

Designing Effective Coral Reef Marine Protected Areas

**A Synthesis Report Based on Presentations
at the 9th International Coral Reef Symposium
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Michael B. Mascia, Ph.D.

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Executive Summary

Coral reef ecosystems provide direct and indirect benefits to millions of people around the world. The long-term sustainability of these benefits is threatened, however, by human activities that impact reefs and reef ecosystems. Traditional efforts to manage human activities and protect coral reefs have proven inadequate, spurring calls for a more ecosystem-oriented approach. Central to this ecosystem-oriented approach to coral reef management is the establishment of marine protected areas (MPAs), a family of spatially-explicit marine management systems that includes underwater parks, fishery reserves, and wildlife sanctuaries.

The promise of MPAs as a management tool has yet to be fully realized, in part because the science underlying effective MPA development and management is poorly understood. At the 9th International Coral Reef Symposium (ICRS) in Bali, Indonesia, dozens of scientists and practitioners presented cutting edge research on coral reef MPAs. This report synthesizes the findings from seventy-four ICRS presentations on MPAs and identifies select MPA policy and management implications from this natural and social scientific research.

Presentations at the ICRS underscored the scientific uncertainty that surrounds the biophysical design of MPAs, but provided some basic "rules of thumb" for MPA policymakers. There was general consensus that MPAs should be designated in high quality habitats, either in the midst of ocean gyres or in 'upstream' locations. Results gave little substantive guidance regarding the proper size for a functional MPA, though some interesting hypotheses did emerge. Researchers indicated that MPAs are more likely to function as relatively independent units than interdependent ecological systems, especially over large spatial scales. Biological performance was not correlated with the spatial extent of coral reef MPAs, suggesting that bigger is not necessarily better.

ICRS presentations provided valuable insights into the sociopolitical characteristics of effective coral reef MPAs. Presenters stressed that MPAs are not a panacea, but rather dependent upon the larger matrix of coral reef management initiatives. If adjacent areas are not well managed, MPAs will likely be insufficient to maintain productive coral reef ecosystems. Presenters demonstrated that devolving authority for MPA development and management to local governments, user groups, and nongovernmental organizations spurs MPA establishment and enhances MPA management effectiveness. Collaborative MPA management structures, however, appear to offer the greatest potential for linking national resources with local interests and knowledge.

Presentations regarding MPA regulatory systems identified emerging "best practices". One of the most contentious debates at the ICRS was whether MPAs should be "no-take" or permit limited extractive use. Though there was no resolution on this point (the answer seems to be "it depends on the situation"), presenters did agree that the rules governing resource use within coral reef MPAs must be clear, easily understood, and easily enforceable. Likewise, internal and external MPA boundaries must be easily recognized by resource users and by enforcement personnel.

Presenters generally agreed that MPA decisionmaking must be an adaptive and broadly participatory process. Such processes permit social learning, build on diverse sources of

knowledge, build trust, and enhance the legitimacy of MPA rules and regulations. Exactly *how* and *when* participation should occur was a matter of contention. MPA advisory committees were viewed as one appropriate mechanism for ongoing stakeholder participation in MPA development and management. Presenters emphasized that mechanisms must be established to ensure that stakeholder representatives are accountable and responsive to their constituents. Finally, presenters noted that differences among stakeholders with respect to their beliefs (i.e., perceptions of how the world works), values (i.e., perceptions of what is good, desirable, or just), and interests (i.e., desired outcomes) often hinder MPA development and management, reflecting the need for decision-makers to agree on *process* before trying to decide *outcomes*.

Discussion of the management and administrative dimensions of MPAs was limited at the ICRS. Presenters noted that devolution of authority for enforcement could enhance capacity, and stressed the need to design enforcement systems that promote accountability among enforcers and appropriate (not draconian) penalties for noncompliance with MPA rules and regulations. Presenters suggested that clear management goals and objectives, as well as environmental education and outreach initiatives, facilitate effective MPA management. Research and monitoring were seen as critical components of MPA management, and speakers stressed the importance of monitoring both biological *and* social performance indicators. Speakers also stressed the importance of collecting baseline data, and sampling at multiple spatial and temporal scales, in order to inform site development, measure change over time, and provide the basis for adaptive management. Finally, speakers noted that enlisting stakeholders in the collection and analysis of research and monitoring data educates participants and builds capacity and trust.

