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DESTRUCTIVE FISHERY AND FISHERY SUSTAINABILITY ASSESSING FISHERY SUSTAINABILITY USING A MULTI-CRITERIA PARTICIPATORY APPROACH : A Case Study of Small Islands in South Sulawesi

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ABSTRACT

The sustainability in the integrated human and nature systems or social–ecological systems (SES) of reef fishery needs attention, because the livelihood of many coastal communities is dependent upon it. Likewise, coral reef ecosystem is important marine resource as a source of biodiversity, a spawning aggregation for various reef fish and biota. However, coral reef ecosystem in South Sulawesi has been pressured by reef-related fishing activities, which include destructive practices of bomb and poison fishing.

This study assesses the condition of fishery sustainability in five selected small islands situated in Taka Bonerate Marine National Park and Spermonde Archipelago, South Sulawesi. Multi-criteria analysis (MCA) is used as a decision-making tool to analyze and evaluate multiple indicators under a participatory group decision-making environment (Mendoza and Prabhu 2004). Four variable criteria of sustainability indicators are included, namely ecological-criterion indicators, economic-criterion indicators, social-criterion indicators, and institutional-criterion indicators. The result of the assessment is analyzed with the state of coral reef and the state of destructive fishery in the area.

Keyword: fishery, sustainability, multi-criteria analysis, participatory approach.

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INTRODUCTION

Coral reef is important marine resource as a source of biodiversity, a breeding place for fisheries, and supplying benefits for human communities, especially those dependent on marine resources, i.e. fishermen and coastal communities. However, threat to coral reef ecosystem and fishery includes the use of bomb and poison that has been dated back since the Second World War (Pet-Soede, et al. 1999). Destruction of coral reef and fishery can contribute to weakening spawning aggregation for various reef fish and biota.

On the other hand, sustainable resource managementhas become the

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central goal of most resource-based management organizations including government, non-government, research and development, and many international organizations (Mendoza and Prabhu 2004). One of the practical initiatives to achieve sustainability is to evaluate or measure sustainability. However, given the uncertainty in environment (Weisbuch 2000) and marine environment (Wilson 2005), a knowledge-based management, that incorporates both local knowledge and scientific knowledge, is inevitable. Increasingly, many scientists are calling for more discussion among stakeholders. "They recognize first that they are not the only experts in the process and second that the uncertainty of the marine environment means that no single form of expertise has the right, or even adequate, answers" (Wilson 2005:4).

The uncertain and dynamic characteristic of social-ecological system (SES) calls for cooperation between scientists and stakeholders. This is a way to promote co-management institutions that needs to be adaptive, because it requires attention to iterative feedback learning from the management experience as it unfolds. This realization has brought in the concept of adaptive co-management (Berkes 2005).

This study proposes a participatory approach to measure fishery sustainability by using a multi-criteria analysis (Adrianto, et al 2005). It aims at assessing the state of coral reefs, destructive fishery and fishery sustainability, and relates them to explain the condition of fishery sustainability.

MATERIALS AND METHODS

Study sites

In order to achieve research objectives, a comparative study is carried out in five small island communities situated in Taka Bonerate Atoll and Spermonde Archipelago, South Sulawesi. The study is primarily based on empirical study. The case studies was carefully selected in order to compare the study sites whose resident fishers involve in destructive fishery, i.e., bomb and/or poison fishing and those communities where destructive-fishing practices are non-existent or trivial (see **Table 1**). Nevertheless, all island fisher communities are situated in coral reef resources and dependent upon reef fishery. The area of each island is around 50 Ha, with population between 400 and 1,300 persons.

Table 1: A comparison of study sites based on the level of destructive fishery

	Spermonde archipelago	**Taka Bonerate MNP**
High destructive fishery	Kapoposang	Rajuni Besar
Trivial or no destructive fishery	Barrang Caddi	Tarupa, Rajuni Kecil

Source: Primary surveys (April-June 2004).

