Marine Protected Areas as Fishery Policy: A Discussion of Potential Costs and Benefits

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Abstract

Marine protected areas (MPAs) are currently receiving considerable attention as a "new" tool to control overexploitation. Many advocates argue that MPAs will provide a plethora of benefits ranging from improved habitat to higher fish stocks with little costs. Fishermen argue, not surprisingly, that the costs resulting from closing areas could be significant and need to be considered in the debate. In this paper, a set of biological, industry, and management hypotheses drawn from the literature analyzing the effects of MPAs are discussed. In doing so, a framework is presented that can be used to assess the expected returns to society from investing in MPAs.

Key Words: renewable resources; fisheries; marine protected areas; no-take zones

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Marine Protected Areas as Fishery Policy: A Discussion of the Potential Costs and Benefits

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I. Introduction

In May 2000, President Clinton issued an executive order that called for the United States to study the development of a vast network of marine protected areas[1] (MPAs) as a way to ensure that marine habitats are preserved and as a way to combat overfishing. The order comes after a decade-long movement within the marine conservation, fishery biology and ecology community calling for the increased scale and scope of closed areas in the management of marine ecosystems. Closing off areas to fishing is not a new management tool, however. In fact, some of the earliest recorded closed areas were in the 19th century Finnish Salmon and Canadian groundfish fisheries. In these cases, critical spawning habitats were closed to fishing. And, while the use of area and time closures has a long history, the new momentum behind MPAs differs from the traditional rationale by focusing on the need to provide protection beyond the spawning grounds and other areas identified as crucial to the life cycle of marine populations.

Even though the use of marine protected areas throughout the world is still limited, there is growing empirical support that the ecological conditions within the protected area improve after the area is closed to fishing. These ecological benefits range from more larger and older fishes and overall higher fish stocks to improvements in habitat (Polacheck 1990; Dugan and Davis 1993; Roberts and Polunin 1991; Carr and Reed 1993; