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Performance, optimum allocation and capacity of catching gear of *Katsuwonus pelamis* in bone bay

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Abstract
The objectives of this research were to (a) determine the fishing gear, (b) define the allocation of suitable fishing gears, (c) evaluate the capacity of selected fishing boats. This research was conducted in Bone Bay area for two years, from February 2015 to February 2017. The method of this research is observation on all fishing gears for Skipjack Tuna and secondary data from Fishery Office of South Sulawesi Province. Data were analyzed with value function method, linear goal program, and data envelopment analysis program. The result showed that best performance gear from technical, biological, social and economic aspects is the ‘Pole and Line’. The optimum allocation of fishing gears is; 42 units for pole and line, 100 units for purse seine, 24 units for trammel net, 191 units for boat lift net and 181 units for stationary lift net. For the fishing boatl was already efficient, with improvement on certain inputs.

Keywords: Fishing capacity, fishing ground, determination, optimization, skipjack tuna

1. Introduction

Researchers around the world had conducted several studies on fishing technology. In The White Nile, Khartoum, Sudan reported selectivity and unselectivity between Gill Net and Seine Net (Beach Net) on multiple uses [1]. In Indonesia, especially in the Bone Bay, the catching of Skipjack Tuna was undergone continuously through the years. And without control from the parties, this practice will reduce the stock of Skipjack Tuna.

The natural resource use in the past was sometimes ignoring the carrying capacity. This behavior, which likely to get short-term benefit needs to be controlled by the government and community. Fishing activities that have possibilities to harm sustainability of marine and coastal resource should be banned.

Determination of the fishing gear with the best performance furthermore followed up with the study of optimization where the goal is to define optimum allocation of fishing gear for skipjack tuna. This score of assignment expected to become a reference for local government to determine the policy for skipjack tuna fishery in Bone Bay. At the end there will be a sustainable skipjack fishery and Indonesia will play an essential role as world primary fishery producer.

[2] used a single-output oriented DEA model to analyze small-scale fisheries capacity on the coast of DKI Jakarta. The results of his research indicate that there has been overcapacity in the fishery of Bubu, Muro Ami, and fishing line so that the input reduction intervention is needed for the tool.

[3] uses a single-output oriented DEA model to analyze shrimp fisheries management alternatives in the Arafura Sea. The results showed that the shrimp trawling fisheries in Arafura were overfishing so that alternative management was recommended in the form of the closing fishing season, reduction of the number of ships and quota arrangement.

[4] using a single-output oriented DEA model to analyze small-scale coastal fisheries capacity with the case study of fishing lines in Pelabuhanratu waters. The results showed that the fishing capture capacity is not optimal and there has been excess capacity. [5, 6], using the DEA input-oriented model to analyze the capacity of the seine trawl fisheries in the Java Sea waters. The results of both studies show that the condition of the seine trawl fisheries in the Java Sea has experienced excess capacity or overfishing.

[7] using single-input oriented and single-output oriented models to analyze the stock and fishing capacity of demersal fisheries in the Togean Islands of Central Sulawesi. The results showed that fishing capacity demersal fishing in Togean Islands during the last eight years showed inefficient levels except in 1999. The inefficiency of fishing capacity have been caused by various factors such as the length of fishing, the number of operation trips, the use of fuel, the length of the net, the volume Bubu, and the number of fishing lines.

The purpose of this study was to review the performance of fishing gear for catching skipjack tuna, to discuss the optimal allocation of the fishing gear for catching skipjack tuna to be developed and to review the fishing capacity of the fishing gear for skipjack tuna in Bone Bay.

The result will provide an empiric description on information of best performance fishing gear and optimum allocation of the fishing gear that can operate in Bone Bay (Bulukumba, Sinjai, Bone, Wajo, Luwu, Palopo, North Luwu, East Luwu, North Kolaka and Kolaka). From the policy aspect, the result of this study will become a reference on sustainable fishing practice on skipjack tuna and to increase production of the significant pelagic fishery.

Materials and Method

The study was conducted in Bone Bay are (Bulukumba, Sinjai, Bone, Wajo, Luwu, Palopo, North Luwu, East Luwu-North Kolaka-Kolaka) for 24 months period (February 2015-February 2017).

Materials and Tools

Materials and tools used for this research are listed in Table 1.