Data collection methods

Data collection for the study is carried out in three different methods. The data on status of coral reefs in the study area are based on secondary data collection, whereas the data on state of destructive fishery is collected through population survey and resource user survey. Finally, the fishery sustainability is assessed by a participatory multi-criteria analysis MCA that collected through focus group discussions. Description about participatory MCA is clarified in the following section. The population survey was carried out in 2004, while the resource user survey was done in 2005. The survey questionnaire includes questions on the use of bomb or poison fishing by the resident

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fishers. The survey in 2004 asked which resident fishers are using bomb or poison fishing. The survey in 2005 asked respondent's assessment on the frequency of bomb or poison fishing in their island, either frequent, rare, or never.

Table 2: Number of respondents for population and resource user survey

Study sites	Respondents for population survey	Respondents for resource user survey
Rajuni Kecil Island	1,071	18
Rajuni Besar Island	387	22
Tarupa Island	709	14
Kapoposang Island	486	37
Barrang Caddi Island	1,337	11
Total	**3,990**	**102**

Source: Primary surveys in 2004 and 2005.

Participatory multi-criteria analysis

To assess the fishery sustainability, this study utilizes a formal methodology called multi-criteria analysis (MCA). MCA is a general approach that can be used to analyze complex problems involving multi-criteria (Mendoza and Prabhu 2003), and have advantages when applied in a complex and stochastic system like fisheries (Adrianto, et al 2005). This method is suitable for three reasons. First, it can deal with mixed set of data, quantitative or qualitative, including stakeholders' opinion. Secondly, it is conveniently structured to enable a collaborative planning and decision-making environment. Finally, it is simple, intuitive, and transparent, while it has strong technical and theoretical support in its procedures.

Following Mendoza and Prabhu (2003), MCA is used as a decision-making tool to analyze and evaluate sustainability under a participatory group decision-making environment. This method can be used for generating criteria and indicators for sustainable resource management, estimating their relative importance, estimating the performance of each indicator relative to its desired condition.

The analysis using MCA approach is done into two parts. The first part is to generate a set of sustainability indicators of fisheries. The methods used in this part of analysis are varied, ranging from expert driven and top-down to bottom up, and locally defined (Adrianto, et al 2004). This study follows a study done by Adrianto et al (2004) and uses a mixed-method approach, in which it combines expert-driven fisheries sustainability indicators (Pitcher 1999) and then these indicators are confirmed to the local stakeholders in order to generate a "locally accepted" fishery sustainability indicators.

The second part of analysis evaluates the sustainability indicators in terms of their importance by ranking each indicators using a 5-point scale namely 1 – less important, 3 – moderately important, 5 – extremely important, and 2, 4 – intermediate value. A different scale is proposed by Mendoza and Prabhu (2003) using 9-point of scale, and Adrianto et al (2005) using 7-point of scale. However, for reason of simplicity during stakeholder meeting, this study uses 5-point scale. Based on these rankings, relative weight of an indicator is then estimated using a formula as follows (Mendoza and Prabhu 2003, Adrianto, et al 2004):

$$w_j = \frac{a_j}{\sum a_j}$$

where a_j is the average weight of indicator j and w_j is the relative weight of indicator j.

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The next analysis examined each indicator by judging their current condition relative to their perceived target or desired condition (Mendoza and Prabhu 2004, Adrianto et al 2005). The desired condition was to reflect or represent a sustainable status of fishery sustainability indicators. In this respect, an MCA approach of 5-point scale is applied, following Adrianto et al (2004), with values 1: extremely weak performance, strongly favorable, 2: poor performance, unfavorable, 3: acceptable, 4: very favorable performance, and 5: state of the art in the region. Then, the sustainability indicator score (SIC) is calculated using a formula:

$$SIC = \sum s_j w_j \qquad (2)$$

where SIC is sustainability index of criteria i (ecology, economy, social, and institution), S_j is the score of indicator j and W_j is the relative weight of indicator j (Eq. (1)).

