Hierarchical Synthesis of Coastal Ecosystem Health Indicators at Karimunjawa National Marine Park

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Abstract. The coastal ecosystem of Karimunjawa National Marine Park (KNMP) is facing various pressures, including from human activity. Monitoring the health condition of coastal ecosystems periodically is needed as an evaluation of the ecosystem condition. Systematic and consistent indicators are needed in monitoring of coastal ecosystem health. This paper presents hierarchical synthesis of coastal ecosystem health indicators using Analytic Hierarchy Process (AHP) method. Hierarchical synthesis is obtained from process of weighting by paired comparison based on expert judgments. The variables of coastal ecosystem health indicators in this synthesis consist of 3 level of variable, i.e. main variable, sub-variable and operational variable. As a result of assessment, coastal ecosystem health indicators consist of 3 main variables, i.e. State of Ecosystem, Pressure and Management. Main variables State of Ecosystem and Management obtain the same value i.e. 0.400, while Pressure value was 0.200. Each main variable consist of several sub-variable, i.e. coral reef, reef fish, mangrove and seagrass for State of Ecosystem; fisheries and marine tourism activity for Pressure; planning and regulation, institutional and also infrastructure and financing for Management. The highest value of sub-variable of main variable State of Ecosystem, Pressure and Management were coral reef (0.186); marine tourism pressure (0.133) and institutional (0.171), respectively. The highest value of operational variable of main variable State of Ecosystem, Pressure and Management were percent of coral cover (0.058), marine tourism pressure (0.133) and presence of zonation plan, regulation also socialization of monitoring program (0.53), respectively. Potential pressure from marine tourism activity is the variable that most affect the health of the ecosystem. The results of this research suggest that there is a need to develop stronger conservation strategies to facing with pressures from marine tourism activities.

Keywords: Ecosystem, Conservation, Karimunjawa, Indicator, AHP

1. Introduction
Indonesia is the world’s largest archipelagic state. All provinces and more than 80% of the districts and municipalities have coastal areas [1]. Indonesia is also known as the center of marine megabiodiversity [2], [3]. In Indonesia, there are about 590 coral species consist of 82 genera [4]. Indonesia
has coral reef area with an estimated area of about 51,000 km², which is the largest coral reef area in Southeast Asia. Some 15 plant families, with 18 genera and 41 species, and 116 associated species are found in the mangrove ecosystems in Indonesia. Indonesian mangrove forest covers an area of 35,337 km², which is 76% of the total mangroves in the Southeast Asia. There are also 13 species of seagrass, covering an area 30,000 km² [1].

Increasing threats to the Indonesian coastal ecosystem was widely reported and contributes to the degradation of ecosystem and resources [5]. Threats are mainly occur on mangroves, seagrass and also coral reefs ecosystem. Mangrove facing various threats, large areas of mangrove have been converted for aquaculture [6]; timber extraction and the expansion of urban areas [7] and also oil palm plantations [8]. Seagrass in Indonesia also have been degraded, about 30–40% of the seagrass beds have been lost in the last 50 years, with as much as 60% being destroyed around Java [9]. Among Coral Triangle Countries, Indonesian coral reef was the most at risk. For about 50% of these reefs, the level of threat is high or very high. Only about 12% is low risk [1].

Healthy coastal ecosystem provides maximum benefits for biodiversity. Maintaining ecosystem in a healthy condition is crucial to maintain biodiversity [10]. Marine Protected Area (MPA) is one of the main strategy to maintain ecosystem in a healthy condition and conserve biodiversity. MPA play fundamental roles in the conservation of biodiversity [11]. Effectiveness conservation management based on MPA strategy need to be evaluated continuously, based on ecosystem condition. Ecosystem monitoring is one of the methods to providing information about effectiveness conservation management. Monitoring is a fundamental part of resource management [12]. Monitoring the condition of the ecosystems in MPA periodically to ensure ecosystem in a healthy condition [10]. A set of systematic and consistent indicators in monitoring program, need to be investigated to indicate the real condition of ecosystem. Present study investigates a set of indicators namely Coastal Ecosystem Health Indicators (CEHI) and perform indicators weighting using hierarchical synthesis. Selected indicator included consistent weighting use to evaluate coastal ecosystem health of Karimunjawa National Marine Park (KNMP).

