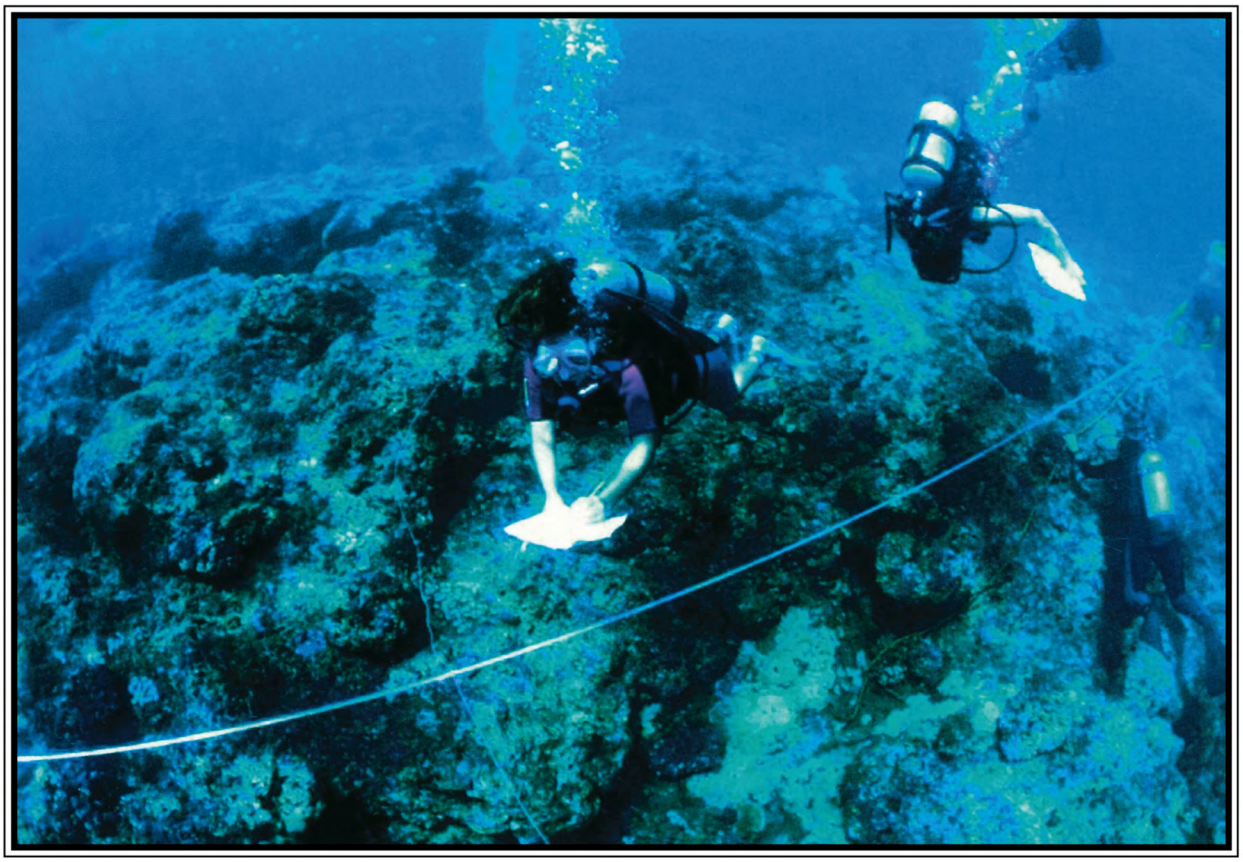
Proceedings of the Hawai'i Coral Reef Monitoring Workshop

June 9-11, 1998 Honolulu, Hawai'i

edited by
James E. Maragos and Rikki Grober-Dunsmore

February 1999



Planning team for Workshop:

Athline Clark, Hawaii Department of Land and Natural Resources (DLNR)
William Devick, Hawaii (DLNR) Division of Aquatic Resources
David Gulko, Hawaii (DLNR) Division of Aquatic Resources
James Maragos, East-West Center
Francis Oishi, Hawaii (DLNR) Division of Aquatic Resources

Sponsored by:

State of Hawaii
Department of Land & Natural Resources
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About the volume editors: James Maragos, formerly a senior fellow at the East-West Center Program on Environment in Honolulu, is now the coral reef biologist with the U.S. Fish and Wildlife Service, Honolulu. Rikki Grober-Dunsmore, formerly a marine biologist at Virgin Islands National Park on St. John, is now a graduate student at the University of Hawai'i-Manoa, Honolulu.

Cover photo: Community-based coral reef monitoring project at Hanalei Bay, Kauai June 1997. (Photo taken by James E. Maragos.)

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Introduction

Preface and Acknowledgements

The idea for the Hawai'i Coral Reef Monitoring Workshop—A Tool for Management evolved over a year-long period beginning in early 1997. At that time the Packard Foundation requested that I organize a small meeting at the East-West Center involving marine scientists and conservationists to discuss marine conservation issues in Hawai'i. In preparation for the meeting, I prepared a paper which discussed among other things the need to organize a coral reef monitoring workshop for Hawai'i. In this context, I consider monitoring to be: multiple quantitative surveys of the same representative coral reef sites over time to detect trends and changes in the status of the ecosystems and key organisms and to determine the probable causes for the changes, if any, that may warrant management interventions. Although the Foundation chose not to fund the workshop, I later received encouragement from Michael Wilson (then Chair of the Hawai'i state Board of Land and Natural Resources), William Devick, (Administrator of Department of Land and Natural Resources (DLNR) Division of Aquatic Resources, DAR), and Dr. Michael Crosby (National Research Coordinator of the Office of Ocean and Coastal Resource Management, OCRM) to develop and submit a more extensive proposal. Later in 1997, the State of Hawaii, through the DLNR, decided to fund the proposal and sponsor the workshop, and it was later scheduled at the East-West Center in June 1998. William Devick of DAR and I served as the lead organizers and co-chairs of the workshop, and we were ably and extensively assisted by several other co-organizers: Athline Clark (DLNR), David Gulko (DAR), and Francis Oishi (DAR). The National Oceanic and Atmospheric Administration, through Mike Crosby of OCRM also organized and funded the travel of several speakers and the participation of several Pacific islanders at the workshop.

The workshop directly serves the needs of DAR since DLNR is charged with managing Hawai'i's unique natural and cultural resources, including six million acres of land, water and ocean in the public trust. To do this, DLNR has adopted the management philosophy of "sustainability- protecting our resources for future generations". Within DLNR, the DAR is charged with the responsibility of managing the aquatic resources under the state's jurisdiction including marine resources such as coral reefs. DLNR understands the importance and need for monitoring natural resources, such as coral reefs, as a basis for assessing the effectiveness of existing management mechanisms, and determining what corrective measures, if any, need to be taken. Without a sustained monitoring regime, the true effectiveness of natural resource management cannot be assessed.

DAR has been monitoring coral reefs and related fisheries over the past several decades at many sites throughout the main islands of Hawai'i. Also, many other scientists, primarily affiliated with the University of Hawai'i, have been monitoring some coral reef sites for as long as three decades, and a listing of most of these earlier studies are included in Appendix D of this volume. However, many of these were not initially designed as monitoring studies, and others suffered from the lack of sustained financial support. Still others were not extensive enough to support generalizations on the condition

and trends of reefs over large geographic areas in Hawai'i. Also, monitoring studies by both DAR and individual scientists have come under extensive criticism in recent years in not being statistically rigorous or designed soundly from a scientific perspective to lead to meaningful or sufficiently sensitive results to justify management interventions. In short, the conclusions often reached by some investigators are challenged by others, and the resolution of these differences in opinion cannot be resolved until a scientifically valid and sustained monitoring program is in place. This, of course, requires cooperation and agreement by all those involved with monitoring, including efforts that are both government and non-government sponsored. No single entity in Hawai'i has sufficient staff and financial resources to support a state-wide coral reef monitoring program, and cooperation will be essential.

The real impetus and motivation for the Hawai'i coral reef monitoring workshop began in 1994, with the beginning of the International Coral Reef Initiative founded by the United States and later adopted by other leading coral reef nations. In 1995 The International Year of the Reef galvanized substantial public enthusiasm for coral reef conservation, including a groundswell of support for community based management in Hawai'i. A manifestation of this public interest was the initiation of several new coral reef monitoring programs in Hawai'i, including some that relied on volunteers, community groups, and non-scientists for accomplishing the monitoring studies. Most of these new initiatives evolved independently, with little coordination. Consequently the new monitoring studies each involved different purposes, relying on different field techniques. Clearly there was a need to gather together, compare notes, and achieve a semblance of cooperation so that future collective efforts could truly serve as a basis for an integrated state-wide coral reef monitoring program. The workshop culminated with these goals to share ideas and opinions and attempt to reach consensus on the goals and directions for coral reef monitoring in Hawai'i.

The idea of developing an integrated coral reef monitoring program, at either a local or international level, is not new. For example, the United Nations, following the 1992 UN Conference on Environment and Development in Rio De Janiero, sponsored several expert meetings leading to the publication of a manual for monitoring coral reefs on a global basis, which identified several goals and preferred field sampling methodologies. This manual has not received widespread support among the global coral reef monitoring community, mainly because most researchers were not involved or consulted during the preparation of the manual, nor was there any attempt to do so. Many scientists don't agree with the recommended methodologies. Any manual developed for global use is bound to lack widespread support unless there is a coordinated effort to enlist widespread input and support. As a result, any manual developed in such a manner will run the risk of not being supported in the "field" and will consequently be ignored. Most recently Jameson et al. 1998 have published a report which reviews the biological criteria that have been used for assessing and monitoring coral reefs. Excerpts of the Jameson et al. report are included as Appendix F of this volume.

An earlier initiative in Hawai'i to develop a coordinated coastal monitoring program began with a workshop in late 1990 and culminated in the 1992 publication "West Hawaii Coastal Monitoring Program: Monitoring Protocol Guidelines". This initiative was sponsored by the West Hawaii Coastal Monitoring Task Force, and financially supported by a local resort interested in developing a small boat marina. There was substantial participation by the scientific and conservation community during the development of the monitoring protocols at the workshop. However, there was little subsequent impetus and motivation to fund and initiate the monitoring program because the marina project was never approved and implemented. Nevertheless, the final recommendations relating to water quality, sediment and, marine life monitoring are worth reviewing, and Appendix E contains the appropriate excerpts from the report of the Task Force.

