Coral Reef Mitigation and Restoration Techniques Employed in the Pacific Islands: II. Guidelines

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Abstract-Direct experience with a number of projects in Hawaii and the U. S.- affiliated Pacific islands leads us to conclude that it is critical to stand back and take an overview of each situation from a broad environmental and economic perspective and not a narrow perspective based on repair and transplantation. Cost effectiveness of previous mitigation and restoration efforts on reefs (repair and coral transplantation) is very low. Protection, rather than restoration of damaged reefs, must be the management focus. Efforts at restoration and preservation must include the adjacent watershed. Restoration activities on the reefs can take focus off the real problem. There is no purpose in restoration efforts on a reef that will be subsequently destroyed by poor land management of the adjacent watershed. Managers must be aware that developers and polluters can use token restoration or mitigation effort as a means of concealing private or public economic gain at the loss of the environment.

I. INTRODUCTION

In the last decade sufficient information has been developed on of coral reef mitigation and restoration to allow the framing of general guidelines for the application of various technical approaches. The point of view presented in this paper is based on our extensive personal experience with various coral reef restoration projects as discussed in a companion paper [1]. The evidence is that restoration and mitigation activities are generally not cost effective and frequently are environmentally ineffectual. Nevertheless, political, economic, social and conservation realities require that we continue to examine the options of reef restoration and mitigation and apply them in appropriate situations. This paper presents a conceptual framework and a series of suggested guidelines for future actions in this area.

II. REEF DEGREDATION AND MANAGEMENT ACTION

Conceptually, factors that degrade reefs fall into two major categories: acute and chronic. Acute factors are intense, but of short duration. Examples are storm wave events, ship groundings and dredging activities. The acute events occur over a short time interval, but the effects on reefs can be very long lasting or permanent as in the case of a dredged reef. Chronic factors include continual damage due to sedimentation, eutrophication, overfishing or introduction of alien species. Reefs fall into a continuum from pristine to highly degraded reefs. A number of acute and chronic factors can co-occur in highly degraded reef environments.

For purposes of this discussion it is useful to define three categories of management action that are related to the degree of reef degradation. These include the options of prevention, mitigation and restoration as discussed below:

Management Option I. (Prevention) includes the management actions of preservation, protection and prevention of damage. Management action insures sustainability primarily through four major activities:

1. Public awareness. Education can lead to action directly impacting the political process governing management decisions. Effective education can lead to increased awareness and empowerment of public on issues concerning the protection of coral reefs.

2. Sound management practices. Setting appropriate rules and restrictions designed to avoid the causes of the reef damage must be in place.

3. Appropriate enforcement practices. Lack of enforcement negates any positive effect accomplished

in the first two activities. Without strict enforcement the restrictions on human activity cannot be implemented. lack of enforcement leads to loss of public support for conservation measures.

4. Assessment and monitoring. Knowledge of the extent of the resource and ability to detect change and causes of these changes provides the means of feedback to managers and "stake-holders" on condition of the reef resources.

Management Option II. (Mitigation) by our definition arises when managers must devise a plan to reduce and offset the damage of an impending negative impact on a coral reef. An example would be to negotiate a plan to reduce the impact of a new harbor and provide a means of offsetting habitat loss.

Actions in this phase must focus on loss of coral habitat, not on loss of coral colonies. The following management actions should be undertaken:

1. Eliminate or reduce habitat loss. This is the first line of defense for environmental protection. Search for alternate sites and methods of construction, develop best management practice criteria for the project so as to reduce area of habitat being impacted.

2. Conduct a thorough cost analysis that must include true long-term cost of negative impact on reef system in the economic analysis generally used to justify the project [2]. Numerous valuations have been made for coral reefs. For example, the Blue Corner area of Palau generates annual revenue of 2.5 million U.S. dollars [3]. A court decision awarded US$2,000,000 to the people of Satawal in compensation for reef damage to 13,000 square meters of reef damaged (US$1,540,000 per hectare of damaged reef) by a ship grounding [4].

3. If there will be unavoidable loss of habitat, then make the best of bad situations by using this as leverage to achieve other positive environmental actions. Such actions can include the establishing marine reserves, construction of well-designed artificial reefs to create new fish/coral habitat, or secure funding for research, education, or other coral reef conservation.

Management Option III (Restoration) by our definition is action taken to correct damage due to a negative impact on coral reefs (e.g. ship grounding) that was unanticipated or preexisting conditions due to past neglect or lack of effective management. Restoration inevitably is a "salvage operation" with "too little, too late" and is very expensive. For example, the cost of installing proper navigational aids is small compared to cost of correcting environmental and economic loss due to ship groundings on reefs.

