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THE EVALUATION MODEL FOR CORAL REEF RESTORATION FROM MANAGEMENT PERSPECTIVE FOR ENSURING MARINE TOURISM SUSTAINABILITY

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Abstract: Coral reefs are proved to be valuable resources for resorts and ecotourism operators that cater to eco-tourists. It is also having commercial values on recreation and tourism industries where local communities and tourism operators gain the revenues from tourists through scuba diving, snorkelling, hotels and related businesses to coral reefs ecosystem. Nowadays, coral reefs have been seriously damaged due to many activities especially by human. This critical situation has led to the growing concern of coral reefs restoration and conservation. However, based on literatures, no evaluation has been conducted towards the effectiveness of coral reefs restoration. Thus, the objective of this paper is to evaluate the effectiveness of coral reefs restoration by selecting Perhentian Island as a focus area. For evaluating the effectiveness of coral reefs restoration, Analytical Hierarchy Process (AHP) and Evidential Reasoning (ER) methods are employed for prioritizing and aggregating the judgements under fuzzy environments. The result has shown that under water's temperature for coral gardening is the most important factor to ensure the effectiveness of coral reefs restoration. In addition, the effectiveness of coral reefs restoration in Perhentian Island is assessed as 67%. This model provides a useful decision-making tool to several related agencies such as Department of Marine Park Malaysia and Reef Check Malaysia for conducting the effectiveness evaluation on coral reefs restoration.

Keywords: Coral reef sustainability, coral reef restoration, analytical hierarchy process, evidential reasoning.

Introduction

Coral reefs have become a main attraction for eco-tourists especially in Malaysia. It also has commercial values on recreational and ecotourism industries where ecotourism operators gain the revenues from tourists' activities such as scuba diving and snorkeling. However, coral reefs have been seriously damaged due to many factors especially by human activities. 87% of coral reefs in Malaysia facing medium or higher threats (Burke *et al.*, 2002; Praveena *et al.*, 2012) while the other study showed that 95% of Malaysia's coral reefs are under destruction and almost half are listed red in critical categories by International Union for Conservation of Nature (IUCN) (Hanifah & Shah, 2016). Over the past 200 years, oceans' acidity has increased by 25% has worsen threats to the coral reefs (Defenders of Wildlife, 2017). To date, 55% of global coral reefs are threatened by overfishing and destructive fishing while 25% of them are threatened by coastal development (The Nature Conservancy, 2017a, 2017b).

Since coral reefs have similar characteristics with the land forest, it has led to many initiatives to conserve and restore coral reefs named as "forest under the sea". Therefore, several stakeholders have agreed the importance of effective management in reducing coral reefs deterioration (Mumby & Steneck, 2008). It is worth mentioning that many efforts have been undertaken for conserving and reserving coral reefs from destruction such as awareness campaign, declaration of protected area and ecotourism. Globally, several organizations have been established as the initiatives to restore coral reefs (e.g. International Coral Reef Initiative, International Union for Conservation of Nature and Global Coral Reef Alliance). While at the regional level, Malaysia has joined the Coral Triangle Initiatives (CTI) with its neighbouring countries (i.e. Philippines, Indonesia, Papua New Guinea, Solomon Islands and Timor Leste). The CTI is established purposely to protect coral reefs by several mechanisms such as collaboration among these countries regarding the reef's conservation, joint monitoring, etc. In Malaysia, few non-profit organizations have also been established aiming to restore the coral reefs such as Tropical Research and Conservation Centre (TRACC) and Reef Check Malaysia.

However, how far the restoration efforts are effective are remain questionable. As a result, this study aims to evaluate the effectiveness of current restoration initiatives by developing an evaluation model for them. In order to achieve this primary aim, firstly, parameters that affecting the effectiveness of coral reefs restoration will be identified. Secondly, these effectiveness parameters will be assessed by using qualitative data. For evaluating the coral reefs restoration, AHP and ER methods are employed for prioritizing and aggregating the judgements under fuzzy environments. Finally, several strategies are recommended in order to enhance the effectiveness of coral reefs restoration. In order to test the applicability of this evaluation model, coral reefs restoration effort in Perhentian Island is chosen as a focus area.