2. Method
Coastal Ecosystem Health Indicators (CEHI) were identified and selected based on field observation and reviewing reference. The weights of importance of the variables on the health of coastal ecosystems were determined through the Analytic Hierarchy Process (AHP) developed by Thomas L. Saaty. The AHP is a basic approach to decision making [13]. The indicators list that consist of Main variables, Sub-variables and Operational variables arranged into a decision tree using the AHP. Four steps are conducted in using the AHP i.e. setting up the decision hierarchy; collecting input data by pairwise comparisons of decision elements; using the eigenvalue method to estimate the relative weights of decision elements and aggregating the relative weights of decision elements [14]. Expert judgments were organized to conduct pairwise comparisons of strength each variables compared other variables. The expert judgments were divided into representative groups namely, coastal manager, local government, academics and non-government organization.

Three main variables were identified namely, State of Ecosystem, Pressure and Management. Each Main variables consist of several Sub-variables, each Sub-variables divided into some Operational variables. The strength of preference is evaluated through a 9-point intensity scale (see table 1). The application of AHP considers consistency in judgment through consistency ratio (CR). Consistency indicates that: if \( a > b \); \( b > c \) then \( a > c \) [15]. The value of CR ranges from 0 to 1, a CR of 0.10 or less is considered acceptable [13].
Table 1. Intensity scale of importance [13]

| Intensity of Importance | Definition                                      | Explanation                                                                 |
|------------------------|------------------------------------------------|-----------------------------------------------------------------------------|
| 1                      | Equal Importance                               | Two Activities contribute equally to the objective                         |
| 3                      | Weak importance of one over another            | Experience and judgment slightly favor one indicator over another           |
| 5                      | Essential or strong importance                 | Experience and judgment strongly favor one criterion indicator over another |
| 7                      | Demonstrated importance                        | A indicator is strongly favored and its dominance is demonstrated in practice|
| 9                      | Absolute importance                            | The evidence favoring one indicator over another is of the highest possible order of affirmation |
| 2, 4, 6, 8             | Intermediate values between the two adjacent judgments | When compromise is needed                                                  |

3. Results and Discussion

3.1. Main and Sub-Variables of Coastal Health Ecosystem

The variables of coastal ecosystem health indicators in this synthesis consist of 3 levels of variable, i.e. main variable, sub-variable and operational variable. As a result of assessment, coastal ecosystem health indicators consist of 3 main variables, i.e. State Of Ecosystem, Pressure and Management. Main variable State of Ecosystem and Management obtain the same value i.e. 0.400, while Pressure value was 0.200 (see Figure 1).

Main variable State of Ecosystem consist of 4 sub-variables i.e. Coral reef, Reef fish, Mangrove and Seagrass. Coral reef gain the best value (0.184), followed by Mangrove (0.090), Coral reef fish (0.069) and Seagrass (0.058), respectively (see Figure 2). In the other main variable, Pressure, the sub-variable Pressure of tourism activity (0.133) get the superior value because of their importance based on rating from expert judgment, while lower value obtain by Pressure of fishery activity (0.067) (see Figure 3). Main variable Management situated two sub-variables i.e. Planning & regulation and also Institutional (0.16) as the highest sub-variable, while the lowest was Infrastructure & Financing Facility (0.08) (see Figure 4). The figures of Operational variables and Sub-variables show original value from Expert Choice software, before adjusted by each Sub-variables values.
3.2. Operational Variables of Coastal Health Ecosystem