The 1998 workshop to develop a coral reef monitoring plan for Hawai'i, as reported in these proceedings, moves beyond earlier efforts for several reasons. First, it was primarily supported and funded by the state agency responsible for management and monitoring coral reefs in Hawai'i. Second, it focused on a reasonably sized "management area" (Hawai'i) within which it is conceivable to invite all of the stakeholders involved in coral reef monitoring or interested in the outcome of the workshop. Third, the heart of the workshop recommendations were derived from facilitated working group sessions, where participants strived to achieve consensus. Fourth, the procedures and organization used for the workshop presentations and working group sessions relied on a steering group comprised of coral reef specialists and professionals trained in group facilitation. Fifth, the development of the monitoring protocols relied on a logical sequence in answering the following questions: Why monitor? What to monitor? How to monitor? When to monitor? And Where to monitor coral reefs in Hawai'i. This is in contrast to most other reviews of monitoring protocols which primarily focus on comparing monitoring techniques without sufficient attention devoted to discussing the reasons for monitoring. Our workshop followed the premise that specific management needs and purposes should form the basis for determining monitoring methods. And finally the workshop relied on the advice of recognized international, national and local coral reef experts who made verbal presentations during the earlier phase of the workshop. Most of the invited speakers prepared peer-reviewed papers which are included in the main body of this volume along with several other invited written contributions. All major steps and findings of the Hawai'i Coral Reef Monitoring Workshop—A Tool for Management are highlighted in the Executive Summary and subsequent chapters of this volume.

Although I have been involved in the monitoring of many reefs throughout the tropical Pacific over the past three decades, I decided to refrain from offering my own contribution and opinions at the workshop and in the proceedings. I felt it was more important to serve as the chief organizer, facilitator, and reporter on behalf of the all the workshop participants. The success of the workshop is not based merely on the technical details and findings, but more importantly on the group consensus reached. The technical details could have easily been handled by a small team of scientists, but in a vacuum these details would not have been any more successful than earlier comparable efforts. Truly it is the group process as well as the final product that should give the workshop findings a better chance of succeeding, at least here in Hawai'i.

Many individuals contributed to the planning, execution, and published results of the workshop. I would especially like to thank the following people for making it a successful venture: Michael Wilson for financial support and a rousing, inspirational opening address; William Devick for financial support and uncompromising institutional support during all phases of the initiative; the rest of the DLNR-DAR planning and organizing team (Athline Clark, David Gulko, and Francis Oishi); the rest of the Scientific Advisory Committee (Dr. Bruce Carlson, David Gulko, Dr. Evelyn Cox, Dr. Richard Grigg, Dr. Cynthia Hunter, Dr. Paul Jokiel, John Naughton, Dr. Ernst Reese, and Dr. Caroline Rogers); the facilitators for the working group sessions (Athline Clark, Dr. Michael Hamnett, and Dave Raney); the other rappateurs for the working group sessions (Dr. Kimberly Lowe and Dr. William Walsh), and the recorders for the working group sessions (Michael Guilbeaux, Randall Harr, Ellyn Tong, and Annette Tagawa). The workshop also benefited from the evening open house at the Waikiki Aquarium, hosted by its Director, Dr. Bruce Carlson and from the post-workshop field trip to Hanauma Bay Nature Preserve, hosted by its manager, Alan Hong.

I also want to give special thanks to all the participants at the workshop who were invited to give both verbal and written presentations including: the Keynote Speaker (Dr. Clive Wilkinson), the International Speakers (Dr. S.M. Al-Moghrabi, Dr. Charles Birkeland, Dr. Gregor Hodgson, Dr. Yossi Loya, Dr. John McManus, Dr. Jamie Oliver, and Dr. Hugh Sweatman,); the National Speakers (James Bohnsack

and Michael Crosby); and the Local Speakers (Dr. Marlin Atkinson, Eric Brown, Dr. Richard Brock, Dr. Richard Grigg, Dr. Leon Hallacher, Eric Hochberg, Dr. Cynthia Hunter, and Dr. Ernst Reese). Other invitees who made verbal presentations (Dr. Paul Jokiel, Robert Nishimoto, and Dr. William Walsh) or who contributed written contributions (Dr. Yannick Chancerelle, Dr. Steven Dollar, Benjamin Haskell, Dr. Richard Holasek, M. Ilan, Alan Kam, Margaret Miller, Dr. Caroline Rogers, Carl Stepath, Dr. Brian Tissot, and Sheila Vegara) are also thanked, as well as the anonymous peer reviewers for all papers.

I would also like to thank those who contributed information to the appendices (Eric Brown, Gordon Chapman, Mark Erdmann, Jennifer Frederick, George Gibson, David Gulko, Dr. Michael Hamnett, Dr. Stephen Jameson, Kennard Potts, and the West Hawai'i Coastal Monitoring Task Force). I also want to thank East-West Center staff for helping during organization and registration for the workshop (Kathy Hirano, Jane Ho, Marshall Kingsbury, June Kuramoto, and Sandra Osaki); and East-West Center Visiting Fellow, Rikki Grober-Dunsmore and consultant Karin Meier for editing and preparing the volume for publication. Ms. Grober-Dunsmore also prepared the brief summaries preceding each section of the written papers. The East-West Center contributed my time for all phases of the workshop and proceedings. Finally I thank all of the other approximately 100 participants not mentioned above (listed in Appendix B) who helped make the workshop a resounding success.

James E. Maragos
February 22, 1999
Honolulu, Hawai'i

Foreword

James Maragos

February 28, 1999

Dear Readers,

This volume presents the written proceedings of the "Hawai'i Coral Reef Monitoring Workshop—A Tool for Management" which was held at the East-West Center on June 9-11, 1998, and financially sponsored by the State of Hawaii Department of Land and Natural Resources, Division of Aquatic Resources. Other sponsors included the East-West Center and the National Oceanic and Atmospheric Administration. The workshop was convened to develop a state-wide plan for monitoring coral reefs in the State of Hawaii. The State faces many demands on its coral reefs which constitute over 80 percent of the coral reefs under US jurisdiction. Hawaiian coral reefs protect coastlines, support recreation, promote preservation of the Hawaiian culture, and provide the foundation for the state's coastal and ocean based visitor industry, the largest in the Nation.

Many reefs in Hawai'i are experiencing increasing levels of stress from natural and anthropogenic sources. Reefs in the main islands are suffering from urbanization, including over-fishing, invasive species outbreaks, coastal development, eutrophication, other sources of chemical pollution, sedimentation attributed to soil erosion, and over use by visitors and recreationists. Even the remote coral reefs of the Northwest Hawaiian Islands are experiencing impacts from ship groundings and unauthorized and destructive fishing practices, with damage from fishing nets that have drifted on to the reefs especially severe. State and federal agencies responsible for reef conservation are assessing and evaluating the condition of reefs throughout the state in order to implement appropriate management interventions to protect reefs and to allow their recovery. Long term monitoring of reefs provides essential information for resource managers because it can document changes or trends in reef conditions over time and help to determine the causes for the changes, if any. The workshop was successful in developing the blueprint for a comprehensive monitoring program for Hawaiian coral reefs, and the proceedings provides a thorough written record of the presentations, discussions and decisions reached during the workshop.

I have been very pleased to have been involved with the planning, organization, implementation of the workshop, and preparation of the written proceedings of the workshop. I have appreciated the strong commitment and support form the key state organizers and sponsors, especially Michael Wilson, William Devick, Athline Clark, David Gulko, and Francis Oishi. I also would like to acknowledge the support of the East-West Center in covering my salary and providing the venue and logistical support

for the workshop. The Center's Publication Sales Office will also handle distribution of the proceedings.

Beginning next month I will be taking a position as Coral Reef Biologist with the US Fish and Wildlife Service in Honolulu. The Service's system of National Wildlife Refuges (NWR) in the Pacific afford protection for more shallow water coral reefs than afforded by any other nation or territory in the Pacific, after Australia. I will be working to develop management plans for the NWR reefs, including implementation of monitoring programs for Hawaiian reefs protected by the Service. Not only will the results of the workshop help guide the Service's decisions in the future, but will help to maintain a close working relationship with our key state government partner, the Division of Aquatic Resources within the Department of Land and Natural Resources, and with other key partners, notable the National Marine Fisheries Service, the University of Hawai'i, and the Bishop Museum.

I want to thank all the participants for attending and contributing to the success of the workshop, and I look forward to working with many of you in the future as we move monitoring programs forward and otherwise afford better protection for the precious coral reefs of Hawai'i.

Mahalo,

James E. Maragos, Ph.D.
Senior Fellow

Foreword

William Devick

Dear Readers,

Hawaii's coral reefs contribute hundreds of millions of dollars annually to the local economy through the visitors they attract and the associated fisheries. Despite the central importance of this resource to Hawai'i, we are just beginning to put sufficient programs in place to detect changes that may signal their future degradation.

Monitoring is a function of management. The overall goal of the workshop was to define monitoring protocols that would help managers revamp current marine resource management strategies and approaches. The workshop employed both local and overseas expertise to identify coral reef monitoring protocols in Hawai'i that would not only be effective, but also compatible with ongoing initiatives outside of Hawai'i.

Coral reefs are at risk from a number of potentially manageable hazards including sediment loading and pollution, overfishing and increased visitor activities which can lead to damage caused by divers, boat anchors, personnel water craft, etc. Coral diseases seem to be increasing globally, perhaps as a result of these stresses and other factors such as El Nino or global warming. Clearly, we need to be able to assess the impacts of these factors if effective corrective measures are to be applied.

Scientists, resource managers, and communities need to pool their knowledge and expertise, and together come up with the best possible methods to protect our valuable coral reef and other nearshore resources to ensure both their ecological and economic viability. Developing the tools to better manage our reef resources for present and future generations is crucial. This first ever gathering in Hawai'i of local coral reef managers, community representatives and scientists with experts from around the world was funded by the Department of Land and Natural Resources (DLNR) to ensure that our monitoring methods are sound, research priorities are appropriate, and that Hawaii's communities have ways to participate in protecting our ocean resources.

