the sustainable catch of crabs (Portunus pelagicus), allowed exploitation efforts, residual resource reserves, and determination of standard crab fishing gear and their fishing power as the basis for follow-up information on the Minister of

Marine Affairs and Fisheries Regulations No. 70/KEPMEN-KP/2016 concerning the crab management plan in WPP RI to create a sustainable crab resource. In detail, the implementation of the research is described in Table 1.

Table 1. Implementation of the research

No.	Destination	Method	Input	Parameter	Analysis	Output
1.	Get maximum production of crab catches in Bangkalan Regency;	Survey	Time series data & catch production in Bangkalan Regency, Madura; Time series data & production of catches/units of fishing gear in Bangkalan Regency, Madura;	The amount of production of crab catch (*Portunus pelagicus*) for the last ten to 14 years in Bangkalan Regency,	The Walter-Hilbron Method	The maximum production of crab catches;
2.	Get the amount of effort to catch crabs / trip in Bangkalan Regency;	Survey , Analysis	Time series data & production of catches/units of fishing gear in Bangkalan Regency, Madura;	The amount of production of crab catch (*Portunus pelagicus*) for the last ten to 14 years in Bangkalan Regency,	The Walter-Hilbron Method	The amount of production / effort to catch crabs / trip effort;
3.	Obtaining a stock of potential sustainable reserves of Rajungan (*Portunus pelagicus*), in Bangkalan Regency,	Survey , Analysis	Time series data & production of catches/units of fishing gear in Bangkalan Regency, Madura;	The amount of production of crab catch (*Portunus pelagicus*) for the last ten to 14 years in Bangkalan Regency, Bangkalan,	The Walter-Hilbron Method	The size of the potential stock of the sustainable reserve of crab (*Portunus pelagicus*), Bangkalan Regency for the next 14 years,
4.	Analyzing the standard type of fishing gear for crabs (*Portunus pelagicus*) and their catching power in Bangkalan Regency,	Survey , Analysis	Time series data & production of catches/units of fishing gear in Bangkalan Regency, Madura;	The amount of production of crab catch (*Portunus pelagicus*) for the last ten to 14 years in Bangkalan Regency, Bangkalan,	The Walter-Hilbron Method	The size of the potential stock of the sustainable reserve of crab (*Portunus pelagicus*), Bangkalan Regency for the next 14 years, .

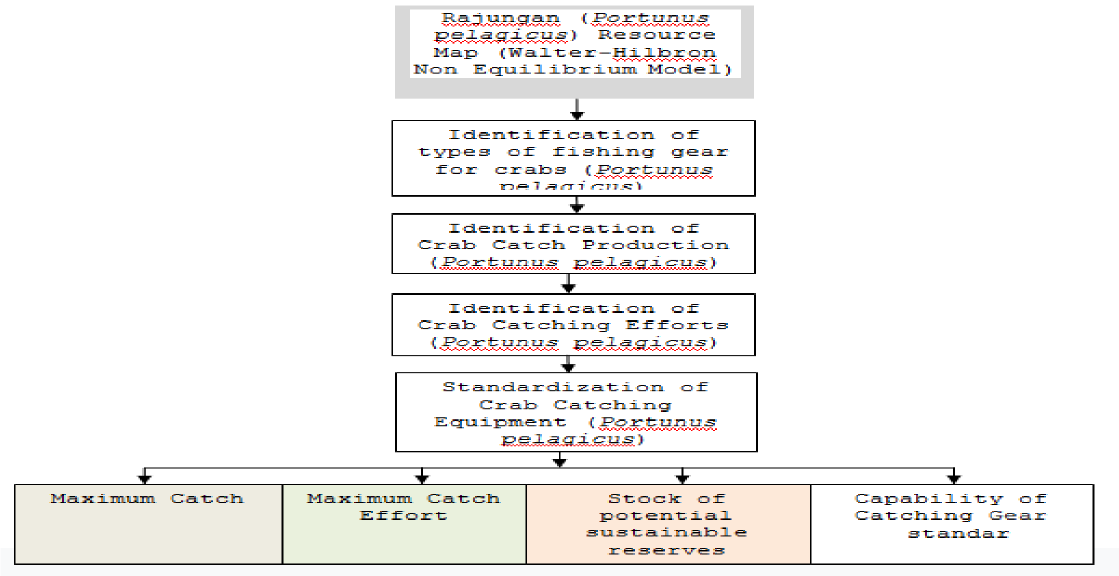

Figure 2. Research flowchart

Walter-Hilbron analysis model

$$P_{(t+1)} = P_t\,[rxP_t - (r/k)XP^2_t] - qxE_txP_t \ldots\ldots\ldots\ldots\ldots(1)$$

Information :

$P_{(t+1)}$: The amount of biomass stock t+1

P_t : The amount of biomass stock t

r :Intrinsic growth rate of biomass (constant);

k :Natural carrying capacity
q :Catchability Coefficient
Et :Number of biomass exploitation efforts t

Equation W-H I :

U_t+1/U_t = 1+r- [r/k*q] x U_t-qxE_t .... (2)

Equation W-H 2:

$U_{t+1}-U_t = r*U_t[r/k*q] \times U_t^2 - q \times U_t \times E_t$ .... (3)

The number of catches C(MSY) and effort (E(opt)) from CPUE analysis results in "equilibrium" (YMSY) conditions was estimated by the following equation:

C_{MY} =1/4 rk
E_{opt} =r/2q
U_t = qxk/2
In[$\grave{U}_{t+1}/U_t$]=r-[q*$\grave{E}_t$+ $\grave{E}_{t+1}$/2]-[(r/qk)*($\grave{U}_t$+ $\grave{U}_{t+1)/2}$]

Estimating parameters under "equilibrium" conditions

C_{MY} = 1/4 rk
E_{opt} = r/2q
U_t = qxk/2
B_e = k/2

where :

Ut = Year's catch
C_{MY} = Maximum sustainable catch;
E_{opt} = Sustainable catch efforts;
B_e = Sustainable reserve potential;
R = intrinsic growth rate (stable);
K = environmental carrying capacity;
q = Catching ability

To find out the utilization rate by comparing the exploitation rate (TE) (%) with the average volume of the last ten years (Ct) divided by the number of allowable catches (JTB) (80), the equation was as follows.