Coral Reef Restoration

Corals are tiny and soft-bodied animals that made up of many tiny polyps. Coral reefs are formed when a colony of corals living together, and it is differentiated through cool water and tropical weather. Natural tropical coral reefs are commonly found along the coastal area within range 4 meters to 10 meters. With natural factors (e.g. climate change, coral bleaching, disease, predation and temperature) and anthropogenic factors (e.g. destructive fishing practices, coastal development, erosion and marine pollution) threatening natural coral reefs globally. These issues are critical especially to countries that having coral islands, particularly in Malaysia. In 2010, the condition of coral reefs has gone even worst after the event of mass bleaching (Praveena *et al.*, 2012). It is also reported that the condition of coral reefs in Perhentian Island is getting critical (Islam *et al.*, 2014).

Several studies have been conducted in the field of coral reef's restoration such as Edwards and Gomez (2007), Chou *et al.*,(2009), Praveena *et al.* (2012) and Rinkevich (2015). Edwards and Gomez (2007) provided the guidelines with simple advices on reefs restoration, while Chou *et al.* (2009) discussed the techniques of reef restoration and Praveena *et al.* (2012) reviewed the threats of coral reefs in Malaysia. Latest, Rinkevich (2015) suggested the gardening concept as a better and active reef's restoration. These studies are however, yet to examine the effectiveness after the implementation of coral reef's restoration, making this research essential.

Restoration initiatives have received a focal idea to cure the degraded coral reefs (Rinkevich, 2005). Protecting coral reefs have become the preferred management option since degradation issues have been highlighted as a major challenge in the future (Wilkinson, 2008; Chou *et al.*, 2009). Even though there is no single most effective strategy to carry out restoration, strategies still need to be planned and implemented (Ng *et al.*, 2016). However, the question has been raised on how far these coral reefs restoration initiatives are effective and is it possible if these initiatives can be evaluated from management perspective. Based on the literature review, no evaluation has been conducted towards the effectiveness of coral reefs restoration, making the current research is essential to fulfill the research gap in this particular area.

Coastal reefs restoration in South China Sea has started since 1990s, aimed to recover degraded reef habitats (Chou *et al.*, 2009). Coral reefs restoration can be grouped into physical and biological restoration (Edwards & Gomez, 2007). The main goal of establishing restoration is to recover and improve the degraded reef from the aspect of ecosystem structure and function. Restoration requires both active interventions with passive management measures to remove impediments to natural recovery (Edwards & Gomez, 2007).

Physical restoration is the initiatives to restore coral reefs from the aspect of ecosystem structure. Under definition by Edwards and Gomez (2007), physical restoration is the restoration activities focuses to repair the reef environment with an engineering focus. It has also been suggested that major physical restoration is only accessible for qualified expert. Literatures have found out that coral nursery, bio-rock process and artificial reefs are categorized under physical restoration (Edwards and Gomez, 2007; Spenhoff, 2012).

Biological restoration is the initiative to restore coral reefs from the aspect of ecosystem function. It has been warned that restoration will not be successful to attempt if biological restoration is not involved (Edwards & Gomez, 2007). Based on literatures, success biological restoration until now is only limited to scales up to a few hectares only. Besides improving management of coral reef areas, Edwards and Gomez (2007) have also suggested local environment as key factor to determine successful biological restoration. In addition, the long term self-sustaining and functioning coral reef community is also important for biological restoration success (Edwards & Gomez, 2007). Coral gardening, culturing and transplantation are found to be under category of biological restoration (Edwards & Gomez, 2007; Rinkevich, 2015).

Methodology

In this paper, two multi-criteria decision-making tools will be employed in the effectiveness evaluation model. An AHP is considered as historical method but frequently used as multi-criteria decision-making tool. It was developed by Thomas L. Saaty in 1970s (Saaty, 1977; Mohd Salleh *et al.*, 2015; Singh *et al.*, 2016). By using an AHP, pair wise comparisons will be conducted in order to compare the relative attributes in the same group. With an AHP, weight will be established to each criterion based on local and global weights, determining the most significant criteria in the evaluation model. On the other hand, an ER method is a new developed multi-criteria decision-making tool which can be used to back up the insufficiency of AHP, besides dealing with uncertain information. To adopt an ER, basic tree structure or hierarchical structure consists of lowest level factors are required (Ahmadzadeh & Bengtsson, 2016). For developing the process of prioritising and evaluating the effectiveness of coral reefs restoration in Perhentian Island, a flow of proposed methodology in sequential order is illustrated in Figure 1 and listed as follows.

Step 1 : The effectiveness parameters for coral reefs restoration are identified through literature review and experts' consultations.

Step 2 : Based on the identified effectiveness parameters (in Step 1), a hierarchical structure is developed.

Step 3 : Based on the identified effectiveness parameters (in Step 1), each of them is compared and assigned with weight by using an AHP method. Data will be obtained from domain experts through pair wise comparisons. This step will further be explained in sub-section 4.2.

Step 4 : The qualitative effectiveness assessment is conducted on each parameter by using subjective judgements. In this step, the qualitative survey will be conducted by interviewing domain experts. This step will further be explained in sub-section 4.3.

Step 5 : The results of AHP (in Step 3) and qualitative assessment (in Step 4) are synthesized by using an ER method.

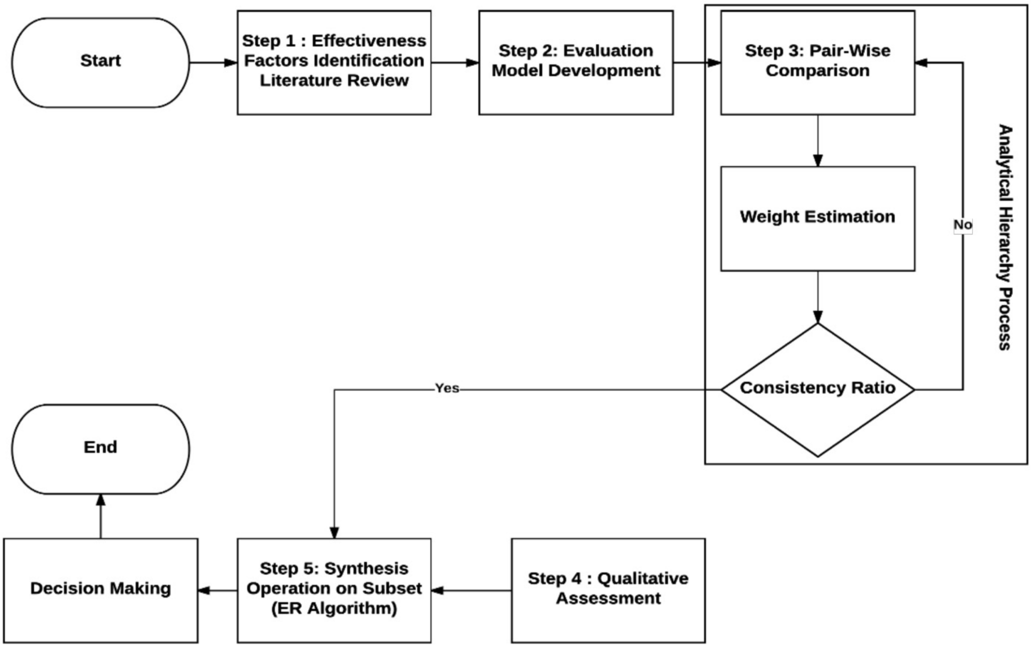

Figure 1: Flow Chart for Coral Reefs Restoration

Test Case: Perhentian Island

In this paper, the effectiveness of coral reefs restoration will be assessed by selecting Perhentian Island as a focus area. Perhentian Island is located 21km off the coast of northeastern Malaysia in the state of Terengganu, which consists of Pulau Perhentian Besar and Pulau Perhentian Kecil (Islam *et al.*, 2014). In this paper, the domain experts were selected based on their education and experience in coral reef's area. The minimum standard for expert's education is degree or higher and they are experienced in coral reefs for at least ten years and above. 15 experts have been requested to participate in this research. Questionnaires were provided to assist the experts during the interview session. Equal weight has been assigned to each expert in order to overcome difficulty in assigning weights for them and to avoid prejudgement.

Effectiveness Factors Identification and Evaluation Model Development (Step 1 and 2)

Effectiveness factors are identified through literature reviews and they have been filtered and verified by the experts. It has been categorized into physical restoration and biological restoration, where both categories consist of two sub-criteria (i.e. artificial reefs and coral nursery under physical restoration while coral gardening and coral transplantation under biological restoration). The lowest level factors were then identified based on categories of sub-criteria. These identified factors are then interpreted into evaluation model as shown in Figure 2.

Pair-wise Comparison (Step 3)

In step 3, an AHP method is used to perform weight establishment for each factor in the evaluation model. Firstly, pair wise comparisons will be conducted based on categories (e.g. physical restoration compared with biological restoration, artificial reefs compared with coral nursery and etc.). The experts' judgement will be used to perform pair wise comparisons which later transformed into weight value. Consistency Ratio (CR) for pair wise comparisons must be less than or equal to 0.1 as to indicate the validity of the judgement. The details of AHP and its algorithms can be found in Saaty (1977), Saaty (1980) and Mohd Salleh *et al.* (2015).

Qualitative Assessment (Step 4)

Owing to a lack of information in the previous research, imprecise information on how to measure the effectiveness of coral reefs restoration quantitatively, a qualitative method can be used in assessing all the effectiveness factors in the evaluation model. There are various methods of qualitative data collection and one of them is through domain expert judgements.

Under fuzzy environments, a qualitative scale can be presented by linguistic variables. Based on Miller's (1956) study, the effective channel capacity is between five and nine equally weighted errorless choices. In this paper, all effectiveness factors are presented by five

