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When can marine reserves improve fisheries management?

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Abstract

Marine reserves are a promising tool for fisheries management and conservation of biodiversity, but they are not a panacea for fisheries management problems. For fisheries that

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target highly mobile single species with little or no by-catch or habitat impact, marine reserves provide few benefits compared to conventional fishery management tools. For fisheries that are multi-species or on more sedentary stocks, or for which broader ecological impacts of fishing are an issue, marine reserves have some potential advantages. Their successful use requires a case-by-case understanding of the spatial structure of impacted fisheries, ecosystems and human communities. Marine reserves, together with other fishery management tools, can help achieve broad fishery and biodiversity objectives, but their use will require careful planning and evaluation. Mistakes will be made, and without planning, monitoring and evaluation, we will not learn what worked, what did not, and why. If marine reserves are implemented without case by case evaluation and appropriate monitoring programs, there is a risk of unfulfilled expectations, the creation of disincentives, and a loss of credibility of what potentially is a valuable management tool.

1. Introduction

Globally, there is a wave of environmental groups, politicians and ecologists pushing for the large-scale implementation of Marine Protected Areas (MPAs),[1] with many calls for protecting 20–30% of the oceans [1]. The establishment of MPAs does not automatically require an outright banning of fishing activities in the designated area which may accommodate fishing and other economic activities under specific management regimes. However, it is often proposed to simply eliminate all consumptive uses (particularly fishing) from those areas, turning all or part of a traditional fishing ground into a no-take MPA or marine reserve.[2] Proponents argue that by eliminating all fishing from an area, marine reserves protect biodiversity, serve as an insurance policy, and benefit ecosystem and fisheries management. Initially, there was a clear distinction between establishing marine reserves for protection of biodiversity and establishing them for fisheries management. Most current calls for large scale implementation of marine reserves argue that they will provide both biodiversity and fishery benefits, whilst potential costs are seldom mentioned [1,2].

While the potential value of marine reserves for the protection of habitat and biodiversity is clear, their potential for improving fisheries management and particularly fisheries yields will be limited unless the roots of fisheries management failures are addressed. The same holds for other management tools. The major problems in fisheries management and conservation stem from improper incentives and institutional structures [3–5] that fail to control the race for fish leading to over-capacity, over-fishing and economic loss. Once overfishing becomes chronic, the socio-economic and political costs of the tough decisions needed for significant

[1] The term MPA is used here to mean areas that are closed to fishing, the meaning that is more widely used by the public. In the scientific literature, these areas are more commonly referred to as marine reserves (i.e., 9).

[2] The difference between marine protected area and a marine reserve is not always clearly made, generating confusion.

improvement represent a major impediment to change. Marine reserves are a tool for specifying the location of fishing; they do not affect the incentives, nor the institutional structures responsible for over-fishing [6]. Furthermore, imposition of ill-considered marine reserves may in fact be detrimental, and it is misleading to promote them as devices always likely to result in improved yields.

Area closures are just one tool of fisheries management and marine reserves implementation needs to be guided by the scientific principles of adaptive management: experimental treatments, controls and evaluation [7]. For marine reserves to be an effective fishery management tool, they need to be considered case by case in light of the objectives and the current state of the fishery. They need to be evaluated and compared to viable alternative fisheries management tools, and used, where appropriate, as one element in a broader package of measures. Planned programs are needed for testing the effectiveness of marine reserves for fisheries management. The utility of marine reserves in relation to alternative tools will likely be very different for different types of fisheries, as discussed below.

In the following sections, the knowledge available regarding the potential role of marine reserves specifically in fisheries management is reviewed.

2. Potential of marine reserves

There are several well-defined ways in which marine reserves may be expected to have merit as a fisheries management tool. These are examined briefly below.

2.1. Increases in yield

The empirical evidence that marine reserves enhance fish yields is sparse [8]. Setting aside a marine reserve initially reduces the area that can be fished, thus reducing yield. The question then is whether the yield in the area remaining open will increase enough to make up for losses from the closed area. We know that in many marine reserves, the abundance and size of fish increases [9]. This is expected. Yield from the fished open area can increase in two ways: (1) bigger fish can swim out of the closed area and be caught, and (2) the larger fish in the closed area can contribute more eggs and ultimately more larvae to the fished open area. However, neither result is guaranteed. If the fish or invertebrates species of concern are sessile they will not move into the fished open area. Conversely, if they are too mobile, virtually all will move into the fished open area, thus removing the anticipated benefit [10,11]. Also, larval dispersal patterns must be such that enough larvae are transported to the open areas [12], and (compensatory) density-dependent growth does not negate benefits within the closed areas [13]. Benefits will accrue only if recruitment to the fished area before its closure was less than the maximum possible. Thus, marine reserves can, subject to the conditions just described being met, increase yields only in fisheries in which heavy fishing mortality has substantially reduced recruitment [14–17]. This is a corollary of a formal result: management based on marine reserves and conventional management are analytically equivalent [18–20] with respect to the yield of the target species.

