



International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)



<http://gssrr.org/index.php?journal=JournalOfBasicAndApplied>

Optimum Compositions of Fishing Units in Five Scenarios of Sustainable Fisheries in Palu Bay

Umar Alatas^{a*}, M. Fedi A. Sondita^b, Ari Purbayanto^c, Anwar Bey Pane^d

^a Faculty of Fisheries, University of Alkhairaat, Jl Diponegoro 39, Palu 94221,
Sulawesi Tengah, Indonesia

^{b,c,d} Department of Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Bogor
Agricultural University, Kampus IPB Darmaga - Bogor 16680 Indonesia

^{a*} email: alatas_umar72@yahoo.com

Abstract

Capture fisheries in Palu Bay, Central Sulawesi Province, are conducted by artisanal fishermen with simple technology. Sustainability of the fisheries is the central issue related to current economic development at the bay. This study compares five scenarios of sustainable fisheries with prevents the fisheries from excessive fishing effort and fish production, protecting critical habitats and fishing ground, and maintaining this fisherman's jobs. The objective is to identify the most optimum composition of fishing units in the bay. The study was started by conducting fisheries census, estimating optimistic potential fish production, identifying fish critical habitats and fishing areas, calculating number of fishermen, and analyzing technical performance of 4 types of major fishing unit. The data were then used to develop some linear goal programming algorithms which were analyzed using Solver add-in of Microsoft Excel. This study concluded an optimum combination of 83 units of hand line, 40 units of gillnets, 20 units of tidal traps and 25 units of lift net (scenario C). The fisheries are expected to produce fish of 320.36 ton.year⁻¹ and keep the job for 238 fishermen. Some consequences of such composition of fishing units are discussed, including local policies to promote fisheries sustainability.

* Corresponding author.

E-mail address: alatas_umar72@yahoo.com.

Keywords: sustainable; fisheries; optimum composition; goal programming; Palu Bay

1. Introduction

Palu Bay is located in Central Sulawesi Province, Indonesia facing Makassar Strait; the bay is 206,93 km² with a winding coastline of approximately 100 km long; its mouth is 9 km wide and the bay is 50 km long while the deepest part is 800 m. The bay has been used by fishermen as their fishing ground, mainly for small pelagic species such as Indian mackerels (*Rastrelliger brachysoma*), eastern little tuna (*Euthynnus* sp), yellow stripe trevally (*Selaroides*), fringescale sardines (*Sardinella fimbriata*), scads (*Decapterus* spp.) and anchovies (*Stolephorus* spp.). Fishing gear operated by fishermen in Palu Bay can be classified as simple technology and fishing activities are conducted by small-scale business units involving 1-3 fishermen per unit. Fishing is normally conducted for less than 12 hours a day (one-day fishing trip) at 1-2 miles from coastlines or fishing bases. A field census conducted by the first author during field observation in March-May 2012 the bay revealed existence of 89 units of handline, 22 units of liftnet, 47 units of gillnet and 19 units of tidal barriers locally called sero. Handlines and gillnets are commonly operated in areas with fish aggregating devices (FADs), in the morning or afternoon. Types of fishing boat used by local fishermen include dug-out canoes, plank-wood boats with paddles, sails or 5.5 HP outboard engines. These simple and small sized fishing gear and equipments with low investment are the main characteristics of the fisheries. While fishing is important business for the 240 fishermen in the bay, economic development at the bay and its surrounding areas has been intensified. Development of intersular passenger port at Pantoloan, two cargo ports at Donggala and Wani, in addition to a fishing port at Donggala, are the most obvious examples of this development. Development of these facilities directly reduced feasible fishing ground due to marine traffics accommodated by the ports which provide services for various types of commercial boats. In 2012, the Pantoloan port accommodated 44.188 arrival passengers and 41.747 departure passengers. In 2011, the ports at Pantoloan, Donggala and Wani all together unloaded 700.606 units of container and uploaded 406.063 units of container. The other ports are Water Police based, a ferry port at Taipa and a navy port and several private ports for mining companies. Local development at the bay has been more intensified and creates some threats to the fisheries. The landscape of the surrounding areas has changed as a result land conversion for industries, human settlement, and public facility development. On the water, the threats include degradation of water quality and marine environment, marine transportation for people and goods, and fisheries activities itself. It is obvious that the small scale capture fisheries operated in the bay are the most threatened local community business. The total area available for fishing is decreasing and fish abundance is lower due to degradation of fish habitats and other factors. Ideally, utilization of renewable natural resources and environmental services can be conducted in harmony given the other activities do not harm the sustainability of the resources and environmental quality. All of these will create losses in terms of long-term utilization opportunity and short-capital. In other words, inefficiency in natural resources utilization must be avoided. Certainly, excessive fishing effort and destructive practices must be avoided.