TE = C_t/JTB x 100% ....(4)

Meanwhile, the dynamics of the reserve stock (Hilborn and Walters, 1992) were related to the catch; is the biomass (B) for the following year B(t+1) can be estimated from the biomass value for the next year (Bt) plus the growth of biomass and minus the exploited biomass multiplied by the effort (ft) to control the biomass(t); equation as follows:

$B_{t+1}=B_t+(rB_t-(rB_t-(r/k)B_t^2)-qf_t\, b_t$ ....(5)

Alternative scenarios for sustainable fishing management based on the current condition of fishing gear, the Number of fishing gear in "equilibrium" condition, and the Number of catches according to the JTB rules (80% potential) and PERMEN-KP Number 70/KEPMEN-KP/2016 concerning Crab Management Plans in WPP RI.

3. Results and Discussion

3.1. Result

Administratively, Bangkalan Regency is included in the East Java Province. Bangkalan District consists of 18 sub-districts including: - Kamal District - Labang District - Kwanyar District - Modung District - Blega District - Konang District - Galis District - Tanah Merah District - Tragah District - Socah District - Bangkalan District - Burneh District - Arosbaya District - District Geger - Kokop District - Tanjung Bumi District - Sepulu District - Klampis District and 332 villages/kelurahan with a total area of 2,093.47 km^2. The district government center is located in Bangkalan City, precisely in Bangkalan City District, where the sea catch includes Tanjung Bumi, Klampis, Kwanyar, and Bangkalan districts. Meanwhile, the number of fishermen and capture fishery production (tonnes) in each sub-district in 2020-2021 is shown in Table 2.

Table 2. Number of Fishermen and Capture Fishery Production (tonnes)/District/Year from 2020 to 2021 in Bangkalan Regency.

No.	Subdistrict	Number of Fishermen Catch		Total Production (tons)	
		2020	2021	2020	2021
1.	Kamal	338	363	181.10	184.10
2.	Labang	522	466	1.173.30	1.183.70
3.	Kwanyar	1571	1345	3.625.80	3.656.30
4.	Modung	272	329	22.10	26.30
5.	Blegah	–	–	–	–
6.	Konang	–	–	–	–
7.	Galis	–	–	–	–
8.	Tanah merah	–	–	–	–
9.	Tragah	–	–	–	–
10.	Socah	799	799	2.946.00	2.973.00
11.	Bangkalan	942	1078	3.441.30	3.471.20
12.	Burneh	–	–	–	–
13.	Arosbaya	772	772	3.102.40	3.130.20
14.	Geger	–	–	–	–
15.	Kokop	–	–	–	–
16.	Tanjungbumi	1321	1321	5.529.90	5.576.50
17.	Sepulu	446	446	1.981.50	1.999.10
18.	Klampis	971	939	4.067.100	4.103.40
	Kab.Bangkalan	7954	7858	26.070.40	26.304.20

Source: Bangkalan Regency Fisheries Service 2021

3.1.1. Climate Physical Condition

Weather conditions at the research site included rainfall, temperature, humidity, and air pressure parameters. While the average air temperature was 22°–34°C, humidity levels were 68%–83%. In the dry season in May-October and the rainy season November-April, the annual rainfall was between 1,200-1,800 mm per year.

Rajungan was a destination for fishing species. Their habitat was at the bottom of the beach with sand, sandy mud, to coral as a substrate, specifically for the *Portunus pelagicus* (swimming crab) species that can swim near the surface (1-60 m depth). The male species were more significant and brighter in color than the female. Guayana from estuary areas to high salinity waters. After becoming young crabs to adulthood and entering the mating period, the female crabs migrate again to high-salinity waters to incubate their eggs. The dominant fishing gear used to catch crabs include Payang, drift gill nets, fixed gill nets, Trammel nets, Sero, Bubu, and other traps, with the number of trips for each fishing gear in Table 3.

Table 3. Number of Trips/Types of Fishing Crab (*Portunus pelagicus*) from 2008 to 2021

Year	Number of Trips/Type of Fishing Equipment Dominant Year 2008-2021						
	Paying	Drifting gill nets	Fixed gill net	Trammel Net	Sero	Bubu	Another trap
2008	35835	126006	71218	48629	56041	0	121009
2009	74289	135359	70688	0	55208	0	128385
2010	63925	117248	61601	0	47285	0	103121
2011	28260	279225	0	433000	0	0	0
2012	34383	342516	0	450320	0	0	0
2013	18055	191520	96480	476300	0	0	7308
2014	25591	323901	134142	490156	0	0	0
2015	4710	0	142200	199180	0	1050	0

2016	5838	0	203109	249047	0	700	0
2017	6657	0	291229	199360	0	8656	0
2018	5086	0	255189	267328	0	69811	0
2019	1256	0	81400	83280	0	21480	0
2020	1413	0	81400	83280	0	21480	0
2021	2025	7068	0	6933	0	7848	0
Total	307323	1522843	1488656	2986813	158534	131025	359823

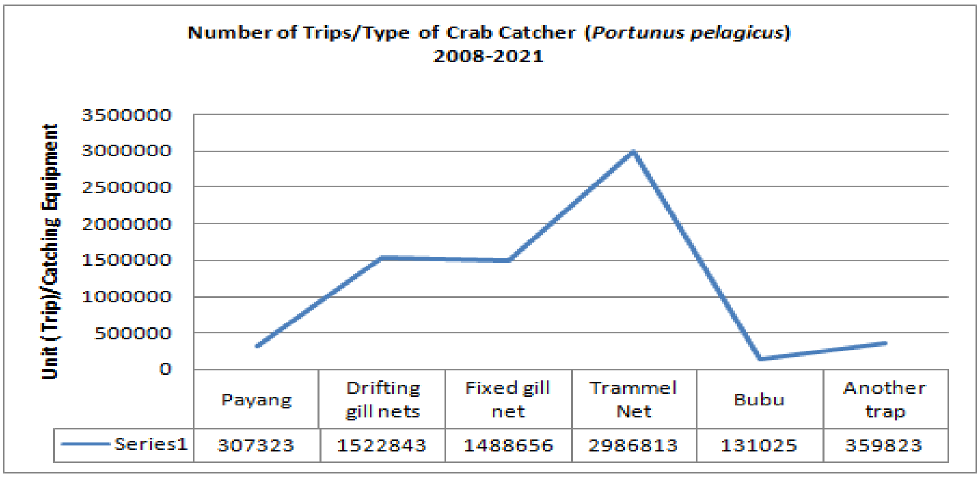

Figure 3. Number of Trips/Types of Fishing Gear for Crab (*Portunus pelagicus*) from 2008 to 2021.