During the ICRS, special emphasis was placed upon the role of no-take MPAs in supporting sustainable coral reef fisheries in Southeast Asia. Community participation, sustainable financing, enforcement, planning and design, and adaptive management were identified as five critical challenges to the development and management of MPAs in the region. At an evening workshop sponsored by NOAA, IUCN, and The Nature Conservancy, participants identified priority actions that would enhance MPA management across the region. These priority actions included training in community-based management, a regional inventory of experiences with sustainable financing, the development of model legislation and policy frameworks for decentralized enforcement, a regional assessment of priority sites for no-take MPAs, and the development of adaptive management pilot projects.

Readers of this report should recognize its limitations. The scientific synthesis presented herein is based on the notes of nine volunteers and the author, who used a standard form to characterize seventy-four ICRS presentations most relevant to MPA development and management. The author synthesized these notes into the report summary, and derived policy implications from the report summaries and his personal knowledge of the natural and social scientific literature. These methods may have introduced uncertainties or biases into the report. Furthermore, neither the research upon which this report is based nor this report itself has been peer-reviewed, and therefore this report does not merit the same level of confidence as refereed research.

SECTION I—Introduction

Coral reef ecosystems benefit millions of people around the world. Coral reefs buffer coastal communities against ocean storms, provide a ready supply of animal protein, and harbor organisms with pharmaceutical properties. As the "rainforests of the sea", coral reefs provide esthetic pleasure to tourists and support tourism-based economies. Scientists value reefs as a living laboratory. Some people derive satisfaction from simply knowing that coral reefs exist.

Human activities threaten coral reefs and diminish the benefits that reefs provide to society (Ang 2000; Harriott and Smith 2000; Rogers and Beets 2000; Samarasekara and Sukumaran 2000; Smith et al. 2000). Agriculture and coastal development pollute coastal waters with sediment and nutrients, smothering reefs and spurring growth of macroalgae. Destructive fishing practices, including the use of explosives, poisons, and fine mesh nets, can reduce entire reefs to rubble or leave them virtually devoid of animal life. Overharvesting by fishers and collectors provides short-term benefits at the expense of long-term sustainability. Boat anchors break apart coral colonies and reduce the physical complexity necessary to support the full diversity of reef species. Nonnative organisms, introduced by aquaculture farms or ship-borne ballast, outcompete native reef species and may induce ecological cascades that threaten the integrity of entire reef ecosystems. Natural events, from hurricanes to disease outbreaks, can exacerbate the impact of these human activities.

Marine protected areas—including underwater parks, fishery reserves, wildlife sanctuaries, and the like—are an increasingly popular policy instrument designed to conserve coral reefs and sustain reef benefits for society.¹ Establishment of MPAs has been demonstrated to increase reef fish and invertebrate abundance, biomass, and species richness (Bohnsack et al. 2000; Halpern 2000; White, Christie, and Deguit 2000). Recent evidence suggests that the biological repercussions of MPA establishment tend to occur quickly (within a few years) before leveling off (Halpern 2000). These biological effects are manifest most strongly in areas and among taxa heavily impacted by human activities (Ormond and Galal 2000; Uychiaoco 2000). The socioeconomic impacts of MPA establishment are less well documented and poorly understood, though it is clear that MPAs usually redistribute access to reef resources and thus redistribute wealth in coastal communities (Dobrzynski and Nicholson 2000; Mascia 2000).

Though some coral reef MPAs represent models of sustainable development, many others fail to meet their policy objectives. To design more effective MPAs, the challenge before scientists and policymakers is to understand why some coral reef MPAs succeed and others fail. This report is designed to assist policymakers and managers by synthesizing findings that emerge from the latest scientific studies of coral reef MPAs and identifying select policy and management implications of this research.

This report is based on seventy-four scientific presentations made at the 9th International Coral Reef Symposium (ICRS) in Bali, Indonesia, from October 23-27, 2000 (see Appendix 1). As the

¹ For the purposes of this report, a marine protected area (MPA) is "any area of the intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (IUCN, 1988). Explicit reference is made to "no-take" MPAs (i.e., MPAs where no extractive uses are permitted) when discussions are restricted to this particular category of MPAs.