To avoid such problem, a specific integrated management is required by positioning sustainable use of renewable resources (i.e. fisheries) as the primary objective. This research is addressing sustainability of the small scale fisheries conducted in Palu bay by promoting optimum composition for gillnet, lift net, tidal trap,

and hand line fishing units in their feasible fishing grounds. This optimum composition was determined by considering maximum annual fish production, feasible area for productive fishing activities, and number of fishermen to be involved in the fisheries.

2. Methods

This research is limited to fishing activities in Palu bay which are represented by 4 types of major fishing units which were operated in Palu Bay, i.e. handing, gill net, tidal barrier, and lift net. Hence, all data on specification of fishing gear, fishing methods and space requirement, fish production, fishing grounds, and fishermen were obtained from samples of these type of fishing units. Field data collection was conducted from April to November 2012.

This study applied linear goal programming approach to solve a multi goal problem [1]. In this study, the multi-goal is related to sustainable fisheries which applies precautionary principle, e.g. avoiding excessive fish production, excessive fishing effort and conflicts among fishermen, maintaining potential fishing ground, but engaging as many existing fishermen as possible. This approach determines an optimum composition of fishing units which satisfies most of goals under some constraints. The constraints in this study are optimistic sustainable fish production, size of feasible fishing areas, and number of fishermen. Methods to determine the constraints are described below.

2.1 Estimation of optimistic sustainable fish production from the bay

Sustainable fish production is one of constraints in determining optimum composition of fishing units in the bay. The bay is surrounded by two regional governments, i.e. Donggala Regency and Palu City. Each local fisheries agency traditionally keep statistics on fish production but mostly based on volume of fish landed at its respective fish landing sites. Therefore, the existing fisheries statistics published by both governments represent volumes of fish landed that are not only fish from the bay but also from Makassar Strait. This means the fish statistics cannot be used directly to establish a constraint in mathematical modeling for optimising composition of fishing units. As an alternative, we conducted a monitoring program to record fish catch for 6 months in-consecutively in March, May, June, August, November and December 2012 from one sample of each type of fishing unit. Each month, 7-10 fishing trips were monitored for each type of fishing unit. Fish production from the monitored fishing units was used calculating an estimate of annual catch 2012 from the bay. For each type of fishing unit, average catch per trip and its standard deviation were calculated each month; these statistics were used to estimate optimistic catch per trip in each respective month by subtracting one standard deviation from the average catch per trip. Therefore, the optimistic catch per trip was lower than the actual average catch per trip. It means fishermen have a greater opportunity to get their catch equal to the optimistic catch per trip than catch equal to the average actual catch per trip.

For each month, each optimistic catch per trip was then multiplied with number of fishing trips that could be made by existing fishing units in their respective months. This calculation resulted in an estimate of total monthly catch of the respective type of fishing unit. The total monthly catch of the six month monitoring then

was used to estimate the catch of the months that were not monitored. Finally, the annual catch from a type of fishing units operated in the bay was calculated. Adding catches from different types of fishing gear resulted in a total annual catch from the bay. Steps in estimating sustainable fish production are as follows:

The average catch per trip of fishing unit u in month m from t fishing trips is:

$$\bar{X}_{u,m} = \frac{\sum_{i=1}^t X_{u,m,t}}{t}$$

Where: $X_{u,m,t}$ is observed catch of fishing unit type u from fishing trip t in month m ;

u is type of fishing unit where 1 is hand line, $u = 21$ is gill nets operated in hand line fishing ground, $u = 22$ is gill nets in gill net fishing ground, $u = 3$ is tidal barriers and $u = 4$ is lift net.