The number of trips/types of crab fishing gear is shown in Figure 3. Trammel net fishing gear had the highest number of fishing trips compared to other fishing gear, while the production of the most catches based on the type of fishing gear was shown in Figure 4.

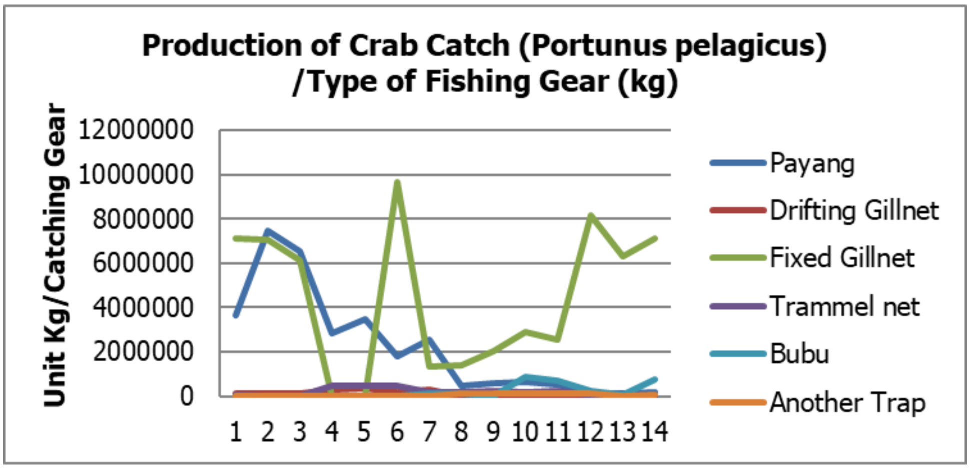

Figure 4. Production of Crab Catch (*Portunus pelagicus*)/Type of Fishing Gear (Kg) from 2008 to 2021.

Based on Figure 4, fixed gill net fishing gear has the highest production of crab catch (*Portunus pelagicus*) compared to other fishing gear. This is influenced by weather, time, place, and the number of tools (Chhom, V. (2012). At the same time, research on fishing gear traps with door position variations is not significant to the selectivity of catch size (Zhang, J. et al., 2021), and trawl fishing gear results in unsustainable resources (Prince, J. et al., 2020). The growth of the crab (Portunus pelagicus), according to Potter, I. C (2013), at the age of one year, has an average carapace width (CW) of 40-100 mm. In contrast, adult crabs reach 18 cm in size (Josileen and N.G. Menon., 2011. The growth rate parameters differ between males and females (Winsland, K. et al., 2013), where the length of the male carapace is more significant than that of the female (Hosseini, M. et al., 2014). However, overall catch production has decreased. This condition follows the research of (Nitiratsuan T. et al., 2013). The relationship between the selectivity of fishing gear and the ecosystem where the habitat of the target species is located is based on Bjordal, A (2009) in Table 4.

Table 4. The score of the relationship between fishing equipment and the aquatic ecosystem

Ecosystem effects by type of fishing gear	Types of fishing gear for crabs (*Portunus pelagicus*) in relation to Aquatic Ecosystem							
	Species Size	Species Type	Species Mortality	Lost fishing gear	Habitat destruction	Energy efficiency	Catch quality	Ecosystem Index Score
Drifting gill nets	8	4	5	1	8	8	5	6,4
Fixed gill net	8	4	5	1	7	8	5	5,4
Trammel Net	2	3	5	3	7	8	5	4.7
Payang	5	5	6	9	4	5	8	6,0
Bubu	7	7	9	3	8	8	9	7,1
Another trap	5	5	8	8	9	9	9	7,6

Source: 2022 Analysis Results

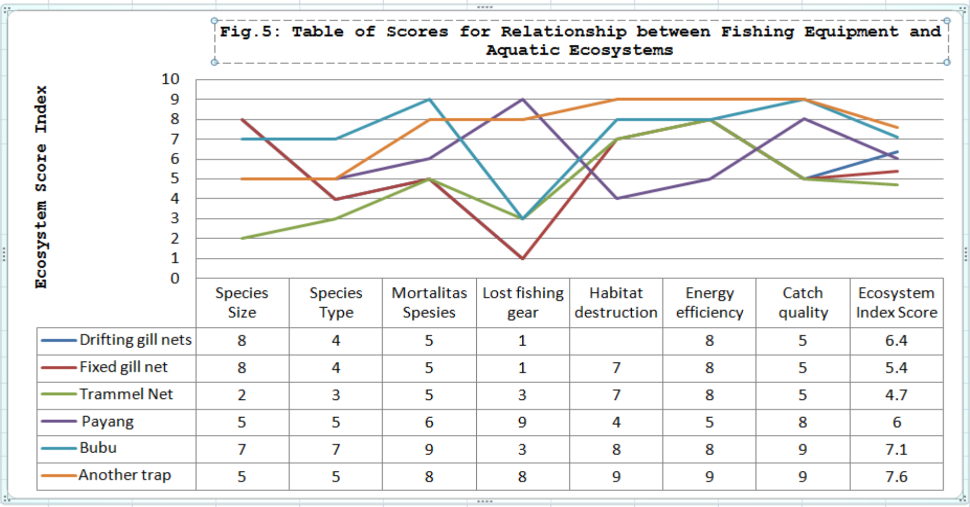

Figure 5. The scores for the relationship between fishing equipment and aquatic ecosystem

The Ecosystem Index score includes the catch's target species and their fishing techniques that can cause environmental damage. Therefore, fishing method techniques and management jurisdictions must be configured to simultaneously meet conservation goals (Samhouri, J. F., et al., 2019). Bycatch means that the target species of the catch are outside the size and target species, including legal and marketable; not marketable; and illegal. Non-economic bycatch is a catch that cannot be marketed, while non-legal bycatch includes species protected by regulations regarding size and species of organisms. Disposal of the trap, due to the catch species' low price and survival, causes inaccurate catch data on land. The application of quotas is where fishermen try to get the maximum value from a limited percentage by only keeping the most valuable part and discarding the rest.

