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Fishing industry development model based on fish resources and environmental carrying capacity in Ternate Fishing Port area, Indonesia

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Abstract

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The potential for fish in FMA-RI 715 reaches 631 703 t/year, but the utilization in North Maluku is only 57.2%, and landed directly in TFP only 0.56–1%. So that there are opportunities to develop the fishing industry, especially with sustainable patterns. This research aimed to analyze the condition of aquatic environment, fish production and its relationship with industrial transactions, and to develop a fishing industry model, based on fish resources and environmental carrying capacity in TFP area. Research used descriptive method, power model, scoring method, and context analysis. The results showed that Ternate's aquatic environment was in unpolluted and safe for industrial fishing operations. Fish production (X) in TFP tended to decrease (2018–2022), but had a positive relationship with industrial transaction value (Y), followed Ln(Y) = Ln(136.686) + (1.37xLn(X)). The developed fishing industry model was divided into three parts, namely: (a) selection of industrial business target fish, (b) industrial development scheme design, and (c) determination of fishing technology. The business target fish were skipjack (*Katsuwonus pelamis*), tuna (*Thunnus* sp.), yellow tail (*Caesio cuning*), grouper (*Epinephelus* sp.), cob (*Euthynnus affinis*), kite (*Decapterus* spp.), blue escape (*Caesio caerulaureus*), bloating (*Rastrelliger* sp.), anchovies (*Stolephorus indicus*) and mackerel (*Scomberomorus commerson*). The industrial development scheme was prioritized in the partnership *platform*. Fishing technology was directed at troll lines, handlines, pole and lines, traps, gillnets, and boat charts.

Keywords: environment; fishing; industry; pollution; power model
Abbreviations: TFP – Ternate Fishing Port; FMA-RI 715 – Fisheries Management Area of the Republic of Indonesia 715

Introduction

Ternate Fishing Port (TFP) is one of the ports that has received important attention to boost fish production in eastern Indonesia. This is because TFP is the largest fishing port in North Maluku Province, and is in the central position of Fisheries Management Area of the Republic of Indonesia 715 (FMA-RI 715), which extends from east to west. The average fish production in TFP during the 2012 – 2016 period, reached 6654 t/year (Jaya et al., 2017; TFP, 2017), whereas in the last 3 years it has decreased. The ups and downs of fish production are strongly influenced by the activities of the fishing industry, especially those, operating large and medium fishing vessels. In 2022, the number of fishing vessels > 30 GT and 5–30 GT in TFP were 48 units and 72 units, respectively, while < 5 GT was 66 units (TFP, 2023).

The fishing industry in TFP is included in the medium and small industry category, which employs less than 100 fishermen, the investment value is < Rp. 15 billion, and the range of operations is local to national (Ministry of Industry 2016; CSA, 2023). The fishing industry generally operates in FMA-RI 715, especially in the waters around Ternate. The fish potential in FMA-RI 715 reaches 631 703 t/year (Suman et al., 2018). Meanwhile, the level of potential utilization of these fish in the North Maluku region was around 57.2% (CSA, 2022), and those that were landed directly through the TFP were only 0.56-1%. This means that there are still opportunities to further develop fishing industry activities. However, to maintain the sustainability of industrial activities, their development must be prospective and appropriate to the carrying capacity of the aquatic environment.

The main determinant of the prospectivity of the fishing industry is the raw materials (fish resources), which are the basis for its development. Several studies state that the fish resource base can strengthen the existence of the fishing industry, because the potential of target fish has been well calculated and there is protection for biodiversity (Bethle et al., 2021; Farthing et al., 2022; Zulfahmi et al., 2022), and transactions are continuous (Ferguson et al., 2022; Lubis et al., 2012). This effort needs to be supported by a good management system and adequate facilities (Jaya et al., 2017; Stringer et al., 2022). For environmental carrying capacity, the most crucial is the condition of the aquatic environment. Pulford et al. (2017) and Naim & Sultan (2019) stated that environmental conditions influence growth and reproduction of fish in large areas. If the waters are polluted, fishing operations also cannot be carried out because their effectiveness is compromised (Muallil et al., 2014; Malta et al., 2019), and the fish caught are not safe for consumption (Najamuddin et al., 2020; Mustaruddin et al., 2023). The carrying capacity of the environment is also influenced by the utilization status of waters and the suitability of fishing operations to seasonal patterns (Thanassekos & Scheld, 2020; Suman et al., 2018).