The standard deviation of catch per trip of fishing unit u in month m is:

$$S_{u,m} = \sqrt{\frac{\sum_{i=1}^t (X_{u,m,t} - \bar{X}_{u,m})^2}{t - 1}}$$

The optimistic fish production of fish per trip of fishing unit u in month m is:

$$\bar{C}_{u,m} = \bar{X}_{u,m} - S_{u,m}$$

If fishing is ideally operated in t trips per month, the estimate total catch of fishing unit u in month m is:

$$C_{u,m} = t_{u,m} \cdot \bar{C}_{u,m}$$

Number of fishing trips for each month was calculated by applying monthly coefficients since all potential monthly fishing trips (t_u) may not be fully utilized. For example, during north-western monsoon season the bay is rough due to strong wind so the fishermen should reduce number of fishing trips. Therefore, the monthly fishing trips were calculated as follows:

$$t_{u,m} = t_u \cdot p_m$$

then the estimate total catch of fishing unit u in month m becomes:

$$C_{u,m} = t_u \cdot p_m \cdot \bar{C}_{u,m}$$

For months with no observation on catch, the total monthly catch is estimated by a linear interpolation using available data, e.g. ($C_{u,m-1}$) and ($C_{u,m+1}$).

$$C_{u,m} = \frac{C_{u,m+1} - C_{u,m-1}}{(m+1) - (m-1)}$$

The total estimate of annual catch from a fishing unit of type u or annual productivity of fishing unit u per year is:

$$C_u = \sum_{m=1}^{12} C_{u,m}$$

In Palu bay, annual small pelagic fish productivity for hand line was 1.32 ton.year⁻¹, gill net was 2.16 ton.year⁻¹, tidal barrier was 1.57 ton.year⁻¹, lift net was 2.72 ton.year⁻¹ while annual anchovy productivity for lift net was 1.16 ton.year⁻¹.

The total estimate of annual catch from all fishing unit of type u is:

$$TC_u = n_u \sum_{m=1}^{12} C_{u,m}$$

Where: n_u is the existing number of fishing unit type u . The total annual catch of all fishing units of all types is used as the maximum limit of fish production from Palu Bay (C_{Max}).

$$C_{Max} = \sum_{u=1}^4 TC_u$$

In Palu bay, there were 89 units of hand line, 47 units of gill net, 19 units of tidal barrier and 22 units of lift nets. Therefore, as a constraint, the maximum annual production (C_{Max}) of small pelagic fish was 308.67 ton.year⁻¹ and anchovies was 25.65 ton.year⁻¹.

2.2 Estimation of sizes of fishing ground and space requirements

Data collected in the census program include types of fishing units operated in an area and position of their fishing areas. Based on records from GPS, the total area for hand line around fish aggregating devices which were also accessible to gillnets was 45.50 km² while the total area of fishing grounds for gill nets outside this area was 21.70 km², for tidal barriers was 15.50 km², and for lift nets was 38.80 km². Hence, the total area of the fishing ground was 121.50 km². Other factors were also considered in determining the potential area of fishing grounds. These were water depth, areas currently utilised by marine transportation and ports, marine tourism and critical marine habitats. The utilized bay areas consisted of shipping lanes (9.76 km²), mining infrastructures (1.41 km²) and tourism areas (3.71 km²) while the critical marine habitats consisted of mangrove areas (18.07 km²) and coral reefs (10.88 km²). While the total area of utilized bay was 14.88 km² and the critical habitats was 28.95 km², therefore, in the bay of 206.93 km² of the bay, there were potential fishing grounds of 163.17 km², however only 121.50 km² is suitable for four fishing units.

