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VIEWPOINT

Dangerous targets? Unresolved issues and ideological clashes around marine protected areas

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ABSTRACT

1. While conservationists, resource managers, scientists and coastal planners have recognized the broad applicability of marine protected areas (MPAs), they are often implemented without a firm understanding of the conservation science — both ecological and socio-economic — underlying marine protection. The rush to implement MPAs has set the stage for paradoxical differences of opinions in the marine conservation community.

2. The enthusiastic prescription of simplistic solutions to marine conservation problems risks polarization of interests and ultimately threatens *bona fide* progress in marine conservation. The blanket assignment and advocacy of empirically unsubstantiated rules of thumb in marine protection creates potentially dangerous targets for conservation science.

3. Clarity of definition, systematic testing of assumptions, and adaptive application of diverse MPA management approaches are needed so that the appropriate mix of various management tools can be utilized, depending upon specific goals and conditions. Scientists have a professional and

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ethical duty to map out those paths that are most likely to lead to improved resource management and understanding of the natural world, including the human element, whether or not they are convenient, politically correct or publicly magnetic.

4. The use of MPAs as a vehicle for promoting long-term conservation and sustainable use of marine biodiversity is in need of focus, and both philosophical and applied tune ups. A new paradigm arising out of integrated, multi-disciplinary science, management and education/outreach efforts must be adopted to help promote flexible, diverse and effective MPA management strategies. Given scientific uncertainties, MPAs should be designed so one can learn from their application and adjust their management strategies as needed, in the true spirit of adaptive management.

5. It is critical for the conservation community to examine why honest differences of opinion regarding MPAs have emerged, and recognize that inflexible attitudes and positions are potentially dangerous. We therefore discuss several questions — heretofore taken as implicit assumptions: (a) what are MPAs, (b) what purpose do MPAs serve, (c) are no-take MPAs the only legitimate MPAs, (d) should a single closed area target be set for all MPAs, and (e) how should policymakers and conservation communities deal with scientific uncertainty?

KEY WORDS: marine protected area; 'No take' marine reserve; biodiversity; conservation; sustainable use; multiple-use marine protected area

INTRODUCTION

The need for increased protection of the world's marine environment has been the source of much recent scientific consideration (ICRS, 2000; National Center for Ecological Analysis and Synthesis, 2001; Society of Conservation Biology, and Marine Conservation Biology Institute [SCB/MCBI], 2001). To that end, marine protected areas (MPAs) are fast becoming a mainstream management tool for conserving biodiversity in virtually all the world's oceans and seas. Several international, national and local level initiatives and mechanisms serve to advance MPAs as vehicles for promoting the long-term conservation and sustainable use of marine resources and biodiversity (Agardy, 1997a; Crosby *et al.*, 2000b; National Research Council, 2001). The first marine protected areas were proclaimed early in the 20th century. Silva *et al.* (1986) listed 430 marine protected areas created by 1985 but most of those covered relatively small coastal areas. By 1995, there were at least 1306 subtidal marine protected areas worldwide, with a median size of 1584 h (Kelleher *et al.*, 1995). This figure is now likely a significant under-estimate given rapid and accelerating progress in MPA establishment, with virtually every coastal country having implemented some form of MPA.

Sectors of society that once opposed such habitat protection have now begun to embrace their use as resulting benefits for conservation and broader societal interests become more evident (Ward *et al.*, 2001; Agardy, in press). In promoting MPAs it is important that there is a good understanding of the conservation science underlying marine protection in terms of the factual foundation and long-term implications. Ignoring this may lead resource managers and policymakers to make ill-informed decisions regarding MPAs, resulting in poor MPA design and performance. We are concerned that significant polarization of views regarding different MPA management approaches is occurring, leading to discord and potentially impeding the use of MPAs to conserve marine biodiversity. As with many popular trends, the fervor to proclaim sometimes untenable policy prescriptions, the tendency to decree as many MPAs as possible, an eagerness to do so without a clear understanding of many of the complexities or balanced framework required, and a zealous 'one size fits all' approach may inadvertently impede success. A policy backlash against the popular use of marine protection tools may loom at the time when MPAs are needed most.

That the broad applicability of the MPA tool has set the stage for differing professional views in the marine conservation community may be seen as a curious paradox. Nonetheless the paradox exists, and these differences of opinion are not benign. If these differences are not addressed, the end result may well be

confusion among decision makers, causing them to reject MPAs or use them in the wrong way. If at the same time decision makers dismiss other legitimate conservation approaches, it could well ultimately lead to a derailment of marine conservation efforts altogether. Professional disagreement coupled with poorly designed, *ad hoc* use and marginal to unacceptable performance of MPAs threaten to limit marine protection worldwide.