Participants

The analysis is based on a participatory approach. Respondents consisted of three types of stakeholders were involved in the analysis, namely fisher, trader or fishing patron, and local policy maker (**Table 3**). Total participants in each island ranged from 6 to 9 persons. This number is not as much as the number of participants involved in other studies. Mendoza and Prabhu (2004) incorporated 10 participants of each forest area, and Adrianto et al (2005) gathered 15 participants of a small island. However small of the participants, they are viewed as representing the view of each island community, while they comprise of three different groups of stakeholder of fishing practice. They are sufficient to portray the fishery sustainability state of each island for this study, but care must be kept in mind to use this result for other purposes.

Stakeholders' views were initially assembled through group discussions, however biased opinions emerged. Therefore, closed individual interviews were then held to gather respective opinions. In this method, each participant was free to pose his views and further question on the objective of the research.

Table 3: Respondents of Participatory MCA

Island	Local policy maker	Trader/ patron	Fisher	Total
Tarupa	1	1	6	8
Rajuni Kecil	3	2	4	9
Rajuni Besar	2	1	3	6
Barrang Caddi	2 *	1	3	6
Kapoposang	1	2	4	7
Total	**9**	**7**	**20**	**36**

Note: One local policy maker is also positioned as trader/ patron.
Source: Survey in Sept-Oct 2005.

ISSN : 1410-5217
Accredited : 23a/Dikti/Kep/2004

RESULTS AND DISCUSSION

Results

Status of reefs corals are vital as spawning grounds for many species of fish and help prevent coastal erosion. The ecological indicator of the coral reefs is based on the living coral cover. This measurement is a useful indication of the quality of reefs. The diversity of reef fishes is correlated with the condition of reefs as determined by the percentage cover of living coral (Soekarno, 1989). The latest investigation of the condition of Taka Bonerate atoll in 2000 shows that the average hard coral cover is 50.1% (Coremap – ACIL 2000 at Appendix 2). Whereas coral reef condition in Barrang Caddi Island is only 25% in good condition, while in Kapoposang is 70% (DKP South Sulawesi 2003).

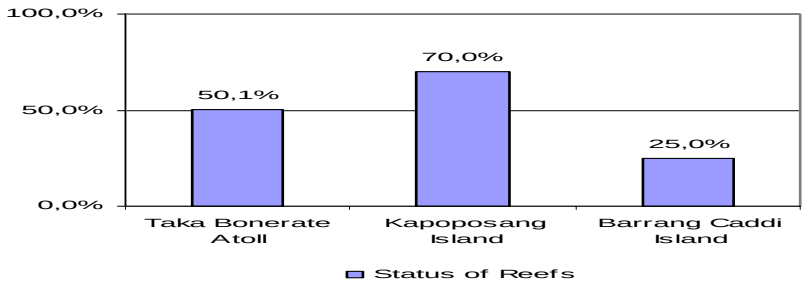
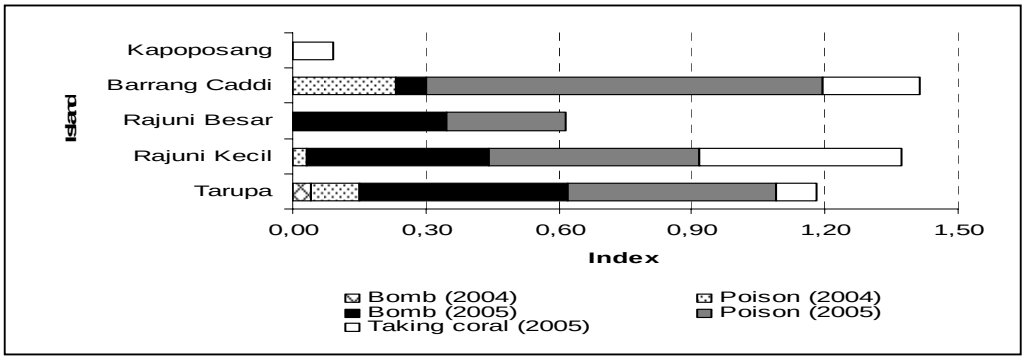


Figure 1. Status of reefs in study sites.