Embayment waters provides a better environment for small-sized fishing boats equipped with simple fishing gear and low-power main engine with basic safety equipments. However, different types of fishing units may require different working environments, particularly working space, due to differences in physical dimension of fishing gear, method in fishing operation, boat maneuver, safety distance among fishing units and behavioral characteristics of target fish. Estimates of size of working space required for each fishing unit from Bay of Palu are presented in (Table 1).

Table 1. Estimates of working space required by 4 types of fishing unit operated in Palu Bay

Type of fishing unit	Principle dimension (m)	Size of working area per unit (m ²)	Nature of working environment	Potential fishing ground
Hand line around FADs	D: 100 – 200 m	500 m x 500 m = 250,000m ²	FAD designated area, deepwater	45.50 km ²
Gill net	L: 100 m	1,000 m x 1,000 m = 1,000.000m ²	Deepwater with no static obstacles, deepwater	21.70 km ²
Tidal barrier	L: 100 m; W: 10 m	800 m of coastline x 1.000 m = 800,000 m ²	Shallow water, intertidal area	15.50 km of coastline or 15.50 km x 1.0 km = 15.50 km ²
Lift net	L: 10 m ; W: 10 m	1.000 m x 1.000 m = 1,000,000m ²	Shallow water, 200 m – 800 m depth.	38.80 km ²

There are multiple goals, i.e. fish production should not exceed the quota which is maximum fish production (C_{Max}), number of fishermen engaged in the fisheries should not exceed 240 persons and existing potential fishing areas should be utilized. We established one objective, i.e. to minimize

$$Z = \sum_{i=1}^n [W_{DB_i} * DB_i - W_{DA_i} * DA_i]$$

Where: DB_i is a deviation when value of goal i is less than its constraint and DA_i is a deviation when value of goal i is equal or bigger than its constraint for equation i ; W_{DB_i} is weight for DB_i and W_{DA_i} is weight for DA_i . The values of DB_i are 0 and 1 while DA_i are 2 and 3; 0 means no objection, 1 means moderate objection, 2 means worse objection and 3 means the worst objection. This study considers the worst situation if number existing fishermen is exceeded, but if number of fishermen is lower than the existing number of fishermen, this study only object moderately.

The objective is subject to resources constraints with the following generic equation:

$$\sum_{u=1}^n a_{i,u} * N_u + W_{DB_i} * DB_i - W_{DA_i} * DA_i = b_i$$

Where: N_u is number of fishing unit type u where 1 is hand line, 21 is gill nets in hand line fishing ground, 22 is gill net in gillnet fishing ground, 3 is tidal barrier and 4 is lift net; $a_{i,u}$ is a constant for fishing unit u at equation i ; and b_i is a constraint for equation i .

Hence, equations for annual fish production as algorithms for determining optimum composition of fishing units are:

$$1.32N_1 + 2.16N_{21} + 2.16N_{22} + 1.57N_3 + 2.72 N_4 + 0DB_1 - 2DA_1 = 309.69 \text{ (ton)}$$

$$1.00N_4 + 0DB_2 - 2DA_2 = 25.65 \text{ (ton)}$$

equations for feasible fishing areas are:

$$0.25N_1 + 1.00U_{21} + 0DB_3 - 2DA_3 = 67.20 \text{ (km}^2\text{)}$$

$$1.00N_{22} + 0DB_4 - 2DA_4 = 21.70 \text{ (km}^2\text{)}$$

$$0.80N_3 + 0DB_5 - 2DA_5 = 15.50 \text{ (km}^2\text{)}$$

$$1.00N_4 + 0DB_6 - 2DA_6 = 38.80 \text{ (km}^2\text{)}$$

and equation for number of fishermen involved is:

$$1N_1 + 1N_{21} + 1N_{22} + 2N_3 + 3N_4 + 1DB_7 - 3DA_7 = 240 \text{ (person)}$$

Values of N_1 , N_{21} , N_{22} , N_3 and N_4 are predicted number of fishing unit which is not negative but subject to operational scenario.

There are several operational scenarios of minimum number of fishing units exercised in this study through the linear goal programming, but only 5 scenarios are presented (Table 2).