Specifically, the workshop attempted to establish agreement on coral reef monitoring protocols, including research methods that will be incorporated into a management plan for Hawaii's reefs. Consensus was sought on prioritizing research needs; establishing a statewide data management system; and assuring that workshop recommendations are consistent with international reef monitoring activities. Lastly, the workshop sought methods to build community education and engage local volunteers in data collections.

DLNR would like to thank our workshop partners, especially James Maragos and local scientific experts who were essential to the design and development of this workshop and who provided their input during the sessions. We would also like to thank the international and local scientists and community members who participated in the workshop and helped to shape the outcomes. Lastly, I would like to thank my staff especially, Francis Oishi, Dave Gulko and Athline Clark, for their many hours of work to prepare for this workshop.

Sincerely,

William Devick
Aquatic Resources Division Administrator

Foreword

Timothy Johns

Chairperson's Message:

The islands of the Hawaiian archipelago have some of the world's most exceptional and beautiful marine environments. Our coral reefs abound with more than 5,000 different known species of incredibly diverse plants and animals – many that are uniquely Hawaiian, found nowhere else on earth.

As the constitutionally designated steward of Hawaii's natural resources, it is our mandate at the Department of Land and Natural Resources (DLNR) to sustain our ocean ecosystem. Under that mandate, the department is charged with managing the fourth largest coastline in the United States and over 410,00 acres of coral reefs.

Hawai'i faces significant challenges in protecting our marine life and reversing the declining environmental trends of the past several years. Few dollars have been traditionally allocated to manage and sustain these resources adequately. Management decisions are often made without the proper data. Gaps in baseline information on coral reef resources are significant and the data to document change over time have been difficult to obtain.

The Department of Land and Natural Resources organized and funded this workshop as a first step in the process to better understand and manage our reef resources. Both international and local expertise was sought in an effort to define the best possible techniques available to us to monitor and assess change on our reefs and use this information to initiate appropriate management activities.

We were pleased with the support and cooperation provided by our many partners in making this a successful workshop. The recommended results go a long way towards providing us with a clear set of guidelines that we can implement to better assess and manage our coral reefs.

Aloha,

Timothy E. Johns
Chairperson
Department of Land and Natural Resources

Executive Summary

James E. Maragos

Introduction

Approximately 145 participants attended the "Hawai'i Coral Reef Monitoring Workshop—A Tool for Management" at the East-West Center during June 9-11, 1998. The workshop was financially sponsored by the State of Hawaii Department of Land and Natural Resources, and co-sponsored by the East-west Center and the National Oceanic and Atmospheric Administration. The overall goal was to develop monitoring protocols to assist managers in implementing needed changes in current coral reef management strategies and approaches in Hawai'i. The objective of the workshop also sought to employ local and overseas technical expertise to design the framework for coral reef monitoring in Hawai'i that would not only be effective, but also supportive of ongoing initiatives outside of Hawai'i, especially global monitoring initiatives. To this end, eight international, three national, and 12 local speakers made presentations during the first day of the workshop, helping to set the stage for the facilitated working group sessions on the following two days. Appendix A provides a copy of the opening program and a complete listing of the speakers and other participants.

The main Hawaiian Islands are surrounded by almost 410,000 acres of coral reefs, and the leeward or northwest Hawaiian Islands and atolls support even larger reef areas. Together these reefs account for 84% of all reefs under U.S. jurisdiction (Miller and Crosby 1998). These reefs contribute hundreds of millions of dollars annually to the local economy through tourism and fisheries. Hawai'i presently lacks long-term programs to detect changes that may lead to the degradation or loss of coral reef resources. Nevertheless, many feel that the reefs in Hawai'i are at risk from sedimentation, over-fishing, destructive fishing practices, pollution, and over-use. Coral diseases and bleaching seem to be on the rise globally. Clearly, we need to be in a better position to gauge these factors accurately and apply the appropriate corrective measures when needed. Scientists, resource managers, and community representatives will all need to pool resources, knowledge, and expertise to pursue the best options for coral reef management.

The workshop provided the first comprehensive effort in Hawai'i for the sharing of ideas and achieving agreement on the important elements of reef management, including monitoring.

An earlier initiative to establish coastal monitoring protocols, primarily for resort development off the Kona coast of the island of Hawai'i, was prepared for the West Hawaii Coastal Monitoring Task Force (1992), but it was not successful in achieving the financial and broad-based institutional support needed for implementation.

Specifically the 1998 workshop sought to establish agreement on coral reef monitoring protocols, including research methods that would be incorporated into a management plan for coral reefs in Hawai'i. The workshop also sought to explore options for a statewide data management system for reefs and to insure that workshop recommendations were consistent with established international reef monitoring programs. Finally, the workshop sought to integrate and engage community-based and volunteer-based monitoring in Hawai'i and to build community education and training opportunities.

Workshop procedures

The workshop progressed through several planned phases. Introductory speakers explained the purpose and need for the workshop and described the specific questions and goals to be addressed. Presentations by several groups of speakers (international, national and local) offered various perspectives on how to design and implement coral reef monitoring programs. An important aim of the presentations was to discuss the strengths and weaknesses of various monitoring approaches and methodologies and to describe the results of actual monitoring studies and how they could influence management decisions. All verbal presentations were completed by the end of the first day of the workshop so that two full days could be devoted to the facilitated working-group sessions and plenary presentations and discussions. The keynote address was given at lunch during the second day of the workshop. The final plenary at the end of the third day reported the results of the workshop and the final recommendations of the workshop participants. The workshop ended with a consensus voice approval of all recommendations.

Everyone who attended the workshop had an opportunity to offer opinions and suggestions during the facilitated working group sessions. Professional facilitators were used to keep the discussions on track, control the flow of the discussions, and to insure that all comments were both heard and recorded. Recorders were assigned to each session to insure that all verbal comments were written on easel paper and later used during the plenary presentations. Rappateurs, distinct from the facilitators and recorders, reported the results of each working group during plenary sessions. The plenary sessions allowed any participant to offer comments to address errors or omissions by the rappateurs. The "easel paper" notes taken during all group sessions were later transcribed, condensed, edited, and are presented in Appendix G. The names of the participants for each of the working group sessions are listed in Appendix B.

Written versions of the verbal presentations were prepared and circulated in draft form before the workshop. Additional written contributions were submitted after the workshop for which there were no earlier verbal presentations. All written papers were then subjected to an anonymous peer-review process over a several month period following the workshop. The final versions of accepted reports (Chapters 1 to 21) reflect changes and improvements suggested during the peer review process. The written reports to follow are grouped into the following topics and sections:

1) Keynote Address (Chapter 1),
2) Overviews of the purpose, benefits and constraints of monitoring (Chapters 2-5),
3) Examples of monitoring methods (Chapters 6-11),
4) Training and volunteer programs (Chapters 12-15),
5) Monitoring programs in Hawai'i (Chapters 16-18), and
6) International monitoring programs (Chapters 19-21).

Ms. Rikki Grober-Dunsmore prepared summaries, introducing and reviewing the highlights of each of these sections.

Presentations by invited speakers

There were twenty verbal presentations during the opening day (June 9, 1998) of the workshop, including 16 by invited speakers. **Michael Wilson**, then Chair of the Department of Land and Natural Resources, and **William Devick**, Acting Administrator for the Division of Aquatic Resources, welcomed participants to the workshop and laid out the background and motivation for a monitoring program to help improve the management of Hawaiian coral reefs. Dr. **James Maragos**, Senior Fellow at the East-West Center, reviewed the workshop procedures and phases, explaining the role of each.

Six presentations were made before lunch and a seventh during lunch on the first day that provided international and national perspectives for coral reef monitoring.

Dr. **John McManus** of the International Center for Living Aquatic Resources Management in the Philippines stressed the importance of involving communities in coral reef assessment and described the status of ReefBase, the global coral reef database and ReefBase Aquanaut, a simple field method for surveying and monitoring coral reefs that can be taught to diving non-scientists, such as non-government organizers and park rangers (see Chapter 14).

Dr. **Charles Birkeland** of the University of Guam reviewed monitoring programs and techniques he has used in Micronesia and American Samoa, pointing out the importance of measuring size distribution of corals to provide more accurate forensic and predictive insights on the condition and recent history of reef areas (see Chapter 7).

Dr. **James Bohnsack** of the National Marine Fisheries Service in Miami reviewed coral reef monitoring in US Atlantic marine sanctuaries and preserves, and the advantages and disadvantages of four kinds of visual fish monitoring methods (see Chapter 10).

Dr. **Hugh Sweatman** of the Australian Institute of Marine Science in Australia, described the Long Term Monitoring Program used at 50 sites along the Great Barrier Reef, including special attention devoted to Standard Operating Procedures to reduce observer, sampling, and statistical errors in the analysis and interpretation of monitoring data (see Chapter 19).

Dr. **Jamie Oliver** of the Great Barrier Reef Marine Park Authority described the Authority's philosophy for reef management, including reliance on a suite of targeted prioritized programs which address specific pre-determined management questions, and the value of sub-lethal stress indicators for site-specific impact monitoring programs (see Chapter 5).

Dr. **Gregor Hodgson** of the Hong Kong University of Science and Technology provided a detailed analysis of the purposes for monitoring coral reefs in Hawai'i and a progress report on Reef Check, the first truly global coral reef monitoring program launched in 1995 in Hawai'i and accomplished by trained volunteers under the supervision of experienced scientists at over 200 reef sites around the world (see Chapters 2 and 15).

The first day's luncheon speakers, Dr. **S. Al-Moghrabi** of the Aqaba Marine Station in Jordan and Dr. **Yossi Loya** of Israel's Tel Aviv University, described the new coral reef monitoring program for the Red Sea Marine Peace Park (see Chapter 20).

There were nine presentations on coral reef monitoring in Hawai'i made by local scientists during the afternoon sessions of the first day.

Robert Nishimoto of the Division of Aquatic Resources reviewed the history and changes to the Division's reef and fish monitoring program since its initiation in 1952, and discussed the successful collaborative effort among several institutions involved with monitoring coral reefs off the Kona (west) coast of Hawai'i Island (see Chapter 17).

