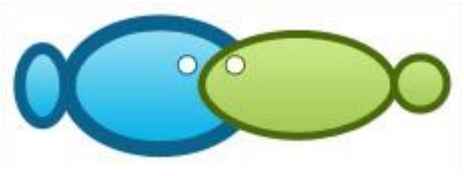

Technical and environmental considerations in the development of capture fisheries in Tukak Sadai Port area, South Bangka Regency, Indonesia

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Abstract. The waters of South Bangka Regency are in the central position of three fish migration routes (Natuna Sea, Malacca Strait, and Java Sea). However, their contributions to the total GRDP of South Bangka Regency were only 7.35%, of which Tukak Sadai Port area was the main contributor. This condition produces opportunities for the development of capture fisheries, especially for superior fishing gears in the Tukak Sadai Port area. The development needs to be studied technically and environmentally, being related to the feasibility of direct operations of fisheries (fishing gears and supporting facilities), and the sustainable use of fish resources in the future. The research aimed to determine superior fishing gears technically and environmentally, and to measure the readiness of supporting facilities to encourage the development of capture fisheries in Tukak Sadai Port. This research used the scoring method and readiness level analysis. The results showed that hand lines (V_{comb}=1.364), gillnets (V_{comb}=1.357), and longlines (V_{comb}=1.32) were 3 superior fishing gears to be developed in Tukak Sadai Port area. Supporting facilities with a high readiness to encourage the development of capture fisheries in Tukak Sadai Port area were freshwater installations (RL=3), roads (RL=2.75), port piers (RL=2.5), communication networks (RL=2.5), and fish auction places (RL=2.375), while there was low readiness for cold storage facilities (RL=0.75).
Key Words: fish resources, fishing gears, readiness level, supporting facilities, waters.

Introduction. When referring to Law RI No. 45 of 2009 and the code of conduct for responsible fisheries (CCFR) issued by FAO (1995), all forms of fishery activities need to be developed to realize regional sovereignty, economic independence, and ensure sustainable community welfare. South Bangka Regency has a great opportunity to do this, because its area is surrounded by vast sea waters. The sea waters are also in the central position of three fish migration routes, Natuna Sea, the Malacca Strait, and the Java Sea (Mayu et al 2018; Febrianto et al 2015). However, the contributions of the fishery sector to the total GRDP of South Bangka Regency were still low, reaching only 7.35%, of which Tukak Sadai Port area was the main contributor (DAFF 2018). Thus, the development of capture fisheries, especially for superior fishing gears, has the opportunity to be carried out in South Bangka Regency.

The development of capture fisheries should be concentrated in the fishing port area, so that an independent and connected fisheries business system can be formed. The fishing port is the main driver of the fisheries business on the island, and it is a link with community activities on mainland. As the largest fishing port in South Bangka Regency, Tukak Sadai Port was believed to be able to realize this business system. The main reason for the fishery business in the fishing port is the intensity of fish landing by fishing gears operating in the area (Merkel & Sløk-Madsen 2019). The more intensive the landing is, the more active business activities in the fishing port are. At this stage, supporting facilities must be able to provide various services needed. These services can

be related to the provision of fishing supplies, handling of caught fish, and other supporting services.

Capture fisheries activities can be sustained if technical and environmental aspects are considered in their development. Technical aspects are related to the operational feasibility of fishing gears (engines, boats and gear) and the technical readiness of supporting facilities in the fishing port. Environmental aspects are related to safety, friendliness, and level of destruction that can occur to the environment if a fishing gear is operated (Mustaruddin et al 2017; Hapsari & Fitri 2016). The environmental issues are very sensitive in South Bangka Regency and have become a conflict source between fishermen, tin miners, and communities (Febrianto et al 2015). Related to this, the development of capture fisheries based on Tukak Sadai Port presented in this study discusses both aspects. The research aimed to determine superior fishing gears for technical and environmental aspects, and to measure the readiness of supporting facilities to encourage the development of capture fisheries in Tukak Sadai Port area, South Bangka Regency.

