SUSTAINABILITY STATUS OF THE ECOLOGICAL DIMENSION IN THE MANAGEMENT OF MARICULTURE DEVELOPMENT AREA 1 (CASE STUDY IN EKAS BAY, EAST LOMBOK REGENCY, WEST NUSA TENGGARA PROVINCE, INDONESIA)

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SUSTAINABILITY STATUS OF THE ECOLOGICAL DIMENSION IN THE MANAGEMENT OF MARICULTURE DEVELOPMENT AREA (CASE STUDY IN EKAS BAY, EAST LOMBOK REGENCY, WEST NUSA TENGGARA PROVINCE, INDONESIA)

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Abstract–The phenomenon of a decrease of water environmental quality caused by internal factor, namely uncontrollable mariculture activities as well as external factors relating to the activities of other land use and up-land (mainland) is worried to be a serious threat to the sustainability of mariculture efforts activities and water ecosystem in general. The purpose of this study is to analyze the sustainability status of the ecological dimension in the management of mariculture development area; and determine priority of policy and management strategies of sustainable mariculture development. The results of study showed that use index values of sustainability status of ecological dimension were in the category "less sustainable" with the sustainability index value of 44.62. The results of the analysis Leverage and Pareto to 17 (seventeen) ecological dimension attribute indicates that there were 10 (ten) sensitive attributes that most influence on the sustainability status of ecological dimensions. In an effort to improve the performance of area management of mariculture in a sustainable manner, we need concrete strategies through improved performance the sensitive attributes based on the priority scale.

INTRODUCTION

The development of mariculture on one side becomes a very important part (Jha *et al.*, 2017) (Arbi *et al.*, 2018) to promote the economic growth and food needs for people that increasing from year to year, but on the other hand should be brought to a condition in which there has been a degradation of the quality of natural resources and environment are improved significantly. The threat to the aquatic ecosystem becomes very worrisome when there is no early anticipation (Shen *et al.*, 2006) in improving the management pattern that is currently done. Some of these potential threats are related to land conversion (Tian *et al.*, 2017) (Wu *et al.*, 2017), biodiversity (Pelicice *et al.*, 2017) (Pofuk *et al.*, 2017), emissions (Chung *et al.*, 2017), waste (Fuhrimann *et al.*, 2017), conflicts of spatial use (Adewolu *et al.*, 2009), potential contamination of inland (Wu, 1995) and potential risk of social activities (Hutchings, 2012) that are destructive.

The phenomenon of a decrease of water environmental quality (Zhou *et al.*, 2009) caused by internal factor, namely uncontrollable mariculture

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activities as well as external factors relating to the activities of other land use and mainland is worried to be a serious threat to the sustainability of mariculture efforts activities and water ecosystem in general. The development of aquaculture in coastal and marine areas in the past two decades has sparked a lot of attention due to the environmental impact thereof (Olsen and Olsen, 2008). Increasing mariculture activities become potential as a source of organic material (Morimoto *et al.*, 2017) in the fill column and seabed, either in solid or suspended form. Solid waste such as unconsumed feed and feces scattered in the water column and accumulate in the bottom waters that have an impact on the benthic environment (Shakouri, 2003). Enrichment of organic matter can lead to decreased productivity and increased mortality of commodities cultivation as a result of sediment conditions under cages. Slamet *et al.* (2009) reveals there is a tendency of ecological pressure on mariculture development areas that is indicated by low diversity indexes of macrozoobenthos.

The development of mariculture uncotrolled in Ekas Bay, unbridled will potentially degrade water quality and ecosystem damage. According to Liang *et al.*, (2015), developing mariculture area which does not consider the carrying capacity of the environment will lead to decreasing quality of the water environment to damage the surrounding ecosystem.

Considering this condition, the study of the sustainability status of mariculture development in Ekas Bay becomes indispensable, as an effort to provide a reference related policy recommendations management strategy for sustainable mariculture development. Sustainability analysis will also be important as an early anticipation, effort to regulate the cultivation system by keeping a positive interaction with the environment as an integral part.