Dr. **Richard Grigg** of the University of Hawai'i in Honolulu reviewed the various merits and pitfalls of scientific design and data collection methods for coral reef studies and stresses the end purposes of such surveys to facilitate data interpretation, especially for management and conservation (see Chapter 3).

Dr. **Paul Jokiel** of the Hawai'i Institute of Marine Biology in Kane'ohe, stressed that the optimal experimental design for coral reefs must include monitoring of those specific physical and chemical factors relevant to biological changes on reefs.

Dr. **Cynthia Hunter** of the Waikiki Aquarium described the first documentation of disease and tumors in Hawaiian corals, and stressed the need to include disease and stress indicators for coral reef monitoring programs (see Chapter 8).

Dr. **Marlin Atkinson** of the Hawai'i Institute of Marine Biology described the importance of measuring bathymetric relief for predicting water movement and mass exchange characteristics at specific coral reef monitoring sites, and he also presented progress on the use of advanced high spatial, and high spectral resolution remote sensors to help researchers better discern the ecological features of coral reef (see Chapter 9).

Dr. **Richard Brock** of the University of Hawai'i Sea Grant College Program in Honolulu evaluated the results of an eight-year coral reef monitoring study to assess the effect of residential and golf course development off Lana'i Island, and raised questions regarding the great expense of some monitoring efforts (see Chapter 18).

Dr. **Leon Hallacher** of the University of Hawai'i at Hilo described the success of the annual training workshop QUEST (Quantitative Underwater Ecological Surveying Techniques) in educating students and monitoring coral reefs using a suite of modern field techniques (see Chapter 13).

Eric Brown of the Pacific Whale Foundation (PWF) on Maui, reviewed the PWF training of volunteers to monitor coral reefs. Although volunteers can contribute financially, logistically and scientifically towards monitoring programs, Brown pointed out that their data still does not measure up to what experienced staff and scientists can acquire, especially for fish species richness and density estimates (see Chapter 12).

Dr. **Ernst Reese** of the University of Hawai'i in Honolulu reviewed the role and value of using indicator species for coral reef monitoring programs, and described the techniques of using butterfly fish as indicator species for reefs both within and outside of Hawai'i (see Chapter 11).

Dr. **James Maragos** closed the first day of the workshop by reviewing the presentations and thanking all participants for their contributions. He then briefly explained the organization, assignments, and procedures of the working group and plenary sessions to be followed during the last two days of the workshop, referring to the handouts provided to participants.

Dr. **Clive Wilkinson** of the Australian Institute of Marine Science gave the Keynote Address during the lunch of the second day of the workshop, providing an update on the Global Coral Reef Monitoring

Network, and also offering recommendations on a proposed monitoring program for Hawai'i (see Chapter 1).

Day 2 of the workshop (June 10, 1998): Working group and plenary sessions on "Why and What Do We Need To Know?"

The opening plenary session was chaired by James Maragos who reviewed the purpose and scope of the working group phase of the workshop. He pointed out that monitoring is an integral part of resource management, but also stressed that monitoring must be relevant to the needs of management. In terms of coral reef management, one fundamental need is determining the status or health of coral reefs. If a particular reef is in good condition then fine, but if the reef is stressed in some way, then "management" will need to know more of the nature of the problems before evaluating and embarking on corrective measures, if any. Since the workshop was to focus on the coral reef management concerns that would benefit from monitoring, the working group participants were first asked to evaluate the management concerns and reasons for coral reef monitoring, or in other words: "**Why do we need to monitor Hawaiian coral reefs?**" After evaluating these reasons, participants were asked whether the reasons or concerns were relevant to monitoring. Furthermore, the participants were asked to identify the specific properties or "parameters" of coral reefs that warrant monitoring to address the management concerns, i.e. "**What do we need to know that can be answered through monitoring?**"

The entire second day of the workshop was devoted to addressing the above two fundamental questions. All participants were assigned to one of three working groups charged with answering the above questions. The workshop organizers strove to insure that a cross-section of scientists, managers, and non-government organizers participated in all three working groups. At the end of the day rappateurs from each of working groups were asked to present the results of the deliberations of their group during the final plenary session. This process allowed all workshop participants to "compare notes" to determine whether there were common concerns among all working groups and whether there were similarities in the parameters recommended for the proposed coral reef monitoring program. Appendices G-1 through G-3 provides summarized notes of the results and recommendations offered at each of the working group sessions.

In general there were similarities in what each of the three working groups concluded to be the major coral reef management concerns that would benefit from a statewide monitoring program. One or more of the groups agreed that coral reef monitoring would need to address the following concerns:

- Natural variability in coral reef community characteristics, both in terms of time and space,
- Effects of urban pollution on coral reefs including sewage discharges and non-point source pollution,
- Effects of sedimentation from soil erosion and runoff attributed to development for agriculture, ranching, game reserves, golf courses, housing, flood control, transportation development, etc.,
- Alien or invasive species effects on coral reefs,
- Impacts of over-fishing/harvesting and destructive fishing pressures on coral reefs,
- Effects of non-extractive uses of coral reef resources and habitats (from anchoring, wading, diving, boating, walking, tourism, recreation etc.),
- Effects of coastal construction on coral reefs (seawalls, beach replenishment, dredging, shore protection, filling, urban and residential encroachment, mariculture, etc.),

- Effects of fuel and cargo spills, ship groundings, and ship wrecks on coral reefs and appropriate remedial measures,
- Effects of natural disturbances on coral reefs (tropical cyclones, bleaching, exposure, flooding, earthquakes, tsunamis, etc.), and
- Increasing public awareness and education about the value and fragility of coral reefs and the need for proper management
- Evaluating the effectiveness of management interventions

Each of these first three working groups also evaluated the parameters needed to address the above concerns through monitoring. Each working group developed a "short list" of core parameters that would be monitored at all coral reef monitoring sites, and additional parameters that would be monitored to address one or more of the above concerns (e.g. "triggers") in more detail, on a "as needed" basis. These parameters conveniently fall into one of the five categories below:

- **benthic parameters** (those relating to bottom environments on coral reefs, such as live coral, other invertebrates, algae, sand, hard reef surfaces, etc),
- **fishery parameters** (those relating to fin-fish and shellfish resources on coral reefs),
- **water quality parameters** (such as sediments, nutrients, salinity, temperature, toxins, etc.),
- **protected marine species** (marine mammals, sea turtles, sea birds), and
- **socio-economic parameters** (such as visitor, recreation, boating, and fishing use).

Indicators including indicator species and indicators of stress and disease were also discussed as important parameters for measuring coral reef health and status. Indicators were eventually included in the recommended framework for a coral reef monitoring program for Hawai'i, and Chapter 11 covers indicator species in detail.

At the final plenary on day two of the workshop, participants agreed that socio-economic parameters were important but mostly beyond the scope of a field oriented reef monitoring program and that several state and federal agencies would need to help and cooperate in providing useful socio-economic information, both to monitoring entities and management organizations responsible for coral reefs. The final plenary of the day also served as the forum for reviewing the results of the three working group sessions and as the basis for organizing the working group sessions for the final day of the workshop.

Day 3 of the workshop (June 11, 1998): Working group and plenary sessions on How, When and Where to monitor coral reefs in Hawai'i, and on data management needs and community based monitoring opportunities.

The final day of the workshop began with a plenary session during which the results of the working group sessions of the previous day were reviewed and integrated. The management concerns that needed to be addressed by a monitoring program were discussed and it was agreed that the key concerns (e.g. **Why to monitor?**) should include those related to fishing/ harvesting, sedimentation, eutrophication, invasive species, and natural variability and diversity of coral reefs. A master list of coral reef monitoring parameters (e.g. **What to monitor?**) was reviewed and approved by the participants, after combining and reviewing the lists developed by all three working groups. The edited notes from the plenary are included in Appendix G-4.

The three morning working group sessions of day three (June 11, 1998) addressed parameters for **Water Quality, Fisheries, and Benthos**. Protected species parameters were assigned to the working group on fisheries. Workshop participants were allowed to attend any session and to move between sessions. The goal of each of these working groups was to flesh out the details of the monitoring protocols, particularly to discuss appropriate methods for measuring the agreed upon parameters (i.e., **How to monitor?**), the high priority sites for establishing monitoring stations (i.e., **Where to monitor?**), and the frequency and timing for the monitoring (i.e., **When to monitor?**). The edited notes from all three morning sessions are included in Appendices G-5, G-6, and G-7 respectively. The results were further integrated and are presented later in the Executive Summary section entitled "Technical framework for a State-wide monitoring program".

The three afternoon working group sessions of day three covered **database management, community/ volunteer monitoring**, and the **technical details of a state-wide monitoring program**. Appendices G-8, G-9, and G-10 are the edited notes from these working group sessions, respectively. Workshop participants were assigned to one of these workshops, based upon a questionnaire filled out by each participant prior to the workshop.

Database Management Working Group

Originally this working group was asked to identify the specific needs for a coral reef monitoring program for Hawai'i. However, the group could not reach agreement on this and decided instead to review the variety of existing database management opportunities to develop a database management system tailored to Hawaiian coral reef monitoring. Existing options include the ICLARM ReefBase system, the Bishop Museum's Hawai'i Biological Survey, a National Oceanic and Atmospheric Administration sponsored coral reef database in the planning stages, a database and geographic information system (GIS) model recently developed for the Republic of the Marshall Islands, a combined State of Hawaii GIS and Environmental Protection Agency's STORET system, and the Division of Aquatic Resources system developed in conjunction with the ongoing Main Hawaiian Islands Marine Resources Investigation (MHI-MRI), which has been compiling data on coral reefs fisheries at several major sites over the past decade.