The mortality rate was caused by the collision of the catch species with the ship's hull. Loss of fishing gear due to snagging corals often occurs in gillnet, trammel, and pot fishing gear. This condition can affect aquatic ecosystems. The impact of habitat destruction is due to fishing gear, damaging coral as a habitat for captured species. The quality of the catch, for example, using gillnets with too long immersion time, can result in a decline in the quality of the caught species, which, ultimately, the catch cannot be marketed. Energy efficiency, especially in fishing fleets using diesel fuel, can affect the fishery's ecosystem. Pollution, this condition contributes to affecting aquatic ecosystems due to combustion gas emissions. This also increases with oil and chemical spills in the sea. Meanwhile, the state of ecosystem indicators is shown in Figure 6.

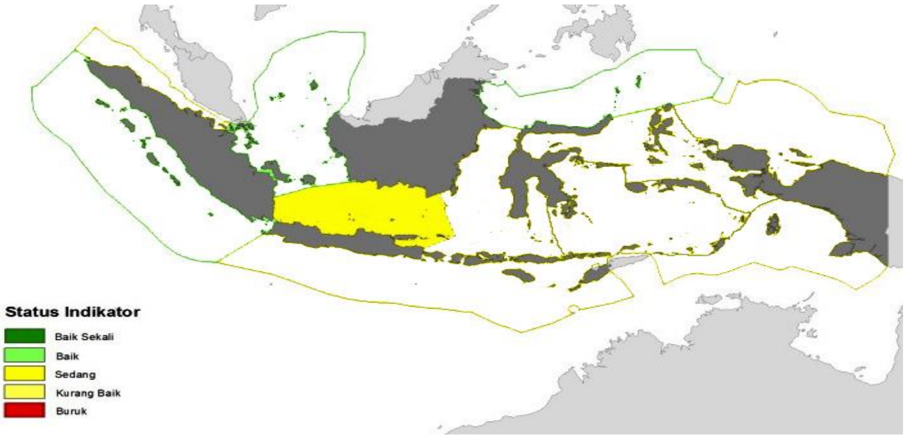

Figure 6. Java Sea Waters Ecosystem Indicator from 2004 to 2017

While the catchment area of Rajugan (*Portunus pelagicus*) in East Java is shown in Figure 7.

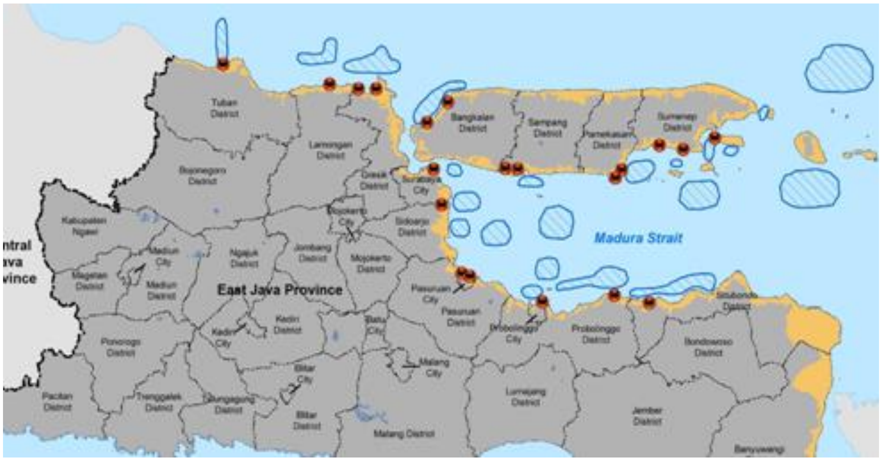

Figure 7. Fishing ground for crab (*Portunus pelagicus*)

Based on ITC Trademap data commodities, crabs (*Portunus pelagicus*) and crabs in 2021, the export value was USD 2.04 B (8.8%) the total import value is below Shrimp, Tuna - Cuttlefish - Octopus (CSG). Based on the total production volume, the position was the lowest compared to other export product commodities. However, from the export price value per volume, it turns out that crabs (*Portunus pelagicus*) and crabs have a higher value. For more details, in the following Figure 8.