MATERIALS AND METHODS

Determination of the study site was referring to Zoning Plan for Coastal, Marine and Small Islands of West Nusa Tengara Province, where focus of the research location is in Ekas Sub-village, Ekas Buana village, Jerowaru Sub-district, East Lombok Regency. Analysis of sustainability conducted to determine the index value and sustainability status of the ecological dimension in the mariculture development sub- zone.

Use of Rap-Fish (Rapid Appraisal for Fisheries) for evaluating the sustainability of the fisheries sector multidisciplinary ordination based on the technique (putting something on the order of attributes measured) by using the approach of Multidimensional Scaling (MDS). The approach is a modification of the program Rap-Fish developed by Fisheries Center, University of British Columbia (Kavanagh and Pitcher, 2004; Pitcher and Preikshot, 2001). Indicators/attributes of Sustainability status is reviewed at each dimension is derived from a combination of the concept of responsible and sustainable aquaculture obtained from various sources.

The attributes used in assessing the sustainability status of ecological dimension is 17 (seventeen) attributes. The attributes are: (1) Site capability and site suitability; (2) Potential disaster risk and contamination; (3) Climate change; (4) The condition of critical ecosystems and habitats; (5) Number of non-natives species that escaped to nature; (6) The use of fish drugs, chemicals and biological materials (FDCBM); (7) The availability of feed sources; (8) Type and feed traceability; (9) FCR (Food Conversion Ratio); (10) The level of the water carrying capacity; (11) The use of seed sources; (12) The availability of quality seeds; (13) Seed traceability; (14) Compliance with environmental certification; (15) The rate of sedimentation; (16) Genesis pests and diseases and pathogen transfer; (17) The level of utilization of the waters of the appropriate carrying capacity of water.

Value index and sustainability status are grouped into four categories, is shown as in Table 1.

Table 1. The Value of the Index and The Sustainability Category

Index value	Sustainable category
00,00 to 25,00	Bad; not Sustainable
25.01 to 50.00	Less; Less Sustainable
50.01 to 75.00	Enough; Fairly Sustainable
75.01 to 100.00	Good; very Sustainable

Sources : (Fauzi and Anna, 2005)

Sensitivity analysis is performed to determine the attributes that are sensitive and affect the sustainability status of mariculture in Ekas Bay. This sensitivity analysis used the attribute leveraging to assess the change in the analytical output from MDS. The effect of each attribute is observed in the change of root mean square (RMS),particularly on the x-axis for resources sustainability scale

(Kavanagh, 2001). While the determination of policy priority and management strategies on ecological dimension is performed manually by Analysis Hierarchy process (AHP) base on expert judgement. AHP is a method of analysis and synthesis that can help the decision making process that is powerful and flexible (Kusrini, 2007).

RESULTS AND DISCUSSION

The index and ecological dimensions of sustainability status

The results showed that use values of sustainability index and status of ecological dimension are in the category "less sustainable" with the sustainability index value of 44.62.

The results analysis of sustainability status of the mariculture development sub zones as Fig. 1.

The index value shows that the mariculture development sub zones in Ekas Bay less than optimal in ecologically qualified. Some consideration of ecological interest is suspected not was the focus of the mariculture management concern, in other side there are external factors i.e. natural factors and uncontrolled impact outside of the on farm activity which potential to disturb the mariculture activities as well as ecosystem in general. This relates to coastal and marine areas characteristics that tend not to be separated from the multi sector in the utilization of existing space.

The analysis results of leverage attributes for the ecological dimension are presented in Fig. 2.