Material and Method

Material and location. The materials and tools used in this research consisted of questionnaires, checklists, camera, and calculators. This research was conducted in South Bangka Regency. The location of field data collection was the Tukak Sadai Port area. The study period extended from June to November 2018.

Data type and collection methods. The data used in this study consists of: technical and environmental data for fishing gears in the Tukak Sadai Port; data on port readiness and supporting facilities such as port piers, fish auction places, cold storage facilities, freshwater installations, roads, electrical installations, and communication networks. Fishing gear data was collected through questionnaires and focus discussions. The port data and supporting facilities data were collected through direct observation and literature review.

Respondents for the fishing gear data were boat owners who account for 5-10% of the population. The selection of respondents was carried out by purposive sampling, so that data could be provided by people who understand well the condition of capture fisheries in Tukak Sadai Port area, and also understand various developing needs for the future. The literature review was conducted by examining study reports and fisheries statistics books, especially related to fishing port services in Tukak Sadai. Those were obtained from the Regional Planning, Research and Development Agency of South Bangka Regency, the Department of Agriculture, Food, and Fisheries of South Bangka Regency, and several colleges.

Data analysis. Data was analyzed using the scoring method and with the readiness level (RL) analysis. The scoring method was used to determine the superior fishing gears, technically and environmentally in Tukak Sadai Port area. Technical and environmental considerations are important, so that fishing gears can be developed optimally by fishermen without disturbing the quality of the waters in the Tukak Sadai Port area. The selection of criteria must be in accordance with the principles of sustainable use and preservation of fish resources and the environment (Pascoe et al 2014; FAO 2014). These criteria are technical aspects consisting of completeness of fishing gear, boat hold capacity, ice loading capacity, number of crew members, engine capacity, and boat size; and environmental aspects consisting of fishing gear selectivity, friendliness to fish habitat, the quality of fish caught, safety for fishermen, consumers, and protected fish, by-catch quantity, and impacts on biodiversity. The results of the analysis of the criteria were standardized using the following calculation formula (Kuntoro & Listiarini 1983):

$V1=(X1-X1_{min})/(X1_{max}-X1_{min})$
$V2=(X2-X2_{min})/(X2_{max}-X2_{min})$
$Vn=(Xn-Xn_{min})/(Xn_{max}-Xn_{min})$
$\sum Vc=XA = V1+V2+...+Vn$
$VA=(XA-XA_{min})/(XA_{max}-XA_{min})$
$Vcomb=\sum VA$

The criteria on technical aspects are: X1 - completeness of fishing gear; X2 - boat hold capacity; X3 - ice loading capacity; X4 number of crew members; X5 - engine capacity; X6 - boat size. V1, V2, V3, V4, V5, and V6 are the function values of X1, X2, X3, X4, X5, and X6 on the technical aspects, respectively. The criteria on environmental aspect are: X1 - fishing gear selectivity; X2 - friendliness to fish habitat; X3 - the quality of fish caught; X4 - safety for fishermen; X5 - safety for consumers; X6 - by-catch quantity; X7 - safety for protected fish; X8 - impacts on biodiversity. V1, V2, V3, V4, V5, V6, V7, and V8 are the function values of X1, X2, X3, X4, X5, X6, X7, and X8 on the environmental aspects, respectively. ∑Vc - the total function value of all criteria; c=1, 2, 3, ..., n (the criteria on assessment aspects); VA - function value of aspect A (XA); A - assessment aspects (technical and environmental aspect). Furthermore, fishing gears that had a high function value from the combined assessment of aspects (V_{comb}) were chosen as superior (50% of the total fishing gears).

Analysis of readiness of supporting facilities used two technical criteria and two socio-environmental criteria. The technical criteria consist of physical condition of the facility, and installed capacity of the facility. The socio-environmental criteria consist of closeness of the facility to the port and residential environment, and activiness of production and its impacts. The RL was determined by the formula:

$RL = (\sum vi)/n$

Where: vi - value of criterion i; RL - readiness level; i=1, 2, ..., n (criteria of physical condition, capacity, closeness, and activeness).