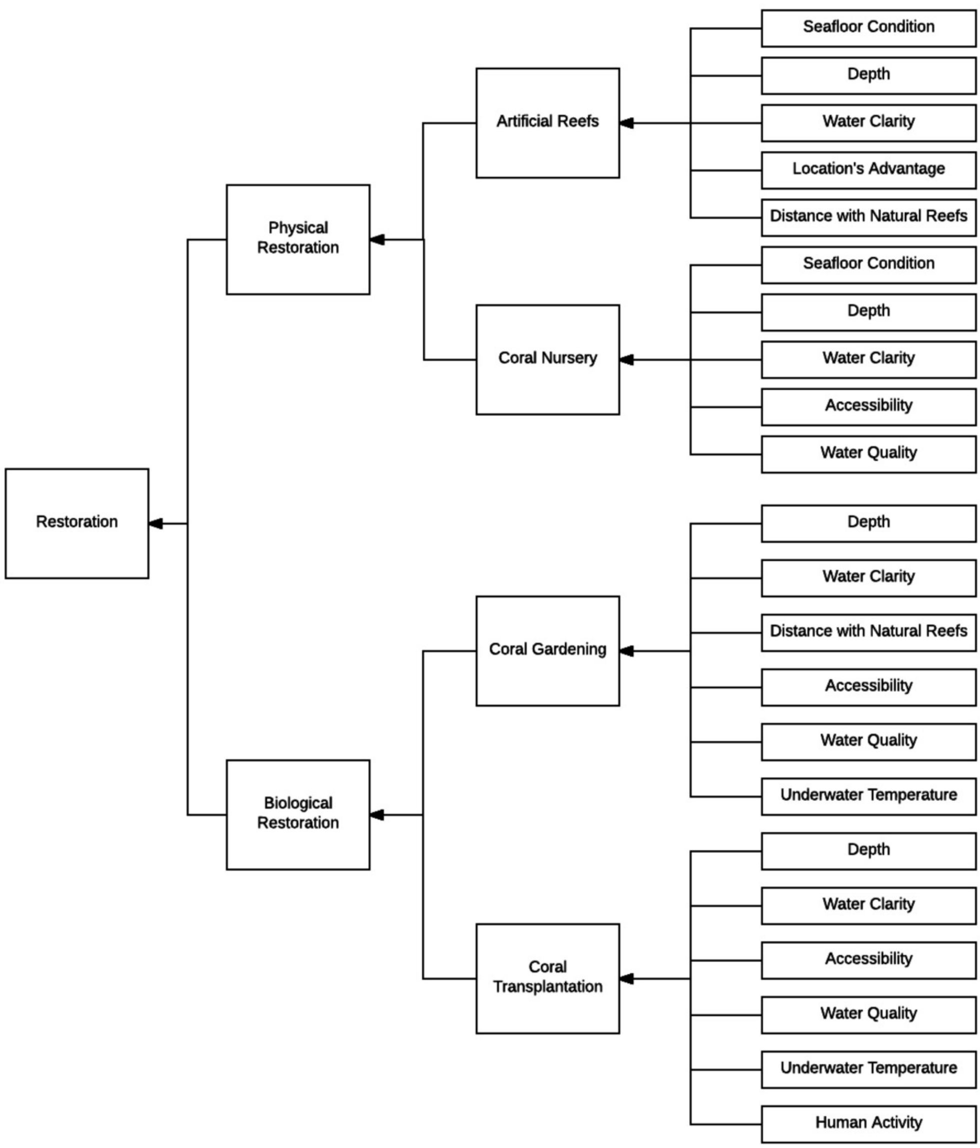

Figure 2: Coral Reefs Restoration Evaluation Model

linguistic terms which are “not effective”, “low effective”, “fairly effective”, “very effective” and “absolutely effective”.

Synthesis Operation on Subset (ER Algorithm) (Step 5)

The main goal of a decision problem is typically unable to be solved directly due to its generality. Consequently, it needs to be disintegrated into a detailed sub-element for example, to evaluate the effectiveness of coral reefs restoration, it can be broken down into two main criterias which are physical (e_1) and biological (e_2) restorations. If the detailed element is still general to be evaluated directly, it can be broken down until it meets the specific elements. For example, physical restoration can be evaluated by artificial reef (e_{11}) and coral nursery (e_{12}) while artificial reef (e_{11}) can be measured by seafloor condition (e_{111}), depth (e_{112}), water clarity (e_{113}), locations advantage (e_{114}) and distance with natural reefs (e_{115}). For synthesizing these evaluations dealing multi-level factors, the ER algorithms can be used (Yang and Xu, 2002) and IDS software will be employed to perform the calculations.

Results and Discussion

Based on the test case in Perhentian Island, bio-rock process and coral culturing are yet to be implemented, thus, these two criteria are not considered to be evaluated and removed from the model (i.e. Figure 2 is the refined model). Based on Table 1, the biological restoration is the highest contributor to increase the effectiveness of coral reef’s restoration with the weight of 0.6526, followed by second main criteria that is physical restoration (0.3474). As shown in Table 1, the global weight can be calculated to indicate the importance of factor in the same level across the group of attributes. Among the sub-criteria, coral gardening (0.4553) acquires the highest global weight, followed by artificial reefs (0.2038), coral transplantation (0.1973) and the lowest is coral nursery (0.1436).

As shown in Table 1, the CR is calculated in order to ensure weights are obtained from valid judgements. The rule of thumb for the CR to be acceptable must be less than or equal to 0.1. In this paper, the CR for main criteria is calculated as 0.0011, physical restoration is 0.0012 and biological restoration is 0.0010. Among the sub-criteria, the CR for coral nursery is calculated as 0.0254, followed by coral gardening (0.0179), coral transplantation (0.0156) and artificial reefs (0.0114). As a result, the pair wise comparisons made by experts and weight obtained from the AHP calculation are proved to be valid.

The results (i.e. global weights for sub-criteria) in Table 1 have been re-arranged from the highest to lowest ranking as shown in Table 2. As an overall, the most three significant sub-criteria are found to be underwater temperature for coral gardening (0.1209), followed by water quality for coral gardening (0.1172) and distance with natural reefs for coral gardening (0.0631). As a result, it is noteworthy to mention that these factors need to give highly attention for enhancing the effectiveness of coral reefs restorations. On the other hand, the least significant sub-criteria is the accessibility for coral transplantation (0.0136) indicate that this factor is not really important among the other factors in the model.