This manuscript seeks to initiate an open and objective discussion regarding the differing views about MPAs that are present and growing in the international marine conservation community. In many informal and formal discussions that we have been involved with recently, it seems clear that there is controversy over the setting of specific targets for minimum spatial areas that need to be closed to various human activities. This confusion is in terms of how much of an area should be set aside, when and why, and how to deal with the inherent scientific uncertainty that surrounds setting such targets. There is a risk that only very restrictive types of MPAs are being focused on as the means to deal with broad marine conservation and sustainable use problems, to the detriment of additional tools such as multiple-use MPAs and wider seascape level ocean governance.

It is essential to fully embrace the range of MPA tools that are available in order to maximize the protection and management of marine biodiversity. The critical issue, therefore, is not 'which MPA type is more useful or legitimate than the others'; rather it is 'which MPA approach(s) should be used for specific purposes and conditions?' To create absolute and inflexible standards and targets that utilize a single approach pushes marine conservation into unnecessary and costly battles that cannot be afforded. Globally, a mix of MPA management tools is required in order to achieve the aims of sustainable use, as codified in international treaties such as the Convention on Biological Diversity (CBD, 2000): multiple-use MPAs designed through the process of participatory goal setting, with no-take areas embedded within them. This approach is already envisaged for terrestrial protected areas (e.g. Bridgewater, 2001).

An open discussion is particularly timely given the formation of an *ad hoc* Technical Expert Group of the Convention on Biological Diversity's Subsidiary Body on Scientific, Technical and Technological Advice that will provide guidance on the application of marine and coastal protected areas worldwide. In addition, the European Union is evaluating its stance *vis a vis* MPA guidelines, and many individual countries (e.g. Australia, Canada, Italy, Philippines, United States, to mention a few) are currently developing national MPA networks. To guide debate on MPA usage we pose several questions that we feel will enable MPAs at global, regional and local levels to meet their full potential. These questions are: (a) what are MPAs, (b) what purpose do MPAs serve, (c) are no-take MPAs the only legitimate MPAs, (d) should a single closed area target be set for all MPAs, and (e) how should policymakers and conservation communities deal with scientific uncertainty?

WHAT ARE MPAs?

To understand the range of views developing in the international marine conservation community, we must begin with an examination of differing perceptions of MPAs at the most basic level. The term marine protected area arose out of a historic quilt of meanings that was formed as protected areas began to spring up in coastal and marine areas around the world, each with its own label and implications. MPAs are variously defined as purely in-water designations, as coastal management units that include terrestrial and marine areas, as strictly protected reserves, or as any kind of marine managed area (Agardy, 1997b). The most commonly used definition of MPA internationally is that provided by IUCN, 'any area of inter-tidal or sub-tidal terrain, together with its overlying water and associated flora, fauna, historical, or cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment' (Kelleher and Kenchington, 1992). This generic description has metamorphosed somewhat in subsequent discussions and treaty negotiations. For example, background documents for the Convention

on Biological Diversity state that 'MPAs are coastal or oceanic management areas designed to conserve ecosystems together with their functions and resources' (deFontaubert *et al.*, 1996). In the United States, MPAs have been defined as 'any area of the marine environment that has been reserved by Federal, State, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural or cultural resources therein' (US Presidential Executive Order 13158, 26 May, 2000). Eichbaum *et al.* (1996) define marine and coastal protected areas as 'areas of the coastal zone or open ocean (or both) that are the target of management for the broad purpose of conservation and sustainable use'. As a result of the diverse definitions and objectives for MPAs, a profusion of specific terms to describe various sorts of MPAs have been adopted, including marine park, marine reserve, fisheries reserve, closed area, marine sanctuary, MACPAs/MCPAs (marine and coastal protected areas), nature reserve, ecological reserve, replenishment reserve, marine management area, coastal preserve, area of conservation concern, sensitive sea area, biosphere reserve, 'no-take area', coastal park, national marine park, marine conservation area and marine wilderness area.

Semantic confusion naturally arises when similar specialized terms are applied to management regimes with different objectives and temporal–spatial scales. For instance, the term 'sanctuary' as used in the US context is a multiple use MPA that is designated under the jurisdiction of NOAA's National Marine Sanctuary Programme, as per example the Florida Keys National Marine Sanctuary. However, 'sanctuary' takes on a different meaning elsewhere in the world — in Great Britain the term has been used on occasion to refer to strictly protected marine reserves in which extractive use is prohibited (Jones, 1994). Given the literal definition of the word 'sanctuary' (A reserved area in which animals or birds are protected from hunting or molestation. The American Heritage Dictionary, 1985), the Jones (1994) definition is logical. This is also the sense in which it is used by the International Whaling Commission (ICRW, 1946). In much of the developing world, the use of the word nature sanctuary (both terrestrial and marine) is becoming problematic as people rebel against what they view as elitist or exclusionary protected areas that provide safe havens for nature and tourists who can buy access, but at the same time provide no benefits to local residents.