Results and Discussion. In this study, the alternatives of superior fishing gear were selected from the fishing gears used actively by many fishermen in South Bangka Regency. The identification results showed that there were 6 such fishing gears, namely gillnets, fish traps, handlines, stationary lift nets, boat lift nets, and longlines. Using the scoring method, the 6 alternative fishing gears were analyzed multidimensionally to determine the priority which can be continuously developed in Tukak Sadai Port area, South Bangka Regency. In addition, they are expected to replace destructive fishing gears, such as trawls, danish trawls, and seine nets (Kurniawan 2019; Mayu et al 2018). The method helps to determine these by assessments of both technical and environmental aspects. Table 1 presents the results of the assessment of the technical aspects that are standardized for the 6 alternative superior fishing gears in Tukak Sadai Port.

Table 1

Standardization results of the assessment of technical aspects

Fishing gears	*V1*	*V2*	*V3*	*V4*	*V5*	*V6*	*∑Vc*	*PO*
Gillnets	1	1	1	1	1	1	6	1
Fish traps	0	0	0	0	0	0.5	0.5	6
Handlines	1	0.5	0.5	0	0	0.5	2.5	4
Stationary lift nets	0	0.5	0.5	0.667	0	0	1.667	5
Boat lift nets	1	1	1	0.667	0.333	1	5	3
Longlines	1	1	1	1	0.667	1	5.667	2

Note: V1 - function value of completeness of fishing gear (X1); V2 - function value of boat hold capacity (X2); V3 - function value of ice loading capacity (X3); V4 - function value of number of crew members (X4); V5 - function value of engine capacity (X5); V6 - function value of boat size (X6); and PO - priority order.

Based on Table 1, the criteria for completeness of fishing gear, gillnets, handlines, boat lift nets, and longlines were among the best, with a function value (V) of 1, each. As for boat hold capacity and ice loading capacity, gillnets, boat lift nets, and longlines, the values were among the largest. For the number of crew members, gillnets and longlines had many members, each with 5 to 8 people. Small crews were found in the fish traps and handlines categories, because both of them are operated by only 1 person. Compared to the other 5 fishing gears, gillnets used bigger machines, around 60-100 HP.

For the criteria for boat size, gillnets, boat lift nets, and longlines generally need a larger boat than the other fishing gears (V6=1). The stationary lift nets did not need or used boats when operating (V6=0). Table 2 presented the results of the assessment of the environmental aspects for 6 alternative superior fishing gears in Tukak Sadai Port.

Table 2

Standardization results of the assessment for environmental aspects

Fishing gears	*V1*	*V2*	*V3*	*V4*	*V5*	*V6*	*V7*	*V8*	*∑Vc*	*PO*
Gillnets	0.5	0.333	0.5	0.5	0	0	0	0.667	2.5	4
Fish traps	1	1	1	0	1	0.5	0.5	0.667	5.667	2
Handlines	1	1	0	1	1	1	1	1	7	1
Stationary lift nets	0	0	0	0	0	0	0	0	0	6
Boat lift nets	0	0.667	0	0.5	0	0	0	0	1.167	5
Longlines	0.5	0.333	0	0.5	0	0.5	0.5	0.333	2.667	3

Note: V1 - function value of fishing gear selectivity (X1); V2 - function value of friendliness to fish habitat (X2); V3 - function value of the quality of fish caught (X3); V4 - function value of safety for fishermen (X4); V5 - function value of safety for consumers (X5); V6 - function value of by-catch quantity (X6); V7 - function value of safety for protected fish (X7); V8 - function value of impacts on biodiversity (X8); PO - priority order.

For fishing gear selectivity criteria and friendliness to fish habitat, fish traps and handlines were among the most selective and habitat friendly (Table 2). For the quality of fish caught, fish traps were the best (V3=1), because fish do not suffer injuries in traps. For the criteria of safety for fishermen, handlines were among the safest (V4=1), while fish traps and stationary lift nets were less secure (V4=0). Handlines have low by-catch, are friendly to biodiversity, and safe for protected fish. Tables 3 and 4 present the results of a combined assessment of technical and environmental aspects, and the results of their standardization.