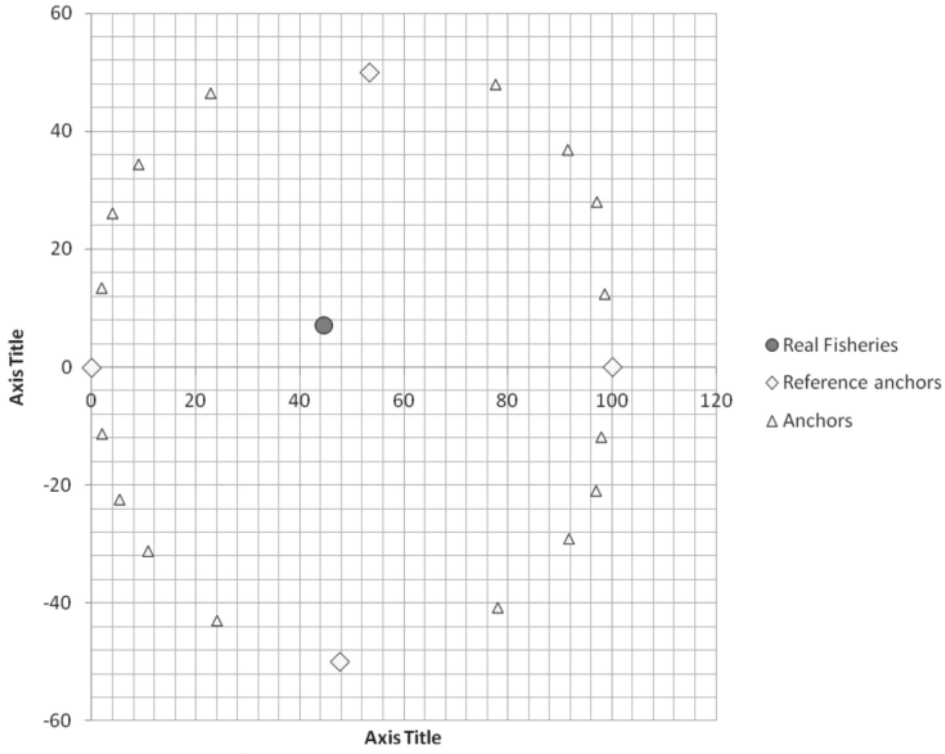

Fig. 1. Index value and sustainability status of ecological dimension

Table 2. Results of MDS analysis, Monte Carlo Analysis and Statistical Analysis

Dimension	Sustainability indexes		Difference	Statistical		Literacy
	MDS	Monte Carlo		Stress	R2	
Ecology	44.62	44.76	0.14	0.12	0.95	3

Source: The results of the analysis (2016)

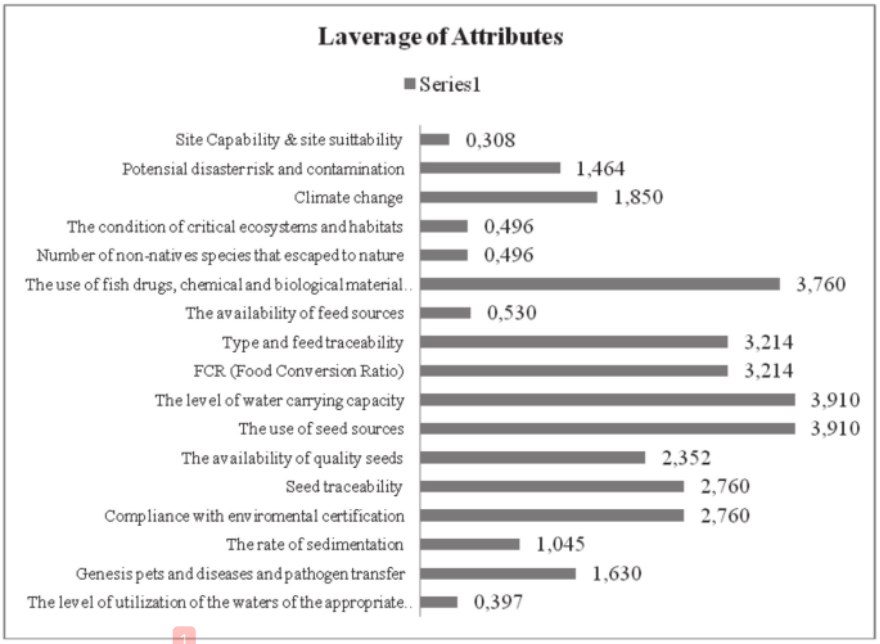

Fig. 2. The analysis result of leverage attributes of ecological dimension

Attribute sensitive of ecological dimension is a factor which is assumed to have a significant effect on the sustainability status of the ecological dimension in the management of mariculture development sub zone in Ekas Bay.