The term 'reserve' may also elicit negative reactions where communities sense that something is being taken away from them in order to reserve resources and rights for others (Milon *et al.*, 1997). This reaction is a severe handicap for biosphere reserves, which promote exactly the opposite approach! Attempts to limit access to these resources, especially fishing rights, has the potential to disrupt the socio-economic stability of coastal communities and result in conflict among user groups with competing interests over the same limited resources. Although the scientific evidence supporting more restrictive access management strategies may be strong, access restrictions will not become a reality without significant stakeholder support (deFontaubert *et al.*, 1996; Agardy, 1997a).

The diverse array of MPA goals, and their order of priority, varies enormously from place to place — so much so that one could almost say that every MPA is unique, having been tailored to meet the specific circumstances of the place where it is established. 'Marine protected area' should be used as a single, general umbrella term which can apply to the wide range of different marine habitat protection strategies identified with each of a broadly accepted typology of terms mentioned previously. Beyond this, however, is the real imperative to focus on what needs to be accomplished for marine biodiversity conservation and then to use the most appropriate tool to achieve that end.

Recent scientific consensus at the American Association for the Advancement of Science (AAAS) meetings of February 2001, as cited in the Scientific Consensus Statement on Marine Reserves and Marine Protected Areas (National Center for Ecological Analysis, 2001) inadvertently created a dichotomy for marine protection with regard to use of MPAs. The statement distinguishes between marine reserve and marine protected area, the former being exclusive of all fishing, disruptive or extractive use (with the exception of scientific research), and the latter referring to multiple-use areas with mixed harvest, restricted harvest, and/or complete harvest prohibition areas. The NCEAS statement does refer to marine reserves as

a special category of MPAs, but then proceeds to contrast the two by stating that MPAs do not provide the same benefits as marine reserves. Yet, such distinctions are artificial given that many marine protected areas contain core areas in which all extractive uses are prohibited. MPAs should be conceived as areas of nested IUCN protected area categories (see Table 1 in IUCN, 1994) — which may change their boundaries both spatially and temporally. (The World Commission on Oceans discusses this in more detail (IWCO, 1998)). We believe that the broad-term MPA should be used to describe the full configuration of protected areas in coastal areas and oceans, as we do in the remainder of this manuscript.

WHAT PURPOSE DO MPAs SERVE?

The fact that MPAs can accomplish a broad range of objectives and have different meanings to different people, underscores the imperative that MPA planners and advocates work to clearly define targeted objectives for MPA networks and individual MPAs (Jones, 1994; Murray *et al.*, 1999; Agardy, 2000a; Crosby *et al.*, 2000b). Management intent and actions clearly depend upon the objectives for the area to be managed. Within a multiple use MPA, no-take areas are obviously managed differently from those areas aimed at resource utilization. In some MPAs, conservation will be the primary motivating force for a restrictive access strategy. In others, the most important objective may be the preservation of traditional use, sustainable use of a particular resource, or a combination of these. Large multiple use MPAs may be designed to achieve a broad range of objectives for the purposes of ecosystem-based management, where the limits of protection in a geographical sense are based on the extent of movements of organisms and physically linked processes (Eichbaum *et al.*, 1996; Agardy, 1999b). Because specific circumstances vary so widely around the world, no model for MPA management objectives will be universally applicable. Management objectives should be tailored to address the specific ecological, cultural and socio-economic problem(s) that the MPA is meant to address (Bridgewater and Coyne, 1997; Agardy, 2000a; Crosby *et al.*, 2000b). First and foremost, MPA practitioners must recognize that the systems they are managing and studying include people and occasionally unique cultures. Cultural parameters are especially important to consider, and can be protected through MPAs, in areas having significant populations of indigenous peoples with traditional connections to the marine environment (Crosby *et al.*, 2000b; Ward *et al.*, 2001).