forum for one of the largest discussions of coral reef MPAs to date, the ICRS presented a valuable opportunity to synthesize current scientific knowledge and derive informed policy prescriptions. Several dozen speakers at the ICRS gave presentations directly related to the development and management of effective coral reefs MPAs, while dozens of others presented cutting-edge science indirectly related to MPA development, management, and performance. Nine volunteers captured data from seventy-four of the presentations of most direct relevant to MPA development and management, using a standardized data collection form (see Appendix 2). The author synthesized these data and derived policy and management implications from this synthesis. While this means of data collection and analysis cannot provide the detail and accuracy of a traditional review of the published scientific literature, it can quickly characterize basic research findings and their policy implications.²

This report includes eight sections and two appendices. Following this introduction, Section II discusses the biophysical dimensions of MPA design. Section III examines the design of MPA governance structures and processes. Sections IV, V, and VI address various aspects of MPA management, including site administration, enforcement, and research and monitoring. Because of the particular emphasis that the ICRS placed upon MPAs in Southeast Asia, Section VII discusses management challenges, best practices, and priority actions for MPAs in the region. The report concludes by noting future research needs. The appendices to this report list the ICRS presentations upon which this report is based and the standard form that volunteers used to record data.

SECTION II—Biophysical Design

Policy Issues

When developing coral reef MPAs, decision-makers face a series of fundamental questions about the biophysical design of a site or series of sites. Where should a MPA be placed? How big should it be? What shape should it have? How many MPAs should be established? How do location, size, shape, and number affect MPA performance?

Numerous scientists addressed these questions at the ICRS. Their collective research provides useful insights for decision-makers.

Where should MPAs be placed?

There was general consensus among scientists that MPAs should be placed in high quality habitat that supports, or has the potential to support, an abundance of marine life (Agardy 2000; Figueira 2000). These productive environments, known as "source" habitats, may enhance the biological productivity of adjacent areas through local migration of adults and longer distance

² As an additional source of insights on the Symposium, the United States Agency for International Development and World Resources Institute are editing a booklet to provide up-to-date information and guidance for managers and policy makers with respect to key coral reef issues, as presented at the Symposium. This synopsis will highlight the management and policy implications on select topics, and include appropriate recommendations for actions at both local and global scales.

larval dispersal (Bohnsack et al. 2000; Figueira 2000; Roberts 2000). Scientists also agreed that MPAs should be strategically placed so that ocean currents either carry larvae onto reef habitat located "downstream" or return larvae to the source MPA through circular ocean gyres (Bohnsack et al. 2000; Roberts 2000).

How big should a MPA be?

A scientific consensus emerged that the proper size for a MPA depends upon the goal of the MPA and the ecology of the relevant species (Agardy 2000; Bohnsack et al. 2000; Roberts 2000). One study suggested that smaller MPAs provide more local fisheries benefits through local migration of adults across MPA boundaries, whereas larger MPAs provide more regional benefits through larval production and recruitment (Roberts 2000). Another study suggested that the optimal size for a MPA intended to provide local fishery benefits is one-to-two times the larval dispersal distance of the target species (Barber and Palumbi 2000).

How many MPAs should be established?

Research presented at the ICRS examined the scientific basis for functionally (i.e., ecologically) interconnected MPA networks. Presenters indicated that larval recruitment is a more localized ecological phenomenon than previously believed, according to both empirical and modeling research (Barber and Palumbi 2000). This research suggests that single MPAs are more likely to sustain themselves over longer periods of time than previously thought. This research also suggests that MPAs are unlikely to sustain each other through long distance larval transport, weakening the scientific rationale for diffuse MPA networks (Barber and Palumbi 2000). One speaker noted that a system of multiple MPAs may be necessary to protect representative habitats (Bohnsack et al. 2000).

What shape should a MPA have?

Little research was dedicated to this question. One researcher suggested that buffer zones may minimize edge effects (Roberts 2000).

Does size, shape, location, or number affect performance?

Two studies directly examined the relationship between biophysical design and MPA performance (Halpern 2000; Uychiaoco 2000). Results suggested that larger MPAs are not necessarily more effective than smaller MPAs. Results also indicate that MPA performance varies by taxa and perhaps by the state of the surrounding environment.

Policy Implications

1. *Place MPAs where they have a chance to work.* High quality habitat is essential for MPAs to conserve marine biodiversity and support sustainable fisheries. MPAs should take advantage of local current patterns, if possible.
2. *Bigger isn't necessarily better.* If well designed and managed, smaller MPAs can provide greater benefits than poorly designed and managed larger MPAs.
3. *It is OK to establish one MPA at a time.* Single MPAs may represent self-sustaining units and therefore may be sufficient to achieve policy objectives.