Table 1: Material and Tools

No	Tools	Amount	Purpose/Usability
1	Fishing Gear	10 % of the population	To catch skipjack tuna
2	Boat	1 unit	Transportation during research
3	*Global Positioning System* (GPS)	1unit	Point hauling position
4	*Fish Finder/Echosounder*	1unit	Determine fish position
5	Questionnaire	10 % of the population	To collect field data
6	Earth Map	One package	Determine sampling area
7	Computer – hardware	1 Unit	Data processing and analysis
8	*Microsoft* Excel, Lindo and DEAP 2.1	1unit	Data processing and analysis
9	Digital Camera	1unit	Documentation
10	Scale	1 unit	To weight the catches
11	Stationary	One package	Data recording

Population and Sampling Technique

Population for this study was all fishers, fish catch and fishing gears in Bone Bay. Sampling size was 10% of the community [8] for each district located in Bone Bay waters.

Data Collection Technique

Secondary data came from Fishery and Marine Office of South Sulawesi Province that covered data on production of skipjack tuna and number of its fishing gear, and total production of marine fishes for the last ten years period (2005-2015) [9].

Primary data collected through direct observation where the researcher was directly involved in the fishing operation. Data collection emphasized the technical, biological, social and economic aspects.

The input and output data of catch fishing capacity

Data required in analyzing the capacity of the skipjack tuna fishing unit were data from boat's panel that are the input and output of catch fishing capacity. Input data consisted of fixed input which include gross tonnage (GT), length and wide of the net (m)/the length of line (set), number of hook, engine power (HP); and variable input which include boat crew (person), gas consumption (IDR), fishing effort (FE) and fishing aids. The output data is single-output that is total fish production data [10].

Study on Fishing Optimization of Skipjack Tuna

The Optimization of Selected Fishing Gear

The allocation optimization on fish catching unit simultaneously can use a goal programming model [11].

Measurement Selected Fish catching capacity

The capacity of utilization was analyzed with data envelopment analysis (DEA). The DEA approach analyzed by DEAP version 2.1 [10, 12].

Result and Discussion

General Condition of Bone Bay

The administrative area of South Sulawesi Province that bordered with Bone Bay waters are the districts of Bulukumba, Sinjai, Bone, Wajo, Luwu, North Luwu, East Luwu and City of Palopo. While the administrative area of South East Sulawesi Province that bordered with Bone Bay waters are the districts of North Kolaka, Kolaka, and Bombana. At the South, it bordered with the Flores Sea.

Study on fishing technology development

Gear performance from technical aspect

Based on the calculation of the overall technical aspects that standardized by the value function [13], Pole and Line was the main priority of catch unit. Scoring and standardized of this technical aspect is presented in Table 3.

Gear performance from biological aspect

Based on the calculation of the overall biological aspects that standardized by the value function [13], Pole and Line was the main priority of catch unit. Scoring and standardized of this biological is presented in Table 2.

Table 2: The calculation of the overall biological aspects that standardized by the value function

Kriteria	X1	V1(X1)	X2	V2(X2)	X3	V3(X3)	V(A)	UP
Pole and line	9	1,00	9	1,00	11	1,00	3,00	1
Trolling	9	1,00	8	0,88	8	0,4	2,28	4
Tuna long line	9	1,00	7	0,75	7	0,2	1,95	5
Drift long line	9	1,00	7	0,75	7	0,2	1,95	5
Set long line	9	1,00	7	0,75	7	0,2	1,95	5
Handline	9	1,00	9	1,00	8	0,4	2,4	3
Payang	6	0	1	0	6	0	1	7
Purse Seine	6	0	2	0,13	8	0,4	2,53	2
Set gillnet	9	1,00	4	0,38	6	0	1,38	6
Encircling net	9	1,00	4	0,38	6	0	1,38	6
Drift gill net	9	1,00	4	0,38	7	0,2	1,38	6
Three layer net	6	0	1	0	6	0	1	7

Note:
X1 = Resource Availability
Three = Catching of small pelagic fish
Six = Catching of small skipjack Tuna and pelagic fish
Nine = Catching of big skipjack Tuna and pelagic fish
X2 = Fishing gear selectivity
1 – 5 = Type of trawl
6 –10 = Type of gillnet
X3 = Fishing duration (1 – 12 month/year)
V(A) = Function value of alternative A (summary of Vi(Xi)
UP = Priority order

Table 3: The calculation of the overall technical aspects that standardized by the value function