Community/Volunteer Working Group

The working group evaluating volunteer/community-based monitoring of coral reefs covered several topics. First, they reviewed a variety of programs now active in coral reef survey and monitoring, including the Pacific Whale Foundation's training program for divers, REEF, Earthwatch , Reef Watchers, QUEST, Reef Check, ReefBase-Aquanaut, OUCH, Great Barrier Reef's Eye on the Reef, Coastal Resource Monitoring Project in the Philippines, Monk Seal Watch Program, Center for Marine Conservation beach cleanup program, and others. Of these several are active in Hawai'i while others are regional and international in scope. Reef Check is presently the only established organized global monitoring program for coral reefs, since no scientifically organized system is yet global. However the Global Coral Reef Monitoring Network is now being organized, and advocates a variety of volunteer programs including Reef Check, ReefBase Aquanaut, and others. Although the working group made no specific recommendations for a preferred volunteer/community-based approach, all active programs should be supported. The working group also recommended to "randomly use different techniques to validate and accomplish cross comparisons" among different approaches, and to develop standard methods for use by volunteers and community groups.

The working group also discussed the pros and cons of using volunteers for coral reef monitoring (see Appendix G-9). Among the many advantages are that such monitoring is inexpensive, attracts motivated people, raises public awareness and support, can mobilize a large "work force", retains excellent local knowledge of reefs, can serve as an early warning network, and is more focused on compliance and enforcement of statutes that protect reefs. Other advantages include the lack of liability and safety constraints that face government and university divers, heavy potential private sector sponsorship, connection to a large political and managerial network, support for community-based management by the Hawaiian community, and the transfer of liability away from government and non-government organizations.

However, there are also many potential disadvantages of relying too heavily on volunteers and community-based monitoring, including the lack of quality control, less scientific oversight, high turnover and less dependability of volunteers, the constant need for fundraising, limitations on the amount of useful data that can be collected, and concerns over the liability of divers and other potentially hazardous activities associated with coral reef monitoring. For example, the Pacific Whale Foundation carries insurance to cover all levels in the training program (including trainers and trainees) while Reef Check relies on certified divers and transfers all risk responsibility to them. Community and volunteer monitoring programs often to not address government management goals and objectives applicable to the reef areas being monitored.

The working group also discussed the need for the organized training and dive certification of volunteers. The process of selecting volunteers is important and standardized curricula need to be developed. Training aids including texts and equipment need to be inexpensive and consistently available. Quality assurance and quality control are needed if the data collected by volunteers are to be used for important management purposes. For example, a certification program for trainees could be required for volunteers successfully achieving a designated level of proficiency, and scientists need to be involved for field checking, site selection, and data interpretation. The trainers themselves need to be experienced divers and knowledgeable about local coral reefs. Database management for volunteers and community groups is also an issue as it is with the technical monitoring plan.

Working group on developing the technical details of a state-wide monitoring program

This working group compiled the information from the afternoon working group sessions of the previous day and developed a coherent framework for a monitoring program for Hawai'i. A composite list of parameters and suitable techniques were developed for benthos, fish, protected species, and water quality parameters. The working group also established the criteria on when and where to establish monitoring sites and recommended a sequence of actions as part of the process of establishing a monitoring program. The recommendations of the working group are summarized below and presented in more detail in Appendix F-10. All recommendations were endorsed by the other participants during the final plenary session of the workshop.

Technical framework for a State-wide coral reef monitoring plan

The participants in the workshop reached agreement on the framework for a plan to monitor coral reefs in Hawai'i. The technical framework should include information on the reasons for the monitoring, characteristics or properties of reefs that need to be monitored, locations for the monitoring, how often the monitoring should take place, details of suitable techniques or methods to accomplish the monitor-

ing. This can be simply summarized as **why**, **what**, **where**, **when**, and **how** to monitor coral reefs in Hawai'i.

The workshop reached consensus that certain features or characteristics of coral reefs should be monitored regularly at a number of core sites throughout the state to assess natural variability in reefs and to differentiate between changes attributed to both natural and human-induced stresses to reefs over time. The features to be monitored include **benthos** or bottom dwelling organisms (corals, sponges and other invertebrates, benthic algae, sea grasses), **fish** (both fin fish and shellfish), **protected species** (including sea turtles, sea birds, and marine mammals), **water quality** (nutrients, chlorophyll, temperature, salinity, suspended solids, turbidity), and **geophysical characteristics** (water circulation, wave exposure, bathymetry, substrate morphology, and weather). The workshop also reached consensus on the specific measurable properties or **parameters** that should be monitored. The priority parameters listed below:

Benthos-

Abundance- measured as *density* (or *frequency*) and *coverage*,

Diversity- measured as the presence of species or *species richness* or via a *diversity index*,

Condition- including the proportion of *bleaching*, *tumors*, and *dead areas* of corals,

Size distribution of population- measured as the *numbers per size class*,

Indicator species- including coral predators such as *Acanthaster*,

Alien and invasive species- particularly their *abundance* and *distribution*,

Recruitment- including the abundance of *larvae*, *new recruits*, or *newly settled corals*.

Fish-

Abundance- measured as *density* or *biomass*,

Condition- including *lesions*, *indicators of poor health*, evidence of *illegal* or *destructive fishing methods*,

Distribution- including *spatial*, *temporal*, and *size classes*,

Diversity- measured as *species richness*, and

Indicator species- possibly including *butterfly fishes* and *alien species*.

Protected species-

Sea turtles- *numbers per species*, *carapace length*, *tumors*, location (*on beach* or *in water*),

Marine mammals- including *numbers per species* and *location*, and

Sea birds- including *numbers per species* and location (*onshore* or *in water*).

Geophysical characteristics-

Wave exposure- location and time of *wave height*, *period*, and *direction*,

Water circulation- direction and strength of wind, wave and tidal *currents*, and *water residence time*,

Bathymetry- *mapped depth contours* of reef sites, and

Geomorphology- *mapped composition* and *origin* of *bottom sediments* and other *substrates*.

Water quality-

Nutrients- *concentration* of organic and inorganic *nitrogen*, *phosphate* and *silicate* in the water,

Chlorophyll- *concentration* of the plant pigment, *chlorophyll a* in the water,

Temperature- *time* and estimates of *surface* and *bottom* water *temperatures* (degrees C),

Salinity- *time* and estimates of *surface* and *bottom salinities* in parts per thousand,

Turbidity- *time* and estimates of *nephelometric turbidity units* or *extinction coefficients*, and

Suspended solids- *time* and *surface* and *bottom* estimates in *milligrams* of solids *per liter*.

Locations for the monitoring program

Monitoring stations should be established or maintained at the following site categories:

Historically monitored sites,

Marine protected areas and "hot spots",

Sites representative of different levels of degradation for each reef habitat type,

Heavy human use areas,

Control or reference areas (where particular sources or types of degradation are absent),

Remote and pristine reef areas,

Sites off both the "wet" (windward) and "dry" (leeward) sides of islands,

Proposed new development areas,

Sites historically relevant due to past impacts, and

Reserve some sites for issues or "triggers" that cannot be predicted in advance (including but not limited to: overfishing, sedimentation, pollution, alien species outbreaks, algal outbreaks, diseases, recovery and restoration, and predator outbreaks (e.g. *Acanthaster*)).

The following representative list of native coral reef habitats should also be included in the monitoring program:

Open coast,

Embayment,

Lagoon,

Atoll reef,

Barrier reef,

Fringing reef,

Channel or pass,

Reef hole or pool,

Seagrass bed, and

Soft bottom.

Timing of monitoring surveys

The workshop recommended the following guidelines on when to monitor coral reefs:

Yearly- corals, other benthos, and reef fish;

Monthly- water quality, initially monthly until variability is established;

Variable- the nature of trigger events would determine appropriate frequencies of sampling;

Once- geophysical parameters during the initial establishment of a site, and repeated if structural changes may result in changes to geophysical regimes at the site.

The sequence of establishing new coral reef monitoring stations- What to do first?

The workshop participants recommended that *site characterization* be accomplished first before the installation of permanent quantitative monitoring sites, which should include the following actions:

- Characterize the bathymetry and prevailing patterns of water movement,
- Consult the literature on the geological record and previous studies in the area,
- Identify freshwater and pollution inputs,
- Compile and verify general species lists,
- Determine the global positioning system (GPS) coordinates,
- Consult maps and aerial photography to map habitats,
- Describe qualitatively the habitats and conditions, and
- Determine adjacent land uses and in-water uses.

Preferred methodologies and techniques for monitoring coral reefs: How to monitor?

The workshop participants concluded that there is no one technique or suite of approaches or any single protocol that would suitable for monitoring all of the above parameters. Appendix G-7 includes a listing of suitable techniques for each of the parameters listed in the framework above as reviewed by the benthos working group. Appendix C is a listing of the strengths and weaknesses of a variety of coral reef surveying techniques evaluated by many of the workshop participants and compiled by David Gulko. Presently, all the scientists involved in monitoring coral reefs would not agree to a standard protocol involving only a single preferred method for each parameter. In reality, each different technique does have unique strengths and weaknesses and can better measure some parameters over others. The Workshop participants recommended the parameters listed above and to use discretion and experience in selecting techniques that would adequately measure each of these parameters.

Permanent vs. random sites?

Random sampling and statistically valid data collection procedures were extensively discussed at the workshop and are covered in several of the papers. In principle most, if not all, field scientists would agree that randomized selection of sampling sites, and proper design of quantitative surveys to facilitate statistical testing are conceptually-desired goals for field surveys. However, for monitoring studies,

where repeated measurements are needed at exactly the same sites at different times, random sampling poses problems. The action of laying a straight transect line across a reef can hardly be construed as random, but if the goal is to monitor the same communities over time, then transect lines at fixed sites are very convenient, if not essential. Power analysis and other techniques can help determine the amount of reef that needs to be surveyed to detect meaningful levels of changes at reef sites over time. Many reefs show high spatial variability over short distances, and diver bottom time is limited and may not be sufficient to survey enough reefs to meet statistical tests. Increased bottom time also translates into increased costs of monitoring and more complex logistics. Additionally, many historic sampling sites are probably inadequate in scope to meet the test of a modern power analysis, yet these earlier sites were chosen as among the highest priority in the framework plan. Although most scientists will agree on the need for sampling design and procedures to produce accurate and meaningful results, it was beyond the scope of the workshop to treat these issues in more detail. Furthermore, the time available during the workshop was insufficient to reach any consensus on these points.

