Establishing Representative No-Take Areas in the Great Barrier Reef: Large-Scale Implementation of Theory on Marine Protected Areas

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Abstract: *The Great Barrier Reef Marine Park, an area almost the size of Japan, has a new network of no-take areas that significantly improves the protection of biodiversity. The new marine park zoning implements, in a quantitative manner, many of the theoretical design principles discussed in the literature. For example, the new network of no-take areas has at least 20% protection per "bioregion," minimum levels of protection for all known habitats and special or unique features, and minimum sizes for no-take areas of at least 10 or 20 km across at the smallest diameter. Overall, more than 33% of the Great Barrier Reef Marine Park is now in no-take areas (previously 4.5%). The steps taken leading to this outcome were to clarify to the interested public why the existing level of protection was inadequate; detail the conservation objectives of establishing new no-take areas; work with relevant and independent experts to define, and contribute to, the best scientific process to deliver on the objectives; describe the biodiversity (e.g., map bioregions); define operational principles needed to achieve the objectives; invite community input on all of the above; gather and layer the data gathered in round-table discussions; report the degree of achievement of principles for various options of no-take areas; and determine how to address negative impacts. Some of the key success factors in this case have global relevance and include focusing initial communication on the problem to be addressed; applying*

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the precautionary principle; using independent experts; facilitating input to decision making; conducting extensive and participatory consultation; having an existing marine park that encompassed much of the ecosystem; having legislative power under federal law; developing high-level support; ensuring agency priority and ownership; and being able to address the issue of displaced fishers.

Key Words: biophysical operational principles, cultural operational principles, economic operational principles, reserve-design software, social operational principles

Establecimiento de Áreas sin Captura Representativas en la Gran Barrera Arrecifal: Implementación a Gran Escala de la Teoría sobre Áreas Marinas Protegidas

Resumen: *El Parque Marino Gran Barrera Arrecifal, con una superficie casi del tamaño de Japón, tiene una red de áreas sin captura que incrementa la protección de la biodiversidad significativamente. La nueva zonificación en el parque marino implementa, de manera cuantitativa, muchos de los principios teóricos de diseño discutidos en la literatura. Por ejemplo, la nueva red de áreas sin captura tiene niveles mínimos de protección de por lo menos 20% de protección por "bioregión" en todos los hábitats y rasgos especiales o únicos conocidos, y tamaños mínimos para las áreas sin captura de por lo menos 10 o 20 km en el diámetro menor. En general, más de 33% del Parque Marino Gran Barrera Arrecifal está en áreas sin captura (4.5% anteriormente). Los pasos hacia este resultado fueron clarificar al público interesado porque el nivel de protección era inadecuado; detallar los objetivos de conservación al establecer nuevas áreas sin captura; trabajar con expertos relevantes e independientes para definir, y contribuir a, los mejores procesos científicos para reforzar a los objetivos; describir la biodiversidad (e.g., elaborar mapas de bioregiones); definir principios operacionales requeridos para cumplir con los objetivos; invitar a la participación de la comunidad en todo lo anterior; reunir y clasificar los datos obtenidos en discusiones en mesas redondas; reportar el grado de logro de principios para varias opciones de áreas sin captura; y determinar como atender a los impactos negativos. Algunos de los factores clave en el éxito de este caso tienen relevancia global e incluyen el enfoque de la comunicación inicial en el(los) problema(s) a resolver; aplicación del principio precautorio; utilización de expertos independientes; facilitación de insumos a la toma de decisiones; realización de consultas extensivas y participativas; haber contado con un parque marino preexistente que comprende la mayor parte del ecosistema; tener poder legislativo bajo ley federal; desarrollar soporte de alto nivel; garantizar prioridad y propiedad de la agencia y tener la capacidad para atender el asunto de los pescadores desplazados.*

Palabras Clave: principios operacionales biofísicos, principios operacionales culturales,principios operacionales económicos, principios operacionales sociales, software para diseño de reservas

Introduction

The value of coral reefs to the global community is estimated to be in the billions of dollars and is derived through provision of goods and services such as food (including fish), coastal protection, recreation, tourism, and wider ecosystem maintenance (Costanza et al. 1998). The net present value of tourism on the Great Barrier Reef alone was estimated to be US$18–40 billion (Carr & Mendelsohn 2003). Such values cannot be maintained if the ecosystem on which they are based declines in health (Cesar 2000; Carr & Mendelsohn 2003).