Kriteria	X1	V1(X1)	X2	V2(X2)	X3	V3(X3)	X4	V4(X3)	X5	V5(X5)	X6	V6(X6)	V(A)	UP
Pole and line	21	1,00	5	1,00	5	1,00	19	1,00	696	1,00	3617	1	6	1
Trolling	18	0,25	2	0,25	5	1,00	4	0,006	125	0,14	2000	0,38	2,08	7
Tuna long line	17	0	1	0	5	1,00	4	0,006	80	0,08	2000	0,38	1,52	10
Drift long line	20	0,75	1	0	5	1,00	4	0,006	52	0,04	2000	0,38	2,23	4
Set long line	17	0	1	0	5	1,00	8	0,5	45	0,03	2000	0,38	1,91	9
Hand line	18	0,25	1	0	5	1,00	4	0,006	80	0,08	1000	0	1,39	11
Payang	17	0	1	0	5	1,00	3	0	61	0,05	1000	0	2,05	8
Purse Seine	17	0	1	0	2	0	13	0,6	49	0,004	1458	0,175	0,84	12
Set gill net	17	0	1	0	5	1,00	3	0	32	0,01	1250	0,09	2,1	6
Encircling net	17	0	1	0	5	1,00	4	0,006	25	0	1250	0,09	2,15	5
Drift gill net	20	0,75	1	0	5	1,00	4	0,006	109	0,125	1250	0,09	3,03	2
Three layer net	20	0,75	1	0	5	1,00	4	0,006	27	0,002	1250	0,09	2,90	3

Note:
X1 = Physical environmental factor influence the fishing gear/operation (score)
X2 = The magnitude of physical factor on gear/gear's operation (score)
X3 = Level of difficulty of the fishing gear operation (score)
X4 = Technology level (score)
X5 = Averate production per trip (kg)
X6 = Average production per labour (kg)
V(A) = Value function of Alternatif A (sum of Vi(Xi))
UP = Priority order

Gear Performance from Social Aspect

Based on the calculation of the overall social aspects that standardized by the value function [13], Pole and Line was the main priority of catch unit. Scoring and standardized of the social aspect of skipjack tuna fishery in Bone Bay is presented in Table 4.

Table 4: the calculation of the overall social aspects that standardized by the value function

Kriteria	X1	V1(X1)	X2	V2(X2)	X3	V3(X3)	V(A)	UP
Pole and line	5	1	20	1	25555	0,57	2,57	1
Trolling	3	0,5	1	0	39583	1,00	1,5	2
Tuna long line	3	0,5	2	0,05	26736	0,6	1,15	3
Drift long line	3	0,5	2	0,05	26736	0,6	1,15	3
Set long line	3	0,5	2	0,05	26736	0,6	1,15	3
Hand line	3	0,5	2	0,05	15972	0,28	0,83	4
Payang	3	0,5	5	0,2	11111	0,13	0,83	4

Purse Seine	1	0	12	0,58	6827	0	0,58	5
Set gill net	3	0,5	2	0,05	26736	0,6	1,15	3
Encircling net	3	0,5	2	0,05	26736	0,6	1,15	3
Drift gill net	3	0,5	2	0,05	26736	0,6	1,15	3
Three layer net	3	0,5	2	0,05	26736	0,6	1,15	3

Note:
X1 = Fishermen acceptance (score)
X2 = Amount of labour per unit of catch (people
X3 = Fishermen income per unit of catch (IDR/day)
V(A) = Value function of Alternatif A (sum of Vi(Xi)).
UP = Priority order

Table 5: the calculation of the overall economic aspects that standardized by the value function