Table 3

Results of the combined assessment of technical and environmental aspects

Fishing gears	*XA1*	*PO1*	*XA2*	*PO2*
Gillnets	6	1	2.5	4
Fish traps	0.5	6	5.667	2
Handlines	2.5	4	7	1
Stationary lift nets	1.667	5	0	6
Boat lift nets	5	3	1.167	5
Longlines	5.667	2	2.667	3

Note: XA1 - technical aspect; XA2 - environmental aspect; PO - priority order.

Based on Table 4, handlines were the superior fishing gear (first priority) to be developed in Tukak Sadai Port area, South Bangka Selatan Regency. Handlines had the combined function value (V_{comb}) of 1.364. Gillnets and longlines were the second superior fishing gears (V_{comb} = 1.357) and third (V_{comb} = 1.32) to be developed, respectively.

Table 4

Standardization results of the combined assessment of technical and environmental aspects

Fishing gears	*VA1*	*VA2*	V_{comb}	*PO*
Gillnets	1	0.357	1.357	2
Fish traps	0	0.81	0.81	5
Handlines	0.364	1	1.364	1
Stationary lift nets	0.212	0	0.212	6
Boat lift nets	0.818	0.167	0.985	4
Longlines	0.939	0.381	1.32	3

Note: VA1 - function value of technical aspect; VA2 - function value of environmental aspect; V_{comb} - combined function value.

To encourage the development of capture fisheries with priority in 3 superior fishing gears, adequate supporting facilities are needed. The supporting facilities can affect fishery activities directly and indirectly in the fishing port (Uda et al 2015; Speir et al 2014). Facilities directly related to fishery activities in Tukak Sadai Port area included port piers, fish auction places, cold storage, freshwater installations, and ice factories. Indirect facilities were electrical installations, communication networks and roads. Figure 1 presented the results of the analysis of the RL of the supporting facilities using two technical criteria and two socio-environmental criteria.

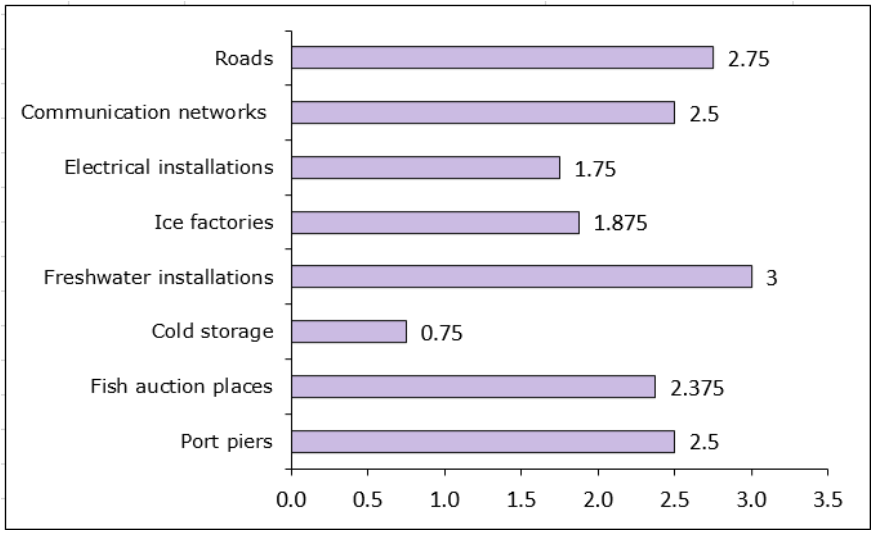

Figure 1. Readiness level of the supporting facilities.

Based on Figure 1, the supporting facilities that had high readiness in Tukak Sadai Port area were freshwater installations (RL=3), roads (RL=2.75), port piers (RL=2.5), communications networks (RL=2.5), and fish auction places (RL=2.375). The high RL of freshwater installations was more influenced by the physical condition that was good, close because it was located in Tukak Sadai Port area, had a large enough capacity, and was used actively (Figure 2).