State of Destructive Fishery

The state of destructive fishery in the studied island is examined from data collected in 2004 and 2005. Data on the practices of bomb, poison and coral taking were composed into indexes, in order to simplify its presentation. Index for poison and bomb fishing is calculated for each year. Index for 2004 is taken from the percentage of fishers using bomb or poison fish. Index for 2005 is calculated from the percentage of responses saying 'frequent' use of bomb or poison fishing by resident fishers.

Figure 2 shows that Barrang Caddi, Rajuni Kecil, and Tarupa had high index of destructive fishery, while Kapoposang and Rajuni Besar were low.



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State of Fishery Sustainability Generation of Indicators

The first part of the multi-criteria analysis is to generate the set of indicators and assess their importance judged by stakeholders. This study used a set of sustainability indicators that consisted of four variable criteria of sustainability indicators, namely ecological-criterion indicators (5 or 6 indicators, differed in each islands), economic-criterion indicators (5 indicators), social-criterion indicators (4 indicators), and institutional-criterion indicators (3 indicators) (**Table 4**). These indicators were modified from fisheries sustainability indicators formulated by Pitcher (1999), Charles (2001), and Adrianto et al (2004), which were presented to stakeholders for discussion on their relevance and assessment. They were slightly modified, for example stakeholders added the indicators of market price and of fishing tools in relation with economic sustainability. In sum, most stakeholders did not reject or modify these indicators. Note that one indicator (i.e., tourism) did not fit to Barrang Caddi Island.

Table 4: List of sustainability indicators for the fishery system

Criteria	No	Indicators	Operational definition
Economy	1	Market price of fish	Fish price compared with historical pattern
	2	Market of fish	Market of fish is mainly local, national, or international.
	3	Income from fishing	Importance of fisheries sector in local economy
	4	Volume of catch	Volume of production compared with historical pattern
	5	Fishing tools	Technology and variation of fishing tools
	6	Tourism	Contribution of tourism for local economy and employment
Ecology	7	Distance to fishing grounds	Distance to fishing grounds compared with historical pattern
	8	Size of fish caught	Size of fish caught compared with historical pattern
	9	Number of fishing fleets	Number of fishing fleets compared with historical pattern
	10	Coral reef ecosystem	Living coral reef compared with historical pattern
	11	Destructive fishing tools i.e., cyanide, dynamite	The use of cyanide and bomb to fish
Social	12	Fishing community growth	Growth compared with historical pattern
	13	Environmental knowledge	Level of knowledge about environmental issues and the fishery
	14	Education level	Education level compared to population average
	15	Conflict status	Level of conflict in fishing i.e., fishing tools, outsider fishers, other sectors
Institution	16	Law enforcement	Formal law enforcement (monitoring, persecution, punishment) in fishery violation
	17	Inclusion or influence of fishers in management	Inclusion of fishers in management of fishery or marine national park or marine tourism national park
	18	Formal and informal fishing regulations	Fishing regulations endorsed by government or fisher community, in terms of restriction in fishing tools and access to fishing grounds

Source: Modified from Pitcher (1999), Adrianto et al (2005), and stakeholder discussions (September-October 2005).

ISSN : 1410-5217
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Indicators

The following results show the importance of indicators which is judged using a 5-point of values by the stakeholders. The results are examined in three parts: average weight; relative weight; and differences on group interests.

Average Weight

According to stakeholder values, all islands regard economic criteria of sustainability as the most important than other criteria. It can be seen from the average weight value, which is calculated in a range from 4.23 to 3.71, showing extremely important to moderately important. However, indicator of tourism in particular is valued as less important. The next important criterion is institutional criteria, with average weight value from 3.99 to 3.71. The following is social criterion, which is calculated in a range from 3.58 to 2.68. The ecology criterion is valued lowest, with average value from 3.40 to 3.10.