Globally, coral reef ecosystems are in decline (Wilkinson 2002; Pandolfi et al. 2003), and efforts to find conservation solutions are increasing. Many have advocated the application of no-take areas: setting aside areas of the marine environment protected from extractive activities such as fishing (Kelleher et al. 1995; Hughes et al. 2003). Some authors have offered guidance on implementing networks of no-take areas (e.g., Sala et al. 2002; Lubchenco et al. 2003; World Parks Congress 2003). Despite this, there have been few real successes in systematic implementation of adequate and representative networks of no-take areas to date (Airamé et al. 2003). Diverse national, cultural, political, and economic obstacles may impede establishing large no-take reserves (Christie et al. 2003), raising the specter that calls for protection of 30–50% of marine habits may be unachievable.

Here we discuss success factors that led to establishing a large, comprehensive, adequate, and representative network of no-take marine protected areas. The authors include managers, planners, and scientists that contributed to the establishment of the new network of no-take areas. The network contains at least 20% of all described "bioregions" in the 344,400 km^2 Great Barrier Reef Marine Park (GBRMP) off eastern Australia and includes 33% of the area overall. This park covers an area bigger than the United Kingdom and Ireland combined or about 85% the area of California. Although state-of-the-art technology and relatively good data were used to establish the GBRMP, neither was perfect or necessary to implement the conceptual approach underpinning the protective system finally adopted. We discuss the main steps in the process applied in the GBRMP as a case study of successfully implementing an extensive system of no-take reserves in a wealthy developed nation and explore what lessons might be learned from this case for implementation in other countries.

Defining the Problem

A review of one section of the GBRMP in the early 1990s generated an awareness at the GBRMP Authority that the amount and distribution of no-take protected areas throughout the park were most likely inadequate to ensure protection of the entire range of marine biodiversity in the park. The Great Barrier Reef ecosystem, like others around the world (Hughes et al. 2003; Jackson et al. 2003), is facing increasing pressures from diverse impacts, including increasing numbers of park users as a result of growth in population and visitor numbers; an increased range of uses; easier human access to wider areas of the park; improved fishing technology that could amplify fishing impacts; increasing competition for use, including extractive and nonextractive uses; increased pollution from longstanding and expanding onshore activities, including agriculture and urbanization; increased vessel traffic; and climate change, including ocean warming.

At the time of the review, 4.5% of the marine park was protected in no-take areas and more than 80% of this area protected only one habitat type in the ecosystem: coral reefs. Yet other habitats interlinked with coral reefs constitute 94% of the park (e.g., seagrass beds, algal or sponge gardens, sandy or muddy seabed communities, and deep ocean trenches). Seventy biophysically distinct "bioregions" have been identified within the park. The bioregions were defined based on a range of inputs, including biophysical data, existing regionalizations, and external, independent expert advice (B. K. et al., unpublished data; Day et al. 2002). We used these bioregions as the major planning units, rather than habitats, to ensure that every part of the park was considered for protection. Few data on species or habitat distribution were comprehensive, and a bioregional approach based on available species and habitat data militated against merely protecting sampling sites where data showed that particular habitats or species exist (Ward et al. 1999; Pressey 2004).

We assessed the adequacy of the existing level of protection and found flaws that placed the system at risk; for example, only 19 of these bioregions had more than 15% of their area protected within existing no-take reserves, 14 bioregions had 0 no-take areas, and only 1 of 135 no-take areas was of adequate minimum size (i.e., > 20 km across) (Day et al. 2002). (The reasoning for a minimum size requirement is described under the explanation of the first biophysical operational principle in Table 1).

Table 1. Biophysical operational principles to help achieve the ecological objectives of the Representative Areas Program.[a]