These studies have discussed fish resources, the aquatic environment, and fishing, but have not yet examined it as an integrated industrial system in fishing port areas. This research tries to integrate/connect the three using quantitative and contextual modeling techniques. The combination of modeling techniques makes it easier to analyze all types of data that are relevant for developing future industrial models (Pei et al., 2019; Tian et al., 2023). This research aimed to analyze the condition of the aquatic environment, fish production and its relationship with the formation of industrial transactions, and to develop a model for developing the fishing industry based on fish resources and environmental carrying capacity in the TFP area.

Materials and Methods

The materials and tools used in this study consisted of questionnaires, *checklists*, stationery, water sample bottles, and cameras. This research was conducted from August, 2020, to February, 2023. The research location was the TFP area, North Maluku Province. The data collected in this study consisted of aquatic environment data, data on fish production and capture fisheries transactions, data on fish potential and protecting biodiversity in Ternate waters, data on fishing technology and fishing ground, as well as data on utilization status and fishing season in the TFP area. Data collection used the method of distributing questionnaires, direct observation, and literature review.

Questionnaires were distributed to collect data on fish potential, transaction value, protecting biodiversity, fishing technology, fishing ground, and fishing season. Respondents were skippers/fishing boat owners (15 people), fish collectors (3 people), fishery investors (3 people), and TFP officials (2 people). The selection of respondents was carried out by purposive sampling by taking into account their activeness, position/position, and length of service. Direct observations were made to collect data on the aquatic environment. There are two observation points, namely around TFP (L1) and north of Ternate Island (L2). Literature review was conducted to collect time series data on fish production, fish utilization status, and other completeness of data that were not fulfilled in the questionnaire and direct observation. The main literature reviewed is Fisheries Statistics Book in TFP, Fisheries Performance Report of North Maluku Province, research results on fisheries and the aquatic environment, as well as regulations related to the development of the fishing industry.

The research data were analyzed using descriptive methods, power models, scoring methods, and context analysis. Descriptive method was used to describe the environmental conditions of Ternate waters and its surroundings. The aquatic environment data had previously been tested in a laboratory and compared with seawater quality standards for marine biota according to Ministry of Environment (2004). Description of the results of the analysis was presented in the form of tables, graphs or relevant images. Power model was used to analyze the dynamics of fish production in relation to the formation of the transaction value of the fishing industry for 5 years (2018 – 2022). To be more accurate, production data and transaction values were presented every six months (semester units). Mustaruddin et al. (2023) and Tian et al. (2023) stated that, the duration of a tight presentation can increase the accuracy of the data in explaining the real system being represented. The power model formula used is:

$$Ln(Y) = Ln(a) + (bxLn(X)),$$

where Y = fishing industry transaction value, X = fish production, a = coefficient of variable X, and d = constant. Furthermore, to measure the performance of the model, two statistical tests were used, namely the Anova test and R square (R^2). The power model obtained is declared eligible if it has an Anova value of < 0.05 and a high R square (R^2) value (Pei et al., 2019).

Scoring method and context analysis were used to build a model for the development of the fishing industry in TFP. The scoring method assists in the selection of fish to target of fishing industry business. Meanwhile, context analysis was used to develop industry development schemes and suitable fishing technology for fish that were targeted by fishing industry. The ultimate goal of using both methods is to obtain a fishing industry development model that is relevant to fish resources prospects and the carrying capacity of the environment where fish are caught. These fish resources dimensions and environmental carrying capacity are in accordance with the principles of Sustainable Development Goals (SDGs) (ECOSOC, 2023). The scoring method formula used is:

$$V(X_i) = (X_i - X_{min}) / (X_{max} - X_{min})$$

$$V(A) = \sum V(Xi),$$

where $V(X)$ = the value function of the X sub-dimension, X_i = the X sub-dimensional value of the i-th fish, X_{min} = the lowest score for the X sub-dimension, X_{max} = the highest value for the X sub-dimension, $V(A)$ = function of the total value of all sub-dimensions for the i^{th} fish, i = 1,2,3......, n (every fish produced in TFP).