Kriteria	X1	V1(X1)	X2	V2(X2)	X3	V3(X3)	X4	V4(X4)	X5	V5(X5)	X6	V6(X6)	V(A)	UP
Pole and line	1447	1	13,9	1	0,11	1	2670	1	109	1	7,43	1	6	1
Trolling	40	0	2,5	0,15	1,67	0,29	68,6	0,003	71,2	0,49	3,98	0,34	1,28	5
Tuna long line	80	0,03	1,6	0,08	1,95	0,16	201	0,05	92,5	0,78	5,37	0,6	1,7	2
Drift long line	80	0,03	1,04	0,04	1,95	0,16	201	0,05	92,5	0,78	5,37	0,6	1,66	3
Set long line	80	0,03	0,91	0,03	1,95	0,16	201	0,05	92,5	0,78	5,37	0,6	1,64	4
Hand line	40	0	1,6	0,08	1,05	0,57	60	0	47,5	0,18	2,82	0,12	0,9	12
Payang	100	0,04	1,22	0,05	1,46	0,39	78	0,07	58,8	0,33	3,23	0,19	1,01	8
Purse Seine	350	0,22	9,72	0,69	2,31	0	365	0,11	33,9	0	2,22	0	1,02	7
Set gill net	50	0,007	0,64	0,01	1,53	0,35	73	0,005	63,4	0,39	3,49	0,24	1,007	9
Encircling net	50	0,007	0,51	0	1,53	0,35	73	0,005	63,4	0,39	3,49	0,24	0,997	11
Drift gill net	50	0,007	2,17	0,12	1,53	0,35	73	0,005	63,4	0,39	3,49	0,24	1,117	6
Three layer net	50	0,007	0,54	0,002	1,53	0,35	73	0,005	63,4	0,39	3,49	0,24	0,999	10

Note:
X1 = Gross income per year (IDR)(X 1,000,000)
X2 = Gross income per trip (IDR per trip)(X 100,000)
X3 = Pay Back of Period (PBP)
X4 = Net Present Value (IDR) (1,000,000)
X5 = Internal Rate of Return (%)
X6 = Net B/C Ratio
V(A) = Value function of Alternative A (sum of Vi(Xi))
UP = Priority order

Gear Performance from financial Aspect

Based on the calculation of the overall economic aspects that standardized by the value function [13], Pole and Line was the main priority of catch unit. Scoring and standardized of the financial aspect of skipjack tuna fishery in Bone Bay is presented in Table 5.

Based on the analysis of those four aspects, the best and proper catching gear to be developed in Bone Bay is Pole and Line. Nevertheless, existing catching gears not necessarily to be eliminated but keep as alternative gears that will be used based on local condition. The overall assessment of these aspect is presented in Table 6.

Table 6: The analysis on those four aspects (Technical, Biological, social and Economic)

Kriteria	V(A1)	V(A2)	V(A3)	V(A4)	Amount	UP
Pole and line	6	3	2,57	6	17,6	1
Trolling	2,08	2,28	1,5	1,28	7,14	2
Tuna long line	1,52	1,95	1,15	1,7	6,32	6
Drift long line	2,23	1,95	1,15	1,66	6,99	3
Set long line	1,91	1,95	1,15	1,64	6,65	5
Handline	1,39	2,4	0,83	0,9	5,52	9
Payang	2,05	1	0,83	1,01	4,89	11
Purse Seine	0,84	2,53	0,58	1,02	4,97	10
Set gillnet	2,1	1,38	1,15	1,007	5,64	8
Encircling net	2,15	1,38	1,15	0,997	5,68	4
Drift gill net	3,03	1,38	1,15	1,117	6,68	4
Three-layer net	2,9	1	1,15	0,999	6,05	7

Note: V(A) = Value function of Alternative A (sum of Vi(Xi))
UP = Priority order

Optimization of Selected Gear

To found out the optimum allocation of catching gear in pelagic fishing without destroying the sustainability of the resource, the optimization was carried out using the Linear Goal Programming [14]. The objectives of this process were as follows:

1. To utilize pelagic fish resource until it reaches the optimum point that matches with production amount at MSY condition,
2. Minimizing constraint to optimize production by the C_{MSY}, the number of the trip by the E_{MSY}, Fuel, Fresh Water, Ice, and Labour based on available stock and maximize exchange.

There were seven targets identified from this optimization of catch fishery:

1. Optimize the catch of skipkjack tuna in accordance with the $Catch_{MSY}$,
2. Optimize catch effort of skipjack tuna in accordance with the Effor E_{MSY},
3. Optimize the use of fuel
4. Optimize the use of fresh water,
5. Optimize the use of ice,
6. Optimize the use of labour
7. Optimize exchange

Based on the objectives and constraints, the 'inequality' was built to solve the problem. In order to determine the allocation of fishing unit in utilization of small pelagic fish, several limiting factors were used such as the amoun of fuel, fresh water, ice, labour and exchange. The equation is as follows:
Minimizing Z = da1 + da2 + da3 + da4 + da5 + da6 + db7
We obtained numbers of the unit of Purse seine, Raft lift net, drift gillnet and set gillnet that is presented in Table 7.