4. *MPA networks must be dense to be effective.* Because larval dispersal appears to be a more localized phenomenon than earlier recognized, MPAs separated by long distances are unlikely to serve as part of a functionally interconnected whole.

SECTION III—Governance

Policy Issues

Decision-makers face a series of fundamental questions regarding the governance of coral reef MPAs. How should MPAs relate to other coral reef management tools? Who should establish MPAs? Who should manage them? What rules should govern MPA resource use? Who should make these decisions? How does MPA governance affect social and biological performance, if at all?

Presentations at the ICRS indicate that while many scientists and practitioners are concerned with these issues, more research is necessary to answer these questions fully. Important insights can be drawn, however, from the collective experiences that scientists and practitioners shared at the ICRS.

How should MPAs relate to other coral reef management tools?

Scientists and practitioners emphasized that coral reef MPAs must be complemented by other marine resource management efforts (Alino et al. 2000; Chou 2000; Kelleher 2000; Waruinge, Nilsson, and Njunguna 2000). Presenters argued that MPAs should be established as part of an integrated approach to coastal management (Beech 2000; Chou 2000; Kelleher 2000).

Anecdotal evidence suggested that integrated coastal management (ICM) can buffer MPAs against human activities and promote healthy ecosystems outside MPAs themselves (Djohani and Dahuri 2000). The development and management of coral reef MPAs can provide important lessons for decision-makers attempting to design and implement large-scale ICM initiatives (Tissot, Walsh, and Hallacher 2000).

Scientists and practitioners stressed that MPAs are not a panacea (Agardy 2000; Alino et al. 2000; Chou 2000; Kelleher 2000). Presenters argued that responsible management of marine resources found outside MPA boundaries is necessary to conserve marine biodiversity and support sustainable fisheries because MPA effectiveness is linked to the health and management of adjacent coral reef ecosystems (Agardy 2000). Evidence suggests that the more heavily degraded the surrounding environment, the more stringent MPA rules must be to achieve conservation goals and support sustainable fisheries (Bohnsack et al. 2000).

Who should establish MPAs?

Presentations at the ICRS suggest that devolution of authority to communities, resource users, and NGOs fosters establishment of coral reef MPAs (Miller et al. 2000; White, Salamanca, and Courtney 2000). In the Philippines, for example, enabling legislation granted local governments the authority to develop, establish, and manage MPAs. This devolution of authority spurred the establishment of MPAs throughout the country (White, Salamanca, and Courtney 2000).

Researchers also demonstrated that statutes which provide mechanisms for formal MPA designation of informal, culturally-based marine management systems (e.g., traditional marine

tenure systems in the South Pacific) encourage site establishment (Mangubhai and Rupeni 2000). While demonstrating the potential to foster MPA establishment through the devolution of authority and inclusion of previously informal governance arrangements, presenters did not suggest that national governments should relinquish the right to establish MPAs themselves.

Who should manage MPAs?

Presenters suggested that user groups, NGOs, local communities, local governments, and central governments have each demonstrated the ability to govern MPAs effectively (Causey 2000; Crawford and Tulungen 2000; Waruinge, Nilsson, and Njunguna 2000; White, Salamanca, and Courtney 2000; Woodley 2000). In some instances, private organizations may have greater interest in or capacity to manage MPAs than government organizations (Crawford and Tulungen 2000; Waruinge, Nilsson, and Njunguna 2000; Woodley 2000). Locally and privately administered MPAs are particularly vulnerable to changes in leadership that diminish their ability or willingness to manage sites (Gulayan et al. 2000; White, Christie, and Deguit 2000). Evidence suggests that collaborative management systems (co-management) can merge national capacity with local interest and knowledge, overcoming many of the weaknesses of community-based and centrally managed MPAs (Kile et al. 2000).

What rules should govern MPA resources?

No scientific consensus emerged on this topic at the ICRS. Some presenters argued that all MPAs should be "no-take" (i.e., prohibit all extractive uses) (Bohnsack et al. 2000). Others argued that rules governing resource use should be shaped by the goals of the MPA rather than a "one size fits all" no-take policy (Kelleher 2000). Presenters widely viewed MPA zoning as a tool to accommodate the interests of different user groups and to satisfy the conservation requirements of different habitats (Dobrzynski and Nicholson 2000).