In step 4, with the help of IDS software, the assessment results for all the lowest-level criteria are obtained and transformed into belief degrees as shown in Table 3. In Table 3, the result of the assessment is presented by the five linguistic terms (i.e. “not effective”, “low effective”, “fairly effective”, “very effective” and “absolutely effective”). From this result, which is associated with a fuzzy set, a single value which is useful to professional decision-makers for ranking the alternatives and for comparison purposes can be evaluated (Salleh, 2015). Therefore, a utility value approach concept developed by Yang (2001) is used in this paper to obtain a single crisp number for every assessment. The utility value as shown in Table 3 represents the effectiveness value of each sub-criteria. By considering 0 is the utility value for “not effective” while 1 is the value for the “absolute effective”, the accessibility

Table 1: Local and Global Weights for Effectiveness Factors

Main Factors	Weights of Main Factors	Sub-Factors	Local Weight	Global Weight	Sub-factors	Local Weight	Global Weight
Physical Restoration	0.3474	Artificial Reefs	0.5866	0.2038	Seafloor Condition	0.1593	0.0325
					Depth	0.1720	0.0351
					Water Clarity	0.2659	0.0542
					Location's Advantage	0.2017	0.0411
					Distance with Natural Reefs	0.2011	0.0410
					CR	**0.0114**	
		Coral Nursery	0.4134	0.1436	Seafloor Condition	0.1538	0.0221
					Depth	0.1146	0.0165
					Water Clarity	0.2367	0.0340
					Accessibility	0.1528	0.0219
					Water Quality	0.3421	0.0491
		CR		**0.0012**	**CR**	**0.0254**	
Biological Restoration	0.6526	Coral Gardening	0.6977	0.4553	Depth	0.1189	0.0541
					Water Clarity	0.1367	0.0622
					Distance with Natural Reefs	0.1385	0.0631
					Accessibility	0.0829	0.0377
					Water Quality	0.2575	0.1172
					Underwater Temperature	0.2655	0.1209
					CR	**0.0179**	
		Coral Transplantation	0.3023	0.1973	Depth	0.1171	0.0231
					Water Clarity	0.1168	0.0230
					Accessibility	0.0689	0.0136
					Water Quality	0.2127	0.0420
					Underwater Temperature	0.2384	0.0470
					Human Activity	0.2461	0.0486
CR	**0.0011**	**CR**		**0.0010**	**CR**	**0.0156**	

for coral nursery is assessed as 0.9353, shown that this factor is the most effective initiatives in Perhentian Island, followed by accessibility for coral gardening (0.89) and distance with natural reefs for coral gardening (0.875). Meanwhile, water quality for coral nursery is assessed as low effective in Perhentian Island where the assessment value for this criterion is only 0.3368. For improvement purposes, the decision makers should pay attention on improving water

Table 2: Ranking Order of the Sub-criteria

Sub-criteria	Global Weight	Ranking
Under water Temperature for Coral Gardening	0.1209	1
Water Quality for Coral Gardening	0.1172	2
Distance with Natural Reefs for Coral Gardening	0.0631	3
Water Clarity for Coral Gardening	0.0622	4
Water Clarity for Artificial Reefs	0.0542	5
Depth for Coral Gardening	0.0541	6
Water Quality for Coral Nursery	0.0491	7
Human Activity for Coral Transplantation	0.0486	8
Underwater Temperature for Coral Transplantation	0.0470	9
Water Quality for Coral Transplantation	0.0420	10
Location's Advantage for Artificial Reefs	0.0411	11
Distance with Natural Reefs for Artificial Reefs	0.0410	12
Accessibility for Coral Gardening	0.0377	13
Depth for Artificial Reefs	0.0351	14
Water Clarity for Coral Nursery	0.0340	15
Seafloor Condition for Artificial Reefs	0.0325	16
Depth for Coral Transplantation	0.0231	17
Water Clarity for Coral Transplantation	0.0230	18
Seafloor Condition for Coral Nursery	0.0221	19
Accessibility for Coral Nursery	0.0219	20
Depth for Coral Nursery	0.0165	21
Accessibility for Coral Transplantation	0.0136	22

quality in Perhentian Island in order to enhance the effectiveness of coral reef restoration.

By using the IDS software, firstly, all the sub-criteria are aggregated to obtain their associated sub-criteria. Secondly, all the sub-criteria are aggregated to obtain their associated main criteria. Finally, all the main criteria are aggregated to obtain a goal value which is the overall effectiveness level of coral reef restoration in Perhentian Island. As shown in Table 4, the evaluation outcomes for sub-criteria are presented where coral gardening as the most effective sub-criteria with the value of 0.7076, followed by coral nursery (0.6312), coral transplantation (0.5892) and artificial reefs (0.5795). For the main criteria, biological restoration is the most effective (0.6862) compared to the physical restoration (0.6036) (Table 5).