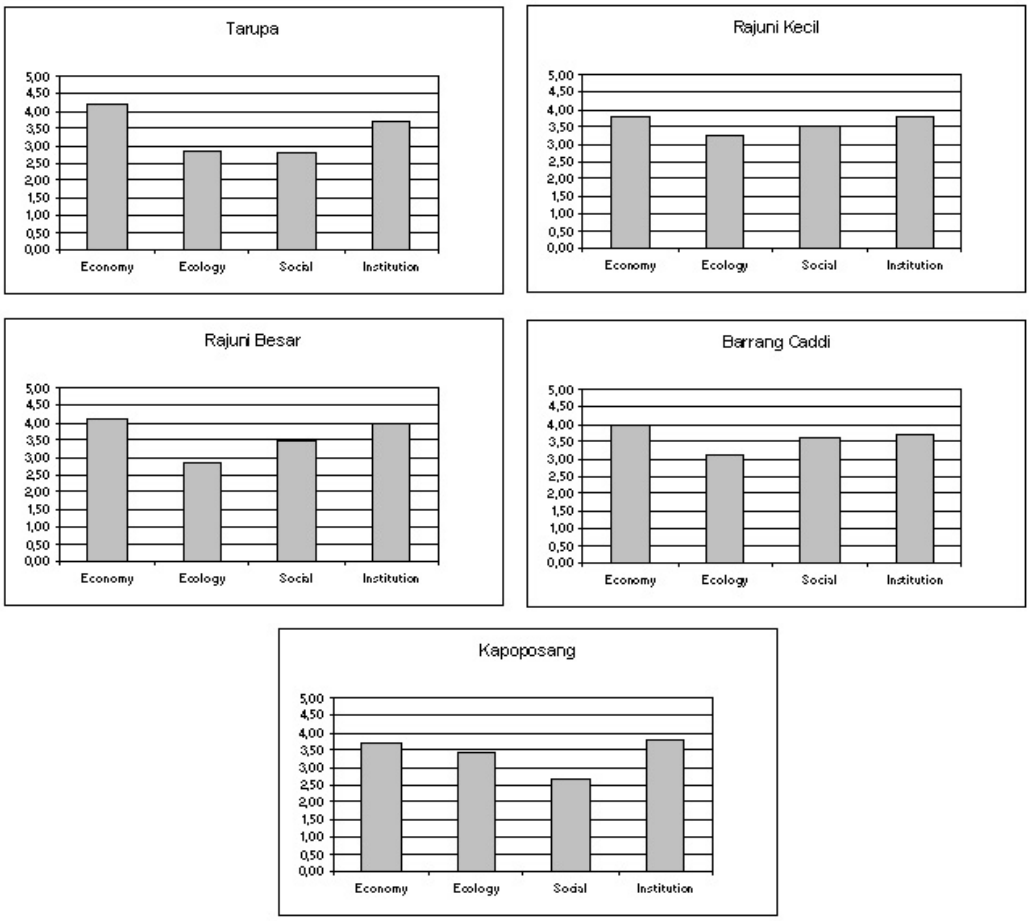

Figure 3: Estimated average weight for fishery sustainability indicators
Note: 1 – less important, 3 – moderately important, 5 – extremely important, and 2, 4 – intermediate value

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Relative Weight

Based on the calculation of relative weights, it can be clearly seen that some indicators are rated higher than others. But the difference is also clear among islands (see **Figure 4**). For example, under the institutional sustainability criteria, indicator 18 (i.e., formal and informal fishing regulations) is higher than other indicators under the same criteria (institutional sustainability). But it only appears for Tarupa, Rajuni Kecil and Rajuni Besar. On the other hand, Barrang Caddi and Kapoposang are valued law enforcement higher. It can be explained by the fact that law enforcement at the sea in Barrang Caddi and Kapoposang is worse than the rest.Indicator 13 (i.e., environmental knowledge), under the social criteria of sustainability, is valued higher in all islands. An important distinction is the indicator 15 (conflict status) which is valued higher than other indicators in the same criteria, particularly in Rajuni Besar and Kapoposang. This occurs because these communities often faced fishing conflicts, while most of their fishers did not use destructive fishing tools while outside fishers often use them in the same fishing grounds.