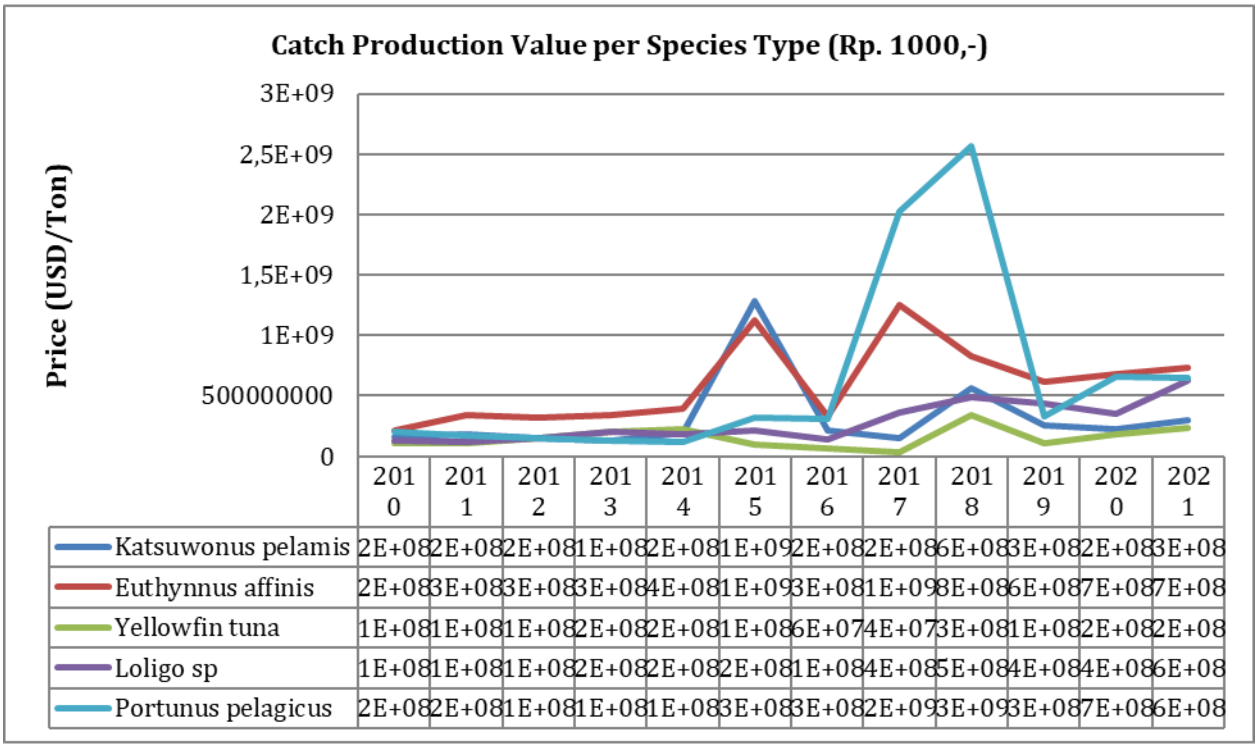

Figure 8. Catch Production Value per Species Type (Rp. 1000,-)

3.1.2. Nature of fishery resources

Fishery resources are renewable, meaning that if the ecosystem is not disturbed, its biological balance will naturally be maintained. It will have a negative impact if it is not utilized. On the other hand, if the utilization is not regulated, it will result in overfishing. Therefore, to avoid the occurrence of "overfishing," it is necessary to manage its resource management, including the use of environmentally friendly fishing gear. In principle, the exploitation of the catch must be based on the natural carrying capacity. This means the yield affects the amount of genuine stock in the waters. The nature of fisheries resources is open access, fishermen can make arrests without rules, and there is free competition, free entry, and exit in the catchment area. Intuitively, open-access conditions in fisheries utilization are almost nonexistent. For example, specific fishing communities make various informal rules approved by the local fishing community.

Without proper management rules in its management, it will affect the sustainability of resources. To create ecosystem-based fisheries management, the level of income of fishermen is necessary to adopt a management jurisdiction to simultaneously fulfill the goals of conservation and development of fishery resources (Samhouri, J. F., et al., 2019). The institutional co-management model is considered more democratic because the Government consciously prepares for the active participation of the community. Based on the Assessment of Fish Stocks in several Fishing Management Areas in Indonesia was based on the species of destination fish, as shown in Table 4.

Table 4. Condition of Fishery Management Area Resources Based on Species Destination Fish catch.

Number	Fishery Management Area	Demersal	shrimp	small pelagic	large pelagic
I	Malacca Strait	Overfished	Overfished	Fully exploited	Uncertain
II	South China Sea	Fully exploited	Moderate	Overfished	Uncertain
III	Java Sea	Fully exploited	Fully exploited	Overfished	Uncertain

IV	Flores Sea and Makassar Strait	Fully exploited	Overfished	Moderate	Uncertain
V	Banda Sea	Under-exploited/ Uncertain	Uncertain	Moderate	Moderate
VI	Arafura Sea	Fully exploited-Overfished	Overfished	Moderate	Uncertain
VII	Tomini Bay and Sulawesi Sea	Moderate	-	Moderate	Fully exploited
VIII	Pacific Ocean and Sulawesi Sea	Uncertain	Uncertain	-	Overfished
IX	Indian Ocean west of Sumatra	Fully exploited	Fully exploited	Moderate	Fully exploited
X	Indian Ocean south of Java	Fully exploited	Fully exploited	Fully exploited	Fully exploited

Based on Table 4, the resource condition of Fisheries Management Area (WPP) III for demersal species and shrimp resources was densely caught. In contrast, small pelagic species were densely seen, and large aquatic species were uncertain. The crab (Portunus pelagicus) is a demersal resource species based on its habitat. At the same time, the Fisheries Management Area III, where this research was conducted, is included in the full catch exploitation criteria.

3.1.3. Estimation of potential capture fisheries resources

Estimating the potential of capturing fisheries resources used a descriptive method with a purposive sampling technique for fishermen and users of fishing gear species of crabs. The data used in this study were primary and secondary. Preliminary data was based on interviews and direct observations in the field, including unique crab fishermen (initial survey of the fishing gear used). In contrast, secondary data was the production of crab catches, types of crab species caught, and the number of fishing efforts. The chart of research activities is shown in Figure 7.