Operational principle	*Explanation*
Ensure local integrity: no-take areas (NTAs) should be at least 20 km long on the smallest dimension (except for coastal bioregions)[b]	Although NTAs may be of various shapes and sizes, 20 km should be the minimum distance across any NTA to ensure that the size of each area is adequate to provide for the maintenance of populations of plants and animals within NTAs and to ensure against edge effects resulting from use of the surrounding areas.
Maximize amount of protection: maximize amount of protection larger (vs. smaller) NTAs have	For a given amount of area to be protected, protect fewer, larger areas rather than more, smaller areas, particularly to minimize edge effects resulting from use of the surrounding areas. This principle must be implemented in conjunction with the third principle.
Replicate: have sufficient NTAs to ensure against negative impacts on some part of a bioregion	*Sufficient* refers to the amount and configuration of NTAs and may be different for each bioregion depending on its characteristics. For most bioregions, 3–4 NTAs are recommended to spread the risk against negative human impacts affecting all NTAs within a bioregion. For some very small bioregions fewer areas are recommended,[c] whereas for some very large or long bioregions, more NTAs are recommended.[c]
Avoid fragmentation: where a reef is incorporated into NTAs, whole reef should be included	Reefs are relatively integral biological units with a high level of connectivity among habitats within them. Accordingly, reefs should not be subject to "split zoning" so that parts of a reef are no-take and other parts are not.
Set minimum amount of protection: represent a minimum amount of each reef bioregion in NTAs	In each reef bioregion, protect at least 3 reefs with at least 20% of reef area and reef perimeter included in NTAs. The number and distribution of NTAs per bioregion are described in the third principle.

continued

Table 1. (continued)

Operational principle	*Explanation*
Set minimum amount of protection: (a) represent a minimum amount of each reef bioregion in NTAs	In each reef bioregion, protect at least 3 reefs with at least 20% of reef area and reef perimeter included in NTAs. The number and distribution of NTAs per bioregion are described in the third principle.
(b) represent a minimum amount of each nonreef bioregion in NTAs	In each nonreef bioregion, protect at least 20% of area. See footnote for special provisions that apply to the two coastal bioregions,[c] which contain finer-scale patterns of diversity because of bays, adjacent terrestrial habitat, and rivers.
Maintain geographic diversity: represent cross-shelf and latitudinal diversity in the network of NTAs	Many processes create latitudinal and longitudinal (cross-shelf) differences in habitats and communities within the Great Barrier Reef World Heritage Area. This diversity is reflected partly in the distribution of the bioregions, but care should be taken to choose NTAs that include differences in community types and habitats that cover wide latitudinal or cross-shelf ranges.
Represent all habitats: represent a minimum of each community type and physical environment type in the overall network[d]	This principle is to ensure that all known communities and habitats within bioregions are included in the network of NTAs. Communities and habitats were identified for protection in no-take areas based on the reliability and comprehensiveness of available data. Habitat-specific objectives[d] help implement this principle, which is intended to ensure that particularly important habitats are adequately represented in the network of NTAs.
Apply all available information on processes: maximize use of environmental information to determine the configuration of NTAs to form viable networks	The network of areas should accommodate what is known about migration patterns, currents, and connectivity among habitats. The spatial configurations required to accommodate these processes are not well known and expert review of candidate networks of areas will be required to implement this principle.
Protect uniqueness: include biophysically special/unique places	These places might not otherwise be included in the network but will help ensure that the network is comprehensive and adequate to protect biodiversity and the known special or unique areas. Aim to capture as many biophysically special or unique places as possible.
Maximize natural integrity: include consideration of sea and adjacent land uses in determining NTAs	Past and present uses may have influenced the integrity of the biological communities and planners consider these effects, where known, when choosing the location of NTAs. For example, existing NTAs and areas adjacent to terrestrial national parks are likely to have greater biological integrity than areas that have been used heavily for resource exploitation.

[a] *See also www.gbrmpa.gov.au for information on the principles, including references.*

[b] *For coastal bioregions: coastal-strip sand (NA1), protect at least six NTAs, each at least 10 km long, spaced approximately 70–100 km apart (bioregion approximately 800 km long); for high-nutrient coastal strip (NA3), at least eight NTAs, each at least 10 km long, spaced approximately every 70–100 km apart (bioregion approximately 1400 km long).*

[c] *These Great Barrier Reef bioregions are excepted: Capricorn-Bunker Mid-Shelf Reefs (RCB2)—include one of the inner two and one of the outer two reefs. This exception exists because RCB2 has only four reefs: deltaic reefs (RA1)—minimum 25% and minimum 15 reefs in one continuous area (exception exists because bioregion is too small for multiple NTAs); high continental island reefs (RHC)—20% of reef perimeter only (exception exists because reef perimeter makes more biological sense for fringing reefs); and central open lagoon reefs (RF2)—3 reefs (very few reefs in this bioregion).*

