E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 76.37
(GIF) Impact Factor: 0.549
IJFAS 2023; 11(2): 106-119

www.fisheriesjournal.com
Received: 20-06-2023
Accepted: 23-07-2023

Samsul Huda
Lecturer, Department of Utilization of Fishery Resources, Faculty of Agriculture, University of Dr. Soetomo, Surabaya 60118, Indonesia

Siti Naviah
Lecturer, Department of Fisheries Agribusiness, Faculty of Agriculture, University of Dr. Soetomo, Surabaya 60118, Indonesia

Dyah Arini
Lecturer, Department of Economics, Islamic University of Malang 071027, Indonesia

Corresponding Author:
Samsul Huda
Department of Utilization of Fishery Resources, Faculty of Agriculture, University of Dr. Soetomo, Surabaya 60118, Indonesia

Crabs (*Portunus pelagicus*) resource mapping Bangkalan Madura waters based (Walter-Hilbron non-equilibrium model)

Samsul Huda, Siti Naviah and Dyah Arini

DOI: https://doi.org/10.22271/fish.2023.v11.i5b.2855

Abstract
This study presents an overview of the condition of the crab (*Portunus pelagicus*) resources in the waters of Bangkalan Madura, as an export commodity its production relies on the catch, one of the locations of the catchment area is in the Fisheries Management Area 712 where this research was carried out. The frequency of fishing efforts continues to increase because of the high economic value, however, there is not much information about the condition of the resources. Descriptive research method with the aim of mapping crab resources based on the "Non-Equilibrium Walter-Hilbron Model". The results showed that the maximum catch production (CMSY) was 63,886.114 kg/year with standard Trammel net fishing gear, the intrinsic growth was 50.91%/year, the carrying capacity of the waters was 50195,336 Kg/year, the dominant species was (*Portunus pelagicus*), the optimal effort (Eopt) was 6363750 trips/year with a potential resource of 25097,668 kg/year. In conclusion, this research can be used as a basis for resource mapping as a follow-up to Minister of Marine Affairs and Fisheries Regulations Number 70/2016 concerning the Management Plan for Crab in the WPP.

Keywords: Crabs, resources, maximum catch production

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 crab (*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 pelagicus*) in Indonesian waters, then 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 in order 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 3 years, where catch production the highest came from Bangkalan. The high demand along with favourable prices has resulted in the increased exploitation of crab catches, plus so far 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 the species *Portunus trituberculatus* is the largest crab in the world, its catch is done commercially throughout the world, the largest total catch (95%) occurs in China including the East China Sea, Yellow Sea, and Bohai Sea [23], this condition is different from the catch in the Sinai Peninsula of Egypt, the research shows that the crab catch is dominated by the species *Portunus pelagicus* (85%) and *Callinectes sapidus* (15%). The absence of management in the utilization of 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 is needed. A coastal area is a vital place for crabs because it is a nursery ground in supporting stock recruitment. The Marine Protected Area (MPA) [5] states that the fishery refugia area is an ideal location for the management of crab fisheries using an ecosystem approach model. The pattern of the spatial distribution of crabs in the waters of the Gulf of Saudi Arabia is mostly near the coast, laying eggs throughout the year, with at least three peaks: winter, late spring-early summer, and autumn [26]. 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 a wide distribution habitat from shallow water to deep water [4]. Meanwhile, natural mortality and catch are factors that will reduce the amount of stock [22], as well as the use of fishing gear that can affect ecosystem fertility [29], 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*) [32]. However, changes in environmental conditions in Western Australian waters affect two determinants of CPUE, including fishing power (q) and abundance (N) [17], a similar study with an ecosystem component approach based on participatory multi-criteria analysis (MCDA).) in New South Wales (NSW) Australia conducted by [10]. 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 [21]. Research in the field of crab cultivation (*Portunus pelagicus*) uses a temperature difference variable before molting with different acclimatization temperatures, it turns out that there is an effect of temperature tolerance on the locomotor activity of the crab (*Portunus pelagicus*) [2]. Meanwhile, the management of crab fisheries based on the spatial zoning of the Pangkep waters of South Sulawesi was carried out by [15], stating that the critical period occurred in vase zoea, megalopa, and juveniles from May to October, with peak spawning in August. Research on the condition of crab stock conditions (*Portunus pelagicus*) in the Persian Gulf was carried out by [12], it turned out that crab stock management was influenced by taxonomic and ecological descriptions, therefore 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 3 years with the aim of providing spawning opportunities at least once to increase nursery stocks [18]. 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 [38]. The problem is how to sustain the current Rajungan resources in terms of existing resource stocks, utilization level maps, types of standard fishing gear, and fishing methods based on resource criteria. This study combines the factors of 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 based on the "Non-Equilibrium Walter-Hilbron Model".

Materials and Methods

This research was conducted using a descriptive method and the sampling technique was carried out by purposive sampling of the catches of fishermen, the fishermen in question were crab fishermen who had fishing gear and several fisherman community leaders and personnel/officers who worked at the Marine and Fisheries Service. This is in accordance with the research objective, which is 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 uses 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), while secondary data is the production of crab catch, the effort to catch for the last 14 (ten years) years.

This study focuses 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 in order to create a sustainable crab resource. In detail, the implementation of the research is described in Table 1: below:

a. Walter-Hilbron analisis analysis model

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

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 l:

$$U_t+1/U_t = 1+r- [r/k*q] \text{ x } U_t-qxE_t \quad (2)$$

Equation W-H 2:

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

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

C_{MSY} =1/4 rk
E_{opt} =r/2q
U_t = qxk/2

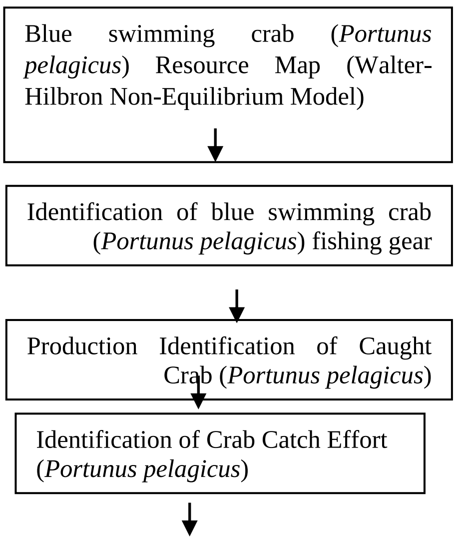
$\ln[\grave{U}_{t+1}/U_t]=r-[q*\grave{E}_t+ \grave{E}_{t+1}/2]-[(r/qk)*(\grave{U}_t+ \grave{U}_{t+1)/2}]$

Estimating parameters under "equilibrium" conditions
C_{MSY} =1/4 rk
E_{opt} =r/2q
U_t = qxk/2
B_e = k/2

where:
Ut = Year's catch
C_{MSY} = 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