MPAs that meet their objective(s) can encourage the creation of additional MPAs. The fishing sector's attitudes toward MPAs in general, and 'no-take' fishery reserves in particular, may be changing over time (Agardy, 1999a, 2000b). MPA fisheries reserves introduced in New Zealand in 1977 faced vehement public opposition. However, 10 years later, 78% of the fishermen interviewed favoured designation of additional reserves (Ballantine (1989) in Bohnsack, 1992). A survey of community reactions toward MPAs in New Zealand suggests that community involvement, along with information dissemination, communication and compromise, are the primary strategies for reducing inter-group conflict in the MPA planning process (Wolfenden *et al.*, 1994). Similar acceptance of the need for MPAs was recognized by fisheries organizations in the UK as long ago as 1992 (National Federation of Fishermen's Organizations, 1992) when they proposed their use together with other measures in response to Government fisheries management proposals. The key to success and broad acceptance, whether for multiple use MPAs or no-take reserves, is a clear articulation of the management problem that the MPA is meant to solve. Such objective setting should be done with scientists working in concert with local communities, user groups, and management authorities—not by scientists in isolation.

NO-TAKE RESERVES: ARE THEY THE ONLY LEGITIMATE MPAs?

No-take MPAs are a relatively new (although marine reserves have been employed by the Government of Barbados since 1981 (pers. comm. P. McConney), and the Organization of Eastern Caribbean States

legislation since circa 1983 — Government of Antigua and Barbuda, 1983; Government of St Lucia, 1984 (P. Murray, pers. comm.); also see Rowley (1994)) and often controversial human-access management tool for replenishing depleted fish stocks. Unlike conventional fishery management strategies, no-take MPAs provide a permanent spatial refuge for living marine resources by banning all fishing and other extractive activities within the reserve's boundaries (see Crosby *et al.*, 2000b).

The vast majority of MPA planners and practitioners around the world recognize the broad array of methods that the MPA toolkit provides, and work to find the most appropriate model to their specific needs and circumstances (Agardy, 2000a; Ward *et al.*, 2001). Yet in the US and much of the developed world, most recent discussions have focused on no-take MPAs for managing fisheries harvest and not on the broader objectives of MPAs. As a result, a rift is developing between those who argue that only no-take MPAs can confer important conservation benefits, and those who argue that MPA benefits are broader than what no-take areas alone can possibly confer. The NCEAS statement crystallized the sharply different perspectives that are emerging between and amongst some MPA theorists and MPA practitioners — particularly those working outside the US and the developed world. It succinctly summarizes the state of scientific knowledge about the benefits of no-take MPAs (which the NCEAS terms marine reserves), and strongly advocates using these to offset impending marine conservation crises in heavily overused parts of the oceans.

The belief that multiple-use MPAs are of somewhat lesser value is also perpetuated in the way the existing IUCN categories for protected areas are applied. Currently only a single IUCN category is applied to any protected area, irrespective of its size or whether it is legally recognized as a multiple use area. Most multiple-use MPAs are currently listed as IUCN Category VI (i.e. a Managed Resource Protected Area). For example, the Great Barrier Reef Marine Park (GBRMP) is currently classified solely as Category VI yet some of the zones within the GBRMP comply with other IUCN categories: the Preservation Zones and Scientific Research Zones equate to Category Ia, and the Marine National Park 'B' Zones equate to Category II. Moreover the extent of the 'no-take' zones (i.e. Categories Ia and II) within the GBRMP covers some 16 000 km^2, which alone is far greater than the total area of many multiple-use MPAs elsewhere in the world (Day and Kelleher, 2001).

The roots of the divergence in MPA ideology is the misconception that the two basic approaches used to promote the long-term, self-perpetuating existence of living natural resources within MPAs are mutually exclusive. The first approach is based on the principle of sustainable use, the second is based on the principle of protectionism through no-take. Sustainable use approaches are predicated on the concept that the living resources of an MPA replenish themselves naturally and can be exploited (i.e. commercial, recreational and/or subsistence) within limits, on a continuing basis without eliminating them or irreparably harming their essential habitat. The traditional management approach to ensure continued extractive uses has been through legislation that restricts human harvesting of particular stocks of fish or invertebrates (Kelleher and Kenchington, 1992).

Natural refuges, i.e. areas too deep and too remote for fishermen to easily access, once sufficed to protect many marine resources (Bohnsack, 1996). Advancements in fishing technologies and increased fishing effort have eliminated most of the natural refugia and led to the decline, and in some cases, collapse of major fisheries around the world. No-take MPAs are being advocated as management tools in areas where over-fishing has led to a decline in commercially important as well as non-targeted marine species. No-take MPAs are especially suited for long-lived demersal species with planktonic larval dispersal and sedentary adults such as invertebrates and reef fish (Hasting and Botsford, 1999), but are less likely to be effective for highly migratory species that spend only a small amount of time in the reserve (Bohnsack, 1996).