Within the ecological criteria of sustainability, indicators of coral reef ecosystem and destructive fishing tools (indicators 10 and 11) are valued higher in most of islands, except in Barrang Caddi. This value corresponds to the fact that Barrang Caddi has half of fishers using poison fishing, and many of their fishing patrons believe that cyanide fishing is not harmful to coral reefs.

Finally, under the economic criteria of sustainability, participants are valued higher on indicators of market fish price and of income from fishing. On the other hand, the indicator of volume of catch is valued less important, because it is market price of fish that gives affect to income, rather than volume. Interestingly, participants in most islands perceive lower value on where fish are marketed (indicator 2), which demonstrates that they have low knowledge on the target market of their fish, but understand that some fish are priced higher than others. However, this situation is not observed in Barrang Caddi, and put higher value on the indicator of market of fish. It clarifies the fact that this island is bordering to Makassar where some export traders are located.

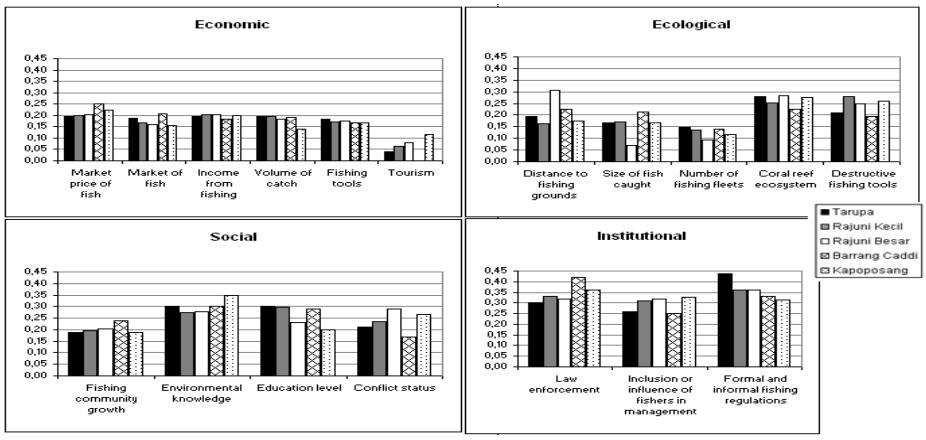

Figure 4: Estimated relative weight for fishery sustainability indicators

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Group Interests

Furthermore, different stakeholder perceives different value or importance of some indicators. A distinction is shown in the value of indicator destructive fishing tools (indicator 11). Fishers using bomb or poison in Tarupa and fishing patrons in Barrang Caddi perceived this indicator as less important and gave weight of 1 or 2. These islands have the highest incidents and fishers using bomb or poison fishing.

Figure 5 represents divergent views of each stakeholder group on the importance of each indicator of sustainability. They are based on average weight. Local policy maker regards the institutional criterion of sustainability as the highest value (4.26), and the second is the economic criterion of sustainability 3.92). Fishing trader or patron view the highest value on the economic criterion (4.05), followed by the institutional criterion (3.29). This order of rank is also viewed by fisher group, who valued the economic criterion as the highest (3.96) and followed by the institutional criterion (3.93).

From their average weight, the ecological criterion of sustainability is ranked as the last value for the fishing trader or patron group (2.28) and the local policy maker group(3.27), and placed on the third rank by the fisher group (3.29). Apparently, the importance of ecological criterion is the least (i.e. 2.28 means less than moderately important) by the fishing trader or patron group compared to other groups.