Table 1: Details of Research Implementation

No.	Objective	Method	Input	Parameter	Analysis	Output
1.	Get the maximum amount of crab catch production in Bangkalan Regency;	Survey	Time series data & catch production in Bangkalan Madura Regency;	The amount of production of crab catches (*Portunus pelagicus*) for the last ten 14 years of Bangkalan Regency,	The Walter-Hilbron method	The maximum amount of crab catch production;
2.	Get the amount of crab catch effort/trip in Bangkalan Regency;	Surveys, analysis	Time series data & production of catch/fishing gear unit in Bangkalan Madura Regency;	The amount of production of blue swimming crab (*Portunus pelagicus*)/fishing gear unit for the last ten 14 years. Bangkalan Regency,	The Walter-Hilbron method	Amount of production / Crab catch effort / trip attempts;
3.	Obtain stocks of potential sustainable reserves of blue swimming crab (*Portunus pelagicus*), in Bangkalan Regency,	Surveys, analysis	Time series data & production of catch/fishing gear unit in Bangkalan Madura Regency;	The amount of production of blue swimming crab (*Portunus pelagicus*)/fishing gear unit for the last ten 14 years. Bangkalan Regency,	The Walter-Hilbron method	The size of the stock of sustainable reserve potential for blue swimming crab (*Portunus pelagicus*), Bangkalan Regency for the next 14 years,
4.	Analyzing the types of standard crab fishing gear (*Portunus pelagicus*) and their catching power in Bangkalan Regency,	Surveys, analysis	Time series data & catch/capability production standard fishing gear/unit for Bangkalan Madura Regency;	The amount of production of blue swimming crab (*Portunus pelagicus*)/ capability/unit of standard fishing gear for the last ten 14 years. Bangkalan Regency,	Metode Walter - Hilbron	Type of standard crab fishing gear (*Portunus pelagicus*) and catching power in Bangkalan Regency.



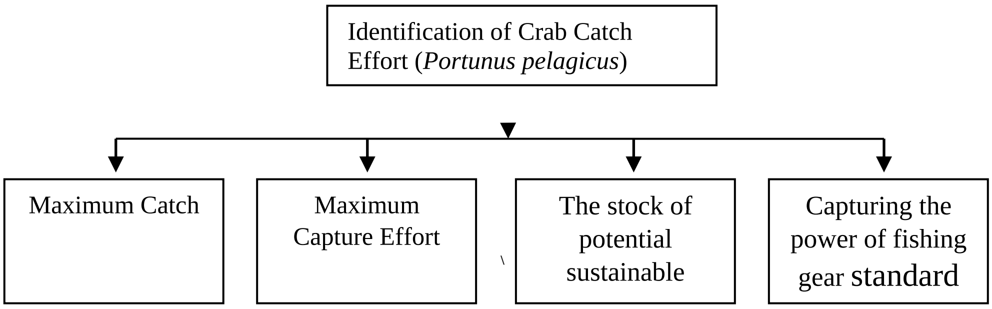


Fig 1: Research flowchart.

To find out the utilization rate by comparing the exploitation rate (TE) (%) with the average volume of the last 10 years (Ct) divided by the number of allowable catches (JTB) (80), so the equation is as follows

$$TE = C_t/JTB \times 100\% \quad (4)$$

Meanwhile, the dynamics of the reserve stock (Hilborn and Walters, 1992) is 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 exploit the biomass (t); equation as follows:

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

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.

Results

Bangkalan Regency Overview

The general description of the Bangkalan Regency includes geographical, administrative, and physical conditions of the region, demography, regional finance, and economy, socio-cultural and institutional.

Geographical

Bangkalan Regency is located at the westernmost tip of the island of Madura, with an area of 1,260.14 km^2 with coordinates 112°40'06"–113°08'04" East Longitude and 6°51'39"–7°11'39" Latitude. South, with regional boundaries as follows:

South side: Madura Strait
North side: Java Sea
West: Java Sea
East: Sampang Regency

Administrative

Administratively, Bangkalan Regency is included in the East Java Province. Bangkalan District consists of 18 sub-districts including: - Kamal District - Labang District - Khanyar 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 km2. The district government centre is located in Bangkalan City, precisely in Bangkalan City District where the catches from the sea include Tanjung Bumi, Klampis, Khanyar, 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: below:

Climate Physical Condition

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

Rajungan as a destination for fishing species, their habitat is 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 are larger in size and brighter in color than the female., ruayanya from estuary areas to high salinity waters, after becoming young crabs to adulthood and enter the mating period, then 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: as follows:

The number of trips/types of crab fishing gear in Fig 2: Trammel net fishing gear has the highest number of fishing trips compared to other types of fishing gear, while the production of the most catches based on the type of fishing gear is shown in Fig 3.

Table 2: Number of Fishermen and Capture Fisheries Production (tons)/District/Year 2020-2021 Bangkalan Regency City.

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.	Khanyar	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
19.	Kab.Bangkalan	7954	7858	26.070.40	26.304.20

Source: Bangkalan District Fisheries Service 2021

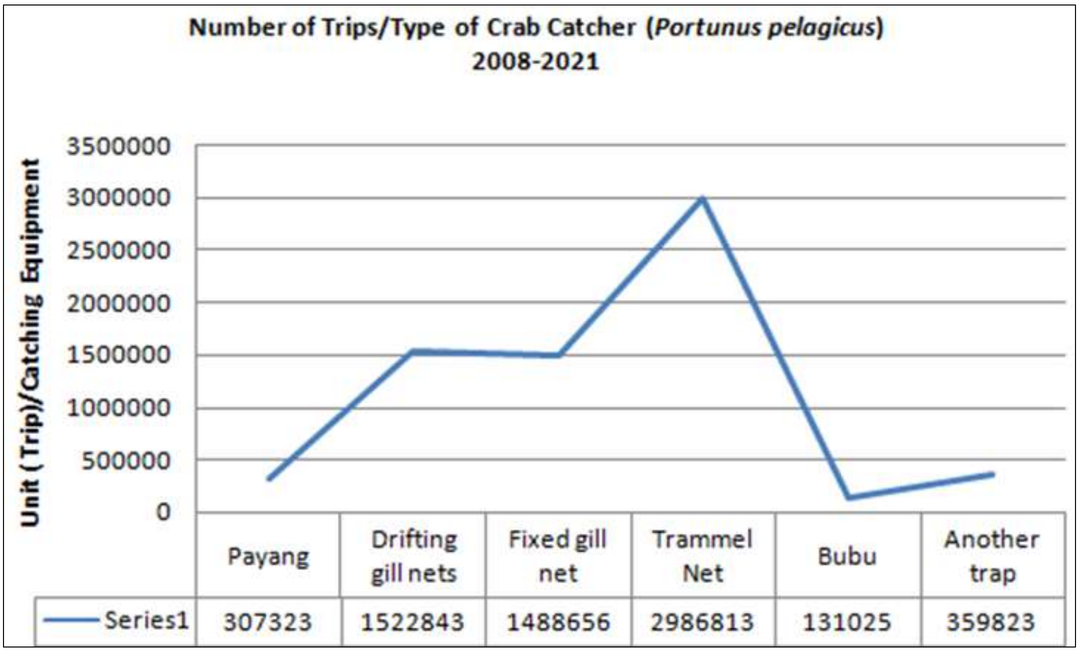


Fig 2: Number of Trips/Types of Fishing Gear for Crab (*Portunus pelagicus*) Year2008-2021