Approximately 50% of the fish with the highest V(A) value is determined as the selected fish/target of the fishing industry business. For context analysis, the things considered in the analysis of industrial development schemes are sources of capital, form of industrial business, target fish, management, wage system, and contract period (if in partnership). Meanwhile, the considerations in determining technology/fishing vessels are technology compatibility with target fish resources for fishing industry, ease of operation, fishing ground, and friendliness to the aquatic environment (Malta et al., 2019; Mustaruddin et al., 2020).

Results and Discussion

The aquatic environment, fish production and its relationship with the industrial transactions

The conditions of the aquatic environment determine the types of fish resources and their distribution patterns in a water area (Speir et al., 2014; Pulford et al., 2017). This is closely related to the need for fish to grow, reproduce, and find food. In general, fish resources require good aquatic environmental conditions, not polluted, rich in nutrients, and their natural characteristics are still maintained. Table 1 presents the environmental conditions of Ternate and surrounding waters.

Based on Table 1, Ternate's aquatic environment was in good condition and relatively safe from pollution. Smell, sea surface temperature (SST), and salinity were still relatively natural and suitable for fish breeding. According to Pulford et al. (2017) and Boschetti et al. (2023), SST affects photosynthesis and the formation of nutrient components needed by fish, while salinity affects fish weight growth and resistance to being in an area of water. Fish that are resistant stay

Table 1. Ternate waters environmental conditions

Parameter	Quality standard*)	Parameter value			Status
		L1	L2	Average	
pH	6-9	6.6	7.1	6.85	Good
Smell	Experience (-)	experience	experience	experience	Unpolluted
Turbidity (NTU)	< 5	4.1	3.5	3.8	Unpolluted
Color (CU)	< 50	32	21	26.5	Unpolluted
DO (ppm)	> 4	5.2	6.5	5.85	Good
Current speed (m/sec)	< 2	1.08	1.38	1.23	Good
SST (^oC)	Experience	29.2	28.5	28.9	Good
Salinity (ppt)	Experience	30.2	31.8	31.0	Good
Chlorophyll-a (mg/m^3)	-	0.24	0.31	0.28	Good
Nitrite (ppm NO_2)	< 0.06	0.060	0.044	0.052	Unpolluted
Hg(ppm)	$\leq$ 0.002	0.0019	0.0012	0.0016	Unpolluted
Pb (ppm)	< 0.001	0.00088	0.00068	0.00078	Unpolluted

Note: *Ministry of Environment (2004), L1 = waters around TFP, L2 = north waters of Ternate Island longer and even breed in these waters. In Ternate waters, this was also supported by high dissolved oxygen (DO) content (5.85 ppm) and good chlorophyll-a (0.28 ppm). The chlorophyll-a content is an indication of the abundance of food needed by fish (Naim & Sultan, 2019). Ternate waters also had a low content of heavy metals (Hg and Pb), so they did not interfere with fish breeding and production results were also safe for consumption (Iau-Ren et al., 2022; Najamuddin et al., 2020).

Fish production in TFP tended to decrease during 2018–2022 (Figure 1). However, the behavior of the semester increased three times, namely in semester 2 (S2) of 2018 (3142 t), semester 2 of 2020 (2679 t), and semester 2 of 2022 (1879 t). This behavior is strongly influenced by the dynamics of the fishing season (Ferguson et al., 2022), and the pattern of preparing fish landing facilities at the port (Jaya et al., 2017). The composition of fish landed in TFP was also very diverse, with 20 species being produced continuously. The fish were julung-julung, rabbitfish, jackfruit seeds, skipjack, squid, yellow tail, cockatoo, red snapper, bloating, grouper, chair, pompano, kite, emperor, blue escape, tuna, trevally, mackerel, anchovies, and cob. The diversity of production results is thought to be due to the condition of the waters that have not been polluted and are still rich in nutrients (Mustaruddin et al., 2020; Tian et al., 2023). Apart from this, the downward trend of fish production in the last 5 years needs to be addressed. One of them is by intensifying fishing industry activities using reliable, environmentally friendly and fish resources-based technology (Thanassekos & Scheld, 2020; Stringer et al., 2022). Muallil et al. (2014) and DMF (2020) stated that the use of technology in fishing, can increase the production of important fish resources fish such as skipjack, tuna, and grouper. This fishing technology also improves the productivity and flexibility of fishermen in catching fish.