Sub-variables were divided into several Operational variables. Sub-variables Coral reef and Coral reef fish consist of 5 Operational variable while sub-variables Mangrove and Seagrass consist of 6 Operational variable. Operational variables of Coral reef i.e. Coral reef percent cover; Coral reef biodiversity; Coral reef similarity; Coral reef dominance and Coral reef cover. The highest and the lowest importance value were Coral reef percent cover (0,058) and Coral reef dominance (0,017), respectively (see Figure 5). Operational variables of Coral reef fish i.e. Species abundance per family, Number of species, Coral reef fish biodiversity, Coral reef fish similarity and Coral reef fish dominance. Coral reef fish biodiversity (0,025) was the highest variables, while Coral reef fish dominance and Coral reef fish similarity, obtain the same value (0,007) (see Figure 6). Operational variables mangrove consist of 6 Operational variable, i.e. Mangrove percent cover; Mangrove density; Mangrove biodiversity; Mangrove similarity; Mangrove dominance and Mangrove cover. The highest and the lowest importance value were Mangrove percent cover (0,019) and Mangrove similarity (0,009), respectively (see Figure 7). Operational variables of Seagrass i.e. Seagrass percent cover; Seagrass density; Seagrass biodiversity; Seagrass similarity; Seagrass dominance and Seagrass cover. Seagrass density (0,012) and Seagrass similarity (0,005) were the highest and the lowest variables (see Figure 8).
Sub-variables Planning & regulation consist of 3 Operational variable while sub-variables Institutional and Infrastructure & financing facility consist of 4. Sub-variables Planning & regulation and Infrastructure & financing facility have Operational variables which have same value that is 0.053 and 0.020 respectively. The highest and the lowest Operational variables in each Sub-variable Institutional were Coordination (0.048) and Number of employees (0.034) (see Figure 9).

3.3. Overall Variables Analysis of Coastal Health Ecosystem
A set of variable that will be used as indicators of coastal ecosystem health have been determined and weighted. The variables consist of 3 level i.e. Main variables, Sub-variables and Operational variables. Afterward, operational variables will be used as indicators of coastal ecosystem health assessment. Based on integrated analysis of AHP to all of variables, 3 variables get the highest value i.e. Pressure of tourism activity (0.064); Coral reef percent cover (0.059) and Coral reef biodiversity (0.051) (see Figure 10).
Figure 10. Overall Variables Intensity Scale

Most of the expert respondents agreed that there is an increasing number of potential pressures derived from tourism activities in Karimunjawa National Marine Park (KNMP). It is in line with the fact that there is an increase in the number of visitors. The number of visitors’ karimunjawa in 2014 increased by nine times greater when compared in 2004 [16]. Increased intensity of tourist visit has the potential to threaten coral reef ecosystem in TNMP [17], [18].

The threat of degradation of ecosystem quality in KNMP arrives particularly from fishery activities and marine tourism activities that are not environmentally friendly [18]. Destructive fishing activities in the form of not environmentally friendly fishing gear and zoning transgressions have been monitored. Moreover, some transgressions in fishing activities have been punished. Contrary with monitoring fisheries activities which has been done, supervision of destructive marine tourism activity has not been optimally monitored. It is seen from the absence of reports of transgressions in marine tourism activity whereas there has been some ecosystem damage due to marine tourism activity. Broken branching corals and massive corals that die from being trampled by tourists found in locations with high marine tourism activity [18]. The high biodiversity of KNMP makes this area as a potential as a tourist destination. Destructive marine tourism activities will cause ecosystem damage and threaten biodiversity. There is a need to develop stronger conservation strategies to facing with pressures from marine tourism activities.

4. Conclusion
Pressure of tourism activity is the variable that most affect the health of the ecosystem in KNMP, based on expert respondents. Tourism activities that are not environmentally friendly have not been optimally monitored. There is a need to develop stronger conservation strategies to facing with pressures from marine tourism activities.

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