In a larger ecosystem or seascape scale beyond commercial fisheries, however, no-take MPAs may not, in and of themselves, deliver long-term conservation in all cases. Multiple use MPA zoning is a way to accommodate multiple users in areas where coastal populations, tourism and resource use conflicts are on the rise (Agardy, 1995; Day, 2002a). Arguments supporting zoning within multiple use MPAs include those

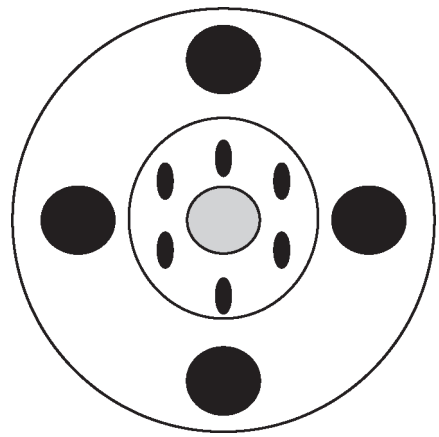
put by Pressey and McNeill (1996) who consider broad-area integrated management (i.e. multiple-use MPAs) more effective than a series of small, isolated highly protected areas. Integration of no-take MPAs within larger multiple-use MPAs should also have lower infrastructure and administrative costs per spatial area than a series of separate small no-take MPAs and multiple use MPAs.

In many areas of the world the cultural identity of the local peoples is intimately linked with traditional uses of the marine environment. As a member of the US Coral Reef Task Force (CRTF), Governor Sunia of American Samoa expressed his concern for the rights of traditional uses of marine resources in the islands. The Governor made a formal request that the specific multiple use MPA design presented in Figure 1 be the preferred option for implementing the 20% no-take coral reef MPA policy of the CRTF, in order to protect the rights of indigenous peoples to periodic cultural and subsistence use in some areas within MPAs (see http://coralreef.gov/Mtg5.pdf for the complete multiple use MPA design motion proposed by Governor Sunia and approved by the CRTF at their August 2000 meeting). Governor Sunia was particularly concerned with ensuring that indigenous peoples have access to conduct traditional extractive uses within a broader multiple-use MPA context. In another example of the values of multiple use MPA with no-take zones, the Kaho'olawe Island Reserve Commission has developed a two-zone management strategy that allows for subsistence gathering of marine resources for specifically approved cultural, religious and education activities by 'Native Hawaiians' (Crosby *et al.*, 2000b). Trans-boundary, multiple use MPAs are also proving a unique vehicle for improving Middle East regional coordination and cooperation in addressing common goals with clear benefits well beyond conservation of marine biodiversity (Loya *et al.*, 1999; Crosby *et al.*, 2000a). The Soufriere Marine Management Area, St Lucia (a multiple use area including no-take marine reserves, fishing priority zones and other use zones) was initially established as a tool to resolve conflicts among that area's users (i.e. fishermen, tourists, yachters, sea bathers, divers) and is considered a success in this regard (P. Murray, pers. comm.).

Given that the fisheries management value of no-take reserves is clear (Hastings and Botsford, 1999; Crosby *et al.*, 2000b; Roberts *et al.*, 2001; Sala *et al.*, 2002), we argue that no-take MPAs should indeed be used, to accrue the full range of benefits they have been shown to provide. However, though we endorse this tactic, we feel the strategy that currently seems to be the focus of much attention — assertive promotion of no-take MPAs as the best and only effective type of MPA — is fraught with risk. Instead, we advocate an approach that utilizes no-take MPAs that are strategically linked with, or an integral part of, multiple use protected areas, especially as needed to address threats caused by overexploitation of resources. No-take MPA designations will not, in and of themselves, deliver long-term conservation in most cases. This is because a) fishing and other extractive uses of the marine environment are not the only activities that negative impact the marine environment, and b) not all extractive uses are unsustainable or disruptive to marine ecology. Multiple use MPAs demonstrate how sustainable use on the one hand and protectionist approaches embodied in no-take provisions on the other can complement each other for successful management, and reflects the concept long articulated by the UNESCO biosphere reserves (Batisse, 1990; UNESCO, 1996; Bridgewater, 1999).

SPATIAL TARGETS: HOW MUCH OF WHAT, WHERE, WHY?

Discussions centred on trying to identify minimum spatial targets for no-take MPAs have been spurred by an increasing frustration among decision makers and managers to what they perceive as a lack of unambiguous data and specific recommendations from the scientific community regarding MPAs. The origin of the 20% no-take MPA recommendation (for review, see Bohnsack *et al.*, in press) was extrapolated from very specific localized studies of particular fisheries within particular habitats - not from representative community ecology data from a wide range of habitat types. The initial science concerning minimum no-take determinations included home range studies and population dynamics data that were



No-take marine reserve zone for strict preservation with entry by permit only and no manipulative research.