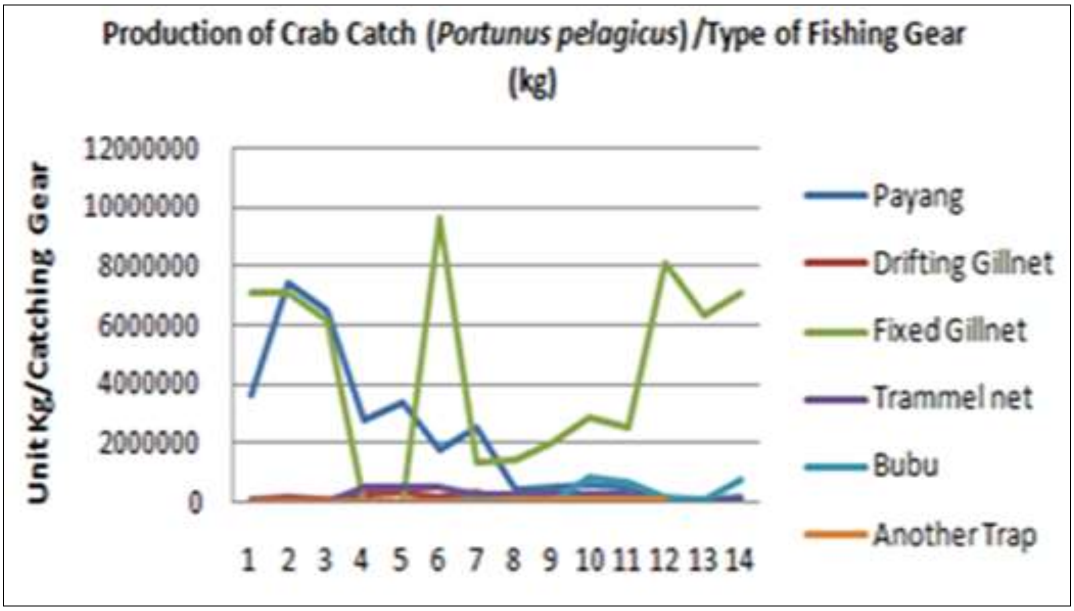


Fig 3: Production of Crab Catch (*Portunus pelagicus*)/Type of Fishing Gear (Kg) Year 2008-2021

Table 3: Number of Trips/Types of Fishing Crab (*Portunus pelagicus*) Years 2008-2021 (unit trip)

Year	Number of Trips/Type of Fishing Equipment Dominant Year 2008-2021						
	Payang	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

Source: 2022 Analysis Result

Based on Figure 4: above, it turns out that 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 number of tools [8], while research on the use of fishing gear traps with door position variations are not significant to the selectivity of catch size [37], the use of trawl fishing gear results in unsustainable resources [24]. The growth of the crab (*Portunus pelagicus*) according to [25] at the age of one year has an average carapace width (CW) of 40-100 mm, while adult crabs reach 18 cm in size [19] the growth rate parameters differ between males and females [35] where the size of the male carapace is larger than that of the female [14]. However, overall catch production has decreased, this condition is in accordance with the research of [34]. The relationship between the selectivity of fishing gear and the ecosystem where the habitat of the target species is located is based on the [6] in Table 4: the following:

Table 4: The Score of the Relationship Between Fishing Equipment and Aquatic Ecosystems

Ecosystem effects by type of fishing gear	Score Value of the Relationship of Fishing Gear with Aquatic Ecosystems							
	Species size	Species Type	Fish mortality	Lost fishing gear	Habitat destruction	Energy efficiency	Catch quality	Ecosystem Index Score
Gillnets drift	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
Seine nets	5	5	6	9	4	5	8	6,0
Trap	7	7	9	3	8	8	9	7,1
Another trap	5	5	8	8	9	9	9	7,6

Source: 2022 Analysis Results

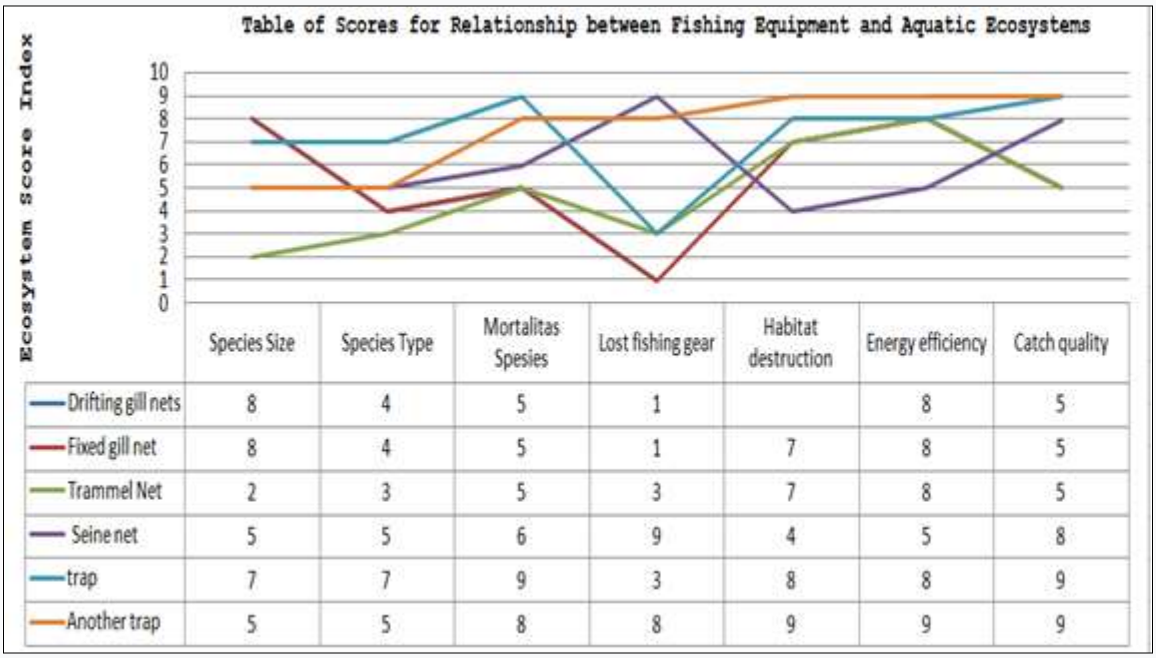


Fig 4: Correlation Score between Fishing Equipment and Ecosystem

The Ecosystem Index score includes the target species for the catch and their fishing method techniques that can cause environmental damage, therefore it requires configuration of fishing method techniques and management jurisdictions to simultaneously meet conservation goals [27]. Bycatch (Bycatch), meaning that the target species of the catch are outside the size and target species, including legal and marketable; not marketable; and/or illegal. Non-economic by-catch is catch that cannot be marketed, while non-legal by-catch includes species protected by regulations, both in terms of size and species of organisms. Disposal of the catch, due to the low price of the catch species, survival, this causes inaccurate catch data on land. The application of quotas where fishermen try to get the maximum value from a limited quota by only keeping the most valuable part and discarding the rest. The mortality rate 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 the use of fishing gear resulting in damage to coral as a habitat for captured species. The quality of the catch, for example the use of gillnets with too long immersion time which 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 that use diesel fuel can affect the fisheries ecosystem. Pollution, this condition contributes to affecting aquatic ecosystems due to combustion gas emissions, this also increases if there are spills of oil and chemicals in the sea. Meanwhile, the condition of ecosystem indicators is shown in Fig 5: below:

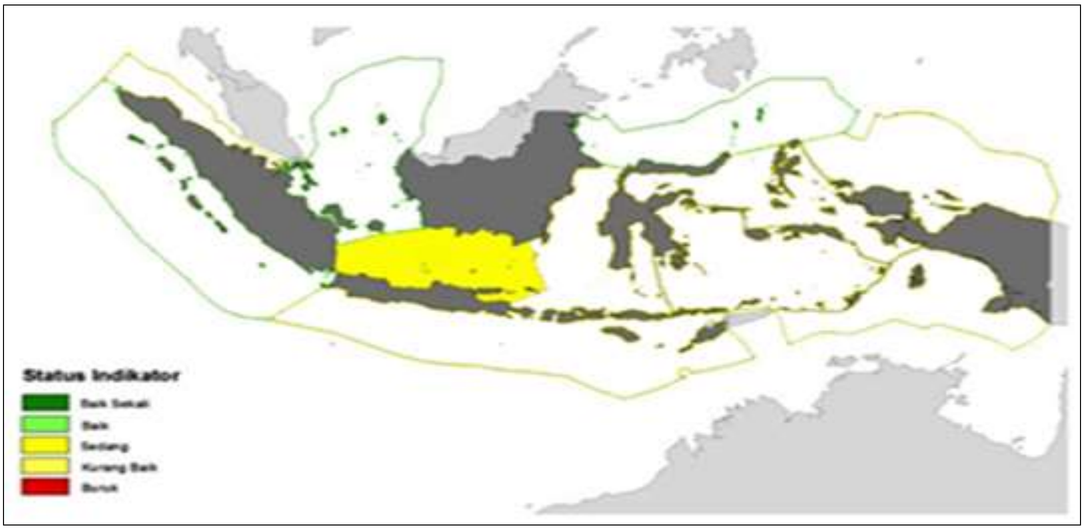


Fig 5: Java Sea Waters Ecosystem Indicator 2004-2017

While the catchment area of Rajugan (*Portunus pelagicus*) in East Java is shown in Fig 6: below:

Fig 6: Fishing ground for crab (*Portunus pelagicus*)

(Results of analysis, 2022)

Based on ITC Trademap data commodities, crabs (*Pertunus pelagicus*) and crabs in 2021 the export value is 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 is the lowest compared to other export product commodities, however, from the value of the export price per volume, it turns out that crabs (*Pertunus pelagicus*) and crabs have a higher value, for more details in the following Fig 7.

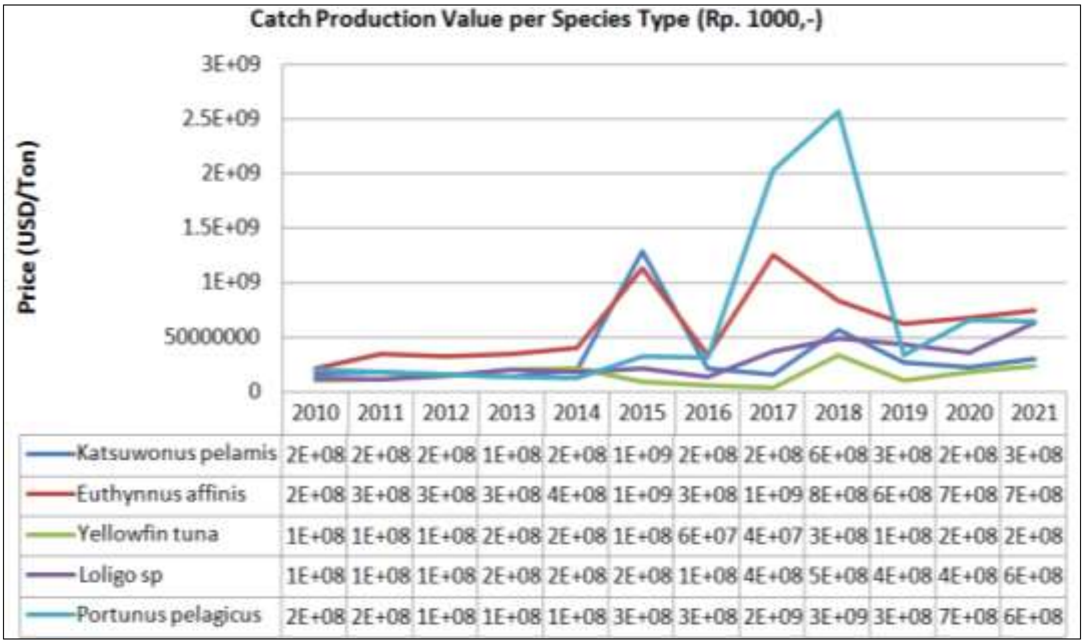


Fig 7: Catch Production Value per Species Type (Rp. 1000,-)

Nature of fishery resources

Fishery resources are renewable, meaning that if the ecosystem is not disturbed, its biological balance will naturally be maintained, and 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 that the amount of catch affects the amount of natural 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 non-existent, for example, certain fishing communities make various informal rules that are approved by the local fishing community. Without proper management rules in its management, it will affect the sustainability of resources, and the level of income of fishermen, while to create ecosystem-based fisheries management, it is necessary to adopt a management jurisdiction so that it simultaneously fulfills the goals of conservation and development of fishery resources [27]. The institutional model of co-management 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 based on the species of destination fish, as shown in Table 5: below:

Table 5: Condition of Fishery Management Area Resources Based on Species Destination Fish catch.

Number	Fishery Management Area	Basic fish	Shrimp	Small pelagic	Large pelagic
I	Malacca Strait	Overfished	Overfished	Fully exploited	Uncertain
II	Sea China South	Fully exploited	Moderate	Overfished	Uncertain
III	Sea a Jav	Fully exploited	Fully exploited	Overfished	Uncertain
VI	Flores sea and Makasar strait	Fully exploited	Fully exploited	Moderate	Uncertain
V	Banda Sea	Under exploited/Un Certain	Overfished	Moderate	Moderate
VI	Arafura Sea	Fully exploited-Overfished	Overfished	Moderate	Uncertain
VII	Sulawesi Sea	Moderate	-	Moderate	Fully exploited
VIII	Pasific 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

***Source*:** Sondita, 2010

Based on Table 5: The resource condition of Fisheries Management Area (WPP) III for demersal species and shrimp resources is densely caught, while small pelagic species are densely caught and large pelagic species are uncertain. Based on their habitat, the crab (*Portunus pelagicus*) is a demersal resource species, while the Fisheries Management Area III where this research is conducted is included in the full catch exploitation criteria.

Estimation of potential capture fisheries resources

The estimation of the potential of capture fisheries resources uses a descriptive method with purposive sampling technique for fishermen, users of fishing gear species of crabs. The data used in this study are primary and secondary data. Primary data is based on interviews and direct observations in the field, including special crab fishermen (initial survey of the fishing gear used), while secondary data is the production of crab catches, types of crab species caught, the number of fishing efforts. The chart of research activities is shown in Fig.8: below:

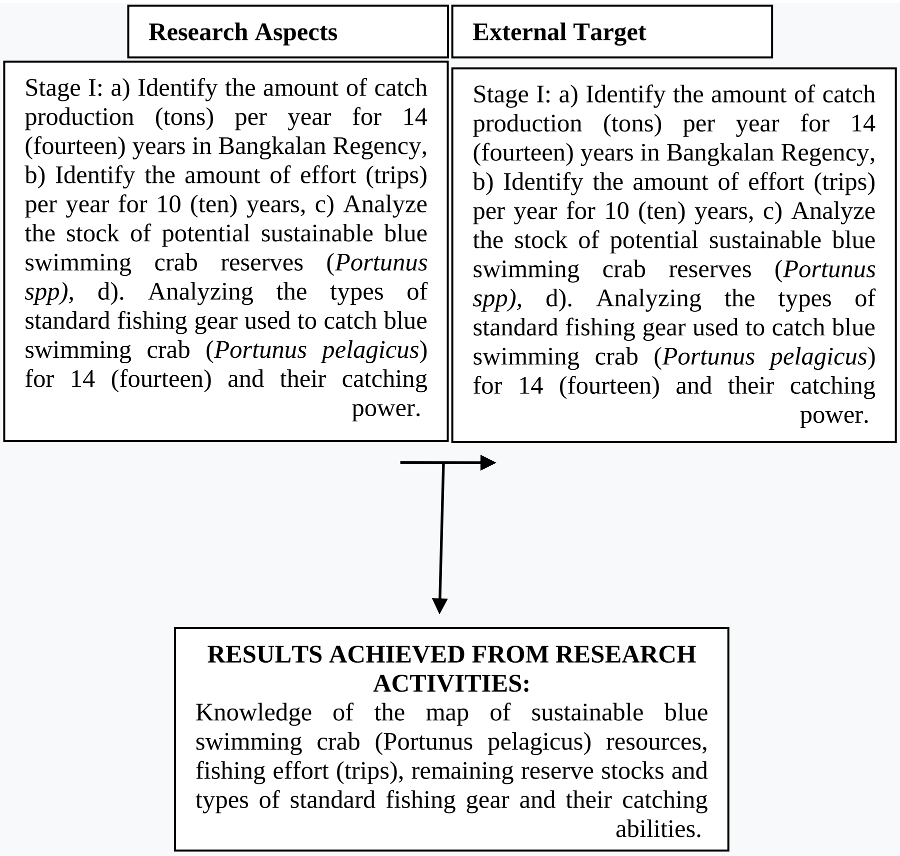


Fig 8: Research Activity Chart

This activity focuses on mapping the condition of the crab (*Portunus pelagicus*) stock in Bangkalan waters, this is an important factor to know as the basis for sustainable development of the Rajungan (*Portunus pelagicus*) resource. Analysis of potential catch stocks is carried out by identifying the dominant type of fishing gear for crabs (*Portunus pelagicus*) by analyzing the amount of fish catch production per unit effort (CPUE).

Discussion

Conversion of Crab Catcher (*Portunus pelagicus*)

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

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

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

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

Where
RFP = fishing gear conversion index
$Ui_{t=1}^{n}$ = Catch per unit effort of each fishing gear
$U_{Alat\ standar}$ = 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 indeI (I = 1 – n)
$E_{i\ (t)}$ = Number of fishing gear type I (in year t (trip/fishing gear)

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 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 conversion of dominant fishing gear used to catch crabs (*Portunus pelagicus*) in Bangkalan waters is shown in Fig.7: below:

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 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 conversion of dominant fishing gear used to catch crabs (*Portunus pelagicus*) in Bangkalan waters is shown in Fig.9: below:

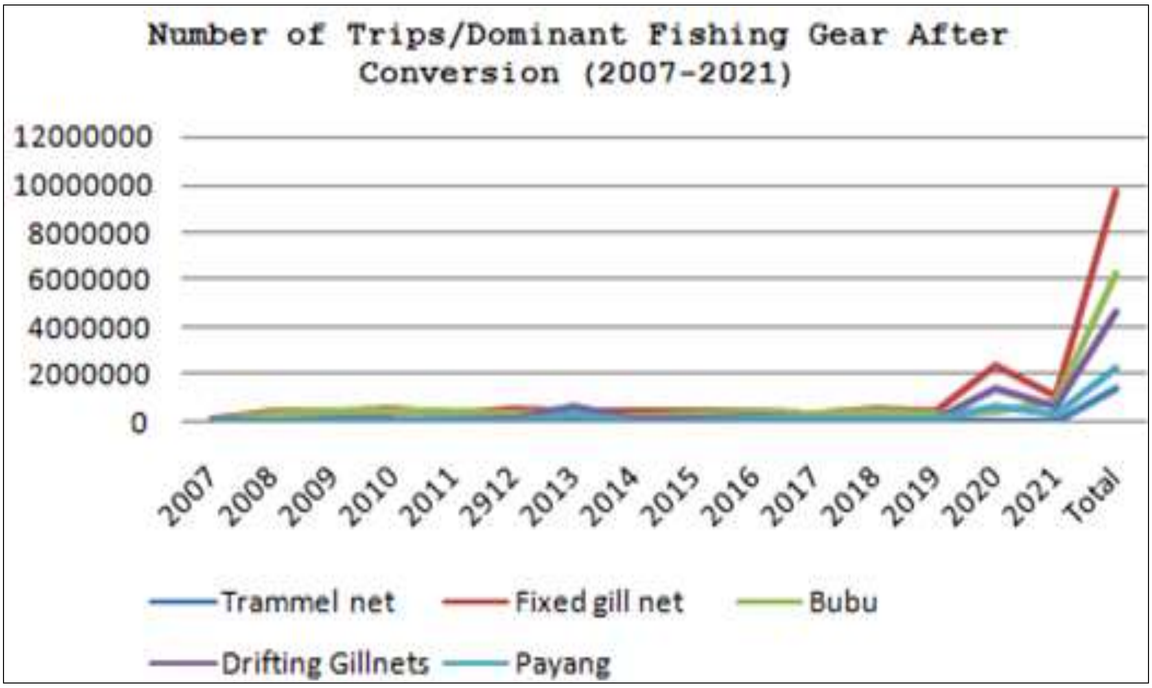


Fig 9: Number of Trips/Dominant Fishing Gear After Conversion 2007-2021 year.

Based on Fig 10 mentioned above, it turns out that the type of fixed gill net fishing gear has the highest number of trips, but after an analysis of the standardization of fishing gear based on the amount of production/type of fishing gear, the value of the Trammel net fishing gear ratio is the standard fishing gear. Indonesia as a tropical area has various types of fishing gear and species ("multi-species and multi-gear"). The analysis requires the standardization of fishing gear, because the efficiency (*catchability*) in the process of catching fish is influenced by fishing tactics and methods (*Fishing method*) as well as the construction of fishing gear. catch used. This stage of conversion of fishing gear aims 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 is obtained before estimating the condition of the maximum sustainable catch (MSY) and the number of trips. allowable catch, which is a condition where the stock is in a state of equilibrium. Meanwhile, the purpose of quantitative prediction is about the allowable catch limit (JTB), the risk of overfishing and providing growth opportunities in order to reach 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). This is in accordance with 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 results of the analysis of the ratio of the average number of catches/trips of the dominant fishing gear of the crab (*Portunus pelagicus*), it is shown in **Table 6: below**.

Table 6: The Ratio of Types of Fishing Crab (*Portunus pelagicus*) Dominant Based on Average Catch/Trip

Tool Type Catch	Average	portion	Effort	CPUE	% CPUE	RPF	Ratio
Seine net	22.8	0.04	50523	0.00043	10.15	0.4390	2.27
Drift Gill net	96.4	0.21	108774	0.00088	20.49	0.8864	1.22
Fixed Gillnet	106.3	0.23	106332	0.00100	23.32	0.9999	1.11
Trammel net	213.3	0.47	213343	0.00100	23.13	1.0000	1
Trap	9.35	0.02	9358	0.0099	23.10	0.9993	2.23
Other Trap	0.24	0.05	5375557	0.0000	0.001	0.0000	2.24
Amount	447.77	1.02	9863887	0.00432	100.00	4.3245	10.07

***Source*:** Analysis 2022

Table 7: Capture Tool Before and After Conversion (Trip)