[d] *Data and objectives to implement the seventh principle:* Halimeda *beds—ensure that NTAs represent 10% of known beds; shallow-water seagrass—ensure that NTAs represent 10% of shallow-water seagrass habitat; deepwater seagrass—ensure that NTAs represent 10% of known deepwater seagrass habitat; algae—ensure that NTAs represent 10% of known algal habitat; epibenthos—ensure that NTAs represent different faunal classes (5% each of echinodermata, sponges, bryozoans, solitary corals, soft corals, foraminifera, brachyura); dugong—ensure that NTAs represent identified dugong habitat areas summing to about 50% of all high-priority dugong habitat; cays—where cays exist within a bioregion, try to include at least two examples of them in potential NTAs; reefs size—capture 5% of reef area in each of five reefsize classes; interreef channels—capture at least one interreef channel in bioregions where they exist; exposure—ensure the entire network captures 5% of reef and nonreef area in each of five wave-exposure classes; islands—where islands exist within a bioregion try to include one example of them in NTAs; oceanographic diversity in water quality—ensure representation of reefs within the natural diversity of water quality (5% of reef and nonreef area in each of nine oceanographic bioregions; 5% of reef and nonreef area in each of four flood frequency classes); adjacent coastal and estuarine habitats (including islands)—locate NTAs adjacent to mangroves, wetlands, and protected areas rather than adjacent to suburbs; and major turtle sites—ensure that NTAs include known major turtle nesting and foraging sites (100% of about 30 sites of the 115 identified—these include both nesting sites and foraging sites).*

Designing a Solution

In response to the recognized inadequacy of existing protection, the GBRMP Authority initiated the Representative Areas Program as a basis for rezoning the park (Day et al. 2002). A first step was to establish an independent Scientific Steering Committee, with expertise in the Great Barrier Reef ecosystem and in its biophysical processes (Table 2). The committee was convened to define operational principles to guide the development of a comprehensive, adequate, and representative network of no-take areas in the park (Table 1).

The principles presented in Table 1 were designed to help achieve the following objectives: maintain biological diversity of the ecosystem, habitat, species, population, and genes; allow species to evolve and function undisturbed; provide an ecological safety margin against human-induced impacts; provide a solid ecological base from which threatened species or habitats could recover or repair themselves; and maintain ecological processes and systems (L.F., unpublished data; Great Barrier Reef Marine Park Authority 2002). The principles in Table 1 were "operational" in that they provided a sufficient level of detail to be implemented in the marine environment.

These principles were developed in a series of meetings and to meet specific management objectives for the Great Barrier Reef ecosystem. They refer to minimum amounts of protection; none of these recommendations is for ideal or desired amounts. Of these minimum recommendations, the experts gave priority to minimum levels of protection per bioregion. The principles were not further prioritized but the experts recommended they be treated collectively, as a package. The Scientific Steering Committee explicitly stated, however, that ideal or desired amounts of no-take areas required for full protection were likely to be greater than indicated by the biophysical operational principles (Great Barrier Reef Marine Park Authority 2002).

The social, economic, cultural, and management feasibility operational principles were developed by the Social, Economic, and Cultural Steering Committee in a series of meetings (Table 3) (Great Barrier Reef Marine Park Authority 2002). These principles address the user and interest groups that have a stake in the management of the GBRMP. These principles applied, as much as possible, to the Representative Areas Program and were subject to the biophysical operational principles. The expertise of this committee was very different from that of the Scientific Steering Committee (Table 2).

Discussing the Problems and Solutions

Starting in 1999, the GBRMP Authority carried out extensive informal communications with stakeholders to discuss the concept of protecting representative areas of each habitat (or bioregion) in the park as no-take areas.

Table 2. Expertise and affiliations of the steering committees charged with guiding the scientific, social, economic, communications, and management feasibility aspects of the Representative Areas Program.

Area of expertise	*Organization*
Scientific Steering Committee	
soft seabed benthos	Commonwealth Scientific and Industrial Research Organisation
seagrasses/epibenthos	Queensland Department of Primary Industries
modeling/statistics	CRC Reef Research Centre
dugong, marine mammal	School of Tropical Environment Studies & Geography, James Cook University
reef and pelagic fish	Australian Institute of Marine Science, CRC Reef Research Centre
coral reefs	Australian Institute of Marine Science
stateside counterpart	Division of Planning and Research, Queensland Parks and Wildlife Service
fishing impacts/design issues	CRC Reef Research Centre
reserve design	Institute for Regional Development, University of Western Australia
Social, Economic, Cultural Steering Committee	
Scientific Steering Committee member (for overlap)	School of Tropical Environment Studies & Geography, James Cook University
day-to-day management	Boating and Fisheries Patrol, Queensland Department of Primary Industries
commercial fisheries	Queensland Seafood Industry Association
heritage values	Commissioner, Australian Heritage Commission
tourism, recreation and public perceptions/values	Department of Tourism, James Cook University
social impact assessment	Centre for Resource and Environmental Studies, Australian National University
indigenous values/use	Aboriginal Coordinating Council
stateside counterpart	Division of Planning and Research, Queensland Parks and Wildlife Service
conservation values/nonuse values	World Wildlife Fund