Roads and port piers also had good physical condition, activeness, and adequate capacity (Figure 2) to support the development of capture fisheries. The auction places/fish markets were also good, but the center of their activities was outside Tukak Sadai Port, namely in the Sukadamai Fish Market area, Toboali City. For activeness, the activity of the auction places was more than ordinary market activity/no auction activity, but its pollution impact is significant (close to the residential environment). Cold storage facilities were not available (activeness value=0; RL=0.75), so they did not support the development of capture fisheries in Tukak Sadai Port area.

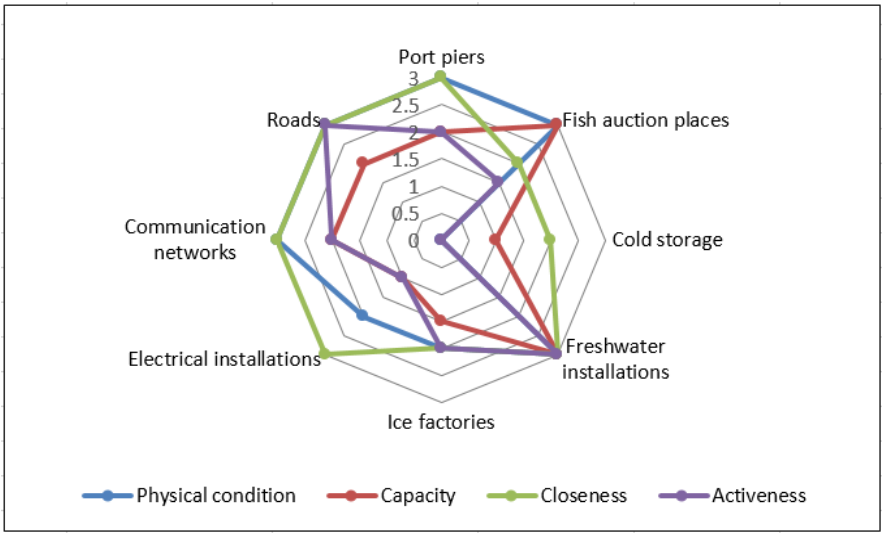

Figure 2. Radar diagram for the value of readiness criteria of the supporting facilities.

Gillnets, fish traps, handlines, stationary lift nets, boat lift nets, and longlines were fishing gears used actively and cultivated by fishermen in Tukak Sadai Port area. According to Hapsari & Fitri (2016) and Nurdin & Grydehoj (2014), activeness is a reflection of the suitability of fishing gears with the potential of fish resources in the waters, while the number of fishermen who work on them is an indication of the continued use of fishing gears in the future. Technically, boat hold capacity and ice loading capacity of gillnets, boat lift nets and longlines were greater than other fishing gears (Table 1), because the length in which the three fishing gears are used once could be longer, more than a few days. Gillnets, boat lift nets, and longlines generally use the boat designed for weekly or monthly fishing operations (Barr et al 2019; Mustaruddin et al 2017).

Regarding engine capacity, only gillnets employ large size engines (Table 1), because they use large fishing gear and are operated dynamically. Gillnet operation by dynamically blocking fish movements requires the use of large boats and nets to get maximum catch (Zydelis et al 2013). This condition was very different from stationary lift nets, which do not use boats (V6=0; Table 1), because they are operated passively on the stationary house (Broadhurst et al 2016; Mustaruddin et al 2015).

Concerning environmental aspects, the high selectivity and friendliness of the fish traps and handlines (Table 2) were more influenced by the operating system using hooks or traps with certain baits, so that only the target fish could be caught. In the future, handlines and fish traps can be directed to support the development of demersal fish potential, such as red snapper (*Lutjanus bitaeniatus*) and grouper (*Plectropomus* sp.). Red snapper and grouper are superior quality fish in South Bangka Regency, with the fourth highest production (1350.34 tons) and fifth highest production (675.2 tons) in 2017, respectively (DAFF 2018).