III. OVER-ARCHING PRINCIPLES OF MITIGATION/RESTORATION

This conceptual framework developed above provides a useful basis for evaluating the application of conservation, mitigation or restoration techniques to various situations. A series of principles are now widely recognized [3]:

1. Insure that the cause of reef damage (e.g sewage, sediment runoff, repeated anchor damage) has been eliminated before initiating restoration and mitigation attempts. This is the most important guideline for reef restoration in damaged areas.

2. Recognize the option of letting nature take its course. In many cases, removal of the stress will result in dramatic improvement in the reef communities due to natural process of reef renewal.

3. Emphasize that a restored reef is not a natural reef - it is still an artificially modified community. Large coral heads can be hundreds of years old and will take hundreds of years to replace. However, effort in this area can be justified as a means to enhance fisheries production, tourism, recreation, aesthetics, research, conservation or other activities.

III. COST-EFFECTIVENESS OF MANAGEMENT ACTIONS.

Information on the cost of restoration and mitigation activities is sparse. Estimates available in the literature range from US$ 13,000 to greater than US$ 100,000,000 per hectare. These estimates seldom include all of the costs of the restoration process [2].

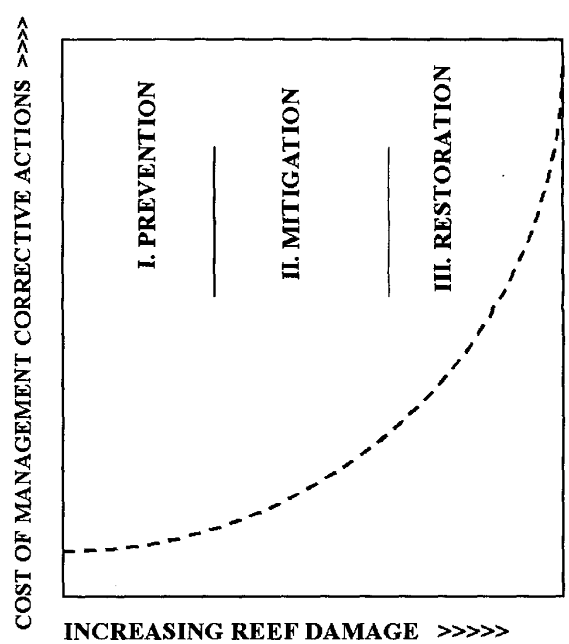

Fig. 1. Relationship between cost of correcting damage to reefs versus degree of damage. Management categories discussed in text are shown as I., II., and III.

The relationship between cost of various categories of management action is presented in Fig. 1. Distance along the abscissa from the origin represents degree of degradation from pristine reef condition. The three categories of management action are shown along the abscissa. The cost category in this model can be viewed as cost of management activity, economic/scientific/aesthetic cost due to loss of valuable habitat or as the total of both. Cost of achieving sustainability increases exponentially with increasing reef degradation. The cost of maintaining reef sustainability clearly shows an escalating cost per unit gain as we move along a management continuum from prevention through mitigation and into restoration.

Effectiveness refers to usefulness or success of each particular management activity in achieving the goal of sustainability of resources. A strong case can be made [1] to support the concept that effectiveness per unit cost shows an exponential decrease as measures are applied to increasingly damaged reefs (Fig. 2).

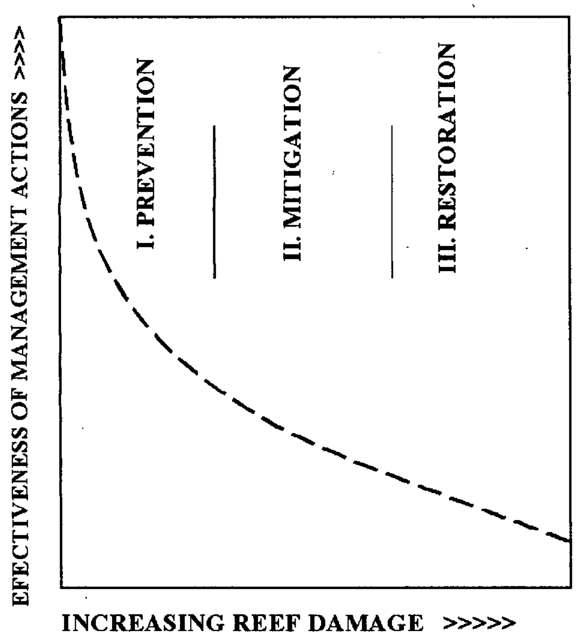

Fig. 2. Relationship between effectiveness of management techniques versus degree of damage. Management categories discussed in text are shown as I., II., and III.