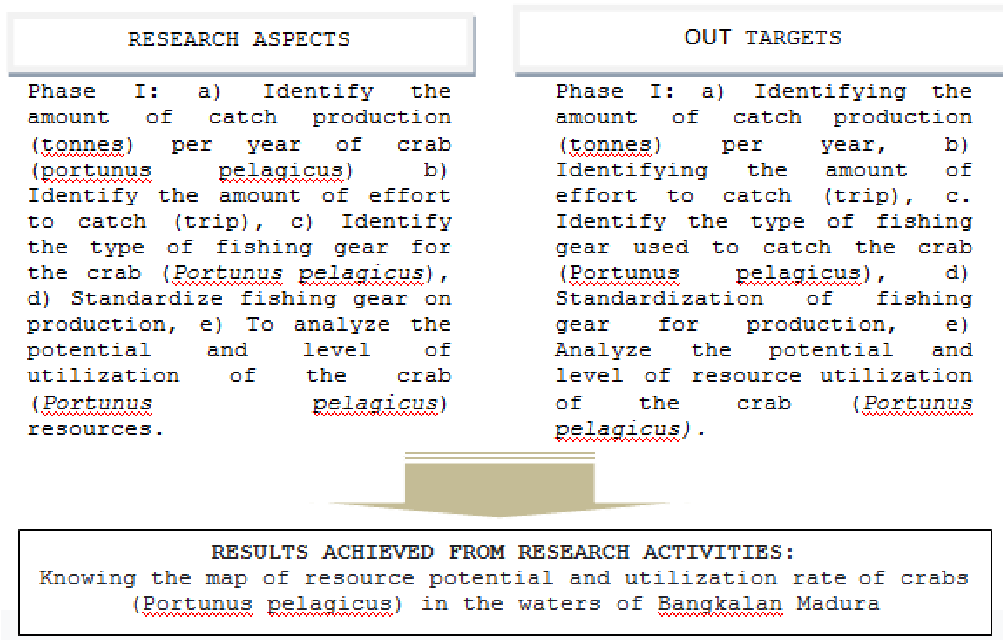

Figure 7. Research activity chart

This activity focused on mapping the condition of the crab (*Portunus pelagicus*) stock in Bangkalan waters. This was essential for the sustainable development of the Rajungan (*Portunus pelagicus*) resource. Potential catch stocks were analyzed by identifying the dominant type of fishing gear for crabs (*Portunus pelagicus*) and exploring the fish catch production per unit effort (CPUE).

3.2. Discussion

3.2.1. Conversion of Crab Catcher (Portunus pelagicus)

Water conditions in East Java are generally multi-gear and multi-species, where several fishing gears catch one fish, while one type of fishing gear can see more than one fish species. Therefore, it is necessary to standardize fishing gear for consistent fishing efforts by selecting one unit of fishing gear as the standard fishing gear based on the fish caught. Further analysis using the following equation:

$$\text{CpUE} = \frac{Qi_{i=1}^{n} * C_{fish}}{Ei_{t=1}^{n}}$$

Where :
CPU = catch per unit of effort
$Qi_{i=1}^{n}$ = Average portion of fishing gear 1 to a total production of crab (*Portunus pelagicus*)
C_{atfish} = Average fish caught by fishing gear
$Ei_{t=1}^{n}$ = The average effort of the catch that is considered standard (trip)

$$\text{RFP} = \frac{Ui_{t=1}^{n}}{U_{Alat\ standar}}$$

Where :
RFP = fishing gear conversion index
$Ui_{t=1}^{n}$ = Catch per unit effort of each fishing gear
$_{Alat\ standar}$d = catch per unit effort of standard tools

$$E_{(Std)t} = \sum_{i=1}^{n} (RFP_1\ x\ E_{i\ (t)})$$

Where :
$E_{(Std)t}$ = number of standard fishing gear in year t (trips/fishing gear)
RFP_1 = Fishing gear conversion index (I = 1 – n)
$E_{i\ (t)}$ = number of fishing gear type I (in year t (trip/fishing gear)

3.2.2. Walter and Hilborn models

The Walter-Hilborn model is a development of the surplus production model, known as the regression model. The difference between the Walter and Hilborn model and the Schaefer model is that the Walter and Hilborn models can provide estimates for the surplus production function parameters r, q, and k, respectively.

$$P_{(t+1)} = P_t + \left[r * P_t - \left(\frac{r}{k}\right) * P_t^2\right] - q * E_t * P_t$$

Where :
$P_{(t+1)}$ = The amount of biomass stock at time t+1
P_t = amount of biomass stock at time t
r = intrinsic growth rate of biomass stock (constant)
k = maximum carrying capacity of the natural environment
q = catch coefficient
E_t = number of fishing efforts to exploit biomass year t (trip/fishing gear)

The dominant fishing gear (*Portunus pelagicus*)/Type of fishing gear.

The number of trips after the conversion of dominant fishing gear used to catch crabs (*Portunus pelagicus*) in Bangkalan waters is shown in Figure 8.

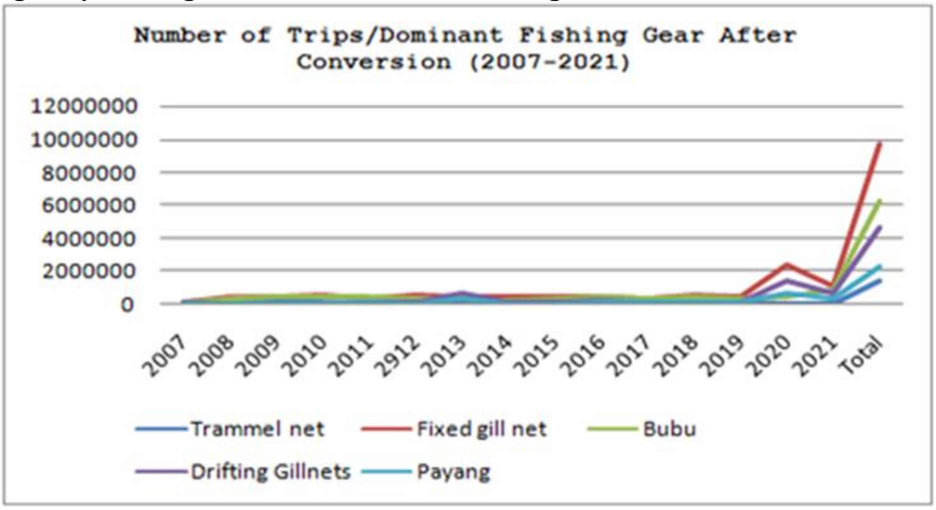

Figure 8. Number of trips/dominant fishing gear after conversion from 2007 to 2021.