For industrial transaction values, the dynamics were somewhat different from fish production, namely fluctuating in a stable pattern during 2018 – 2022 (Figure 1). This stable transaction value was influenced by selling prices, which tend to increase even though fish production decreases. TFP (2023) stated that the average price of fish in 2022 will reach IDR 28 686 per kg, an increase compared to 2018 (IDR 21 396 per kg), and 2020 (IDR 21 862 per kg). If the transaction value is compared to the amount of fish production each semester, then the ups and downs of the transaction value were more dynamic. Tangke (2020) and Thanassekos & Scheld (2020) stated that the transaction value of fisheries has quite complex dynamics influenced by the composition of fish caught, fish quality, fish logistics flows, and competition, which leads to adjustments to transaction prices. This condition causes the relationship between increased production which is not always linear with the formation of transaction value. Table 2 presented the results of the statistical test of the power model in analyzing the non-linear relationship between fish production and the formation of the transaction value of the fishing industry in TFP.

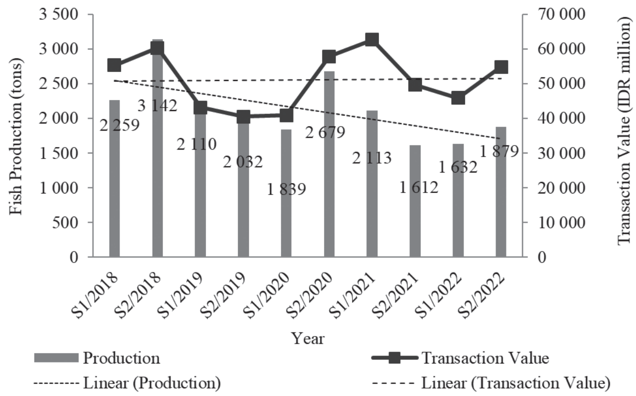

Fig. 1. The dynamics of production and transactions in the fishing industry in the TFP in 2018–2022

Based on Table 2, the power model had an Anova value of < 0.05, which was 0, so it fulfilled the requirements to explain the relationship between fish production, and the formation of the transaction value of the fishing industry in TFP. This model also had a high R square value, which was 0.798. The R square value represents the model's ability to explain the influence of one or more independent variables on the dependent variable, which is shown in a certain relationship pattern (Pei et al., 2019; Mustaruddin et al., 2023). Table 3 presented the results of the model coefficient analysis regarding the relationship between fish production and the transaction value of the fishing industry.

Table 2. The results of the statistical test of the power model of the relationship between fish production and the formation of the transaction value of the fishing industry

Model	Anova	R	R square	Adjusted R square	Std. error of the estimate
Power	0.000	0.893	0.798	0.773	0.267

Note: The independent variable is Production, The dependent variable is Transaction_Value

Table 3. Results of the coefficient analysis of the power model of fish production with the formation of the fishing industry transaction value

Power model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. error	Betas		
Ln(Production)	1.370	0.244	0.893	5.619	0.000
(Constant)	136.686	409.271		0.334	0.747

Note: The dependent variable is Ln(Transaction_Value)

Based on Table 3, the relationship between fish production and the formation of the fishing industry transaction value in the TFP, followed the power model $Ln(Y) = Ln(136.686) + (1.37 \times Ln(X))$, where Y was the fishing industry transaction value and X was fish production in TFP. This power model could explain 79.8% of the effect of fish production on the ups and downs of the transaction value of the fishing industry. The value of 79.8% is quite reasonable considering that fish landed in TFP are generally sold fresh, and not many fishing industries, or fisherman owners carry out further handling before the fish they catch are sold. However, the results of the previous analysis showed that fish production in TFP tended to decrease. If it continues, it can disrupt the transactions that are formed and even the sustainability of the fishing industry activities in TFP. This can be anticipated by strengthening industrial development schemes (Mustaruddin & Astarini, 2019; Thanassekos & Scheld, 2020), by taking into account the superiority of fish resources and environmental carrying capacity in TFP area (Melissa et al., 2015; Naim & Sultan, 2019).