Finally, with the effectiveness value of 0.6696 (Figure 3), the coral restoration in Perhentian Island is considered as closed to very effective. Figure 3 indicates that the coral reefs restoration in Perhentian Island are more towards effective. It meant that the current initiatives by stakeholders are moving towards the goal which is to ensure 100% effective. In addition, stakeholders need to work out with new strategies to enhance the effectiveness of coral reef restoration in Perhentian Island such as community-based management (CBM), conservation integration, benchmarking with other successful restoration area, etc. Since the bio-rock process and coral culturing are yet been implemented in Perhentian Island, it is

Table 3: The belief degrees of all sub-criteria (lowest level criteria)

Lowest Level Criteria	Not Effective	Low Effective	Fairly Effective	Very Effective	Absolutely Effective	Utility Value
Seafloor Condition for Artificial Reefs	0	0.1526	0.4122	0.3777	0.0575	0.5850
Depth for Artificial Reefs	0	0.0912	0.3769	0.3419	0.1900	0.6577
Water Clarity for Artificial Reefs	0	0.1864	0.4987	0.2860	0.0289	0.5393
Location's Advantage for Artificial Reefs	0	0.1033	0.2650	0.3447	0.2870	0.7038
Distance with Natural Reefs for Artificial Reefs	0.3226	0.1290	0.1710	0.2065	0.1709	0.4435
Seafloor Condition for Coral Nursery	0	0.0284	0.3195	0.5343	0.1178	0.6854
Depth for Coral Nursery	0	0	0	0.6221	0.3779	0.8445
Water Clarity for Coral Nursery	0	0	0.1770	0.5398	0.2832	0.7765
Accessibility for Coral Nursery	0	0.0251	0.0251	0.1332	0.8166	0.9353
Water Quality for Coral Nursery	0.1210	0.4974	0.2951	0.0865	0	0.3368
Depth for Coral Gardening	0	0	0.1293	0.2931	0.5776	0.8621
Water Clarity for Coral Gardening	0	0.1739	0.6087	0.2174	0	0.5109
Distance with Natural Reefs for Coral Gardening	0	0	0	0.5000	0.5000	0.8750
Accessibility for Coral Gardening	0	0	0	0.4400	0.5600	0.8900
Water Quality for Coral Gardening	0	0.4068	0.4705	0.1227	0	0.4272
Underwater Temperature for Coral Gardening	0	0.2000	0	0	0.8000	0.8500
Depth for Coral Transplantation	0	0.1538	0.1538	0.4615	0.2309	0.6924
Water Clarity for Coral Transplantation	0	0.1210	0.4945	0.2970	0.0875	0.5878
Accessibility for Coral Transplantation	0.0925	0.1993	0.4260	0.1280	0.1542	0.5130
Water Quality for Coral Transplantation	0.0857	0.2566	0.5720	0.0857	0	0.4144
Underwater Temperature for Coral Transplantation	0.1212	0	0	0	0.8788	0.8788
Human Activity for Coral Transplantation	0.1236	0.2703	0.3592	0.2162	0.0308	0.4401

Table 4: Evaluation outcomes for sub-criteria

Sub-Criteria	Not Effective	Low Effective	Fairly Effective	Very Effective	Absolutely Effective	Utility Value
Artificial Reefs	0.0568	0.1297	0.3687	0.3135	0.1313	0.5795
Coral Nursery	0.0436	0.1874	0.2029	0.3328	0.2333	0.6312
Coral Gardening	0.0524	0.1244	0.2150	0.1896	0.4186	0.7076
Coral Transplantation	0.0826	0.1648	0.3281	0.1613	0.2632	0.5892

Table 5: Evaluation outcomes for main criteria

Main Criteria	Not Effective	Low Effective	Fairly Effective	Very Effective	Absolutely Effective	Utility Value
Physical Restoration	0.0483	0.1443	0.3139	0.3320	0.1615	0.6036
Biological Restoration	0.0541	0.1273	0.2381	0.1807	0.3998	0.6862