In addition, in order to determine which attributes are most sensitive levers on each dimension do Pareto analysis. Pareto analysis result toward ecological dimension attributes shows there are 10 sensitive attributes impact to ecological dimension sustainability status i.e. (a) The level of water carrying capacity; (b) The seed sources use; (c) the use of fish drugs, chemical and biological material (FDCBM); (d) feed type and traceability; (e) FCR (Food Conversion Rate); (f) compliance of environmental certification; (g) seed traceability; (h) availability of qualified seed; (i) Climate change; and (j) Pest and desease of fish (PDF) and transfer pathogens occurrences.

With regard to the effect of each sensitive attributes of the ecological dimension toward the sustainability status of a mariculture development sub zone could be described as follows:

The level of the water carrying capacity

This suggests that the water environment capacity factors become a prerequisite that must be considered in the development of mariculture area. It means that in any planning of mariculture activities, study on the carrying capacity of water based on the level of conformity of the water must be conducted first, so that the management of mariculture can be done in a responsible and sustainable. In addition, the water carrying capacity factor is also very important as an early anticipation, effort through the management of mariculture in a controlled and can synergize with other sector activities in the utilization of space in both intra and inter zoning.

The results of the study on the carrying capacity through the waters capacities approach of the sites study showed that the level of water carrying capacity included in the moderate category or 50-75% water is suitable for the mariculture development. However, this value may change depending on how the pattern of cultivation management is carried out. The measurement result of water quality parameters at site study indicates increasing levels of nitrite and phosphate, which exceed the quality standards set by the Minister of Environment Decree No. 51 of 2004. This was confirmed by the conclusion of a previous study conducted Kristanti (2006) that there are indications began to decline in the carrying capacity of water

Ekas bay, so there needs to be regulation and management of mariculture activities more expensive aspects of ecological sustainability.

The use of seed sources

Attribute the use of seed sources here to give an idea about the origin of seeds used, especially relating to the use of non-native species either as a result the introduction of alien species, genetically modified seeds, and the result of cross breeding. Research and engineering development, especially related to seed quality improvement shall be conducted continuously in order to speed up the volume of aquaculture production. One of the effort which has been carried out is through cross breeding technology, which produced hybrid grouper type. In other hand, this effort gives a positive value, especially in the effort to increase aquaculture production. Nevertheless, on the other hand, in the context of the environmental aspects, introduction of hybrid fish should consider prudential aspects, especially negative impacts potential on the biodiversity specifically biodiversity of fish resources.

According to Rahardjo (2011) that the entry of alien species to nature area is not only through introduction but various ways. One of the ways is escapes species mean aquaculture species separated from the production sites and entering the nature. Besides that, escapes from production sites are not only a financial loss for the farmer, but can also have an adverse effect on the surrounding ecosystem, including species, particularly in the case where the cultured species may be a non-native. Escapes can be prevented by either the type of production system in place or by management measures such as barrier use. However, in some cases escapes can be significant in both numbers and impact (Marine Conservation Society, 2014).

Use of Fish Drug, Chemical and Biological Materials (FDCBM)

The use of Fish Drugs, chemical and biological material in the mariculture production process should be a concern, therefore the negative impact toward potential risks, food safety as well as water environment can be anticipated and controlled from the beginning.

In contrary, along with paradigm of global consumer community toward consuming of safety food, it is regulated then at the level of global fisheries trade was regulated and set up required standards of quality and safety food of aquaculture production results referring to the FAO- *code of conduct for fisheries responsibility* at the level of global fish trade. Guidelines for Assessment of Good Aquaculture Practices (GAP) issued by the Ministry of Marine and Fisheries said that the Danger related to fish drugs (including antibiotic) in cultivation is remaining of residue in the final product. Therefore, the targets of the GAP implementation should reduce the use of fish drugs and other which the main target is to improve biological safety system and decrease the outbreaks and risks incidence.