Two points were clear from the presentations on this topic at the ICRS. First, presenters stressed that rules governing resource use within MPAs must be clear, easily understood, and easily enforceable (Gulayan et al. 2000; Kile et al. 2000; Mascia 2000). Resource users and enforcement personnel must easily recognize MPA boundaries (internal and external) designated in a culturally appropriate way (e.g., landmarks vs. GPS positions) (Kile et al. 2000; Mascia 2000). Rules governing resource use must assign clear resource use rights so that users know when they are breaking rules and when they are not, and so that compliance can be easily monitored and enforced (Mascia 2000).

Second, MPA decisionmaking must be adaptive (Roberts 2000). It is implausible that the first rules chosen to govern a MPA will be perfect. Even if rules are appropriate when first established, shifting social and biological conditions will likely reduce their efficacy over time. Presenters emphasized that decision-makers must be willing and able to revisit and refine MPA rules governing resource use (Haskell and Delaney 2000; Roberts 2000).

Who should participate in MPA development and management?

Presenters emphasized that MPA development and management should be a broadly participatory process that includes relevant resource user groups, government agencies, and nongovernmental organizations (Dobrzynski and Nicholson 2000; Haskell and Delaney 2000; Kelleher 2000; Tissot, Walsh, and Hallacher 2000). Presenters held different opinions, however, about *how* and *when* participation is necessary (i.e., what *is* a broadly participatory process?). Some presenters argued that all stakeholders should participate relatively equally in MPA

decisionmaking in all phases of development and management (Kile et al. 2000). Other presenters were more cautious, suggesting that the participation of resource users and nongovernmental organizations be limited to a consultative role regarding site boundaries and resource use rules (Garrison et al. 2000).

Presenters agreed on several specific points regarding MPA decisionmaking processes. First, participatory decisionmaking is a time consuming process with short-term costs and long-term benefits (Kelleher 2000). Second, resource users can provide valuable information that substantively improves MPA design (Kile et al. 2000; Roberts 2000). Local ecological knowledge, for example, can aid in the selection of MPA boundaries and use zones. Third, stakeholder participation in the development of MPA rules can dramatically enhance the legitimacy of these rules in the eyes of affected individuals (and thus increase compliance) (Mascia 2000; Woodley 2000). Resource users are more likely to follow, and government agencies are more likely to enforce, rules that each helped to write. Fourth, mechanisms must be established to make stakeholder representatives responsive and accountable to their constituent groups (Dobrzynski and Nicholson 2000). This ensures that individuals represent the interests of their constituent group rather than their own personal interests. Fifth, differences among stakeholders with respect to their beliefs (i.e., perceptions of how the world works), values (i.e., perceptions of what is good, desirable, or just), and interests (i.e., desired outcomes) often hinder MPA development and management (Miller et al. 2000; Woodley 2000).

How should decisions be made?

Multiple speakers suggested that clearly defined and mutually agreed upon decisionmaking criteria facilitate subsequent decisions (Grober-Dunsmore and Ridgely 2000; Haskell and Delaney 2000; Miller et al. 2000). In Hawaii, for example, the development of rules governing *how* the location of 'no-take' MPAs would be chosen (e.g., only coral reefs more than ten miles away from a fishing community could be considered for no-take status³) simplified subsequent selection of these areas (Grober-Dunsmore and Ridgely 2000). Speakers also emphasized that the rules that govern decisionmaking can substantially affect the outcome of these decisionmaking processes (Grober-Dunsmore and Ridgely 2000). Different voting systems (e.g., consensus vs. majority decisionmaking), for example, can dramatically affect the nature of group decisions.

How does MPA governance affect performance, if at all?

Little scientific research directly addressed this question. One study suggested that clear resource boundaries, clear resource use rights, participatory decisionmaking processes, and resource use rules explicitly linked to local conditions are positively correlated with MPA performance (Mascia 2000). Another study suggested that the "level of democracy" in a community is positively correlated with the performance of community-based MPAs in the Philippines (Pollnac, Crawford, and Gorospe 2000).

Policy Implications

1. *MPAs are just part of the story.* As one of many coral reef management tools, MPAs should be designed to complement existing fisheries management and integrated coastal

³ The example in parentheses is hypothetical.

management initiatives. MPAs alone may be insufficient to conserve biodiversity and support productive and sustainable fisheries.