Table 3. Social, economic, cultural, and management feasibility operational principles to help maximize positive and minimize negative impacts on people's uses and values in implementing the Representative Areas Program.

Operational principle	*Explanation*
Complement human uses and values: maximize complementarity of no-take areas with human values, activities, and opportunities	place no-take areas in locations that have been identified through a consultative process which is participatory, balanced, open, and transparent; that traditional owners have identified as important and in need of high levels of protection; that minimize conflict with indigenous people's aspirations for their sea country; that the community identifies as special or unique (e.g., places of biological, cultural, aesthetic, historic, physical, social, or scientific value); that minimize conflict with noncommercial extractive users such as recreational fishers; that minimize conflict with commercial extractive users; that minimize conflict with all nonextractive users
Consider all costs and benefits: ensure that final selection of no-take areas recognizes social costs and benefits	include recognition of relative social costs and benefits, including community resilience; spatial equity of opportunity within and between communities, including clan estates; planned and approved future activities; and requirements for monitoring the effectiveness of the new zoning plan
Recognize management and tenure arrangements: maximize placement of no-take areas in locations that complement and include present and future management and tenure arrangements	include existing or proposed zoning plans, management plans, or other related management strategies for marine areas by federal, state, or local government authorities; existing or proposed tenure and management strategies for coastal areas (mainland and islands) in the region; and Native Title claim areas and issues
Maximize user compliance: maximize public understanding and acceptance of no-take areas and facilitate enforcement of no-take areas	have no-take areas that have simple shapes; have boundaries that are easily identified; and are fewer and larger rather than more and smaller

Specifically, they discussed the various phases of the Representative Areas Program:

(1) classification, describes the biological diversity of the entire park;
(2) review, evaluates the adequacy of the existing network of no-take areas;
(3) identification, identifies potential networks of no-take areas that achieve the biological objectives of the rezoning process;
(4) selection, integrates social, economic, cultural, and management factors into development of potential networks to maximize beneficial and minimize detrimental impacts;
(5) draft zoning, invites public comment on a draft zoning plan that displays the proposed new zoning, including the recommended network of no-take areas;
(6) final zoning; and
(7) monitoring, monitors effectiveness of the new zoning plan.

These phases overlapped and ran concurrent with extensive public consultation to bring information into the decision-making process as well as to deliver information about the program. A new zoning plan was the tool that delivered the outcomes of the Representative Areas Program. The entire process, excluding the monitoring program, took about 6 years (Day et al. 2003).

Shortly after beginning these communications, it became clear that the community understanding of the range of threats to the GBRMP was generally poor; therefore, support for and interest in a possible solution were low. Accordingly, the GBRMP Authority initiated a campaign to raise awareness of the threats. The lesson learned was that introducing a solution without clarifying the problem would not work.

During these informal discussions, feedback was explicitly sought on the proposed bioregions. This aspect of the communications was successful. It helped build more robust and justifiable bioregions and involved the community, via a nonconfrontational mechanism (that is, describing the bioregions), in building the foundations of a representative network of no-take areas. The process helped build a greater understanding and ownership of the issues, the underlying concepts, and the rezoning process.

During the first formal community participation phase, the principles were made public and the GBRMP Authority asked people to say where they would and would not like to have new no-take areas and to provide comment on any other aspect of park zoning. The coupling of biological and social principles with other available information was useful in the communication and subsequent planning and negotiation stages. The approach of layering all available biophysical, social, and economic information to develop, as far as possible, positive outcomes for all was largely well received.