Table 2. Minimum number of each type of fishing unit for five scenarios of fishing existence in Palu Bay

No	Types of fishing units	Scenario A (□ 0 unit)	Scenario B (□ 15 units)	Scenario C (□ 20 units)	Scenario D (□ 45%)	Scenario E (□ 50%)
1	Hand line	≥ 0	≥ 15 units	≥ 20 units	≥ 40	≥ 44
2	Gill net 1	≥ 0	≥ 15 units	≥ 20 units	≥ 0	≥ 0
3	Gill net 2	≥ 0	≥ 15 units	≥ 20 units	≥ 21	≥ 23
4	Tidal barrier	≥ 0	≥ 15 units	≥ 20 units	≥ 8	≥ 9
5	Lift net	≥ 0	≥ 15 units	≥ 20 units	≥ 9	≥ 11

Note: Gill net 1 is operated in FAD fishing grounds open to both hand lines and gill nets, Gill net 2 is operated in non-FAD fishing grounds open to gill nets.

Scenario A represents a default minimum composition when number of each type of fishing units can be 0 (or absence) but not negative figure. Scenario B and C represent compositions of fishing units when each type is minimally represented by 15 and 20 units respectively. Scenario D and E represent compositions of fishing units when each type is minimally represented by 45% and 50% from the baselines (or existing number of fishing units). The B and C scenarios represent a policy of minimum existence of the current fishing units operated in the bay while the D and E scenarios represent a moderate approach since they do tolerate around 50% reduction of number of fishing units.

Optimum composition of fishing units satisfying the objective and constraints for each scenario was calculated by applying Solver add-in from Microsoft Excel. The software will identify composition of fishing units when the Z value is minimum. Difficulty in establishing integer output of numbers of fishing units was approached by simply dropping the decimals. This approach is moderate since the new deviation from the same objective is not far from the calculated minimum value of Z. Therefore, there are 5 optimum compositions of fishing units. The best scenario is selected for optimum composition of fishing units with the lowest value of Z.

3. Results

The five selected scenarios provide different optimum compositions of fishing units, but scenario C provides the minimum value of Z, i.e. 7 (Table 3).

Table 3. Optimum compositions of fishing units for five scenarios of sustainable fisheries in Palu Bay

No.	Types of fishing unit	Baselines	Scenario A (□ 0 unit)	Scenario B (□ 15 units)	Scenario C (□ 20 units)	Scenario D (□ 45%)	Scenario E (□ 50%)
1	Hand line	89	124	94	83	103	101
2	Gill net	47	0	30	40	21	23
3	Tidal barrier	19	19	19	20	19	19
4	Lift net	22	25	25	25	25	25
Total		177	168	168	168	168	168
Value of Z		-	9	9	7	9	11

The selected scenario resulted in a composition fishing fleets consisting of 83 fishing units of hand line, 40 fishing units of gill net, 20 fishing units of tidal barriers, and 25 fishing units of lift net. Such composition of fishing units is expected to produce fish of 320.36 ton.year⁻¹ consisting of 295.36 ton.year⁻¹ of pelagic species and 25.00 ton.year⁻¹ of anchovies (Table 4). The fisheries will provide 238 jobs for local fishermen while the total area utilized will be 97.60 km².

Table 4. Fisheries parameters for five scenarios of sustainable fisheries in Palu Bay

No.	Fisheries parameters	Baselines	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
1	Fish production (ton.year ⁻¹)						
1.1	Pelagic species	309.69	261.51	286.71	295.36	279.15	280.83
1.2	Anchovies	25.65	25.00	25.00	25.00	25.00	25.00
	Total	334.34	286.51	311.71	320.36	304.15	305.83
2	Fishing ground (km ²)						
2.1	Hand line	67.20	24.80	33.80	36.60	20.60	20.20
2.2	Gill net	21.70	0.00	15.00	20.00	21.00	23.00
2.3	Tidal barrier	15.50	15.20	15.20	16.00	15.20	15.20
2.4	Lift net	38.80	25.00	25.00	25.00	26.00	25.00
	Total	143.20	65.00	89.00	97.60	82.80	83.40
3	Fishermen (person)	240	237	237	238	237	237