Fishing industry development model based on fish resources and environmental carrying capacity

The developed fishing industry development model was divided into three parts, namely: (a) selection of industrial business target fish, (b) industrial development scheme design, and (c) determination of technology/fishing vessels to operate. The preparation of this model used the fish resources approach and the carrying capacity of the environment. This is because the activity of the fishing industry is very dependent on the condition of fish resources and the carrying capacity of the environment, where the target fish are caught. The dimensions of fish resources can be seen from the transaction value, fish potential, and protecting biodiversity (Melissa et al., 2015; Ferguson et al., 2022; Zulfahmi et al., 2022). Meanwhile, the carrying capacity of the environment that stands out influences the operation of the fishing industry in a water area, including the condition of the aquatic environment, the utilization status of fish, and the distribution of target fishing seasons (Hermanto et al., 2019; Mustaruddin & Astarini, 2019; Farthing et al., 2022). Table 4 presented the results of the analysis of industrial business target fish using both approaches to the two dimensions.

Referring to Table 4, the fish selected as targets for the fishing industry business in the TFP were skipjack, tuna, yellow tail, grouper, cob, kite, blue escape, bloating, anchovies and mackerel. These fish had a better total value function (VA) from the combination of fish resources dimensions and environmental carrying capacity dimensions than other fish. For example, skipjack had a VA = 5.500, because the transaction value reached IDR 28.97 billion/year, abundant fish potential (found in many fishing grounds in Ternate waters), utilization status was still under exploited, not too affected by water quality in a particular aquatic environment (can migrate), and can be caught throughout the year (4 fishing seasons). Lubis et al. (2012), Borland & Bailey (2019) and Uzunova et al. (2015) stated that fish that can be caught throughout the year and the transactions are good, will have an impact on the fishing industry's operations continuing and the best prices can be enjoyed.

Yellow tail, grouper, kite, tuna and mackerel, can also be caught all year round. Tuna (VA = 4.912) had fair transaction value (Rp 19.81 billion/year), and could be caught in many fishing grounds. Grouper (VA = 4.112) and blue escape (VA = 3.675) were open to development opportunities on an industrial scale (*underexploited*), much needed by the market, and inhabit scattered coral areas in Ternate waters. Specifically for grouper, it was directly purchased by Hong Kong and Taiwanese ships that came to TFP (DMF 2020; Tangke, 2020). Besides being able to be caught throughout the year, fish that live in this coral area also help natural processes and environmental conservation at the bottom of the waters (Anna et al., 2017; Najamuddin et al., 2020; Mustaruddin et al., 2020). This is certainly positive for the sustainability of the fishing industry operations in Ternate waters and its surroundings.

Furthermore, industrial development schemes for selected fish businesses could be offered in two schemes, namely the independent scheme and the partnership scheme. The partnership scheme can be the main option if investors are not yet willing to invest independently, for example because they do not know much about the conditions of TFP or some

Table 4. Results of analysis of fish that are the target of the fishing industry business in TFP

Alternative target fish for industrial business	Dimensions of fish resources			V1	Dimensions of environmental carrying capacity			V2	VA
	V_{11}	V_{12}	V_{13}		V_{21}	V_{22}	V_{23}		
Julung-Julung (*Hemiramphus lutkei*)	0.074	0.000	0.500	0.574	1.000	1.000	0.500	2.500	3.074
Rabbitfish (*Siganus* sp.)	0.053	0.500	0.500	1.053	1.000	1.000	0.000	2.000	3.053
Jackfruit seeds (*Upeneus mullocensin*)	0.093	0.500	0.500	1.093	1.000	0.000	0.500	1.500	2.593
Skipjack (*Katsuwonus pelamis*)	1.000	1.000	0.500	2.500	1.000	1.000	1.000	3.000	5.500
Squid (*Loligo* sp.)	0.029	0.500	0.000	0.529	0.000	0.000	0.500	0.500	1.029
Yellow tail (*Caesio cuning*)	0.13	0.500	1.000	1.630	1.000	1.000	1.000	3.000	4.630
Cockatoo fish (*Scarus croicensis*)	0.006	0.500	0.000	0.506	1.000	0.000	0.000	1.000	1.506
Red snapper (*Lutjanus* sp.)	0.047	0.000	0.000	0.047	1.000	0.000	1.000	2.000	2.047
Bloating (*Rastrelliger* sp.)	0.167	0.500	0.500	1.167	1.000	1.000	0.500	2.500	3.667
Grouper (*Epinephelus* sp.)	0.112	0.500	0.500	1.112	1.000	1.000	1.000	3.000	4.112
Chair (*Nemipterus hexodon*)	0.011	0.000	0.500	0.511	1.000	0.000	0.500	1.500	2.011
Pompano (*Caranx ignobilis*)	0.023	0.000	0.000	0.023	1.000	0.000	0.000	1.000	1.023
Kite (*Decapterus* spp.)	0.194	0.000	0.500	0.694	1.000	1.000	1.000	3.000	3.694
Emperor (*Lethrinus lentjan*)	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.500	0.500
Blue escape (*Caesio caerulaureus*)	0.175	0.500	0.500	1.175	1.000	1.000	0.500	2.500	3.675
Tuna (*Thunnus* sp.)	0.412	1.000	0.500	1.912	1.000	1.000	1.000	3.000	4.912
Trevally (*Selaroides leptolepis*)	0.072	0.500	0.500	1.072	1.000	1.000	0.000	2.000	3.072
Mackerel (*Scomberomorus commerson*)	0.016	0.500	0.000	0.516	1.000	1.000	1.000	3.000	3.516
Anchovies (*Stolephorus indicus*)	0.101	0.500	0.500	1.101	1.000	1.000	0.500	2.500	3.601
Cob (*Euthynnus affinis*)	0.206	0.500	0.500	1.206	1.000	1.000	0.500	2.500	3.706