Regarding the criteria of fishermen safety, handlines are the best (Table 2) because they are operated purely on the boat. If lines get hung up, they can generally be cut immediately without having to dive into the waters. This is in contrast to fish traps and stationary lift nets that usually require fishermen to dive if they are stuck at the bottom. Therefore, fish traps are not recommended to be operated in coastal waters that have high rocks and waves in recent years (DAFF 2018; Mustaruddin et al 2011). This condition has several positive impacts on the long-term operation of handlines, namely the low number of by-catch, it is more friendly to biodiversity, and protected fish are safer. The capture of protected fish is strongly influenced by the minimal interaction of handlines with the waters, because they can use hooks with certain baits preferred by the target fish (Borland & Bailey 2019).

The choice of handlines as the first superior fishing gear compared to the other 5 fishing gears (Table 4) is reasonable. This was influenced by the excellent performance of

handlines on the environmental aspects (VA=7) and good performance on the technical aspects (VA=2.5). Gillnets and longlines have the second and third priority, respectively. The three fishing gears are expected to guarantee the sustainable use of the potential of fish resources, so as to have a real positive impact on the welfare of fishermen and coastal communities in Tukak Sadai Port area. In addition, the investments of capture fisheries both sourced from domestic and foreign investments are also more developed (Sumaila et al 2016; Mustaruddin et al 2015). Going forward, the investment in capture fisheries and preparation of supporting facilities in Tukak Sadai Port area must be directed to support the development of the three types of fishing gears. Handlines can be offered to all stakeholders because they do not require large investment costs, but can catch the economically important fish (Wiyono 2011). Longlines and gillnet can be offered to large investors, both domestic and foreign.

Regarding supporting facilities, the majority (62.5%) had a high readiness level, and only cold storage facilities had low readiness (Figure 1). High readiness of roads (RL=2.75) was due to their relatively large size (provincial roads), and construction, being paved (RPRDA 2018). The port piers had similar values (RL=2.5), although their activities in landing the fish caught were not maximized. Auction places/fish markets had a low value for the activeness criteria (Figure 2). The absence of auctions causes fishermen to sell at lower prices. However, the Sukadamai Fish Market is crowded and it helps fishermen to sell their fish caught directly. Crowded fish markets, with many transactions, help fishermen to find alternative buyers, even though the selling price is very dynamic (Saha et al 2018). The activities of fish market and supporting economy accelerate the distribution of fish caught from fishing ports to consumers (Pascoe et al 2014). Related to the pollution impact which tends to increase in the Sukadamai Fish Market, the Government of South Bangka Regency will relocate the market to Tukak Sadai and activate fish auctions in Tukak Sadai Port (RPRDA 2018).

Cold storage facilities need to be given priority in the development of capture fisheries in Tukak Sadai Port area. The absence of cold storage (activeness value=0) was very detrimental to fishermen, especially in the seasons with big catch, because it forced fishermen to sell immediately the perishable fish. Big intermediaries make a profit through low-priced purchases and high-interest capital loans (Lubis et al 2012). If cold storage facilities are available, fishermen can store the fish, waiting for a better price. The presence of cold storage is a major consideration in the investment in the processing industry in the fishing port area (Merkel & Sløk-Madsen 2019). Cold storage facilities are needed to store raw materials for the processing industry (Otero et al 2019). Ice factories and electrical installations had a RL of 1.88 and 1.75, respectively (Figure 1). The survey results showed that there was only one ice factory in the Tukak Sadai area, located in the capital of the Tukak Sadai District, while electrical installations had a low capacity and were often not usable. Ice factories are vital for the supply of ice for fishing and distribution of fish. Ice factories and cold storage facilities support the rapid handling of fish in the port, while electrical installations are the main requirement for the operation of ice factories and cold storage facilities (Terehovics et al 2018; Levsen & Karl 2014).

Conclusions. Through technical and environmental considerations, the superior fishing gears to be developed in Tukak Sadai Port area were handlines (V_{comb}=1.364), gillnets (V_{comb}=1.357), and longlines (V_{comb}=1.32). The supporting facilities with high readiness to encourage the development of capture fisheries in Tukak Sadai Port area were freshwater installations (RL=3), roads (RL=2.75), port piers (RL=2.5), communication networks (RL=2.5), and fish auction places (RL=2.375), while those with low readiness were cold storage facilities (RL=0.75).

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