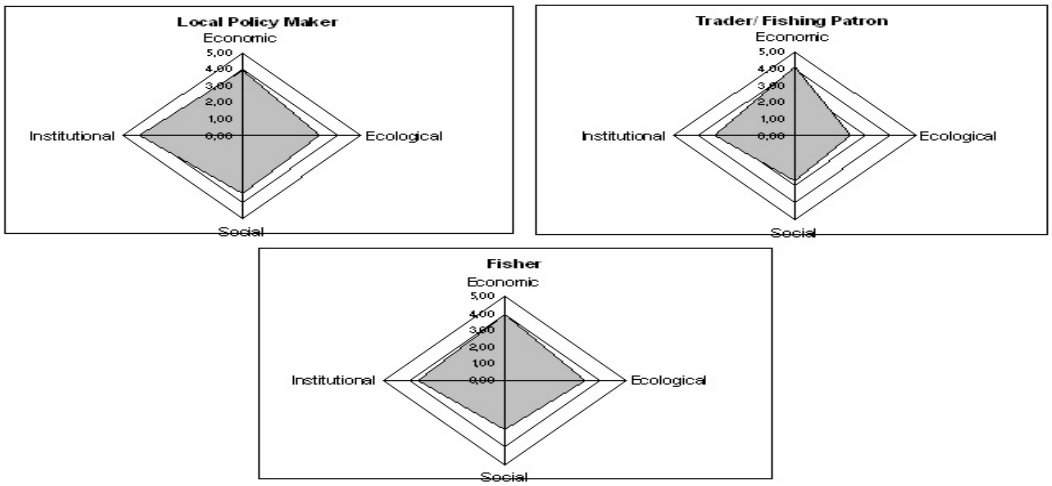

Figure 5: Indicator importance (average weight) based on group interests

Sustainability Index of Criteria

The next part of analysis is to estimate the "sustainable state" elaborated from the perceived targets or conditions judged by the stakeholders. This analysis is started by judgments of the stakeholders to score the perceived targets of each indicator followed by the calculation of sustainability index of criteria (SIC). The results are presented in **Figure 6**. It shows that the economic criterion of sustainability is the highest among other sustainability criteria in Tarupa, Barrang Caddi and Rajuni Kecil, with SIC 3.70, 3.25 and 2.94 respectively. These three islands have more fishers doing destructive fishing than others. On the other hand, on islands where destructive fishing fishers are limited, the social criterion of sustainability has the highest SIC, i.e. Rajuni Besar (3.11) and Kapoposang (2.93).

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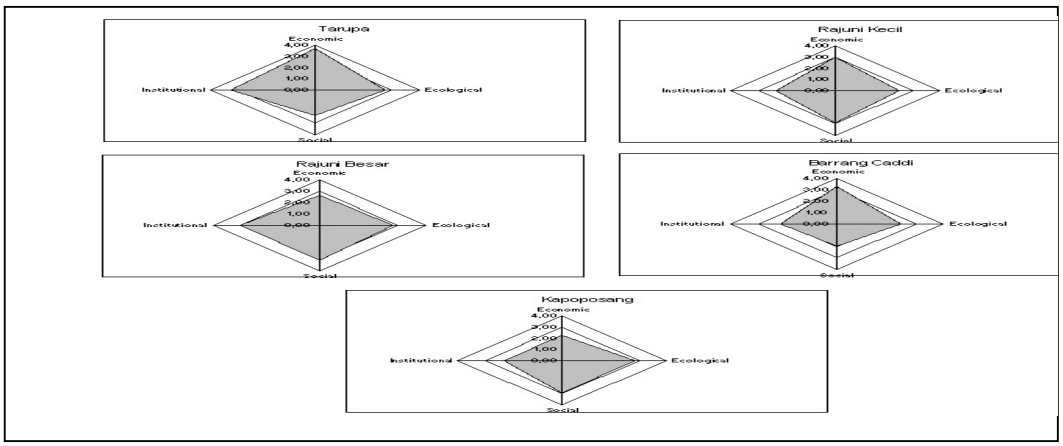

Figure 6: Sustainability index of criteria of fishery system

Discussion

Resource system in the study sites is characterized by coral reef ecosystem. Taka Bonerate atoll where Tarupa, Rajuni Kecil and Rajuni Besar islands are located, have the average percent cover of coral colonies 40 to 59% in 1989, and 50% in 2000. Coral reef condition in Kapoposang Island in 2003 is 70% in good condition, while in Barrang Caddi only 20%. Much of the degraded condition of the reef is due to direct human conduct e.g., fishing using bomb and poison, also coral taking.