Reserve-Design Software for Decision Support

Sala et al. (2002) discuss the theoretical application of reserve-design software that was used for the Great Barrier

Reef and the Channel Islands, California. The software allows multiple sets of data and multiple objectives and social costs to be considered simultaneously to derive various, relatively optimal, options for networks of no-take areas in the GBRMP (Ball & Possingham 2000; Possingham et al. 2000; McDonnell et al. 2002; Lewis et al. 2003). Spatial data about use derived from fisheries or submissions were summarized and used in the analyses. In the case of the Great Barrier Reef Representative Areas Program, there were millions of alternative arrangements of no-take areas that would have satisfied most of the operating principles. Finding minimum-impact, optimal solutions from such a large array would have been beyond manual calculation, and the software was useful for providing an efficient beginning point for developing a draft zoning plan. The concepts outlined in the principles can be implemented without access to such software but less effectively and without consideration of as extensive a range of possibilities.

Beyond Decision Support to Decisions

Although it is important that the reserve-design software made maximum use of all available data, much of the important information was not vested in data sets amenable for use in such software (Lewis et al. 2003). Expertise from people inside and outside the GBRMP Authority had to be incorporated explicitly into decision making. Information from people making formal submissions was made available through either analysis of the textual input or geographic information system (GIS) analysis of the detailed spatial input. These layers of information and other available data were projected for use in structured round-table planning discussions that drew on in-house expertise. Without the GIS technology, physical maps would serve the same purpose, albeit less easily.

A key foundation for the entire process was the assessment of mapping solutions (any network of protected areas) against the biophysical and socioeconomic operational principles. Tracking how well the developing and evolving networks of no-take areas (and other kinds of protected areas) achieved these principles greatly influenced round-table decision making. The evolution of the final map required staff understanding of various stakeholder positions, continual reference to the principles, and reference to the variety of data. Staff knowledge reflected sectoral and/or geographic expertise gained over many years, understanding of formal submissions and data, and was augmented during the two formal community participation phases. The 10 or so staff contributing to each of these round-table discussions had expertise in planning, traditional owner and other indigenous uses and values, fisheries, conservation biology, tourism, compliance, shipping, water quality, on-the-water marine park management, and coastal development. Staff advice was delivered to senior managers at the GBRMP Authority, then, finally, after further revision, to Parliament. The final zoning plan satisfied the majority of the principles, and in particular the minimum levels of protection per bioregion.

The Outcome—an Improved Network of No-Take Areas

A priority in implementation of a new network of protected areas for the marine park was maximizing complementarity with people's uses and values. Nonetheless, the biophysical operational principles were critical to achieve the objectives of reviewing zoning of the park. The rezoning has been largely successful in attaining these principles (Table 4).

More than 33% of the GBRMP is now in no-take areas; this was an outcome of the process and principles, not a target itself. Before this rezoning only approximately 1/10,000th of the world's oceans were protected from all forms of fishing (Roberts & Hawkins 2000), not including the 16,000 km^2 of no-take areas in the previous GBRMP. This new level of protection increases the global amount of marine no-take areas more than fivefold (Fig. 1).

Not all aspects of each principle were achieved, however (Table 4). Achievement of some biophysical operational principles was compromised to accommodate people's uses and values, particularly recreational and commercial fishing uses. This compromise was a transparent acknowledgment of the importance of people's values in the process and the willingness of the government to be responsive to public input.

Key Success Factors

Several factors were central to the eventual success of the GBRMP zoning review, although the importance of each was not necessarily recognized at the time it occurred: focusing initial communication on the problems to be addressed; applying the precautionary principle; using independent experts; facilitating input to decision making; conducting extensive and participatory consultation; having an existing marine park that encompassed much of the ecosystem; having legislative power under federal law; developing high-level support; ensuring agency priority and ownership; and being able to address the issue of displaced fishers. These factors may be significant for other nations wishing to implement systematic networks of no-take protected areas, and are presented in no particular order.

Focusing Initial Communication on the Problem to be Addressed

Communication about the existing and potential threats to the Great Barrier Reef ecosystem, including information about risks and uncertainty, was not originally

Table 4. Degree to which the new zoning plan for the Great Barrier Reef Marine Park achieves the biophysical operational principles.