Buffer zone of no-take marine reserve that can be used for manipulative research and education, or traditional use zones.

Secondary zone of marine reserves that may serve as (1) experimental reserves for manipulative research and comparison with natural areas; (2) recreation non-consumptive use zones; (3) education zones, and (4) traditional use zones.

Secondary or fringing buffer zone managed for limited consumptive uses and all other non-consumptive uses such as recreation and education.

Figure 1. Schematic representation of a generic zoning strategy in a multi-use MPA (after Crosby *et al.*, 2000b, and Salm and Clark 1984).

used to predict the minimum area needed to reach a particular fisheries management goal (i.e., sustainability). Bohnsack *et al.* (in press) '...support a goal of fully protecting a minimum of 20–30% of coral reef habitat within no-take marine reserves until better estimates are obtained.' Yet the 20% figure has been adopted as the mantra of some MPA advocates targeting a wide range of objectives under a diverse spectrum of ecological and social conditions.

The use of such universal targets can be made particularly confusing if specific objectives that the 20% no-take MPA target aims to attain are unstipulated. If it is to protect the biological diversity at a particular site, additional questions must also be addressed. Will the objective be achieved solely by regulations applying to the 20% or will it depend on the quality of management of the other 80%? If it is to maintain biodiversity and the ecological processes that sustain biodiversity, will a 20% no-take protected area have any measurable effect? Does the ease of convenience in selecting a single rule-of-thumb figure for all situations run the risk of selecting meaningless spatial threshold targets, given the unique and variable

reproductive biology and life history of specific targets and distinct ecological characteristics that are necessary for sustained ecosystems, habitat and community structure integrity? Moreover, by concentrating scientific energies and debate on trying to determine a single, simplistic spatial target, are we inadvertently diverting valuable, scarce time and financial resources toward targets that operate independent of the real world — possibly missing the intended conservation outcome?

The 20% figure has been elevated to a dogmatic standard for the minimum proportion of a type of ecosystem that must be delineated as no-take MPA in order for the MPA to be effective in protecting natural resources. The US Coral Reef Task Force has set a national target of 20% for no-take MPAs in coral reefs under US jurisdiction, and the figure has even come up as a potential target for all marine ecosystems within US jurisdiction (e.g. discussions leading up to the US MPA Executive Order of 2000). Other countries (i.e. Australia, Bahamas, Canada, Galapagos Islands, Philippines) are following the US lead in adopting the 20% figure, without open objective discussion on possible shortcomings of doing so in all situations. It may indeed be valuable to set a target of 20% (or 15% or 22%, etc.) as a programmatic goal for total spatial coverage for a particular ecosystem type in order to achieve specific objectives. An important caveat is that it is usually counterproductive to religiously adhere to such a target in all ecological and socio-economic situations (Lauck *et al.*, 1998).

Establishing target goals for MPAs that are based on best available information would certainly be useful for building momentum for improving MPA programmes around the world. However, though it is alluring to think that a single spatial target will truly describe the minimum area of no-take protection needed to maintain productivity and biodiversity (as in species assemblages) of any given ecosystem, it is probably disingenuous to make the claim. Studies of highly productive and dynamic temperate water systems like those of Georges Bank and the California Bight suggest that nearly three quarters of fish habitat area would need to be set aside as no-take in order to derive the kinds of fisheries management and biodiversity benefits that scientists advocating 20% no-take claim their formula will accrue (Parrish, 1999; National Research Council, 2001). A very real danger of blindly advocating the 20% minimum no-take target for all ecosystems and conditions is that such rigorously designed MPAs may not meet expectations — risking elements of the public and the decision makers who represent them abandoning support for MPAs altogether.

Adherence to strict minimum area targets of 20%, or any other figure, for all marine ecosystems will lead towards a dangerous tendency: creating a false sense of security that marine conservation issues are being dealt with adequately. A hypothetical situation may progress as follows: a mythical country's new government regulations require an agency with jurisdiction over a highly threatened coastal area to set 20% of the area aside as a no-take MPA. The managing authority rushes to fulfill the target, imposing no take restrictions in a single no-take MPA in the remotest part of the area, where extractive activities are essentially non-existent anyway (explaining why a quick response was possible in the first place). Having achieved the target, the decision maker can pat themself on the back, congratulate the managing agency, and walk away from the real and persistent problems that remain: uncontrolled use in areas outside the 20% restricted area, use conflicts and animosity towards regulators, point and non-point source pollution, environmentally damaging coastal development and construction, etc. The result is a situation in which the 20% target has indeed been reached, and yet 80% of the ecosystem remains as threatened (or even worse off) than before the management measure was instituted. Slowly, over time, 80% of the ecosystem is destroyed and the 20% no-take MPA area is all that is left.