FCR (Food Conversion Ratio)

FCR is the ratio between the weight of total feed given and weight of fish meat produced. FCR becomes important because it is as a reference or an indicator of the feed efficiency level and commonly

Table 3. Results of AHP analysis to assessment of ecological dimension policy priority weight according to expert opinion

Sensitive factor of ecological dimension	Results weighted votes						
	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average	Priority
The level of the water carrying capacity	0,380	0,370	0,346	0,332	0,416	0,369	1
Compliance of environmental certification	0,308	0,313	0,319	0,334	0,256	0,306	2
The use FDCBM	0,225	0,213	0,198	0,190	0,257	0,217	3
Genesis HPI and transfer pathogens	0,070	0,071	0,073	0,077	0,072	0,073	4
Seed traceability	0,056	0,065	0,062	0,065	0,046	0,059	5
Climate Change	0,054	0,053	0,054	0.056	0,040	0,051	6
The availability of quality seeds	0,051	0,050	0,050	0,053	0,053	0,051	7
FCR	0,036	0,035	0,053	0,038	0,071	0,047	8
Type and feed traceability	0,024	0,024	0,024	0,024	0,024	0,024	9
The use of seed sources	0,017	0,016	0,015	0,015	0,016	0,016	10

Source: The results of the analysis (2016)

used to determine the level of aquaculture production efficiency. The higher of the FCR value is assumed, giving impact on the increase in the farmed feed disposal to the environment. The results of interviews with respondents and the result of its calculation show the average value of FCR for grouper culture is > 6, whereas for lobster farming is > 9. This value indicates that the level of feed efficiency is still low. It shall be known that the feed used in the production of the mariculture with floating net cages system is 100% trash fish feed.

Use of feed trash has opportunity to give higher potential contamination in the waters through remaining feed disposed into coastal waters compared with artificial feed (pellets). Sutarmat et al (2003) in his research concluded that commercial feed has an efficiency of 65.29%, while natural food / trash is of 17.96% efficiency so trash feed is suspected giving bigger negative impact on the environment than commercial feed.

Type and feed traceability

Observations and interviews with respondents farmers showed that the feed used during the production process is a trash fish feed originating from the natural catchment. In relation to the potential sewage cultivation, the study results showed that trash fish feed is more produce effluent of N so that more potential for water contamination (Leung *et al.,* 1999). Whereas in the context of the ecological dimension in this study, attribute types and feed traceability focused to see the descriptions of the use of the type of feed and feed resources that will be closely linked to efforts to sustainable feed supplies.

The use of trash fish feed relies on wild caught besides not able to guarantee the availability of continuous and appropriate amount, also because it was feared would affect the availability of existing fish resources especially obtained in ways that are not environmentally friendly and sustainable potential neglect. Thus, it would be highly counterproductive to efforts to achieve food security, although generally indicated fish farmers who used an uneconomical fish species. Dependence of fish feed ingredients from fish meal, causing long-term problems not only because it affects the high cost of production, but further would potentially threaten the biodiversity of fish in aquatic ecosystems. The use of shmeal and sh oil derived from marine species of sh for aquaculture also has implications for human food security (Allsopp *et al.,* 2008).

Compliance of environmental certification

Issues related to sustainability, food safety and treacibility, enviromentally friendly, animal welfare and social responsibility to be a part that becomes the focus of attention of global consumer society. This can be evidenced by the start inclusion of these issues in terms of global trade standards, whether it is private or public standards. Asrefers to the guidelines FAO- code of conduct for aquaculture responsibility (CCRF) which gives directives to the management of aquaculture is done responsible and sustainable.