Workshop participants recommended including a combination of permanently "fixed" and randomly selected sites for the monitoring program. In particular, corals, other benthos, and fish populations should be monitored repeatedly at some of the same permanent sites. Permanent sites also allow some of the same organisms, such as corals to be monitored at the individual or colony level, an added advantage over non-fixed sampling sites. Permanent sites resurveyed repeatedly over time also appeals to the common-sense inclinations of many policy makers and managers. If reef conditions "worsen" at one or more of these sites, it will raise the expectations of these decision-makers to pay more attention, should management intervention be warranted. Video and photographic evidence can supplement other data to document the decline or recovery of individual corals and communities and can be better understood by the most "lay" people in our communities.

Conclusions

The findings, conclusions, and recommendations developed by each of the working groups during the last two days of the workshop were approved by a unanimous voice vote at the end of the final plenary session. The recommended framework for a coral reef monitoring plan for Hawai'i had the complete support of the participants at the workshop. Other recommendations including a listing of a preferred suite of techniques for use in field surveying and monitoring are covered in the appendices. Unfortunately the workshop participants could not reach a decision on the database management requirements for the monitoring program, which is the most important unresolved requirement for a successful monitoring program.

The Workshop likewise did not reach consensus on any preferred community/volunteer based program, except for blanket support of all programs. It would be desirable for all volunteer or community based initiatives to agree to **some** standard protocols to allow their combined efforts to have a more global dimension and impact. On the other hand, it is not necessary for **all** parameters monitored by volunteers and communities to be the same everywhere. Each community will have local issues and concerns that to some degree are unique. For example, the concern over the conservation of the threadfin or *moi* (*Polydactylus* sp.) by the local community at Mo'omomi, Moloka'i will have little relevance to most of the remainder of the Pacific and other tropical oceans where this fish is not found. Yet, the concern over this fish is the main driving force by that community to establish a community-based monitoring program in Mo'omomi and adjacent bays. To some degree, local community-based monitoring and scientifically based global monitoring will follow separate goals and tracks. It is likewise desirable for

some (but not all) of the effort of each community-based monitoring initiative to contribute to the overall global monitoring program and to global conservation of coral reefs.

In conclusion, the workshop succeeded in establishing a framework for a coral reef monitoring program for Hawai'i and enlisting the support of all key local residents and many of the top international scientists involved with coral reef monitoring. The approach used for the Hawai'i workshop may be useful for other regions desiring to organize their coral reef monitoring programs. In Hawai'i the workshop has already stimulated a greater degree of cooperation and teamwork in promoting better management of reefs, including the development of the Coral Reef Assessment and Monitoring Program (CRAMP), the Hawaii State of the Reefs Report (Clark and Gulko 1998), the U.S. Fish and Wildlife Service sponsored Marine Ecosystems Geographic Information System proposal (MEGIS), and Hawai'i representation on the U.S. Coral Reef Task Force. The U.S. Fish and Wildlife Service protects many coral reefs throughout Hawai'i and other U.S. areas in the insular Pacific as part of its National Wildlife Refuge system, and plans to adopt the protocols recommended at the workshop for establishing long-range monitoring programs for coral reefs in these refuges.

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Presenter Abstracts & Outlines (In Order of Presentation)

ReefBase 3.0 and the ReefBase Aquanaut System

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Abstract

ReefBase is a key element in global efforts to improve the management of the world's coral reefs. The ReefBase database was developed to address the needs to determine the status of reefs and to facilitate research and management activities through the consolidation and broad dissemination of existing reef information. ReefBase serves as the central database of the Global Coral Reef Monitoring Network, and as a repository for data from a variety of research activities. In order to broaden the range of people contributing useful data to the database and to specific management evaluations, the ReefBase Aquanaut System was developed. In this system, professional SCUBA instructors are trained to teach SCUBA divers in a simple method for the ecological surveying and monitoring of coral reefs. The method involves the use of 5 m transect lines divided into 50 cm sections. Data are quantified within a virtual quadrat alongside the line, within line intercept segments, and by point intercept and modified nearest neighbor approaches. Data are compatible at general levels with that from Reef Check and ASEAN-Australian Line Intercept surveys. The method is particularly useful for government and NGO non-specialist researchers, park rangers and others who must monitor reefs.

Coral Reef Monitoring in Micronesia & American Samoa

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Abstract

The point-quarter method has been used by the University of Guam to assess the coral communities in Micronesia and American Samoa since the 1970s because the emphasis on size distribution data for the corals allows more accurate forensic and predictive insights than do the extrinsic statistics of living coral cover, population density, and species diversity. As long as the objective is to document change in a coral community through time at a particular location, the standardized use of quadrats or transects is good because of the artificially reduced variance of the extrinsic data. However, if the objectives are to deduce past events, identify the ecological processes, and to assess the conditions of reefs, the intrinsic data from the point-quarter method are more true and effective.

Coral Reef Monitoring in US Atlantic Marine Sanctuaries & Preserves

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Abstract

The Florida Keys reef system extends over 240 km and is under eight levels of protection by several state and federal agencies. Reef monitoring of the benthos and fishes in the Florida Keys is intended to detect resource changes, evaluate the success of restoration efforts, and increase the knowledge and understanding of marine ecosystems. A hierarchical monitoring approach seeks to answer management questions across disciplines with a focus on the effects of 19 no-take zones established by the Florida Keys National Marine Sanctuary in 1997. Level I focuses on critical factors at specific sites. Level II monitoring covers a broader area at lower intensity. Level III focuses on ecosystem changes using volunteer monitoring. Sanctuary Program coordination ensures that: the parameters measured are relevant for both scientific and management purposes, and that the same sites are being monitored so that benthic and fish monitoring complement each other. The initial phase is a 5-year effort to test the hypothesis that the intensity of extractive effort (including commercial and recreational fishing, spearfishing, marine life collecting, and recreational collecting) has no effect on the composition, abundance, and sizes of reef fishes, lobsters, or sessile benthic organisms. The research design is set up to test specific hypotheses involving the effects of no-take marine reserves and trophic interactions using primarily stationary plot sampling by scientists and roving diver surveys by volunteers. Advantages and disadvantages of four visual fish monitoring methods are compared: stationary plot, belt transect, timed search, and roving diver.

The Australian Institute of Marine Science's Coral Reef Monitoring Programs on the Great Barrier Reef

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Abstract

Several scientific activities at AIMS come under the general heading of reef monitoring. The largest of these is the AIMS Long-Term Monitoring Program. This program involves a full-time field team who make annual surveys of 50 reefs chosen to represent three positions across the GBR lagoon at six latitudes.

Benthic organisms are surveyed by videography on five permanently marked 50 m transects in each of three sites on the NE aspect of each reef. These records are analyzed using in-house software to sample 150 points per transect and calculate percent cover values for hierarchically-arranged benthic categories.

A prescribed set of reef fish species are censused visually on the same transects; larger, more mobile species on a 5 m wide belt, damselfishes on a 1 m wide belt.

The perimeters of core survey reefs plus a number of additional reefs are surveyed by manta tow for crown-of-thorns starfish and cover of living and dead coral on a 10-point scale.

The program staff also includes a reef scientist, a biostatistician, a field team manager and a database administrator.

Extensive effort is given to quality control including Standard Operating Procedure documents, field calibration of observers, observer comparisons for video analyses, verification of benthic organism identifications, and error trapping and statistical checking of data as they are entered.

Coral Reef Monitoring Programs and Management of the Great Barrier Reef

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Abstract

Monitoring is a general term that encompasses a wide range of activities and objectives. No single monitoring program is able to adequately address all of the scientific and management requirements of an environmental management agency. A suite of targeted prioritized programs, which address specific pre-determined management questions, is likely to be the most effective approach to developing state-wide monitoring. Coordination and summary of existing programs conducted by different groups is an important component of any state-wide approach. On the Great Barrier Reef, a five yearly State of the Reef Report is a major vehicle for the summary, interpretation and synthesis of all monitoring programs. The variables monitored, and the scales and frequency of monitoring, vary considerably from program to program and are determined largely by the questions addressed. Careful determination of the questions and objectives to be addressed by each monitoring program is perhaps the single most important determinant of a successful monitoring program. In addition, prior determination of the limits of acceptable change for a monitoring variable is an important but often neglected aspect of monitoring. Specific limits are often impossible to set, but a flexible set of decision criteria has been found to be effective on the GBR. Sublethal stress indicators are particularly useful for site-specific impact monitoring programs, but very few parameters have been developed for routine use.

What is the Purpose of Monitoring Coral Reefs in Hawai'i?

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Abstract

Before embarking on an ecological monitoring program, it is important to define the objectives. The monitoring program can then be designed to fulfill those objectives. If the purpose of monitoring is to assist resource managers, then a number of important questions should be considered during the design process including:

1) Who is going to do the monitoring and analysis, and what resources are (should be) available to support it?
2) What natural and anthropogenic impacts are expected?
3) What natural variation in population parameters is expected?
4) What are the spatial and temporal scales of interest?
5) What variables (population levels, physiological status) are most important to monitor from economic, social, and ecological perspectives?
6) What variables can be monitored most efficiently in terms of useful information content per unit of monitoring effort?
7) What quantitative and null hypotheses can be used to test whether a change is statistically significant?
8) What sampling design (temporal and spatial) including controls will be used? What statistical procedures will be used to test the hypotheses?
9) What level of change is ecologically significant?
10) How will the cause of a significant change be determined?
11) What options are there for management action in response to a change, and what level of reef change should trigger a change in management?
12) What quality assurance procedures are needed to ensure that the data are correct?
13) What are the deficiencies of the design and how will they be dealt with? Once these questions have been answered, a useful, cost-effective monitoring program can be set up.

A Presentation of The Red Sea Marine Peace Park Coral Reef Benthic Communities: Ecology and Biology Monitoring Program

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Abstract

The Red Sea region supports some of the highest levels of coral species diversity in the world. In terms of reef building corals, approximately 50 genera exist in the Middle East Seas region. However, the ability of these and other coral reef ecosystems to exist in balanced harmony with other naturally occurring competing/limiting physico-chemical and biological agents has been severely challenged in the last several decades by the dramatically increased negative and synergistic impacts from poorly managed anthropogenic activities. In the Middle-Eastern Seas, the major threats to reefs stem from (1) urbanization and tourism, (2) oil exploitation and transport, and (3) industrial pollution and sewage discharges. Population growth and tourism is increasing throughout the region. Degradation of coral reefs is also occurring from heavy souvenir collection, and there is also evidence of increased damage to Middle East reefs from predation by sea urchins, crown-of-thorns starfish, and gastropods. Reef flats in the Gulf of Aqaba are also subjected approximately twice a year, to extreme low tides, which causes increased exposure of corals to air, high temperature and solar radiation.