Based on Figure 8, the fixed gill net fishing gear type had the highest number of trips. Still, after analyzing the standardization of fishing gear based on the amount of production/type of fishing gear, the value of the Trammel net fishing gear ratio was the standard fishing gear. As a tropical area, Indonesia had various fishing gear and species ("multi-species and multi-gear"). The analysis requires the standardization of fishing gear because the fishing gear's efficiency (catchability) was influenced by fishing tactics and methods (Fishing method) and the construction of fishing gear catch used. This stage of conversion of fishing gear aimed to unite trip units per fishing gear as a production factor variable to analyze stock estimates and capture fisheries status so that a uniform effort trip per fishing gear (effort) unit was obtained before estimating the condition of the maximum sustainable catch (MSY) and the number of trips.

The allowable catch was a condition where the stock was in equilibrium. Meanwhile, quantitative prediction aimed to reach the permissible catch limit (JTB), the risk of overfishing, and provide growth opportunities to get the size according to applicable regulations (Regulation of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number l/PERMEN-KP/2015). Under the Government's policy (kep.18/men/2011) regarding a balanced management system between resource utilization and conservation efforts, fishing activities that are not environmentally friendly are vulnerable to ecosystem damage. Based on the analysis of the ratio of the average number of catches/trips of the dominant fishing gear of the crab (Portunus pelagicus), they are shown in Table 5.

Table 5. The ratio of types of fishing crab (*Portunus pelagicus*) dominant based on average catch/trip

Tool Type Catch	Average catch	Porsi	Effort	CPUE Rata²/Trip	% CPUE	RPF	Ratio
Payang	22.18	0.04	50523	0.00043	10.15	0.4390	2.27
Drifting gillnet	96.4	0.21	108774	0.00088	20.49	0.8864	1.22
Fixed gillnet	106.3	0.23	106332	0.00100	23.12	0.9999	1.11
Trammelnet	213.3	0.47	213343	0.00100	23.13	1.0000	1
Bubu	9.35	0.02	9358	0.00099	23.10	0.9993	2.23
Trap	0.24	0.05	5375557	0.00000	0.001	0.0000	2.24
Amount	447.77	1.02	9863887	0.00432	100.00	4.3246	10.07

Table 6. Capture tool before and after conversion (trip)

Fishing gear before conversion						Fishing gear after conversion					
Year /RPF	Trammel net	Fixed net	Bubu	Drifting net	Payang	Year /RPF	Trammel net	Fixed net	Bubu	Drifting net	Payang
	1	0.99	0.98	0.88	0.43		1	1	1	1	1
2007	16662	176437	42799	124939	124939	2007	16662	176419.5	427050.7	42705.7	3860.3
2008	74771	45976	44043	858732	987379	2008	74771	459718.3	404120.7	404120.7	38367.8
2009	89210	478640	487149	62840	62840	2009	89210	478592.4	486830.7	486830.7	27592.8
2010	88105	433778	431794	10868	710868	2010	88105	578233.5	431511.8	431511.8	7724.1
2011	57598	584192	460267	21259	721259	2011	57598	433734.9	459966.2	459966.2	3350.6
2012	48848	480617	361869	141349	141439	2012	48848	584133.9	361632.5	361632.5	62105.4
2013	96565	480617	340416	826844	826844	2013	96565	480569.2	340193.6	340193.6	63064.3
2014	38873	500324	291879	184050	184050	2014	38873	480569.2	291688.3	291688.3	80815.7
2015	38735	472004	364130	185686	185686	2015	38735	500274.3	363892.1	363892.1	81534.1
2016	78730	436050	479526	287780	287780	2016	78730	471957.1	479212.6	479212.6	126363.2
2017	15169	588344	394412	215603	215603	2017	15169	436006.7	394154.3	394154.3	94670.5
2018	80590	588344	46490	223850	223850	2018	80590	588285.5	460189.1	460189.1	98291.7
2019	70286	453119	332592	232968	232968	2019	70286	453074.0	332374.7	332374.7	102295.4
2020	82526	238113	469008	162410	162410	2020	82526	380876.3	468701.5	468701.5	713137.5
2021	49981	117543	386619	579428	794280	2021	49981	175316.1	865629.0	865629.0	348765.6

3.2.3. Trammel net fishing gear construction

Trammel Net was a type of fishing gear for crabs (Portunus pelagicus) that was introduced after the Presidential Decree 39 of 1980 concerning the prohibition of trawl fishing gear in Java, known as longish nets to catch shrimp. The shape was four squares consisting of three layers of netting, of which two layers were on the outside and one layer in the middle (inside). A buoy was attached to the upper rope and weighted at the bottom to be upright in the water. The net material was made of synthetic Polyamide (PA), and the edge (selvage) was made of Polyethylene (PE). In detail, the construction of this trammel net consists of several parts, including:

Webbing body

Most crabs were stuck in this position, where the mesh size was smaller than the two outer layers. The thread diameter was 210 dp, the mesh size was 1.75 inches (38.0 mm), the length was 65.55 m (1,550 points), and the height was 50 points. In the outer layer of the net body, the thread size was more significant, namely 210 d6, 18 eyes long, and seven eyes high, with a mesh size of 10.5 inches.

Edge of the net (selvage/srampat)

Material from double yarn, 40 mm mesh, consists of 2 eyes on the top edge of the net and seven eyes on the bottom edge of the net. The net material was Polyethylene, size 210 d6. The edge net consisted of the upper and lower ris ropes as a connection to the body of the net, while the lower ris rope was 33 m long. On the top strap was attached a plastic buoy No. 18 with an installation distance of 40 cm to 50 cm. The float rope was made of Polyethylene material with a diameter of 3 – 4 mm, equipped with a ballast (14 grams/piece), and the distance between the weights was 20 cm. The material was Polyethylene, and the main buoy was added as fishing gear as a complement.