In Indonesia CCRF has been adopted as the standard / reference for the implementation of Good Aquaculture Practices certification, which in implementation encourage each aquaculture business unit to apply the rules or principles of Good Aquaculture Practices (GAP). The aquaculture business unit obtains a certificate that legally declared to have made the efforts of aquaculture management responsibility, so that their products can be accepted by the market.

The observations in the area of research and study documents of GAP certification assessment report on the Marine and Fisheries Agency West Nusa Tenggara Province concluded that the level of compliance with environmental certification is very low, it is shown with the percentage of mariculture business units that are certified aquaculture <25%.

Seed Traceability

In the context of sustainable aquaculture, the use of seed sources not only be able to guarantee the quality and productivity of mariculture, but on the other hand the use of seed sources should be declared safe for the survival of biodiversity. In other words, the use of the seeds should be held accountable and traceability. The Government has provided guidance for the use of the seed source is through a policy of Good Breeding Practices (GBP) certification, one of which is required is that the use of seeds should be able to trace and come from the hatchery that has been certified.

The results of surveys and interviews with respondents showed that grouper seed obtained from government-owned hatchery that has been certified GBP that is the Lombok Mariculture Center. But, specifically for the lobster seed growers rely 100% caught from the wild. Dependence on natural seeds feared would threaten the availability

of lobster resource in nature. These conditions also impact in a decrease in the availability of supplies of seed for cultivation in the study sites.

The availability of quality seeds

The availability of quality seeds to be very important in ensuring the sustainability of mariculture activities, so that these factors had an impact on the ecological dimensions of sustainability status. The results of observation and interviews with farmers concluded that overall seed grouper comes from a certified hatchery, so there is a guarantee of quality. However, as recognized farmers in terms of quantity is sometimes insufficient, so they need to bring the seeds from outside of Lombok that is from Situbondo, East Java Province.

As for the lobster seed obtained from nature around the Ekas Bay which is the central of natural lobster seed. Observations in the field related to the supply guarantees, indicate that the supply of quality seeds has not been able to provide for optimal seed needs, or still in the range of 75% - 90% of the total seed requirement.

Climate change

Several studies on the phenomenon of climate change, showing their impact on the marine environment changes, among other indications of sea level rise, increased sea water temperatures, and extreme climate patterns and tend to be choppy. This condition directly affected mariculture activities, where climate change significantly affect the change in the pattern of the optimal cultivation season which tends to be shorter.

Observation results of the Meteorology and Geophysics Agency conclude that the phenomenon of global warming is happening at some period time last has directly led to change climate significantly. The Effect of climate change impacts on mariculture activities strengthened by the results of interviews with respondents farmers, who complain of climate change / weather are unpredictable and tend to be extreme, so the impact of the decline in mariculture production. Changes in water environment of fluctuating trigger the appearance of pests and diseases in fish. The impact of climate change affects the activity of marine aquaculture, the percentage impact of the range of> 25% -50% of production failures occur.

The incidence of pests and diseases of fish (PDF) and transfer pathogens

Along with changes in the quality of the water environment, due to the less responsible management, it is directly triggered the emergence of various pests and diseases of fish, which is currently a major constraint on mariculture activities. The results of interviews with respondents of farmers showed that the prevalence of pests and diseases of fish greatly affects the decline in production of aquaculture, where the level of effectiveness of countermeasures pest and disease very low at less than 20% incidence can be tackled effectively.

Test the validity and accuracy of the analysis of MDS

Reult Analysis of Monte Carlo and analysis Multidimensional Scaling (MDS) at the level of 95%, the value of sustainability index of the ecological dimension on management of mariculture development sub zone in Ekas Bay showed the difference in value of the two analyzes are very small. The coefficient of determination (R^2) of the analytical results Rapfish for management of mariculture development sub zones on the dimensions is 0.95, while the stress value of 0.12 . Of the values mentioned above, indicates that the attributes that are used to assess the status of the sustainability of ecological dimension is quite sufficient. Kavanagh and Pitcher (2004) mention that all the attributes used in the assessment of the status of sustainability are considered sufficiently accurate and reliable if it has a stress value <0.25 and the coefficient of determination (R^2) close to the value of 1.0.