Capture Before Convert Tool					Capture After Convert Tool				
Year/ RFP	Trips/fishing gear				Year/ RFP	Trips/fishing gear			
	Tramel net	Fixed Gillnet	Trap	Drift Gillnet		Tramel net	Fixed Gillnet	Trap	Drift Gillnet
	1	0.29309	0.4121	0.136478		1	1	1	1
2007	16662	176437	142799	124939	2007	16662	517119	20291.7	17051.4
2008	74771	459764	404385	87379	2008	74771	131572.2	57463.1	11925.3
2009	89210	478640	487149	62840	2009	89210	140284.5	69223.8	85762.2
2010	88105	578291	431749	108687	2010	88105	169491.3	61357.9	14833.3
2011	57598	433778	460267	212597	2011	57598	127135.9	65403.9	29014.8
2012	48848	584192	361869	141439	2012	48848	171220.8	51421.5	19303.3
2013	96565	480617	340416	826844	2013	96565	140864.0	48373.1	12846.0
2014	38873	480617	291879	184050	2014	38873	140864.0	48373.1	12846.0
2015	38735	500324	364130	185686	2015	38735	146639.9	41476.0	25118.7
2016	38735	472004	479526	287780	2016	38735	138339.6	51742.8	25342.0
2017	78730	436050	394412	215603	2017	78730	127801.8	56045.9	39275.6
2018	15169	588344	460490	223850	2018	15169	172437.7	65435.6	29425.0
2019	70286	453119	332592	232968	2019	70286	132804.6	47261.3	31795.0
2020	62526	2381113	469008	1624102	2020	62526	697880.4	66646.0	21654.1
2021	49981	1175433	866195	794280	2021	49981	344507.6	123086.3	18401.3

***Source*:** Analysis 2022

Trammel net fishing gear construction

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

Webbing body

In this position, most of the crabs are caught stuck, where the mesh size is smaller than the two outer layers. The thread diameter is 210 dp, the mesh size is 1.75 inches (38.0 mm), the length is 65.55 m (1,550 points) and the height is 50 points. In the outer layer of the net body, the thread size is larger, namely 210 d6, 18 eyes long and 7 eyes high with a mesh size of 10.5 inches.

Edge of the net (Selvage/srampat)

Material from double yarn, 40 mm mesh, and consists of 2 eyes on the top edge of the net and 7 eyes on the bottom edge of the net, the net material is Polyethylene, size 210 d6. The edge net consists of the upper and lower ris ropes as a connection to the body of the net, while the lower ris rope is 33 m long. On the top ris strap is attached a plastic buoy No. 18 with an installation distance of 40 – 50 cm, the float rope is made of Polyethylene material with a diameter of 3 – 4 mm, equipped with a ballast (14 grams/piece) and the distance between the weights is 20 cm, the material is Polyethylene, as a complement, the main buoy is added as a fishing gear.

Estimation of crab stock (*Portunus pelagicus*)

Analysis of the estimation of the mapping of the potential of the Rajungan (*Portunus pelagicus*) resource is an important aspect of policy, whether the resource is degraded or otherwise, this condition can be used as a reference early warning signal. Although the nature of these resources can be renewed (renewable), if management is not carried out in their utilization, it can lead to overfishing. This analysis is based on the aspect of trips per fishing gear. The crab (*Portunus pelagicus*) is dominant in the condition of open access resources for the period 2008-2021. 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, 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 over fishing occurred in 2022 with optimal effort (Eopt) of 6363750 trips/year, so that the utilization rate exceeded 100%. The sustainability of the crab (*Portunus pelagicus*) resource is influenced by genetic diversity, population spatial connectivity and management actions [31]. Furthermore, the critical period (zoea, megalopa, juvenile) occurs in May and October with peak spawning in August, this condition is influenced by factors suitability of water quality, environmental conditions, catchment area and life cycle of the crab (*Portunus pelagicus*) [15], even the juvenile phase of survival decreased at the highest temperature of 32

°C [2]. While feed and density factors have no significant effect on growth rates and survival [1], the types of food vary which reflects the ability to adopt different ways of eating and tend to be omnivores [26]. Even to create sustainable crab (*Portunus pelagicus*) resources, according to [7] in the future, it will require adaptive management of each fishery system, the establishment of a mechanism for decision making, strengthening of knowledge-based fisheries management capacity, law enforcement and alignment of interests and understanding there is complexity in the ecological management of fishery resources. This is in accordance with the research of [11] that national integration is needed to create sustainable crab (*Portunus pelagicus*) resources, such as Governor Decree no. 523/93/2017 concerning the Establishment of the Central Java Rajungan Fishery Management Committee (*Portunus pelagicus*) which aims to increase stocks with proper monitoring programs and community commitment to avoid overfishing. 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 **Fig.10**: below

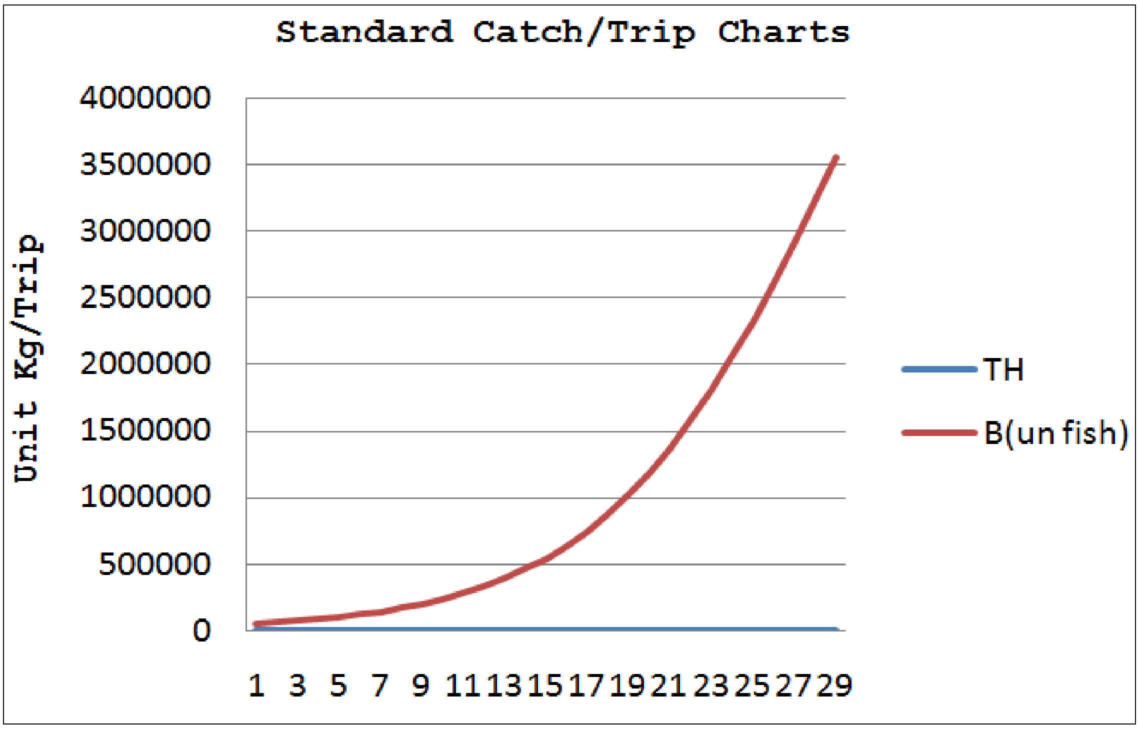


Fig 10: Crab Stock Dynamics Chart (*Portunus pelagicus*) With Open Access Limits With Amount of Biomass No Cat