Israel's Nature Reserves Authority and Inter-University Institute, and Jordan's Aqaba Region Authority and Marine Science Station have joined together in collaboration with NOAA and USAID to initiate a cooperative research, monitoring and management program to address pressing environmental and development issues in the Red Sea Marine Peace Park (RSMPP). The overall goal of this project is to foster cooperation and collaboration among Jordan and Israel in studying, managing, promoting awareness of, and protecting their shared marine resources. The two countries plan to address this goal by implementing a long-term monitoring and research program, and by participating in cooperative management and education/outreach activities related to the RSMPP.

The RSMPP benthic monitoring program is aimed at assessing community trends of the benthic coral reef organisms in the north end of the Gulf of Aqaba. This will be achieved by concentrating on three main topics:

Monitoring community structure, and population changes.
Continuous assessment of larval production, dispersal and recruitment.
Examination of regeneration capability of the reef major benthic components.

A description of the coral reefs of the RSMPP, a preview of the RSMPP benthic monitoring program and techniques, as well as data gathered during some of the longest studies of stony coral community structure which exhibits collapse of a coral reef and the problem of the ecosystem recovery due to human perturbations, will be presented.

Hawai'i Division of Aquatic Resources Reef Monitoring Program: *He Puko'a Kani 'Aina*

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Abstract

The Hawai'i Division of Aquatic Resources (HDAR), Department of Land & Natural Resources manages the State's marine and freshwater resources through various programs. The Governor's recent Ocean Initiative provided funding support to increase vigilance on Hawaii's coral reefs. We are presently reviewing our "historical" reef monitoring methods and adopting appropriate changes without compromising the Division's existent database.

Reef surveys started in 1952 with the primary function to provide snapshots of a reef area. A single long transect was preferred over shorter replicates since the objective was to sample larger areas with time and manpower constraints. Data was simply presented as general summaries.

Recently, we implemented a reef monitoring program along the Kona coast of the Big Island to determine the potential impact of aquarium fish collection and non-consumptive SCUBA diving on select reefs as well as to establish long-term reef monitoring sites. Collaboration with the University of Hawai'i at Hilo (UHH) marine science faculty and students provided the training and manpower. A community volunteer group, ReefWatchers, and a few UH researchers, round out the team approach to protecting and preserving Hawaii's reefs.

Merits and Pitfalls of Data Collecting Methods on Coral Reefs

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Abstract

Various merits and pitfalls of scientific design and data collecting methods for coral reef studies are described. Monitoring programs are pre-requisite to effective management but should be question-driven designed to test specific hypotheses. Tests of significance should include comparisons between impacted areas and representative control stations. Data collection at each station should be replicated and randomized. Care should be exercised to minimize observer bias. Choice of transecting method should be based on case-specific criteria. Over-standardization may be inefficient and costly. The most important merit or pitfall is the question asked. Surveys designed to determine only what is there will rarely explain causation. The end purpose of a coral reef survey should not be data only, but rather, the interpretation of the data and wise application for purposes of management and conservation.

Monitoring of Environmental Factors on Hawaiian Coral Reefs: Past, Present and Future Approaches

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Abstract

Forcing functions influencing coral reef communities include a variety of physical and chemical factors falling into the areas of meteorology, hydrology, and oceanography. It would be desirable to measure the full array of important parameters, but monitoring programs are inevitably limited by time and resources. Therefore, selection of parameters, sampling location and sampling frequency is often determined by availability of research funds. Optimal experimental design must include monitoring of those specific physical and chemical factors that are relevant to biological changes on reefs. Review of past efforts allows ranking of the relative importance of various environmental factors for different Hawaiian coral reef habitats. Further, these measurements can be summarized according to availability, cost and effectiveness as predictors of reef alteration.

Monitoring the Impacts of Tissue Necroses and Tumors on Hawaiian Reefs

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Abstract

A variety of methods were used to quantify the distribution and temporal progression of tissue necroses and tumors on coral colonies at three sites in Hawai'i. Distribution and abundance of diseased tissues were recorded as well as changes in overall coral and algal abundance through the analysis of permanent macrophotography stations and video transects of survey areas. The incidence and extent of necroses, as well as the amount of algal-turf covered surface area, increased with increasing colony size; the incidence of tumors on coral colonies was independent of colony size. Both coral necroses and tumors usually led to the loss of coral tissue, although recovery and regeneration sometimes occurred from the edges of healthy tissue with time. Coral and algal abundance remained nearly constant through time at the Honolua and Puako reef sites. However, mean percent of coral cover declined by 10% over a one year period (1992 – 1993) at Hanauma bay, with a concomitant increase in turf algae.

These studies provide the first documentation of disease and tumors in Hawaiian corals. Although the potential causes of many coral necroses are still conjectural, bacterial aggregates found in tissues of *Porites lobata* and *Porites evermanni* from Hanauma Bay were similar to those found in *Porites asteroides* in the Caribbean. Such bacteria may be mutualistic in healthy corals but become opportunistic pathogens when corals have been environmentally stressed. Potential stresses may include elevated nutrient levels that encourage algal overgrowth, mechanical abrasion from shifting sand or fish predation, smothering of tissues from episodically high levels of sedimentation, and/or other factors that are currently unidentified. Finer-scale and longer-term studies of temporal changes on reefs will provide information necessary for understanding the full ecological impact of coral diseases in Hawaiian reef ecosystems.

Bathymetry and Digital Remote Sensing of Coral Reefs

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Abstract

Topographical relief is correlated to the energy dissipated from flowing water by the reef community, and thus is an important parameter for calculations of mass exchange of metabolites between coral reef benthos and the water column. Such calculations can provide estimates for impacts of point and non-point source metabolites. I recommend obtaining topographical relief for all monitoring sites in the Hawaiian Islands.

The poor spatial and spectral capabilities of airborne photographic and satellite multispectral imaging systems has limited their use to mapping only broad geomorphological coral reef zones. Newer, high-spatial and high-spectral resolution remote sensing systems provide data that enable researchers to discern reef ecological communities. Water column optical properties may spectrally alter the remotely-sensed signal in high-resolution imagery. Our approach is to measure and analyze *in situ* spectral reflectances of reef benthos and substrates. The reflectances are used as bottom boundary conditions in a radiative transfer model that predicts light available to a remote sensor under a variety of conditions. Results indicate that water column corrections are necessary when the bottom is deeper than 3 m in clear water, and deeper than 1 m in high chlorophyll water. A non-corrective classification algorithm has been successfully applied to imagery of a shallow patch reef in Kane'ohe bay, O'ahu.

Monitoring Development on the South Coast of Lana'i Island: A Synopsis of Eight Years of Data

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Abstract

This study was undertaken to monitor the possible impact caused by the development of a resort, golf course and residential area around Hulopoe Bay on the south coast of Lana'i Island. Other than the small boat harbor at Manele bay adjacent to Hulopoe Bay, there is no development of Lana'i's south shore. Because of the well-developed marine communities, Hulopoe and Manele Bays were declared a marine life conservation district (MLCD) in 1976. This monitoring program has been focused in waters fronting the development at Hulopoe and to the east. A control site was established at Makole about 4 km east of Hulopoe; in total, 21 water quality and 10 marine biological stations for monitoring have been established encompassing more than 13 km of coastline. Data have been collected on 24 occasions spanning the period from December 1989 through December 1997. The first five sampling events comprise the "preconstruction" period (prior to golf course and residential construction) and the remainder sample during and after the construction period. Sampling methodologies have followed protocols developed by the West Hawai'i Coastal Monitoring Task Force. These include quantitative sampling of water quality parameters specified by the Hawai'i State Department of Health (DOH) as well as marine community parameters (abundance and diversity of fish, corals, other invertebrates and algae). Water quality is monitored from the shore to a point more than 700 m seaward and marine communities from shore to depths of 20 m. This study found weak gradients in some water quality parameters that decrease in a seaward direction at locations fronting intermittent streams particularly following a heavy rainfall. Several water quality parameters (nitrate, ammonia, chlorophyll-a and turbidity) were often out of compliance with state standards; however non-compliance appears to be a coastwide phenomenon not related to the development at Hulopoe Bay. Statistical analyses comparing the pre-construction to the during/post-construction period found significant differences in some parameters but none of these differences were related to the development. The analysis of marine fish and benthic communities noted no unusual components present. Coral communities are well-developed in the waters fronting the development but have always had greater coverage at the control site. Hurricane Iniki which occurred in September 1992 impacted marine communities to a greater extent in Hulopoe Bay than at the control site probably due to the direction of impinging waves. This 95-month study found no impact to marine communities related to the development. However, natural events such as high rainfall and Hurricane Iniki have had demonstrable transitory impacts ranging from weeks (water quality) to more than 5 years in coral communities due to the hurricane. Thus, despite the implementation of an integrated monitoring program designed to quantitatively discern anthropogenic impacts, none have been found. These results are not surprising in light of the environmental awareness among agencies, the public and planners today. This environmental awareness brings into question the necessity of detailed monitoring programs such as this study represents. Perhaps the limited financial and human resources could be better used elsewhere.

Quantitative Underwater Ecological Surveying Techniques (QUEST): A Coral Reef Monitoring Workshop

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Abstract

QUEST is a coral reef workshop taught at the University of Hawai'i at Hilo that is designed specifically to train students in a comprehensive suite of modern reef monitoring techniques. The classroom curriculum is designed to provide students basic background on faunal identification, coral reef ecology, surveying methods, experimental design, statistics, data processing, report writing, and oral presentation. The surveying methods taught were selected because they are widely utilized by the scientific community, easy to teach, and logistically practical in most field situations. Methods employed include: fish strip transects and rapid visual transects; quadrat intersects, percent area estimation, and photoquadrat and video quadrat methods for sampling attached epi-fauna and -flora; and quadrat search and nearest neighbor method for mobile invertebrates. In addition to providing trained personnel for coral reef monitoring, the course generates data useful for detecting large-scale changes in coral reef communities.