Table 7: Comparison optimal value of optimized parameters

No.	Catching Gear	Optimum (unit)	Actual (unit)	Plan	
				Addition	Reduction
1.	*Payang*	0	90	0	0
2.	Purse seine	0	804	0	0
3.	Pole and Line	41	12	29	0
4.	Trolling	0	1217	0	0
5.	Drift gillnet	0	817	0	0
6.	Encircling net	100	100	0	0
7.	Three-layer net	24	24	0	0
8.	Raft Driftnet	191	191	0	0
9.	Steady Net	181	181	0	0
10.	Tuna long line	0	171	0	0
11.	Drift long line	0	21	0	0
12.	Set long line	0	210	0	0
13.	Other lines	0	1007	0	0
14.	Set gillnet	0	2452	0	0

To optimize fishing activities in Bone Bay, there should be an addition for the number of the vessel for the value of X3 (Pole and Line) from the initial amount of 12 units to be 41 units. For the value of X6 (Encircling net), X7 (Three layers net), X8 (Raft Drift net), X9 (Steady Drift net) no need to increase the amount, while for other catch gear it was recommended to stop the use (score is 0).

Measurement of Selected Catching Capacity

Based on analysis of DEA single-output for pole and line vessel, the range of Catching Unit (CU) was between 0.837 – 1.000 (Figure 1). There are 6 out of 9 boats that have optimum catching capacity score (CU) as much as 1, while the other 3 have CU range between 0.837 – 0.909.

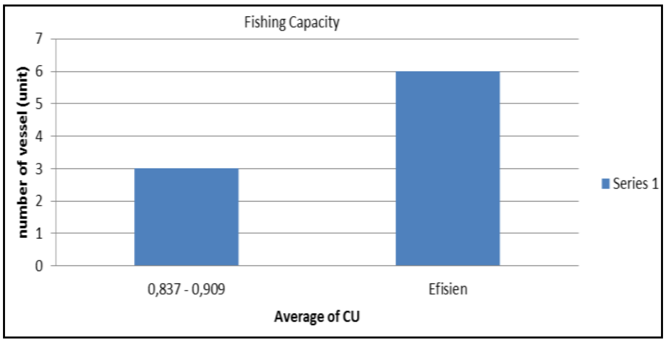

Fig 1: Average distribution was of total catching capacity score of pole and line boat with the single-output approach.

The VIU level of pole and line boat can be measured by the ratio of optimal input used (target) with actual data (observation). The optimal input is the input used at full technical efficiency condition (optimal capacity). If the VIU ratio is less than 1, then there has been a surplus of the variable input, indicated we need to reduce the used of that input [15]. Level of VIU of pole and line boat operated in Bone Bay water showed the score of 1 mean the capacity level was already optimal.

The level of Variable Input Use (VIU) of pole and line boat with the single-output analysis is shown in Table 8. Level of VIU indicated that the average of VIU of boat length, width, loading capacity, engine power, crew, and fuel are under 1, mean not yet optimal. The only optimal score gained by operational catching day with the value of 1.

Table 8 showed the VIU of boat two, fourth, six, eigth and nine had the same score, which was 1, indicated these boats were already optimal at variable input use. At craft three and seven, only crew VIU and catching day were optimal, while another VIU was under 1. At boat five, the VIU of GT, HP, Fuel, and catching day were equal to 1, where VIU of P, L and crew were under one.

The VIU level of pole and line boat have been measured by the ratio of optimal input used (target) with actual input (observation). The optimal input is the input used at full technical efficiency condition (optimal capacity). If the VIU ratio is less than 1, then there has been a surplus of the variable input, indicated we need to reduce the used of that input [15].

In total, the projection of improvement at single-output approach is reducing the VIUs of boat length by 13.4%, boat with by 9.23%, loading capacity by 12.13%, engine power by 25.9%, crew by 4.4%, and fuel by 16.59%. The VIU for an operational day was one indicated optimal level. The improvement effort in to bring up the utilization capacity to optimal concentration was done by adding to output or reduction on input [10].

The efficiency of shrimp trawlers in the Arafura Sea can generally be increased by reducing effort (day trip) by 11.17%, reduction of GT by 15.45%, decreasing service life by 17.74%, decreasing cost by 16.34% [3].