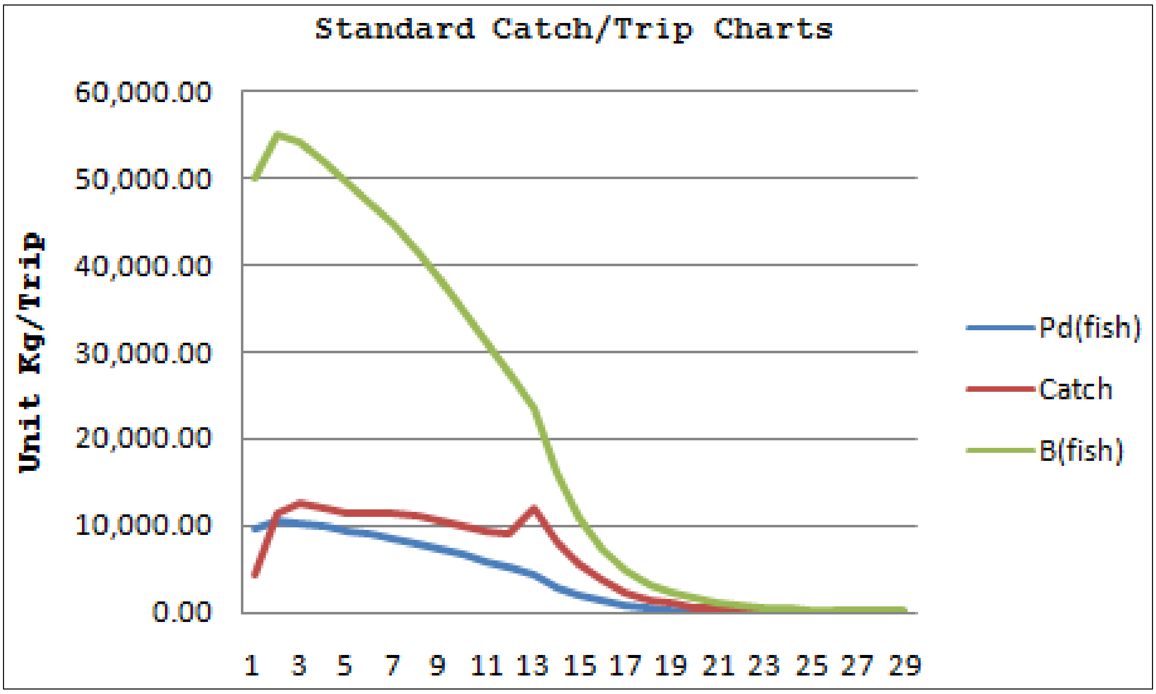


Fig 11: Crab Stock Dynamics Chart (*Portunus pelagicus*) Open Access Limits wit Amount of Captured Biomass

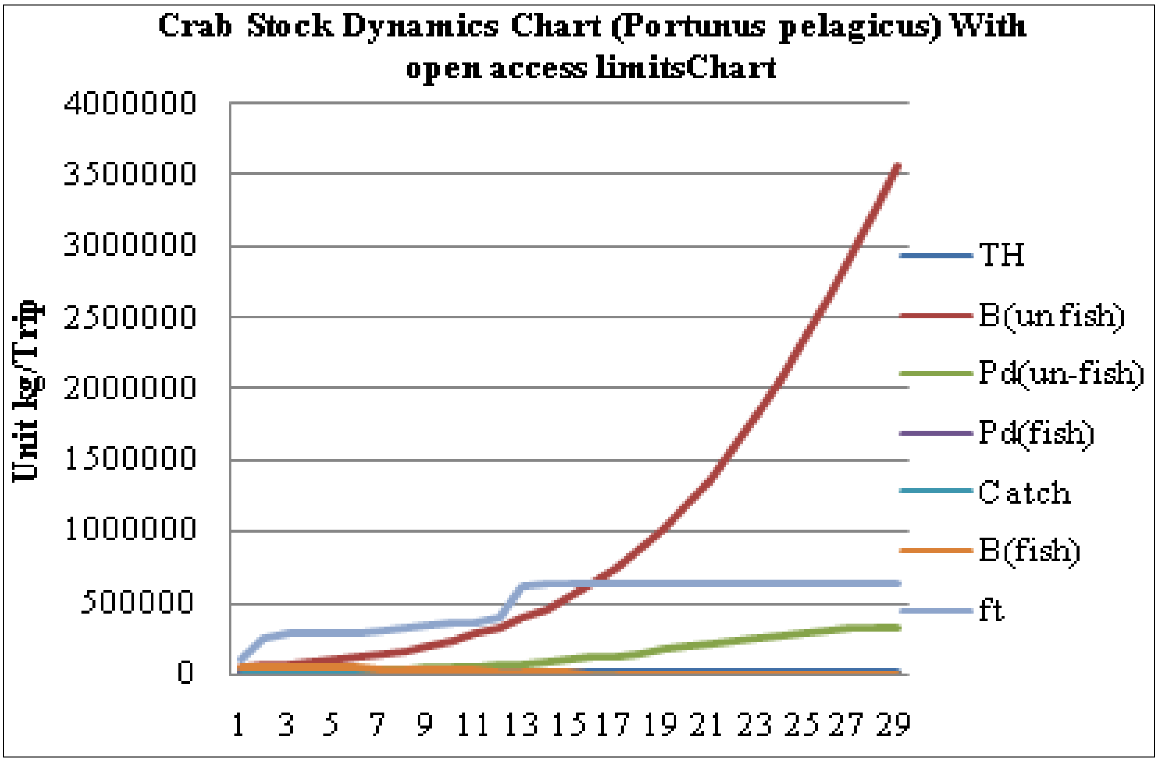


Fig 12: Crab Stock Dynamics Chart (*Portunus pelagicus*) With Open Access Limits

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

Conclusion

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

Recommendation

It is necessary to do further research using analytical models including (Gonadal maturity level, size of weight and width as well as the use of environmentally friendly fishing gear in a sustainable manner).

References

1. Ariyati RW, Rejeki S, Bosma RH. The Effect of Different Feed and Stocking Densities on Growth and Survival Rate of Blue Swimming Crablets (*Portunus pelagicus*). IOP Conference Series: Earth and Environmental Science. 2018;116(1):1-8. https://doi.org/10.1088/1755-1315/116/1/012071
2. Azra MN, Chen JC, Hsu TH, Ikhwanuddin M, Abol-Munafi AB. Growth, molting duration and carapace hardness of blue swimming crab, *Portunus pelagicus*, instars at different water temperatures. Aquaculture Reports. 2019;15(September):1-6. https://doi.org/10.1016/j.aqrep.
3. Azra MN, Ikhwanuddin M, Abol-Munafi AB. Behavioural data on instar crab movement at different thermal acclimation. Data in Brief. 2019;22:998–1002. https://doi.org/10.1016/j.dib.
4. Bay L, Buton C, Hamid A, Wardiatno Y, Tumpal D, Lumban F, Riani E. Distribution, body size, and eggs of ovigerous swimming crab (*Portunus pelagicus* Linnaeus.). 2016;4(September):108–116.
5. Botsford LW, Micheli F, Hastings A. Principles for the design of marine reserves. Ecological Applications. 2013;13(1):S25-S31.
6. Bjordal A. Regulation of Fishing Gears and Methods. Centre for Development Cooperation in Fisheries, Institute of Marine Research, A Fishery Manager's Guidebook, Second Edition; c2009.
7. Chen Z. Developing a pilot quota-based fishery management system for Fujian's Portunid crab fishery, 2019, 28-38. http://hdl.handle.net/1773/44349
8. Chhom V. Status of Blue Swimmer Crab (*Portunus* spp.) Fishing in Chang Hoan and Kep Thmey Fisheries Community, Kampot Province, 2012, 133-139.
9. CIESM. Portunidae, *Portunus pelagicus*; c2000. http://www.ciesm.org/ atlas/*Portunus pelagicus*.html. Download 3 Oktober 2020.
10. Fowler AM, Hall KC, Liggins GW, Chick RC. Prioritising fished stocks for monitoring and assessment: A decision analysis approach for diverse fisheries of limited commercial value. Ocean and Coastal Management. 2021;199(September 2020):105404. https://doi.org/10.1016/j.ocecoaman.
11. Ghofar A, Redjeki S, Madduppa H, Abbey M, Tasunar N. Inclusive blue swimming crab fishery management initiative in Betahwalang Demak, Indonesia. IOP Conference Series: Earth and Environmental Science. 2018;116(1):1-10. https://doi.org/10.1088/1755-1315/116/1/012068
12. Giraldes BW, Al-Maslamani I, Al-Ashwel A, Chatting M, Smyth D. Basic assessment of *Portunus segnis* (Forskål, 1775) - A baseline for stock management in the Western Arabian Gulf. Egyptian Journal of Aquatic