Estimation of crab stock (Portunus pelagicus)

Analysis of the estimation of the mapping of the potential of the Rajungan (*Portunus pelagicus*) resource is an essential aspect of the policy. This condition could be used as a reference early warning signal whether the resource was degraded or otherwise. Although the nature of these resources could be renewed (renewable), if management is not carried out in their utilization, it can lead to overfishing. This analysis was based on the aspect of trips per fishing gear. The crab (*Portunus pelagicus*) was dominant in the condition of open-access resources from 2008 to 2021. Topographically, the Madura Strait is a semi-enclosed sea with the border of the Kamal estuary in the west and a group of small islands in the east. The coast is shallow and protected. The waves are relatively low and can be accessed by small-scale capture fisheries. The results showed that: the maximum catch of crab (*Portunus pelagicus*) (CMSY) was 63886.114 kg/year at equilibrium conditions so that overfishing occurred in 2022 with optimal effort (Eopt) of 6363750 trips/year so that the utilization rate exceeded 100%. The intrinsic growth rate of stable biomass stock (r) crab (*Portunus pelagicus*) of 50.91% / year, maximum carrying capacity of water (k) of 50195.336 Kg/year, ability to catch (q) of 0.00000004 and crab resource potential (Be) of 25097,668 kg/year, more details can be found in Figure 8.

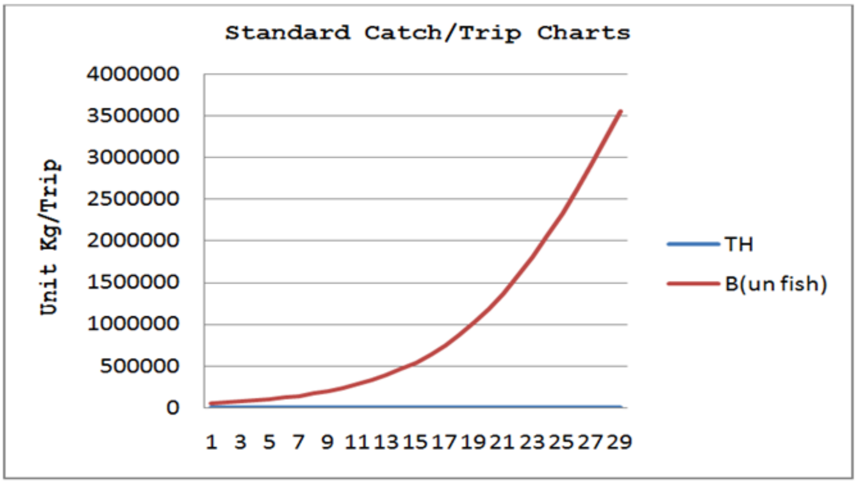

Figure 8. Crab stock dynamics chart (*Portunus pelagicus*) with open access limits with the amount of biomass no catch

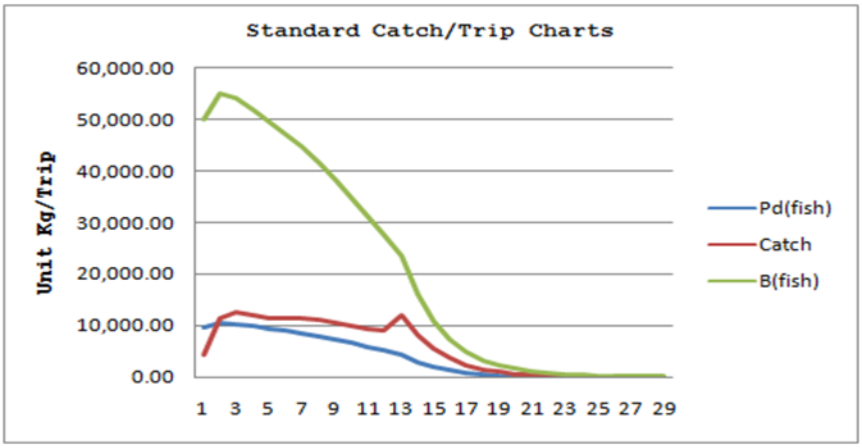

Figure 9. Crab stock dynamics chart (*Portunus pelagicus*) open access limits with the amount of captured biomass

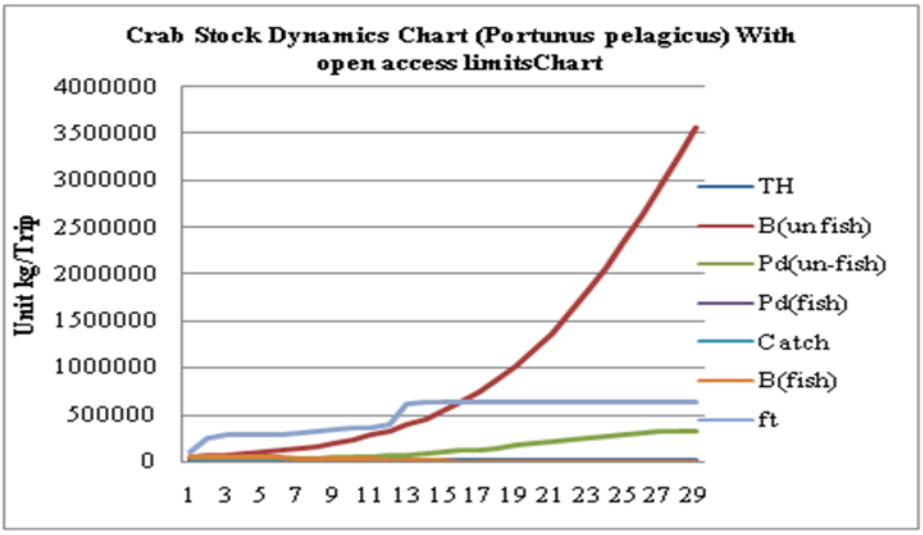

Figure 10. Crab stock dynamics chart (*Portunus pelagicus*) with open access limits

Based on the graph, stock dynamics with standard trip/gear limits in open access biomass conditions, the amount of crab (Portunus pelagicus) biomass in 2029 remains 14%.

4. Conclusion

Maximum catch production (CMSY) of crab (Portunus pelagicus) was 63,886.114 kg/year. The intrinsic growth rate was 50.91%/year, and the water carrying capacity was 50195,336 Kg/year, dominant species (Portunus pelagicus). Meanwhile, the optimal Effort (Eopt) was 6363750 trips/year with a potential resource of 25097,668 kg/year. In the balance condition in 2022, there will be overfishing, and the standard type of fishing gear was a Trammel net with a fishing capability of 0.0000004.

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