2.2. Buffer against uncertainty

Conventional management through catch or effort controls can fail due to stock assessment errors and inadequate institutional frameworks. To the extent that marine reserves may be effective at protecting breeding stock, they may help to buffer the impact of such failures [3,21,22]. However, persistence of populations in marine reserves, and their ability to replenish surrounding areas, depends on the reserve configuration and larval dispersal patterns, which are poorly known [23]. Thus, while MPAs have the potential to reduce uncertainty in the effects that fishing regulations will have, lack of relevant biological knowledge adds uncertainty. It should also be mentioned that other methods (e.g. seasonal closures to protect juveniles) can potentially have similar or even stronger effects than marine reserves in that respect [24].

2.3. Reduced collateral ecological impacts

Fishing has wider impacts on marine ecological systems, not just on target species [25]. Marine reserves can reduce impacts of fishing on benthic habitats, by-catch and protected species, and ecosystem structure and function. To the extent that the objectives of fisheries management have been broadened to include concern for such impacts [26,27], reserves are potentially an important tool in meeting such specified objectives.

2.4. Stocks of sedentary organisms

The term "sedentary", as used here, does not mean immobile. Sedentary organisms are those whose movements are short-range when compared to the spatial scale of the fishing process (fleet displacements) and/or pelagic larval dispersal. Marine reserves are one form of spatial management. For sedentary species, it has long been recognized that spatial management can be more easily understood, accepted and implemented than catch limits [28,29]. In the case of many fisheries targeting relatively small stocks of sedentary organisms, conventional stock assessment and catch regulation are unlikely to be affordable or effective. Instead, locally supported regulations, including spatial management such as marine reserves, have been shown to provide significant benefits in some cases [30,31]. In addition, global catch controls may be inappropriate for many sedentary invertebrates in terms of their population biology. For example, broadcast spawners require high-density concentrations in order to reproduce successfully, and these high-density concentrations are the first ones targeted by a fishery regulated by catch or effort limits. Spatial management may achieve larger reproductive outputs than global controls for comparable harvest rates.

2.5. Multispecies fisheries

When a fishery targets a multispecies complex, existing catch and net size limits may be poor management tools for some species. For example, in many fisheries the chief management tool currently used is ITQs/TACs.[3] These apply to a few species, whilst the fisheries may land dozens or even hundreds of species and discard many more.[4] Extending quota management to all species in such multispecies cases is not practicable. Even if sufficient data were available, such fisheries are rarely profitable enough to afford the assessment costs. Prohibiting landings of some protected species or sizes may simply force dumping. Setting catch limits on every species would practically close the fishery because at any time at least one species would likely need protection. Properly designed marine reserves may be a cost-effective management tool for such fisheries.

2.6. Improved knowledge

Marine reserves may provide valuable scientific reference areas to serve as controls (in the absence of take) on trends in fish production, age, size and sex structure of the stock, as well as on impacts of fishing on habitats [32,33]. Closed areas may provide the best basis for understanding the broader impacts of fishing on ecological systems. The spatial scale of the reserves would need to be appropriate to the life history of the species, but stock assessments that include data from an unfished control site would be highly informative. Such reference areas are particularly appropriate during the development of new fisheries, when sustainable exploitation rates of newly exploited species are highly uncertain, so that there is risk of over-fishing [34]. Carving out marine reserves from conventional fishing grounds, however adds on uncertainty concerning the induced behaviour of fishers and resulting fishing and societal costs [19].

3. Potential and actual problems with marine reserves

Conversely, marine reserves present problems under a number of circumstances which are reviewed briefly below.

3.1. Effects of spatial shifts in fishing effort

A consequence of closing an area to fishing is for the fishing effort to move elsewhere, which may have a number of undesirable consequences [35][5] that in most

[3] The total allowable catch (TAC) is the catch limit for a whole stock. The way in which that limit is allocated and managed will vary between management regimes. Individual transferable quotas (ITQs) are one was of allocating and managing TACs.