4. Discussion

Embayment waters provide some advantages to local community in terms of accessibility and physical protection from natural hazards. Land configuration provides protection hence embayment waters are usually chosen as locations of harbors and ports. These advantages attracts various types of business to concentrate in Palu Bay, include marine tourism, marine transportation, capture fisheries and aquaculture [2, 3]. Land-based facilities that provide services to these activities and other types of business create a complexity in managing the bay. Several factors threatening sustainability of capture fisheries are due to from inappropriate perspectives on the consequences of excessive exploitation on the renewable resources by maximizing volume of fish production to gain more profits, and ignoring the relationships among the ecosystems, fish resources and fishermen [4].

Various scenarios of sustainable fishing can be developed. Application of precautionary approach suggested in Code of Conduct for Responsible Fisheries [5] can be applied by limiting total amount of fish production or landings, number of effective fishing units, certain specification of fishing gear, limiting fishing efforts, opening and closing fishing seasons, permanent closure of fish habitats, etc. The scenario C provides some application of this code of conduct by limiting number of fishing units, limiting volume of annual fish production and securing fishing grounds from further reduction.

To promote sustainability of the fisheries, local governments need to establish some policies for protecting the fisheries with a confidence that existence of sustainable fisheries will promote not only economic opportunity but also social opportunity through healthy environment of Palu Bay. The policy may address some issues of internal aspects of the fisheries for avoiding inefficiency in terms of overfishing, excessive investment, catching improper size of fish and excessive discarded by-catch, reducing potential conflicts among fishing fleets, open and closed fishing seasons. These will require some strategies which are basically transforming the open-access regime to limit-entry regime [6]. For external aspects of the fisheries, a special policy is needed to securely position the

fisheries as main factors promoting environmental health of the bay by allocating of some areas for fishing grounds and protecting of critical marine and coastal habitats. This policy is very ideal since they covering many issues related to capture fisheries, coastal management and marine protected area [7].

Positioning sustainable fisheries in Palu Bay as constraints to other human activities while promoting sustainability and healthy of marine ecosystem requires special effort. One of them is a strong local policy supported by businesses that may be supported by higher decision making bodies. Marine transportation facilities and activities needs to be adapted according to the requirement of sustainable fisheries. Also, the activities of land-based mining facilities need to respect regulations that protecting environmental quality, such as minimizing sedimentation and damage to some critical habitats. Marine protected areas need to be established with objectives of protecting them from further degradation [8].

Sustainable fisheries in the embayment waters, such as Palu Bay, can be used as an indicator of healthy aquatic ecosystem. A good ecosystem where habitats are sufficiently functioning should support fish to complete their life cycle hence maintaining a balance between their removals through fishing and recruitment. In a good aquatic ecosystem where fish is available, ambient environment is usually at its natural state. It means public surrounding the bay will have opportunity to enjoy clean, pleasant aquatic environment. This idea means also that promoting sustainable fisheries will promote benefit to coastal communities beyond fishing communities [3].

This study provide some scenarios of spatial allocation for small scale fishing business with simple fishing technology in an embayment waters. Fisheries managers are offered to limit the fish production based on the history of the local fisheries, restricting number of fishing effort by applying optimum composition, promoting space allocation. The proposed composition of fishing units implies reduction of 6 fishing units of hand line and 7 fishing units of gill net with addition of 1 fishing unit of tidal barrier and 3 fishing units of lift net.

In terms of additional units required arrest if the arrest was the second unit to be improved mesh size of 0.5 cm have a low level of selectivity, if there is no change in mesh size of existing units arrest, the arrest of the two units are not recommended for the addition of units arrest, this is in line with what was proposed by [9] that the mesh size has the greatest influence on the selectivity of fishing gear.

Both reduction and addition of certain fishing units should not be a big issue for the fisheries in the bay because such changes are not quantitatively substantial. However, before applying such recommendation, local fisheries authorities should establish and perform a monitoring and evaluation (M&E) program to measure some key indicators of the fisheries. Results of M&E program can be used to determine strategies that prevent the fisheries from unwanted direction [10].