2. *Use MPAs as policy experiments.* Lessons learned from MPA development and management initiatives can inform fisheries policy and coastal management.
3. *Devolve authority for MPA establishment.* National governments can stimulate development and establishment of MPAs by sharing their authority to designate MPAs with local governments, NGOs, and resource users.
4. *The best MPA managers aren't necessarily government officials.* Delegating full responsibility for MPA management to NGOs, user groups, or local communities can enhance site effectiveness.
5. *Consider co-management.* Shared responsibility for MPA management can build upon government capacity and local interests, knowledge, and legitimacy.
6. *Good rules are clear rules.* Clear MPA boundaries and clear rules governing MPA resource use facilitate compliance and simplify enforcement.
7. *Decisionmaking should be adaptive.* If a MPA is not meeting its policy objectives, decision-makers should not hesitate to revise the rules governing MPA resource use and decisionmaking in an effort to enhance performance.
8. *Encourage participatory decisionmaking.* Bringing diverse stakeholder groups into MPA decisionmaking processes can improve the substance and legitimacy of these decisions.
9. *Stakeholder representatives must be accountable to their constituents.* To ensure that representatives represent constituent interests rather than their own, mechanisms should be established to make representatives accountable to their constituents. Accountability-enhancing mechanisms include elections, consultative sessions, and open meetings.
10. *Decide on process before deciding on substance.* Identifying basic rules and criteria for decisionmaking (i.e., process guidelines) before attempting to make substantive choices about MPA rules and regulations may help to reduce conflict and facilitate informed choices. Process guidelines can help to overcome differences in beliefs, values, and interests among diverse stakeholders.
11. *Governance matters.* Governance variables shape MPA performance, so investing time and energy in "getting governance right" is worth the effort.

SECTION IV—Enforcement

Management Issues

Though it was widely recognized that enforcement is critical to MPA performance, few presentations at the ICRS dealt with the enforcement of MPA rules and regulations. As a result, it is only possible to make a few simple observations.

Who should enforce MPA rules and regulations?

Presenters noted that, in addition to government officials, resource users and local community members can effectively enforce MPA rules and regulations (De Meyer 2000; Foale, Rebi, and Hite 2000; Mascia 2000; White, Salamanca, and Courtney 2000; Woodley 2000). Community-based enforcement may not be sufficient to address large scale threats, however, underlining the need for partnerships and collaborative enforcement (Mous, Muljadi, and Pet 2000; Pajaro et al. 2000). Regardless of who is charged with enforcement of MPA rules, research suggests that enforcers must be accountable to resource users (Mascia 2000).

What form should enforcement take?

Evidence suggested that effective enforcement can include notification and education of violators as well as more traditional mechanisms such as warnings, fines, and incarceration (Woodley 2000). Research indicated that penalties for noncompliance should be graduated (e.g., increase with the severity of the offense) and context-dependent (e.g., penalties in the aftermath of relatively extreme poverty might be less severe than penalties during a time of relative prosperity), in order to ensure that punishment fits the crime (Mascia 2000).

Management Implications

1. *Shared enforcement is better enforcement.* Enlisting the aid of resource users and others in MPA enforcement efforts will enhance enforcement capacity and likely increase compliance with MPA rules and regulations.
2. *Accountable enforcement is better enforcement.* Establishing mechanisms to ensure that enforcement personnel are accountable for their actions will foster more fair and active enforcement of MPA rules and regulations.
3. *Make punishment fit the crime.* Excessive penalties for noncompliance undermine the legitimacy of the enforcement system and encourage further noncompliance.

SECTION V—Site Administration

Management Issues

Numerous presenters used anecdotal evidence to discuss elements of MPA administration. Several important themes emerged from these presentations.

First, presenters suggested that broadly representative MPA advisory committees enhance management effectiveness (Galvis 2000). Like other participatory mechanisms, advisory committees can provide substantive insights into site development and management (Haskell and Delaney 2000). Likewise, advisory committees can enhance the legitimacy of management activities in the eyes of represented stakeholder groups (Haskell and Delaney 2000).

Second, presenters suggested that clear management goals and objectives facilitate effective MPA management (Cadwallader 2000). Ranking threats to the achievement of management

goals is one way to identify priority MPA management activities (Chadwick 2000). Because management goals are value-based, however, selecting management goals and making them operational can be a contentious process (Cadwallader 2000). Compromise in pursuit of a MPA's primary objective is a robust management strategy (Kelleher 2000).