Detailed economic analysis of reef value, economic benefits derived from reefs and costs of restoring reefs is still in a primitive state with little data available [2]. However, the qualitative relationship as shown in Figs. 1-2 can be defended with available information. Comparing the cost versus effectiveness plots leads to several important conclusions:

- Effectiveness of management options decreases rapidly with increasing degradation while cost increases dramatically.
- Cost-effectiveness is low in the "mitigation" category and minuscule in the "restoration" efforts. Therefore, there will be little motivation for financial support and little effort will be directed at severely degraded reefs. Therefore, we must prevent reefs reaching this state.
- In many cases, resources expended on restoration would have been more cost-effective if applied to prevention, preservation and protection. Limited resources will be directed at more cost-effective measures to protect reefs that are not severely degraded.
- Scientific research on various environmental issues will produce information that lowers the cost of management while increasing the effectiveness of management practices. Research on coral reef management increases cost-effectiveness of actions across the entire range of management activities.

IV. USEFULNESS OF TRANSPLANT - SEEDING TECHNIQUES IN REEF MANAGEMENT.

Techniques such as coral transplantation have limited effectiveness [5]. However, existing techniques have been employed with positive results in some cases [1]. Technical details concerning the "when, where and why" of coral transplantation, seeding and other restoration activities are as follows:

Transplant-seeding techniques can be used effectively as a tool under Option I to propagate and increase numbers of rare species and thereby meet management goals of protecting rare species and maintaining biodiversity [6]. The techniques are invaluable as research tools to develop information (e.g. toxicity bioassays) that lead directly to more cost-effective techniques to safeguard and protect reefs from subtle environmental stresses. These techniques can be used to produce cultured corals for the aquarium and curio trade and eliminate impacts of harvesting corals from the wild [7].

In Category II (Mitigation), transplant-seeding techniques have a limited applicability in offsetting damage. Corals that will be destroyed by dredging or filling can be transplanted to another suitable site, used to establish brood stock in culture facilities, used for exhibit in public aquariums, etc. In cases of ship grounding or anchor damage to reefs the area is modified by the drainage but not irreversibly lost as in dredging and filling. Transplant-seeding actions are of dubious value, as they do not replace lost habitat [1, 5].

In Category III (Restoration), transplant-seeding techniques can be used to accelerate the re-establishment of coral reefs in severely damaged environments once the causative destructive factor has been removed. Otherwise one is attempting to establish corals in an unfavorable environment. Cost of reef restoration is extremely high. Effectiveness of transplant/seeding activity is very low compared to natural recovery processes in situations where the environmental insult has been removed [1].

In extreme cases, modification of the physical environment may be undertaken in an attempt to correct degradation. Such actions could include dredging to remove accumulated sediments and or toxic materials, modification of the area to improve flushing and circulation, modification of substrata (increasing relief, rugosity, adding hard substrata as boulders, etc.).

V. CAUTIONS AND CAVEATS IN THE SCIENCE OF REEF RESTORATION.

We must be aware of number of potential pitfalls that can lead to misunderstanding and misuse of the restoration/mitigation concept. Such misuse could result in a great loss to the environment. Be aware of the following:

1. Developers and polluters can use token restoration or mitigation effort as a means of concealing private or public economic gain at the loss of the environment.

2. Efforts at restoration and preservation must include the adjacent watershed. Restoration activities on the reefs can take focus off the real problem. There is no purpose in restoration efforts on a reef that will be subsequently destroyed by poor land management of the adjacent watershed.

Conclusions

- Reef protection is the most cost effective method of achieving sustainability goals for reefs and should be the focus of management activity.

- Before undertaking any restoration activity on a degraded reef it is critical that the cause of the damage be identified and eliminated.

- Watershed management is inseparable from coral reef management. An integrated land-ocean plan is necessary, especially in cases involving chronic degradation of reefs due to sedimentation, eutrophication or shoreline construction activities.

- Reef repair, coral transplant and artificial reefs are often the first mitigation and restoration techniques that come to mind, but can be the least effective in many situations. We emphasize the role of numerous other tools that serve to meet the objectives of mitigation and restoration. These include elimination of anthropogenic stresses derived from watersheds, enforcement of existing regulations, establishing new regulations where needed, education of the public and establishment of marine reserve networks.

- Effective research and monitoring is a vital component of any mitigation or restoration plan. The research component should monitor the restoration area and evaluate the success and cost effectiveness of the effort.

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