HOW MUST WE DEAL WITH SCIENTIFIC UNCERTAINTY?

A positive aspect of this debate is that new paradigms and approaches are emerging that provide MPA planners, scientists, and decision makers with guidance on how to proceed in the face of scientific

Table 1. Statistical approach for determining MRV size (from Crosby *et al.*, 2000b, after Kripke and Fujita 1999)

Assume: biomass is proportional to habitat area for species 'a', and

Where: F = estimated fishing mortality of species 'a'
B = estimated initial biomass species 'a'
$F \times B$ = allowable catch of species 'a'
U_B = statistical uncertainty of B
U_F = statistical uncertainty of F
Error_{max} = maximum error in estimating remaining biomass after harvest
Size_{MR} = per cent of species 'a' total habitat that should be included in a marine reserve

Then:
$\text{Error}_{max} = F + (F \times UF) \times B - (B \times UB)$, and
$\text{Size}_{MR} = (\text{Error}_{max}/B) \times 100$

uncertainty. For example, the US non-governmental organization Environmental Defense has proposed utilizing the statistical uncertainty of biomass and fishing mortality to determine no-take MPA size (Kripke and Fujita, 1999). Their approach is to ensure that at least the difference between the estimated and actual remaining biomass levels of a commercially harvested species is protected within the marine reserve habitat (see Table 1). However, few if any marine ecosystems are well enough understood (in terms of ecological or socio-economic variables) to allow accurate predictions (at a statistical level of significance even approaching 95% certainty) to be made about the quantitative outcomes of any management action, whether it is over a season, or over 5, 10 or 50 years. Indeed, none of the changes now seen in New Zealand's no-take MPAs (Towns and Ballantine, 1993; Babcock *et al.*, 1999; Kelly *et al.*, 2000; Willis *et al.*, 2000) were or could be predicted at the outset of their program. What is known is that spatial management, including restrictions on certain forms of destructive fishing and habitat alteration, have a high probability of improving ecosystem health and productivity — not just inside the boundaries of areas specified as no-take, but surrounding areas as well. However, the minimum proportion of an ecosystem, and specific protection levels, that must be implemented to derive these benefits is far from certain (as previous section on 20% minimum areas for no-take MPAs illustrated).

This is not to say that we do not currently know enough to take strong action now. Greater use of well-designed and managed MPAs will undoubtedly benefit coastal and marine ecosystems, and their human components, if they are designed to be flexible and adaptive. In the tradition of true adaptive management, we can and should use MPAs to derive better information about effective design criteria, including minimum sizes and the extent to which some areas within MPAs should be deemed off-limits to extractive uses, i.e. no-take areas (Agardy, 1999b). In fact, without setting up such natural experiments, we will likely never know how effective we can be in marine resource management and conservation (Parma *et al.*, 1998).

Thus, we come to an important point in the interaction of science and policy concerning marine ecosystem management and marine biodiversity conservation — the precautionary approach (see Foster *et al.* (2000) for a general overview, and Dayton *et al.*, 1995; Eichbaum *et al.*, 1996; Bohnsack, 1999; Agardy, 2000b; Crosby *et al.*, 2000b for reviews of its use in the MPA context). By employing the precautionary approach, management of marine systems goes from being reactive to proactive, from responding to damage and threats to avoiding them. Given the changing dynamics of human populations with increasing resource demands and the limited effectiveness of international efforts to conserve global biodiversity, an accurate presumption would seem to be that without modification to current modes of anthropogenic interaction with the ecosystems in which they are components, the health (see Crosby *et al.*, 2000b) of marine ecosystems will continue to deteriorate. Under such circumstances, MPAs provide an

opportunity to apply the precautionary approach in a physical setting and protect marine resource from the dangerous threats of over exploitation, habitat destruction and pollution (Eichbaum *et al.*, 1996).

A recent evaluation of the use of scientific data and analyses in habitat conservation plans (Watchman *et al.*, 2001) concluded that uncertainty can be minimized by providing greater opportunities to adjust management plans in response to new information or changing environmental conditions. The public, as well as managers, scientists and policy makers, should be involved in critiquing the effectiveness of the management strategy. The evaluation process should allow managers to assess the extent to which earlier stated objectives for the MPA have been met, and make periodic shifts in the focus of the management technique by applying knowledge gained from past experiences. Such approaches recognize and seek to balance the need to conserve the structure of natural ecosystems with the need to maintain a healthy economy. Most management actions, however, need to be in place for a reasonable period of time to be effective or to enable an assessment of their effectiveness (Day, 2002b). Nevertheless all management practices should be periodically reviewed and updated where appropriate, particularly when a management change results from new data, 'in-the-field' experience, or the result of external circumstances such as technological, social, political or environmental/natural changes.