Biophysical operations principle	*Level of achievement*
No-take areas (NTAs) are at least 20 km along the smallest dimension (except for coastal bioregions)	52 of 122 offshore NTAs > 20 km across at some point, previously only 1
Coastal bioregions:	coastal bioregions:
NA1—include 6 NTAs, each at least 10 km long and each separated by 70–100 km	7 NTAs > 10 km long
NA3—include at least 8 NTAs, each at least 10 km long and each separated by 70–100 km	17 NTAs > 10 km long (NTAs spread north and south along the coastline, most separated by a maximum 70–100 km)
Have larger (vs. smaller) NTAs	average size of an NTA increased 5 times to 700 km^2
Have sufficient NTAs to ensure against negative impacts on some part of a bioregion	recommended level of replication achieved for all bioregions
Where a reef is incorporated into an NTA, the whole reef should be included	rate of split zoning reduced from ~10% to an estimated 8%, despite many more reefs being in NTAs
Represent at least 20% of reef area and of reef perimeter per reef bioregion in no-take areas	reef bioregion percentages range from 20% to 47%, with a mean of 18%; reef perimeter percentages range from 18% to 47%, with only 2 of 30 reef bioregions have < 20%
Represent at least 20% of each nonreef bioregion in no-take areas	nonreef bioregion percentages range from 20% to > 90%, with a mean of 34%
Represent cross-shelf and latitudinal diversity in the network of NTAs	yes, reflected in bioregions and habitat protection
Represent a minimum amount of each community type and physical environment type in the overall network of NTAs:	
Halimeda beds 10%	yes
shallow-water seagrass 10%	yes
deepwater seagrass 10%	yes
algae—known habitat 10%	yes
epibenthos—5% of different faunal classes	yes
dugong habitat (~50% of area of 29 sites)	yes
with cays capture two examples	yes for 8 of 12 bioregions
interreef channels—capture a least one per bioregion where they exist	yes for 13 of 17 bioregions
capture 5% of reef area in each of five reefsize classes	yes
oceanographic diversity in water quality:	
5% of nonreef area in regionalization	yes for 15 of 16 nonreef area
5% of reef area in regionalization	yes for 15 of 16 reef area
5% of nonreef area in flood plume categories	yes
5% of reef in plume categories	yes
major turtle habitat (20% foraging)	yes except for two green turtle populations
all high-priority turtle nesting sites	yes, flatback & green > 75% area; loggerhead & hawksbill > 40% area
Maximize use of environmental information to determine the configuration of NTAs to form viable networks	yes (e.g., inclusion of important source reefs for reproductive propagules)
Include biophysically special/unique places	yes for 28/53 high priority sites; additionally 3 > 50% in NTAs, 4 > 25% in NTAs
Include consideration of sea and adjacent land uses in determining no-take areas	complementarity with terrestrial conservation reserves substantially increased

identified as an issue that required discussion. But because these risks were not widely understood, it emerged clearly that explaining the need for action was essential to garnering support for a successful solution.

Application of the Precautionary Principle

The science was far from perfect, and the decision to proceed without perfect knowledge was a key factor in the success of the program. Some available information indicated that populations of key species were in decline (Williams 2000), especially those directly or indirectly affected by fishing activities. This information was considered sufficient evidence that the ecosystem was at risk. More than 60 data sets were available to help describe biological and physical parameters of the Great Barrier Reef ecosystem (B. K. et al., unpublished data). Arguments to postpone protection to gather further information were used as a delaying tactic only by those

Figure 1. Location and extent of the Great Barrier Reef Marine Park and location and size of the new marine no-take areas (dark gray shading).

who considered their interests best served by minimizing no-take areas.

Use of Independent Experts

Independent experts greatly assisted in the identification of bioregions specific to the Great Barrier Reef and development of reserve-design software and operational principles relevant to biodiversity protection objectives. Collectively, more than 30 experts contributed to the rezoning of the GBRMP. The bioregions and principles were made public before development of any maps of new zoning. These "products" were powerful because of their independent status and their wide availability for discussion and critique early in the planning process.

Early Input from Stakeholders

Before drafting any maps, stakeholders were asked where new no-take areas should be located. Stakeholders included commercial and recreational fishers, traditional owners and other indigenous groups, tour operators, recreational users, researchers, local communities, local governments, state government, various ministers, and the general public. Although asking for input about new no-take areas generated complaints about obfuscation (e.g., "...show us the map, we know you've got one already"), inviting input ultimately provided another key foundation for delivery of an acceptable, well-informed, and balanced final map. Gathering data from the public that were then demonstrably used in defining a draft map was more effective in enhancing support than if the management agency had produced maps without demonstrable community input. How the public input was used to develop the zoning plan was then described in detail in a publicly available draft and in the final zoning report. Additionally, we invited people's questions on how their information was used in follow-up meetings and information sessions. Final decision making, however, rested with the government, and this was made clear in every instance. In other cases even greater levels of involvement in decision making may be desirable.