Third, presenters noted that the leadership and integrity of a MPA manager are individual attributes that foster effective management (Kelleher 2000).

Fourth, presenters noted that management plans require different levels of specificity at different spatial scales (Skeat et al. 2000).

Management Implications

1. *Establish advisory committees.* The guidance of broadly representative advisory groups enhances MPA effectiveness through improved decisionmaking and legitimacy.
2. *Set goals and rank threats.* Setting goals and ranking the threats to achieving these goals facilitates identification and prioritization of necessary management responses.
3. *Be honest.* Trust is an essential component of participatory decisionmaking, so MPA personnel must lead the way towards building trust among diverse stakeholders by maintaining their honesty and integrity.

SECTION VI—Education, Financing, and Research and Monitoring

Management Issues

Researchers at the ICRS alluded to the importance of environmental education as the precursor to public awareness and support for coral reef MPAs and other management initiatives. While there was no discussion of "best practices" in environmental education, researchers did identify a handful of specific educational activities that had been successful in their individual experiences. Two well recognized strategies were mentioned: site visits to other MPAs and involving stakeholders in research and monitoring activities (Crawford and Tulungen 2000; van Lavieren 2000; Waruinge, Nilsson, and Njunguna 2000). Habitat mapping was also mentioned as a way to raise awareness among stakeholders (Alino et al. 2000).

Despite the widely acknowledged importance of financing to the efficacy of large-scale MPAs, there was little discussion of this topic at the ICRS. One presenter did note that user fees can support MPA management (De Meyer 2000). Another presenter noted that financial sustainability must be considered at the earliest stages of MPA development (Kelleher 2000).

Several presentations at the ICRS alluded to the importance of research and monitoring within MPAs, though few presenters gave substantive suggestions for improving research and monitoring activities. Speakers stressed the importance of collecting social and biological baseline data as the basis for informed MPA site development, rigorous measurement of site

performance, and adaptive management (Dobrzynski and Nicholson 2000; Haskell and Delaney 2000). Speakers also emphasized the importance of collecting data at ecologically and socially relevant spatial and temporal scales in order to measure MPA performance over time (Lincoln Smith et al. 2000). Modeling was seen as a useful tool for generating predictions and testable research hypotheses, complementing empirical research. Presenters stressed the need to share research results with stakeholders and, if possible, make research and monitoring participatory activities that include relevant stakeholder groups (van Lavieren 2000).

Management Implications

1. *Educate.* Use whatever creative means possible to share information regarding coral reefs and coral reef MPAs. Mechanisms for educating the public include trips to other MPAs, participatory research and monitoring, and public information sessions.
2. *Collect social and biological baseline data.* Baseline data can enhance MPA effectiveness by informing the design of both biophysical and governance systems. The presence of social and biological baseline data also permit more accurate measurement of MPA performance.
3. *Measure both biological and social performance.* MPAs usually have both biological (e.g., maintain viable fish stocks) and social (e.g., enhance livelihoods of fishermen) objectives, so it is critical to measure both biological and social performance indicators in order to evaluate MPA effectiveness over time.
4. *Sample wisely.* Data must be gathered at socially and ecologically relevant temporal and spatial scales in order to inform adaptive MPA management.
5. *Share the results.* Sharing research results with stakeholders informs, educates, and builds trust.
6. *Make research and monitoring participatory.* Enlisting stakeholders in data collection and analysis educates participants, builds capacity, and fosters trust.

SECTION VII—MPAs in Southeast Asia

At the ICRS, special emphasis was given to MPAs in Southeast Asia, particularly the relationship between 'no-take' MPAs and sustainable fisheries. Twelve presentations focused on no-take MPAs in Southeast Asia as part of the minisymposium *Designing Effective Coral Reef MPAs: Lessons Learned across the Sciences and around the World*, and numerous other presentations in other minisymposia also discussed MPAs in the region. Rili Djohani, Chair of the Working Group of Southeast Asia, World Commission on Protected Areas-Marine (WCPA-Marine), facilitated an evening workshop to discuss challenges, opportunities, and priority actions for no-take MPAs in the region. More than forty MPA practitioners and other experts attended this workshop, which was sponsored by NOAA, IUCN, and The Nature Conservancy.

Five issues emerged from these presentations and discussions as pivotal to effective MPA development and management in Southeast Asia: community participation, financing, enforcement, planning and design, and adaptive management. At the evening workshop, participants identified numerous mechanisms for addressing these challenges, with particular emphasis upon actions relevant to no-take MPAs that support sustainable fisheries.