The surveys in 2004 and 2005 show that the use of bomb and poison fishings have been proliferated, particularly in Tarupa, Rajuni Kecil and Rajuni Besar. The rate poison fishers in Barrang Caddi largely stay unchanged. Kapoposang remains do not have fishers using bomb or poison fishing. The results from the sustainability index of criteria (SIC) in each island are comparable with the rate of destructive fishery.

- In Tarupa, the economic indicator is high, while there were high incidents and resident fishers using destructive tools.
- Rajuni Kecil has high both the economic and social indicators.
- Rajuni Besar has more balanced on three criteria of sustainability: institutional, social and ecological, but quite low on the economic variables of sustainability. There were limited fishers using bomb or poison fishing, even though now the number is increasing.
- Barrang Caddi is similar with Tarupa, having high economic criterion of sustainability. But it has low in other criterion of sustainability: institutional, social and ecological. One half of the fishermen in this island have been using poison fishing.
- Kapoposang has high on social and ecological criterion of sustainability, but low in economic and institutional.

The findings from this study is similar to the application of Rapfish (Rapid Appraisal for Fisheries) in assessing twelve fishing tools used in the coastal area of Jakarta (Fauzi and Anna 2005). Rapfish is a technique to assess the status of fisheries in a multidisplinary nature that consists of ecology, social, economic, technology, and ethic components. The technique is distinct from that of used in this study, in which it utilizes a Multi-Dimensional Scaling (MDS). The shows the fishing tools that characterized as inactive and utilized in the bay (i.e., hook and line, portable traps) have the ecological sustainability in between good and bad, but

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have a bad score of the social sustainability. This is different from the fishing tools that characterized as active and utilized out of the bay (i.e., gill net, muroami, purse seine) that have a relatively bad score in the dimensions of technology and ecology, but have a relatively good score in the dimensions of economy and social. This shows that the active fishing tools tend to create ecological problems, such as by catch, non-selective, and catch before maturity. On the other hand, the inactive fishing tools tend to be passive, more selective and traditional, therefore relatively not destructive. This is similar to this study that sustainability index of criteria are comparable with the rate of destructive fishery.

On the policy implication of the MCA application, the study conducted by Adrianto et al (2005) can be example compared. The study assessed the fishery sustainability indicators using the Yoron Island fisheries as a case study. The result shows that sustainability index for the ecological indicators is the highest among other sustainability variables (SIC=3.79). It is followed by the economy indicators (SIC=3.57), community indicators (SIC=3.26), and policy indicators (SIC=3.20). The stakeholder opinion demonstrates that policy and community sustainability variables are considered more important than the ecological and economic variables. In this case, fishery development policy in Yoron Island should pay more attention on the community and policy sustainability.

CONCLUSION

The study concludes that the sustainability index of criteria (SIC) in each island could be comparable with the rate of destructive fishers. In general, islands with low rate of destructive fishery have low on the economic criterion of sustainability, like in Rajuni Besar and Kapoposang islands. But these islands have high ecological criterion of sustainability. In contrast, islands with high economic criterion of sustainability have high number of fishers using bomb or poison fishing that is Tarupa, Rajuni Kecil and Barrang Caddi.

The study shows that the idea of sustainability in different aspects – ecological, social, economic and institutional – can be introduced and assessed at the local level, especially to resource users. The process uses a mixed-method approach, in which it combines expert-driven fisheries sustainability indicators (Pitcher 1999) and then these indicators are confirmed to the local stakeholders in order to generate a "locally accepted" fishery sustainability indicators.

This undertaking promotes a recognition to the ability of local resource users to assess and eventually to be responsible and guard the resource system they are dependent upon. The method of participatory multi-criteria analysis can complement other scientific undertaking in planning, development, and management of social-ecological systems (SES) in the coastal area.

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