Research. 2016;42(1):111-119. https://doi.org/10.1016/j.ejar.
13. Hilborn R. Sustainable Exploitation of Renewable Resources. Annual Review of Ecology and Systematics. 1995;26(1):45–67. https://doi.org/10.1146/annurev.ecolsys.26.1.45
14. Hosseini M, Pazooki J, Safaie M, Tadi-Beni F. The Biology of the Blue Swimming Crab *Portunus segnis* (Forskal, 1775) along the Bushehr Coasts, Persian Gulf. 2014;1(2):81–92.
15. Kasmawati I, Asbar E, Asmidar. Fisheries Management of Blue Swimming Crab (*Portunus pelagicus*) based on Zoning Area in Pangkep Waters, South Sulawesi, Indonesia. IOP Conference Series: Earth and Environmental Science. 2019;253(1):1-10. https://doi.org/10.1088/1755-1315/253/1/012031
16. [ITIS] Integrated Taxonomy Information System. Rutaceae ff North America Update, Database (Version 2011). The Flora of North America Expertise Network; c2011. https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=501574#null. [Diakses 21 Oktober 2019].
17. Johnston DJ, Yeoh DE, Harris DC. Environmental drivers of commercial blue swimmer crab (*Portunus armatus*) catch rates in Western Australian fisheries. Fisheries Research. 2021;235(November 2020):105827. https://doi.org/10.1016/j.fishres.
18. Johnston D, Harris D, Caputi N, Thomson A. Decline of a blue swimmer crab (*Portunus pelagicus*) fishery in Western Australia-History, contributing factors and future management strategy. Fisheries Research. 2011;109(1):119-130. https://doi.org/10.1016/j.fishres.
19. Josileen Jose, Menon NG. Larval stages of blue swimmer crab, *Portunus pelagicus* (Linnaeus,1758) (Decapoda, Brachyura). Crustaceana. 2011;77(7):785-803.
20. Kangas MI. Synopsis of the biology and exploitation of the blue swimmer crab, *Portunus pelagicus* Linnaeus, in Western Australia. Fisheries Research Report. 2014;(121):1-22.
21. Karar S, Hazra S, Das S. Assessment of the heavy metal accumulation in the Blue Swimmer Crab (*Portunus pelagicus*), northern Bay of Bengal: Role of salinity. Marine Pollution Bulletin. 2019;143(April):101-108. https://doi.org/10.1016/j.marpolbul.
22. King M. Fisheries Biology, Assessment and management. Fishing News Books. Oxford. London, 1995, 117
23. Liu S, Sun J, Hurtado LA. Genetic differentiation of *Portunus* trituberculatus, the world's largest crab fishery, among its three main fishing areas. Fisheries Research. 2013;148:38-46. https://doi.org/10.1016/j.fishres.
24. Prince J, Creech S, Madduppa H, Hordyk A. 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. 2020;36:101309. https://doi.org/10.1016/j.rsma.2020.101309
25. Potter IC, De Lestang S. Biology of the blue swimmer crab *Portunus pelagicus* in Leschenault Estuary and Koombana Bay, South-Western Australia. Journal of the Royal Society of Western Australia. 2013;83(4):443–458.
26. Rabaoui L, Yacoubi L, Lin YJ, Joydas TV, Maneja RH, Dagoy J, *et al*. Distribution, abundance, and life history traits of the blue swimming crab *Portunus segnis* (Forskål, 1775) in the Saudi waters of the Arabian Gulf. Regional Studies in Marine Science. 2021;46:101895. https://doi.org/10.1016/j.rsma.
27. Samhouri JF, Ramanujam E, Bizzarro JJ, Carter H, Sayce K, Shen S. An ecosystem-based risk assessment for California fisheries co-developed by scientists, managers, and stakeholders. Biological Conservation. 2019;231(December 2018):103–121. http://doi.org/10.1016/j.biocon.2018.12.027
28. Sondita MFA. Manajemen Sumber Daya Perikanan. Jakarta: Universitas Terbuka; c2010.
29. Tran PD, Nguyen LT, To PV, Nguyen KQ. Effects of the trap entrance designs on the catch efficiency of swimming crab *Charybdis feriata* fishery. Fisheries Research. 2020;*232*(February):105730. https://doi.org/10.1016/j.fishres.
30. United States Agency International Development (USAID). Protokol Pengumpulan Data Perikanan Rajungan (*Portunus pelagicus*), USAID Indonesia; c2015.
31. Madduppa H, Martaulina R, Zairion Z, Renjani RM, Kawaroe M, Anggraini NP, *et al*. Genetic population subdivision of the blue swimming crab (*Portunus pelagicus*) across Indonesia inferred from mitochondrial DNA Implication to sustainable fishery. PLoS ONE. 2021;16(2 February):1-15. https://doi.org/10.1371/journal.pone.0240951
32. Naimullah M, Lan KW, Liao CH, Hsiao PY, Liang YR, Chiu TC. Association of environmental factors in the Taiwan strait with distributions and habitat characteristics of three swimming crabs. Remote Sensing. 2020;12(14). https://doi.org/10.3390/rs12142231
33. Nédélec C, Prado J. (eds.). FAO Catalogue of Small Scale Fishing Gear. Blackwell Science Ltd., Oxford, 1989, 224.
34. Nitiratsuwan T, Tanyaros S, Panwanitdumrong K. Journal of Science and Technology Distribution of berried female blue swimmer crabs *(Portunus pelagicus Linneaus*, 1758) in the coastal waters of Trang province, southern Thailand. 2013;7:52-59.
35. Windsland K, Hvingel C, Nilssen EM, Sundet JH. Evaluation of von bertalanffy growth curves for the introduced red king crab (*Paralithodes camtschaticus*) in Norwegian waters. Fisheries Research. 2013;145:15–21. doi:10.1016/j.fishres.
36. Zainal KAY. Natural food and feeding of the commercial blue swimmer crab, *Portunus pelagicus* (Linnaeus, 1758) along the coastal waters of the Kingdom of Bahrain. Journal of the Association of Arab Universities for Basic and Applied Sciences. 2013;13(1):1-7. https://doi.org/10.1016/j.jaubas.
37. Zhang J, Pei Z, He P, Shi J. Effect of escape vents on retention and size selectivity of crab pots for swimming crab *Portunus* trituberculatus in the East China Sea. Aquaculture and Fisheries. 2021;6(4):340-347. https://doi.org/10.1016/j.aaf.
38. Zhang T, Sun Y, Song K, Du W, Huang W, Gu Z, *et al*. Microplastics in different tissues of wild crabs at three important fishing grounds in China. Chemosphere. 2021;271:129479. https://doi.org/10.1016/j.chemosphere. juvenile and adult.