[4] Australia's south east trawl fishery, for example, catches well over 100 species, of which up to 80 are sometimes landed, but only 18 are currently managed by quotas [37].

[5] Rijnsdorp et al. [35] for example, showed that a closed area for protection of cod in the North Sea led to unintended transfer of effort to areas where skates and long lived benthic species were more vulnerable.

cases remain un-analyzed. If a reserve were large relative to the dispersal of adults and juveniles, protecting 30% of the area would lead to a 30% reduction in potential yield. Unless the quota or effort were reduced by 30% outside of the reserved area, the sedentary stock outside would be severely over-fished. If catch limits were reduced proportionally, the conservation benefits would come primarily from having reduced the overall catch, not from having closed the area to fishing. The spatial re-allocation of effort that occurs when areas are closed can have detrimental impacts on target species, non-target species and habitat in the areas that remain open. The impact of effort re-allocation must always be considered when planning the deployment of marine reserves.

3.2. Stocks of highly mobile organisms

Many of the species caught in industrialized and some artisanal fisheries are so mobile that marine reserves would have to be very large to effectively protect breeding stock. With mobile stocks, closing some areas imposes economic inefficiencies, forcing the catch to be taken at other times and places. The stock would not be protected without additional measures, but economic costs would be imposed [19].

3.3. Better options may be available

When existing fisheries systems protect the breeding stock through catch, size or area limits, it is unclear that imposing reserves will provide additional yield benefits. Where conventional fisheries management systems have not protected breeding stocks, such as New England groundfish and in many European fisheries, scientific recommendations have not been implemented. Similar problems may befall marine reserves. Marine reserves may also increase costs and overcapitalization, potentially defeating conservation purposes [19]. Many countries have attempted to impose top–down catch or size regulations on local fishermen with little success. Top–down imposition of reserves is equally unlikely to work; what is needed, as for any management measure, is bottom-up support of fishery stakeholders and communities. In addition, the possibility of using particular regulations of fishing operations in marine protected areas should also be carefully considered as an alternative to outright banning of the fishery.

3.4. Hardship to fishing communities

Fishing communities, just as many fish stocks, may have complex spatial structure and limited mobility. Marine reserves may cause extreme hardship to fishing communities, shortening fishing seasons, forcing fishers to travel much farther to unfamiliar grounds, increasing risk to the smaller vessels and to people [19]. Indeed, marine reserves that are large enough to protect some widely spread species may exclude local people from any form of fishing. The spatial structure of the fish and the human community must be considered in the analysis of marine reserves.

4. How should we proceed?

The empirical evidence of the positive effects for fisheries attributed to MPAs and marine reserves is scarce [36] and it is obvious that marine reserves have benefits (and costs) beyond fishing. However, as with terrestrial national parks, for example, they are proposed not only to prohibit fishing, mining, or dumping, but to preserve ecosystem functions and processes, and to provide opportunities for numerous other forms of human enjoyment. It can be argued that many of the short-term costs of marine reserves to fishing could be offset by other, long-term benefits to society, but this is also likely to vary from case to case. In this paper, we have intentionally considered marine reserves from a fisheries angle and agree that an integrated, multiple use perspective (as in an Integrated Coastal Areas Management framework) would be necessary to reach broader conclusions.

Marine reserves can be appropriate as a tool for the conservation of identified habitat, species and community biodiversity. However, to minimize the yield losses to fisheries, and to achieve the desired conservation benefits, reserves need to be evaluated in the context of: (1) clear biodiversity, ecosystem and fisheries objectives; (2) the social and institutional ability to maintain and enforce the closures; (3) existing fisheries management actions they could complement under certain conditions; and (4) the ability to monitor and evaluate success. Unqualified advocacy for no-take marine reserves, sometimes hidden under advocacy for MPAs in general, ignores the need for their scientific evaluation and the potential negative impacts to stocks, yields, and communities.

We need to learn how marine reserves (and MPAs in general) might be used to improve fisheries yields, and this will need careful experimental design and evaluation using the principles of adaptive management. Reserves of different sizes need to be set up in different environments with replicates and controls. Long-term evaluation needs to be in place and criteria for success need to be determined a priori. As the lack of scientific studies and inadequate sampling will be a major impediment to the successful implementation and evaluation of marine reserves, the appropriate scientific frameworks for their placement and evaluation are critical.

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