Priority management policies and strategies on an ongoing basis

The result of an Analysis Hierarchy process (AHP) analysis (Table 2) shows that the factors sensitive to be used as a reference priority management policies in order to ensure the sustainability of ecological aspects of mariculture development sub zone, as can be seen in the Table 3 below.

Formulation of management policy strategies of mariculture development sub zones is done by reviewing the policy priorities of the factors sensitive to the ecological dimension. Assessment of the attributes lever (sensitive factor) carried out in order to map out the causes of the problem, and a problem-solving scenarios, so that will directly result in positive impacts for performance improvement of the sustainability status of a mariculture development sub zone in Ekas Bay.

Elaboration of strategies related to the improvement of performance factors sensitive ecological dimension is mapped based on priorities respectively as follows:

First priority: Improve and maintain the water environment carrying capacity so that it can support the management of mariculture development sub zone. Policy strategies that can be taken are : (a) Encouraging environmental monitoring activities as part of the mariculture environment control program; (b) Encourage the application of mariculture more efficient and environmentally friendly; (c) Reduce nutrient wastes by developing the integrated multi-trophic aquaculture (IMTA) systems.

Second priority: Increase compliance of environmental certification to mariculture business units. Policy strategies that can be taken are: (a) Increase the number of GAP certification auditors ; (c) Encourage the provision of value-added products of aquaculture that have met environmental certification (a certified of GAP and similar),

Third priority: Use of Fish Drugs, Chemical and Biological Materials (FDCBM) recommended. Policy strategies that can be taken by Encouraging effectiveness of registration program and control the circulation of FDCBM, and monitoring residue and the environment.

The fourth priority: Countermeasure incidence of pests and diseases of fish (PDF) and transfer pathogens. Policy strategies that can be taken by Improving knowledge and understanding of farmers about the types of PDF and ways to overcome them.

The fifth priority: Improving the climate change mitigation . Policy strategies that can be taken are: (a) Encourage the adoption of best management practices (BMP) in the management of mariculture, especially related to control procedures fluctuating environmental changes; (b) Monitoring of water quality parameters (biophysical) and oceanographic time series to see the trend of environmental change.

Sixth Priority: Increased seed traceability system. Policy strategies that can be taken are: (a) Encourage the application of Good Breeding Practices (GBP) certification in the entire hatchery, both large and small; (b) Control the use of seed sources through the creation of regulations / rules relating to the default settings catching seed from the wild

Seventh priority: Ensuring continuous availability of quality seeds. Strategies that can be taken by encouraging the strengthening of the capacity of the hatchery certified.

Eighth priority: Improving feed efficiency by lowering the level of FCR (*Food Conversion Ratio*). Policy strategies that can be taken are: (a) Improving feed efficiency through better feed management; (b) Substituting use trash fish feed with artificial feed more efficient and environmentally friendly

The ninth priority: Ensuring type and traceability of feed used to minimize the use of trash fish feed. Policy strategies that can be taken are: (a) Provide guidance in feed utilization of trash to be obtained by means of sustainable fishing; (b) Substituting use trash fish feed with artificial feed more efficient and environmentally friendly.

The tenth priority: Ensuring the use of quality seed source, traceability, and safe for the preservation of biodiversity. Policy strategies that can be taken are: (a) Strengthening the network of breeding fish and create guidelines introduction of nonnative species through socialization of guidelines related to the introduction of non-native species in mariculture; (c) Doing the application of escape management effectively in order to avoid the cultivation escape to the nature.

CONCLUSIONS

In general, mariculture development sub zone in Ekas Bay has biophysical characteristics and location capabilities (*site suitability*) are still feasible for the mariculture development, with indicators of suitability of the main parameters of more than 80%. While analysis result of the sustainability status of ecological dimension in the management of a mariculture development sub zone in the category of "Less Sustainable". Therefore, be required an effort to ensure the management of mariculture development responsibly and sustainably through improved performance attributes of ecological dimension is based on the priority scale.

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