Denying uncertainty is a huge risk we cannot afford to take. When MPA advocates make sweeping statements about the benefits of MPAs, expectations are raised in user groups and put MPA cynics on their guard. Striving to meet these often unrealistically high expectations then puts unnecessary pressure on MPA managers, threatens the continued existence of these MPAs, and even endangers future MPA designations. The consequences are not just disappointments and bruised egos — in many cases in some parts of the world, sunset clauses are written into MPA legislation, requiring that certain targets (usually increases in fishery biomass) be reached within a certain timeframe lest the MPA be revoked, or at a minimum, deprived of its funding. While it is imperative that performance be strictly monitored in all MPAs, we should be wary of traps that unrealistic targets pose for conservation interests.

CONCLUSIONS: INADVERTENT CONSEQUENCES AND THE DANGERS OF DERAILMENT

The broad spectrum of MPA management approaches (which include no-take areas) form a key element of the overall framework needed to manage resources for sustainable use, safeguarding ecosystem function and biodiversity and/or providing a framework for supporting uses of resources and space with a minimum of conflict. They can range from small closed areas or harvest refugia designated to protect a specific resource or habitat type, to extensive multiple-use MPA areas that integrate the management of many species, habitats and uses in a single, comprehensive plan. Like their terrestrial counterparts, MPAs provide not only for the protection of critical habitats and endangered species, but serve important roles in public education and outreach on the social, economic and ecological benefits of marine resource protection and in the actual safeguarding of certain economic, social and cultural aspects of human societies. By employing a framework for the application of adaptive management, MPAs can establish and maintain feedback loops between science and policy. Finally, multiple-use MPAs address the differing sets of objectives demanded by a wide variety of stakeholders or constituents, thereby providing a framework for resolving conflict among the users of marine and coastal ecosystem services.

Yet the ideological divide that has emerged between and amongst some scientists, resource managers, and policymakers threatens to cast a shadow on how MPAs are viewed by society, and whether they achieve their full potential. The blanket assignment and advocacy of empirically unsubstantiated rules of thumb in marine protection provides dangerous targets for conservation science and may inflate expectations of end results, risking the abandonment of MPAs by decision makers as a management tool that was tried and failed. What is needed is clarity of definition, systematic testing of assumptions, and adaptive application so that the appropriate mix of marine resource management tools can be elucidated

and undertaken depending upon the conditions that warrant them. While this may not be as easy to advocate with decision makers and donors, scientists nevertheless have a professional and ethical duty to map out those paths which are most likely to lead to improved understanding of the natural world, whether or not they be convenient, politically correct or publicly magnetic.

Because variation describes the natural world, so too management interventions must be variably tailored to address the disparate and often highly site-specific conditions (biological, socioeconomic, cultural, and institutional) operating in the natural environment. Therefore, while convenient and useful for scientific advocacy, conservation scientists and managers need to be very careful in setting prescriptive, 'one-size-fits-all', ecological rules of thumb unless they are thoroughly grounded in empirical evidence or natural law. Moreover, currently fixating professional debate and resource allocation on addressing the issue of 'how much in total' without adequate answers to the questions of 'what' (definitional), 'for what' (objectives), 'for whom' (audience and social equity), 'how' (applying the appropriate mix of protection tools given operating conditions), and 'where' (more often than not, there are options as to which areas might be protected) may be counter-productive to the global needs for increased marine protection and counter-intuitive to the scientific understanding that is needed.

All who work in marine conservation, whether through advocacy, as purveyors of scientific information, or as practitioners (or trainers of practitioners), welcome the newfound and widespread interest in MPAs that has emerged in the last couple of years. The burgeoning body of scientific publications on MPAs could and should be useful in helping to enhance favourable public opinion regarding MPAs. At the same time, the quest for rigor can cultivate inflexibility by some, and threatens the progress made to date. Narrow interpretations of what constitute valid MPAs, objective setting that is done by a single special interest group as opposed to the broadest possible array of stakeholders, and adherence to scientifically questionable targets that raise expectations and create easy outs for decision makers, are all extremely dangerous tactics that will not serve marine conservation interests well in the end.

Ideological clashes regarding ecological and socio-economic value of different types of MPAs, and specific minimum spatial targets, should not be allowed to fester and impede crucial conservation efforts. We are hopeful that mature, constructive dialogue and information exchanges on the issues discussed here will help chart a renewed and more positive course for employing multiple use MPAs including no-take zones as important tools for long-term sustainable use and conservation of marine systems.

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