Extensive and Participatory Consultation

Thorough consultation with key stakeholders was a critical factor that led to the success of the final no-take network which became law. The linking of science, scientists, and community participation was an essential three-way dynamic in the process. The public was provided with hundreds of thousands of maps to assist them in providing their input. We used direct mail, meetings, a toll-free telephone number, the Internet, and advertising to distribute information to the public. Meetings also provided an important forum for management agency staff to gather information informally. All 30,000 formally submitted comments were analyzed and entered into a database and GIS. All the formal and informal information was used in the decision-making process. In all communications, achieving a minimum of 20% protection in no-take areas per bioregion was emphasized, and many people provided input that took this into consideration.

Existence of a Marine Park

Before embarking on the review of protective zoning, the GBRMP had existed for more than 25 years and contained a spectrum of zoning with varying levels of protection. The existing zoning provided a clear and understandable framework within which ecosystem management could be improved. Mobilization of the community to support greater protection was probably more achievable given this existing, familiar framework of area-based management. Our experience suggests that establishment of broad management frameworks within which various levels of protection are implemented and adaptively managed may be useful elsewhere.

Legislative Power under Federal Law

An act of Parliament enables management of the GBRMP through legal support for the implementation and maintenance of marine-park zoning. This legislative obligation allows the GBRMP Authority to effect the changes required for adequate ecosystem protection despite a level of opposition from some sectors of the community. So, although we facilitated bottom-up input, top-down legislative support was also very important.

High-Level Support

The government's Ocean's Policy (Environment Australia 1998) and the Australian Federal Minister for the Environment supported the Representative Areas Program implemented in the GBRMP. As far as possible, the GBRMP Authority staff worked with stakeholders and decision makers to ensure a high level of ownership of the Representative Areas Program at all levels of society. The ownership was engendered, in part, through judicious negotiations wherein stakeholders and decision makers could see both the agency's commitments to the primary conservation objective of the program and a willingness to accommodate people's concerns. This ownership enabled the GBRMP Authority to deliver the new zoning plan despite the fact that members of some sectors continued to view implementing a network of no-take protected areas as undesirable. Many now see the new zoning plan as "their" legacy to the future.

Agency Priority and Ownership

Ownership of the program and outcomes was also generated within the organization responsible for production of the new park zoning, namely, throughout the GBRMP Authority. Genuine pooling of resources, expertise, and capabilities was one of the enabling features in delivery of the new zoning plan that implemented the Representative Areas Program. This was delivered by delegating and coordinating responsibilities for various aspects of the process to the respective senior managers within the GBRMP Authority.

Addressing the Issue of Displaced Fishers

A possible impediment to the new plan could have been the absence of structural adjustment (e.g., the buyback of fishing licenses) for displaced fishers. A federal government commitment to structural adjustment was of both social and environmental importance and led to greater community acceptance of the socially or economically negative consequences of the new zoning.

Conclusions

Because the pressures and risks for coral reef ecosystems are relatively generic throughout the tropics, a strong basis exists for motivating more systematic and holistic protection of coral reef ecosystems globally (Hughes et al. 2003; Pandolfi et al. 2003). Under different circumstances some of the success factors described above may not be important, or other, different, factors may be crucial. Despite this, the lessons from the Great Barrier Reef experience offer insights into the hurdles and challenges that may be generic and may facilitate efforts to establish marine networks of no-take areas elsewhere.

The concepts and approaches applied in the process of reviewing Great Barrier Reef zoning can be applied elsewhere regardless of the level of available data or technical support. The generic, applicable steps are to (1) define and discuss the problem; (2) decide on objectives; (3) engage relevant and independent experts; (4) compile existing biophysical, social, economic, and cultural data; (5) describe the biodiversity (e.g., through bioregions); (6) define operational principles that will achieve the objectives; (7) invite community input on all of the above; (8) gather and layer data in round-table discussions; (9) for each alternative map of no-take areas, report the degree of achievement of principles; and (10) have mechanisms by which to address any negative impacts. The hurdles that remain will be political and legal and unique to each situation.

The true success of any management initiative can be measured only in outcomes versus outputs. The Great Barrier Reef Marine Park Authority has delivered an important output—a new zoning regime. Existing and new monitoring programs are being reviewed and designed to enable assessment of the new zoning regime against biological, social, and economic outcomes.

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