Workshop participants identified four priority actions to enhance community participation in MPA development and management in Southeast Asia. Participants identified training in community-based management, including facilitation training, as the single greatest priority. Research into renewable resource use and the development of alternative livelihoods, gender-sensitive training for resource users and managers in integrated coastal management, and broad-based environmental education materials were also deemed priority actions at the regional level.

With respect to financing, workshop participants identified a suite of regional priorities. Foremost among these was the development of a regional inventory of experiences with sustainable financing. Participants also emphasized the need to build links between individual MPAs, WCPA-Marine Southeast Asia, and key financial organizations. Participants suggested that pilot activities could benefit the entire region by providing a proving ground for legislative frameworks and revenue generating mechanisms such as value-added services and products, user fees, and incentive-based conservation activities.

With respect to enforcement, workshop participants identified three priority actions. The greatest single need identified was the development of model legislation and policy frameworks for decentralization of enforcement. Staff exchanges (e.g., rangers, managers, etc.) and broad-based education and training workshops were also identified as regional priorities. Workshop participants also noted the need to promote the ASEAN agreement on nature conservation and to develop model legal, policy, and management protocols to overcome constraints at regional and national levels.

Participants identified three priority actions for Southeast Asia with respect to MPA planning and design. Most important was a comprehensive regional assessment to determine site locations for no-take MPAs that would support sustainable fisheries. Participants suggested that this could be done through a workshop of regional experts and an interdisciplinary review of existing data. Second, workshop participants proposed development of a regional inventory of information on MPAs and management effectiveness. Third, participants suggested that preparation and dissemination of practical guidelines for the design of no-take MPAs was a regional priority. Other regional actions identified by participants included lobbying, research on MPA design, and research on ecological connectivity.

Finally, with respect to adaptive management, workshop participants identified several regional priorities. The development of pilot projects, general training workshops, and a workshop on performance indicators and analysis were identified as the major priorities for furthering adaptive management in the region. Other possible regional actions included the development of an adaptive management "report card" for individual MPAs in the region, cross-site visits, formation of an advisory committee of scientific and practitioner experts, and dissemination of adaptive management "success stories" throughout the region.

SECTION VII—Conclusions

As the forum for one of the largest collection of talks on MPAs to date, the ICRS presented a unique opportunity to review cutting-edge science and derive science-based policy prescriptions. Though presentations at the ICRS demonstrate how far the science of MPAs has come, it also demonstrates how far the natural and social sciences still need to go. In the future, policymakers would benefit from analytical studies with large samples that attempt to explain general MPA phenomena or provide robust policy prescriptions. With focus on key policy questions, the natural and social sciences can contribute to the development of informed MPA policy and management initiatives.

Readers of this report should recognize its limitations. The scientific synthesis presented herein is based on the notes of nine volunteers and the author, who used a standard form to characterize seventy-four presentations given at the ICRS. The author synthesized these notes into the report summary, and derived policy implications from the report summaries and his personal knowledge of the natural and social scientific literature. These methods may have introduced uncertainties or biases into the report. Furthermore, neither the research upon which this report is based nor this report itself has been peer-reviewed, and therefore this report does not merit the same level of confidence as refereed research. Accordingly, the research syntheses and policy implications outlined in this report are best viewed as "working hypotheses" subject to revision or rejection.

Working hypotheses are clearly better than no hypotheses, however. Some of the policy prescriptions detailed in this report are little more than common sense. Others are counterintuitive. All are designed to inform and to guide decision-makers in their efforts to design and manage more effective coral reef MPAs, thereby conserving reef ecosystems and supporting sustainable fisheries.

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Appendix 2. Data Recording Forms

PLEASE PROVIDE BASIC INFORMATION ABOUT THE PRESENTATION HERE:

Minisymposium Number:

Presentation Title:

Presentation Author(s):

Research Location (state, country, etc.):

PLEASE DESCRIBE THE PRESENTATION HERE:

1. What was the **research question** that the presentation tried to answer?
2. What was the **research design** for this study? (e.g., single case study v. comparative case study v. modeling; data collection methods; etc.)
3. What were the **principal results** or findings of this study?
4. What were the **conclusions** (e.g., “lessons learned”, management/policy implications) of this study?
5. What **future research needs** (i.e., “unanswered questions”) did the presenter identify?