Note: V_{11} = value function of transaction value, V_{12} = value function of fish potential, V_{13} = value function of protecting biodiversity, V_{21} = value function of utilization status, V_{22} = value function of the aquatic environment, V_{23} = value function of fishing season, V1= value function of fish resources dimension, V2 = value function of environmental carrying capacity dimension, VA = total value function

of the investment funds are still being used elsewhere. The principle of the partnership scheme is investment cooperation involving many parties in fishing industry activities, such as private investors, state-owned investors, central government, local government, and local fishermen. To support its smooth operation, it is hoped that the Government (Central or Regional) will play a large role in developing fleets/ships, developing fishing ports, increasing accessibility (roads, access to information, and markets), as well as building supporting facilities (Jaya et al., 2017; Bethel et al., 2021; Hadjinikolova et al., 2010).

Private or state-owned investors can play many roles in capital, technology provision, and human resource development. Regarding human resources, investors are expected to be able to increase the capacity of fishermen who are employed, namely transforming traditional fishermen into modern capacities. This is because often the transformation initiated by the government fails due to the inability of local fishermen/workers to adapt to industrial work (Hermanto et al., 2019; Mannaart & Bentley, 2022; Camara et al., 2023). This transformation can be carried out by sending recruited local fishermen/workers for internships in other advanced fishing industries. Apprenticeships are important for increasing worker skills in the use of fishing technology and business management (Farthing et al., 2022; Mannaart & Bentley, 2022), as well as increasing understanding of the importance of preserving fish resources and the aquatic environment which is the habitat of fish (Mustaruddin & Astarini, 2019; Naim & Sultan, 2019; Daris et al., 2022).

- In detail, the design of the fishing industry development scheme in the partnership *platform* was explained:
- Capital investment/investment goods: The government was preparing fishing vessels, where the Central Government is preparing vessels > 30 GT and the North Maluku Provincial Government was preparing vessels < 30 GT. While investors prepared costs for technology transfer, human resource development, and initial working capital.
- Form of business: fishing industry with a legal entity with an agreed composition of shares.
- Target fish for business: skipjack, tuna, yellow tail, grouper, cob, kite, blue escape, bloating, anchovies and mackerel.

- Manager: submitted to investors for a period agreed in the contract (eg 2 years or 5 years). Investors had to employ local fishermen to operate fishing vessels, the candidates for which are prepared by the North Maluku Provincial Government (DMF, 2020; Stringer et al., 2022). Provision of workers through apprenticeships and others was handed over to investors as needed for the proper operation of the industry.
- Wages system: wages for local fishermen who employed were given in the form of profit sharing, where the arrangements were adjusted to the regulations in force in the North Maluku Province.
- End of contract period: investors could extend the partnership or carry out independent development after learning from the success experienced.