Training and Applicability of Volunteers to Coral Reef Monitoring

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Abstract

Hawaiian coral reef ecosystems are coming under increasing pressure from natural and non-naturally occurring disturbances. In an effort to detect spatial and temporal changes in the structure of the coral reef community, coral coverage and reef fish density and diversity were documented at selected sites along the Maui coastline using standard transect methodology and SCUBA. Physical parameters examined were wave exposure, water motion, sedimentation levels and water quality (temperature, salinity, and turbidity). State and federal agencies in Hawai'i are unable to conduct intensive long-term monitoring of coral reef ecosystems with current resources so this project utilizes volunteers that are coordinated through Earthwatch. Volunteers come from around the world for 2-week sessions and are trained in all phases of data collection techniques. Volunteers contribute financially, logistically, as well as scientifically.

Findings to date indicate that natural factors such as wave energy can affect density patterns of reef organisms over a very short period (e.g. 4-5 days). Human use patterns, if intense enough, may gradually alter both density and diversity over an intermediate time scale (2-5 years). Since 1994 when our sampling effort was pooled for each site, the nine long-term monitoring sites have experienced varying degrees of change in coral coverage and density.

Species richness of coral was highest at Honolua Bay (16 spp.) and lowest at the Puamana Offshore site (3 spp.). Fish species richness is highest at Honolua North (95 spp.) and lowest at Oluwalu Offshore (67 spp.). The highest coral coverage was found at Kahekili site 2 (57.4%) while the greatest number of fish per transect occurred at Honolua North (220.2/250m^2). The lowest coral coverage (0.3%) and fish density (19.0/250m^2) occurred at the Puamana Offshore site. The relationship between coral coverage and coral diversity in Hawai'i indicates that when coral coverage exceeds 40%, stands of a few dominant species (e.g., *Porites* spp.) results.

Seasonal trends in water motion appear to be the major factor structuring coral reef communities around Hawai'i. Sedimentation and other water quality parameters do not appear to dramatically influence coral reef communities in high-energy environments due to flushing and rapid dilution.

Comparison of coral data between volunteers and staff is difficult since data collection is usually under the direct supervision of staff members. Fish data collected by volunteers indicate that fish density and species richness estimates are significantly lower than staff estimates but only for certain sites and time periods. Linear regression analysis suggests, however, that relative trends between volunteer and staff data sets are similar for fish density, species richness and species diversity.

Monitoring reefs to develop indices of reef health and examining human use patterns will provide tools for more effective management of tropical ecosystems. This work takes on particular relevance within boundary waters of the newly created Hawaiian Islands Humpback Whale National Marine Sanctuary.

The Use of Indicator Species for Coral Reef Monitoring

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Abstract

Indicator species are used successfully in the assessment of ecological conditions in both aquatic and terrestrial environments. Only recently, however, has the indicator species method been applied to coral reef ecosystems. This is unfortunate as the method has many advantages over conventional monitoring methods which have dominated coral reef research.

Conventional monitoring programs are often expensive, time consuming, require scientifically trained personnel, involve complex sampling schedules, and require the processing, storage and analysis of samples. Photographic sampling methods, which at first glance appear to be an excellent choice, are expensive and analysis time is extremely time-consuming. Furthermore, permanent transecting lines or pins may not be permitted in preserves and sanctuaries.

In contrast, the use of indicator species has many advantages. It is less expensive and does not require scientifically trained personnel. It eliminates the costs in time and money of establishing a conventional sampling plan, including the archiving, storage and analysis of samples. It is not necessary to leave permanent markers in the field.

When should the use of indicator species to monitor coral reefs be the method of choice? When gradual change is suspected due to low but chronic input of pollutants into a reef area where previous baseline data do not exist, and when funds are limited and scientifically trained personnel are not available. These conditions exist in many developing nations where coral reefs are an important resource and there is need for conservation and management.

Choosing the best one or two species to serve as indicators is extremely important. It necessitates knowledge of the life history and behavioral ecology of species, which are abundant, conspicuous, diurnal, long-lived, site attached, and dependent on the ecosystem to be monitored for their food and shelter. Fortunately, this information often exists in one area where the species was studied and can be applied effectively elsewhere. Thus, for example, it is possible to recommend species of butterflyfishes as potential indicator species for many reefs in the Indian and Pacific oceans based on studies in Hawai'i, Guam, Australia, the Marshall Islands, and French Polynesia.

Establishing Coral Reef Monitoring in the Hawaiian Islands: The GCRMN Philosophies and Strategies for Community-Based Monitoring

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Abstract

The most effective way of managing coral reef resources in developing countries is through the direct involvement of user communities. This can only occur if these communities are aware of damage to reefs and probable causes, as well as being provided with assistance to implement management. The Global Coral Reef Monitoring Network seeks to raise that awareness by involving all users in gathering data on the status and trends in coral reefs using basic methods. Three levels of monitoring are identified: community, government and research, with the intensity of monitoring increasing with each level. Community level monitoring will use Reef Check methodology and approaches, with government level monitoring using a more detailed form of this monitoring. Methods for research level monitoring should be selected by the scientist in response to specific questions and habitats. A call is made on the Hawaiian government and science community to establish wide-scale monitoring in the region, assist communities with monitoring and assist other countries in the Pacific to establish monitoring Networks.

Sampling May Be Haphazardous to Your Reef Monitoring Program

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Abstract

Because of the difficulty of collecting data underwater and the time and depth constraints imposed by SCUBA diving, most monitoring programs designed to document changes in coral reefs over time have been lacking in spatial scale and statistical rigor. Although reef scientists understand the importance of random sampling, few if any monitoring programs have sampling designs based on random selection of study sites. If our goal is to accurately assess the changes in coral reefs on a local, regional or global scale we must have confidence in the data we are depending on. This paper describes a statistically rigorous approach to sampling of coral cover based on the videotaping of randomly selected transects on coral reefs and compares this video method to the more widely-used linear chain transect method.

A Long-Term Marine Environmental Monitoring Program to Assess the Effects of Sewage Discharge on a Coral Reef

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Abstract

Fifty-six repetitive surveys of benthic community structure have been conducted from 1987-1998 to assess the effects of discharge of treated sewage effluent on coral reef community structure off of Sandy Beach, O'ahu, Hawai'i. Results of the monitoring program establish that coral communities adjacent to the outfall are not significantly different than at the control station in terms of coral cover and species-cover diversity. In addition, the long-term data set reveals that there is no decreasing trend in coral cover that can be attributable to the effluent discharge; rather during the last four years, cover has increased at the diffuser site. Water chemistry monitoring reveals that inorganic nutrient concentrations are increased within a small area directly over the diffuser, while there are no apparent effects to water clarity. These results point out the importance of employing long-term monitoring protocols that supply an adequate database for unambiguous interpretation of anthropogenic influences to reef communities. The monitoring results also corroborate findings from other reef areas that nutrient subsidies *per se*, without other factors associated with eutrophication processes, are not detrimental to coral reef communities.

Coral Reef Monitoring in French Polynesia

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Abstract

Since 1990, two long-term coral reef monitoring programs have been underway in French Polynesia:

The first concerns temporal evolution of reef populations situated at Tiahura, on the northwest coast of Moorea Island. This program monitors yearly changes in the number of individuals of various groups of reef dwellers (algae, corals, echinoderms, mollusks, and fishes). Twenty permanent stations on the reef flat and outer slope are being sampled yearly by use of the line intercept and quadrat techniques. Since 1991, continuous temperatures recordings are being made hourly across the reef flat and down to 40 m on fore reef outer slope. Data analyses show a relative stability of the coral reef as a whole ecosystem since 1990. Nevertheless, some changes due to coral bleaching mortality in 1991 and 1994 were demonstrated. This first program for the barrier reef monitoring is looking at yearly modifications due to anthropogenic events and natural ones.

The second monitoring program is more widely spread among fourteen French Polynesia islands. These islands are both volcanic islands (Society, Marquesas, Australes archipelagos) and atolls (Tuamotu Archipelago). The targeted geomorphological feature is the upper forereef outer slope, between seven and fifteen meters depth. This area of the reef was chosen for monitoring because geomorphological features here are quite similar for all islands thus allowing geographic comparisons to be made. Also, the upper reef slope is the place where carbonate production, coral growth and coral diversity is highest. The main objective of this program is to monitor for decades or centuries the reef dynamic in relation to natural events (cyclones, bleaching, *Acanthaster* infestation) or global change events. Presently there is no anthropogenic degradation on outer slope reefs in French Polynesia. At monitoring sites, the sampling methods consist of photographing (20 mm camera length) one square meter quadrats placed at twenty successive positions permanently marked along a tight wire cable. This technique permits sampling over time at exactly the same sites. Surveys for each monitoring site are normally conducted once every three years and more frequently in case of catastrophic events like cyclones or coral bleaching events. Surveys on one site require two divers and approximately two hours of underwater work.

Total and by genus planar percentage cover of coral was obtained by analyzing photographic records for the areas surveyed. Since 1997, these photographic surveys are being conducted by one kilometer manta tow surveys on both sides of a site. Total percentage cover range is between two and fifty-six percent, depending on the monitoring sites. Preliminary analysis of the results shows that an upper, outer slope coral reef community can rapidly change. The general trend is an increase in coverage since 1992 following a major bleaching event in 1991 (in 1991, depending on the genus, 10 to 25 % of the colonies died). A 1994 bleaching event caused much less coral mortality. At some monitoring sites, coral coverage increased three fold since the beginning of the surveys. This can be explained by the absence of major catastrophic events (cyclone, bleaching, infestation, etc.) after 1991 that are probably dynamic determinants in the coral community. Nevertheless the 1997/1998 ENSO event has effected some islands such as Raiatea, where waves caused by the cyclones Martin (Nov. 97) and Osea (Nov. 97) explain the very low value of coral percent coverage there.

At present (April 1998), a bleaching phenomena has begun in several reefs at French Polynesia islands and could involve important changes in cover and in genus composition. The monitoring network will determine the geographical range and extent of the coral bleaching event and mortality.