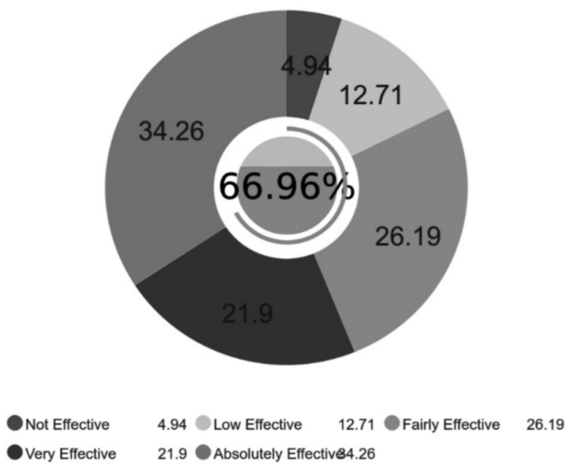

Figure 3: The overall effectiveness level for coral reefs restoration in Perhentian Island

proposed that these two initiatives will be the new alternatives to enhance coral restorations in Perhentian Island.

Based on the current research, the abnormal rises of sea temperature led to coral bleaching and even coral reef's death if this phenomenon occurs in long term. The process from living corals to bleach only take days or weeks, the same goes to the process from bleached corals process to dead corals. Even though coral reefs has resilience to self-recover from bleached corals back to healthy corals which take weeks or months to process, but in order to recover dead corals back to healthy corals, it takes up to months or years, or maybe even worse that the corals are permanently dead.

Global climate change has led to three sub-causes that directly or indirectly affect the survival of coral reefs, namely temperature stresses, tropical cyclone and also rises of sea level. Global climate change has interrelation link with anthropogenic as the occurrence are due to carbon emission from human daily activities (i.e. open burning, gas emission from mobile vehicle and gas from manufacture industry). Besides, the increase of carbon emission is also the cause of ocean acidification. The slow growth rate of coral reefs (0.3 to 2 centimetres a year for "massive" corals) is one of the severe challenges for coral reefs to withstand (Scuba Diver, 2016). When sea level rises, the coastal coral reefs are relatively further from sunlight, which disturb the coral reefs to absorb sunlight for survival and thus leading to coral reef's dead. The result from this research also proved that underwater temperature for coral gardening is the most important to ensure the effectiveness of coral reef restoration in Perhentian Island.

Conclusion and Future Research

In Malaysia, the awareness of restoration is yet to achieve as high as conservation. The concept of restoration was established to recover and improve the degraded reef from the aspect of ecosystem structure and function. This paper has proposed the effectiveness evaluation of coral reefs restoration in Perhentian Island. Firstly, the effectiveness parameters for coral reefs restoration are identified with the combination of literature review and expert consultation. 22 effectiveness parameters have been identified in this research. Secondly, a hierarchy structure is developed based on the identified parameters and this model is named as the evaluation model for coral reefs restoration. This evaluation model is used to assess the coral reefs restoration initiatives in Perhentian Island by considering four main categories (i.e. artificial reefs, coral nursery, coral gardening and coral transplantation). Thirdly, pair wise comparisons are employed for assigning the weight for each parameter. Fourthly, subjective judgements are used to assess the effectiveness of each parameter qualitatively. Finally, the results of AHP and qualitative assessment are synthesized by using the ER algorithms with the help of IDS software. The results have shown that the coral gardening is the most significant criteria and the overall effectiveness level of coral reefs restoration in Perhentian Island is only 66.96%, which is closed to very effective.

Meanwhile, a study on balancing the biological and management perspectives are suggested for future research in order to increase the accuracy of measurement. Besides, the future research can be conducted on setting up a realistic benchmarking to be used as a standard measurement for stakeholders to evaluate the coral reefs restoration. Finally, another focus area for future research is the development of new strategies to enhance the effectiveness value of coral reefs restoration.

The implication of this research paper can assist government's department (e.g. Department of Marine Park Malaysia) or NGOs that involves in restoration projects on how to assess the effectiveness of coral restoration. The result also expected to provide users the knowledge on effectiveness level of coral restoration projects in Perhentian Island.

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