The ultimate goal of the industrial development scheme was to provide an alternative, stimulate and encourage the development of the fishing industry in the TFP area. The industrial development scheme in the partnership *platform* is a catalyst because it is easier to implement, capital/investment goods corporations occur, it benefits many parties, and it is inherent in shared responsibility (Muallil et al., 2014; Camara et al., 2023).

For fishing technology, it should be a technology/fishing vessel, that is suitable for catching fish selected as fishing industry targets, can be operated by local fishermen, and is friendly to the aquatic environment. The results of the context analysis stated that the types of fishing technology were troll lines, handlines, pole and lines, traps, gillnets, and boat charts (Table 5). Each type of technology/fishing vessel was effective in catching certain fish, which were the target of the fishing industry business in TFP. For example (a) troll lines could catch skipjack, tuna, and cob, (b) traps could catch grouper and yellow tail, and (c) chart boats were effective at catching anchovies. This technology/fishing boat was used by local fishermen in the TFP area (Naim & Sultan, 2019; Yulieny et al., 2020; TFP, 2023), making it easier when they are involved in the future.

The six fishing technologies were also environmentally friendly and non-destructive to basic aquatic ecosystems. For example traps, the installation location could be chosen in fishing ground (Table 5), where there were no coral reefs and the operation was carried out silently. Troll lines and handlines only cought the target fish according to the bait and hook size, and the boat charts did not sink to the bottom of the water during operation (Anna et al., 2017; Malta et al., 2019; Mustaruddin et al., 2020). Technology with characteristics like this can minimize the destructive impact of fishing, preserve fish resources, and in the long term guarantee the sustainability of fishing industry activities in TFP and its surroundings.

Conclusion

Ternate's aquatic environment was in good condition/unpolluted and safe for industrial fishing operations. Fish production (X) in the TFP tended to decrease during 2018–2022, but had a positive relationship with the formation of the fishing industry transaction value (Y), followed the power model $Ln(Y) = Ln(136.686) + (1.37 \times Ln(X))$. The developed fishing industry development model was divided into three parts, namely: (a) selection of industrial business target fish, (b) industrial development scheme design, and (c) determination of technology/fishing vessels to operate. Based on the assessment of the fish resources and the carrying capacity of the environment, the fish selected to be the business targets for the fishing industry in the TFP were skipjack, tuna, yellow tail, grouper, cob, kite, blue escape, bloating, anchovies and mackerel. The industrial development scheme was prioritized in the partnership *platform* (the government as the provider of ships and investors as providers of working

Table 5. Fishing grounds and fishing technology for selected target fish

Selected target fish	Fishing ground coordinates	Fishing technology
Skipjack (*Katsuwonus pelamis*	0°42′53.1″N 127°11′19.3″E; 0°52′53.0″N 127°00′02.0″E; 0°24′56.8″N 126°49′45.8″E	troll lines, pole and lines
Yellow tail (*Caesio cuning*),	0°43′05.7″N 127°14′01.1″E; 1°00′03.4″N 127°17′14.5″E	traps, handlines
Bloating (*Rastrelliger* sp.)	1°04′17.7″N 126°59′56.4″E	gillnets
Grouper (*Epinephelus* sp.)	0°42′23.2″N 127°17′01.6″E; 0°49′12.1″N 127°26′03.7″E	traps, handlines
Kite (*Decapterus* spp.)	0°49′32.4″N 126°53′09.3″E; 0°27′39.6″N 127°07′34.4″E	gillnets
Blue escape (*Caesio caerulaureus*)	0°43′05.7″N 127°04′21.0″E	gillnets, handlines
Tuna (*Thunnus* sp.)	0°46′29.3″N 126°46′42.6″E; 0°59′22.7″N 127°00′57.5″E	handline, troll lines, pole and line
Mackerel (*Scomberomorus commerson*)	0°52′56.4″N 127°23′18.1″E;	gillnets, handline
Anchovies (*Stolephorus indicus*)	0°41′34.1″N 127°16′13.5″E	boat charts
Cob (*Euthynnus affinis*)	0°52′53.0″N 127°00′02.0″E; 1°04′29.6″N 126°51′27.3″E	troll lines, gillnets

capital as well as managers). At the end of the contract period, investors are given the freedom to extend the partnership or choose *a platform* independent after learning from the success experienced. Fishing technology for industrial operations was directed at troll lines, handlines, pole and lines, traps, gillnets, and boat chart.

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