The application of spatial allocation needs to be supported by a strong policy which basically manages conflicts among resources users. Space is a type of common goods or resources that requires governance to achieve its optimum public utility. Excessive utilization performed by each resource users will worsen the conflicts which may not be realized until some of them experience poor performance of their business, e.g. failure to create profit or less benefit. Development of effective local regulation on marine space allocation is very urgent as a tool in

managing marine resources that promote sustainability of the fisheries. In this case, the entire 143.20 km² of fishing grounds should be kept for fisheries activities beside the proposed optimum composition of fishing units will utilize only 97.60 km². The 'un-utilized' fishing grounds are not wasted of resources since it gives more opportunity to the fish resources to relax fishing pressures. Hence, keeping the fish exploitation at a moderate state.

5. Conclusion

The sustainable fisheries in Palu Bay should consist of 83 hand line, 40 gill net, 20 tidal traps, and 25 units lift net fishing units. Such composition of fishing units is expected to produce fish of 320.36 ton. year⁻¹ consisting of 295.36 ton of pelagic species and 25.00 ton of anchovies. The fisheries will provide 238 jobs for local fishermen. A total of 143.20 km² of the bay should be allocated for fishing area while the critical habitats for fish and other marine organisms must be assigned as marine protected areas, i.e. 18.07 km² of mangrove area and 10.88 km² of coral reefs.

This spatial arrangement will promote the sustainability of the fish resources, reduce conflicts among the fishing fleets, and prevented the fisheries in the bay from other human activities threatening its sustainability. Strong policies that promote sustainability of the fisheries and environmental health of the bay are urgent to anticipate further negative impacts of economic development in short future.

References

- [1] Ignizio, J.P., C. Romero. "Goal Programming: Encyclopedia of Information Systems." *Elsevier Science*. Vol. 2, pp. 489-500. 2003.
- [2] Ansar. "Menuju kebijakan pengelolaan Teluk Palu yang harmonis." *Media LITBANG Sulawesi Tengah*. Vol. 4 (2), pp. 142-148. 2011.
- [3] Lutfi. "Identifikasi Pengaruh Perubahan Fungsi Lahan Terhadap Sosial Ekonomi Masyarakat di Pinggiran Kota (Studi kasus: Kecamatan Palu Utara)." *Jurnal MEKTEK*. Vol. 8 (1), pp. 128-137. 2006.
- [4] Wiadnya, D.G.R, R. Djohani, M.V. Erdmann, A. Halim, M. Knight, P.J. Mous, L. Pet-Soede. "Kajian Kebijakan Pengelolaan Perikanan Tangkap di Indonesia: Menuju Pembentukan Kawasan Perlindungan Laut." *Jurnal Penelitian Perikanan Indonesia*. Vol. 11(3), pp. 65-77. 2005.
- [5] (FAO) Food and Agriculture Organization. *The Code of Conduct for Responsible Fisheries*. FAO of the United Nations, Viale Delle Terme di Caracalla. Rome, Italy. 1995.
- [6] Stobutzki, I.C., G.T. Silvestre, L.R. Garces. "Key issues in coastal fisheries in South and Southeast Asia, outcomes of a regional initiative." *Fisheries Research*. Vol. 78, pp. 109–118. 2006

[7] Balgos, M.C. “Integrated coastal management and marine protected areas in the Philippines: Concurrent developments.” *Ocean & Coastal Management* 48: 972–995. 2005.

[8] Angulo-Valde, J.A. and B.G. Hatcher. “A new typology of benefits derived from marine protected areas.” *Marine Policy*. Vol. 34, Pp. 635 – 644. 2010

[9] Fridman A. *The calculation in designing Fishing Tool*. Revision was developed by PJG. Carrothers. Translators Team BPPI. Semarang 300p. 1986.

[10] Forst, M.F. “The convergence of Integrated Coastal Zone Management and the ecosystems approach.” *Ocean & Coastal Management*. Vol. 52, pp. 294–306. 2009.