The analysis of the capacity of pelagic fishery in the coastal waters of North Sumatra Province, stated that the potential of efficiency improvement on 13 seine trawlers is by adding big pelagic fish production by 13.60%, GT reduction by 13.46%, reduction of length ship of 14.27%, decrease of HP by 22.20%, decrease in trips by 24.77%, and reduction of crew by 11.70%. Potential efficiency improvements to 96 vessel charts are: with GT reduction of 21.29%, reduction of vessel length by 19.92%, a decrease of HP by 20.15%, trip reduction by 20.05%, and boat crew reduction by 18.59 % [16].

The results of capture fisheries capacity analysis in the management of fishing fleet in Gorontalo Province stated that in order to increase the efficiency of 20 ring trawlers in the northern waters of Gorontalo can be done by reducing the size of GT vessels by 16.39% capture of 47.96%, reduction of trips per month by 18.16%, and reduced operating costs by 17.50%. Improving the efficiency of 11 trawlers in Gorontalo's southern waters can be done by reducing ship size by 27.97%, reducing fishing time by 29.49%, reducing the number of trips per month by 26.87%, and reducing operational costs by 15, 67% [17].

In detail, the excess capacity of pole and line boat's input was obtained by substracted optimal score (target) with observation value (actual) and presented in Table 8. It has appeared that the highest exceeded capacity value is input variable of engine power (HP), while the lowest cost came from input variable of the boat crew.

Table 8: Comparison of exceed capacity, variable input use (VIU) and improvement potential pole and line for single-output

No.	Description		Unit	Total
1.	Exceed capacity			
	a.	Boat length (L)	Average (%)	- 3
	b.	Boat width (W)	Average (%)	- 2,06697
	c.	Boat capacity(GT)	Average (%)	-2,71503
	d.	Engine Power (HP)	Average (%)	-5,81198
	e.	Boat Crew	Average (%)	-1
	f.	Fuel	Average (%)	-3,7132
	g.	Catching Day	Average (%)	0
2	VIU Level			
	a.	Boat length (P)	Average (%)	0,96606
	b.	Boat width (L)	Average (%)	0,97933
	c.	Boat capacity (GT)	Average (%)	0,97285
	d.	Engine power	Average (%)	0,94188
	e.	Boat crew	Average (%)	0,99382
	f.	Fuel	Average (%)	0,96286
	g.	Catching day	Average (%)	1
3.	Potential Improvements			
	a.	Boat length (P)	Average (%)	-13,409321
	b.	Boat width (L)	Average (%)	-9,238888
	c.	Boat capacity (GT)	Average (%)	-12,13557
	d.	Engine power	Average (%)	-25,97824
	e.	Boat crew	Average (%)	-4,469774
	f.	Fuel	Average (%)	-16,59716
	g.	Catching day	Average (%)	0

Table 9: VIU pole and line in bone bay waters

VIU							
Vessel	**Boat length (P)**	**Boat width (L)**	**Boat capacity (GT)**	**Engine power**	**Boat crew**	**Fuel**	**Catching day**
1	1	1	1	1	1	0,889	1
2	1	1	1	1	1	1	1
3	0,933	0,97	0,88	0,533	1	0,833	1
4	1	1	1	1	1	1	1
5	0,8958	0,95	1	1	0,944	1	1
6	1	1	1	1	1	1	1
7	0,865	0,89	0,87	0,944	1	0,94	1
8	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1
Average	0,966	0,979	0,97	0,94	0,99	0,96	1

Based on the calculation of catching capacity of pole and line vessel in Bone Bay, the Catching Unit score at cingle-output approach was 0.933 in total.

Analysis of DEA single-output showed a capacity unit score for pole and line boat in overall was already optimal (with the score of CU=1). The result is assumed based on the used of input and output that generally maximal at the single-output approach. Improvement is needed by adding the output to the single-output path. Improvement effort for optimal utilization capacity can be made by combining the production or reducing the input [10].

Conclusion

1. Catching with the best performance from technical, biological, social and economic aspect is pole and line.
2. The allocation of skipjack tuna catching gear that was being operated within Bone Bay is pole and line 42 units, encircling net 100 units, three layers net 24 units, boat drift net 191 unit and steady drift net 181 unit.
3. The capacity of selected fishing boat capacity, in general, was already efficient in term of the use of input, indicated with score 1.

Recommendation

The other nine catch gears operated in Bone Bay waters were not recommended to was continued to use because they were threatening the sustainability of the resource, hence required for alternative environmentally friendly gears.

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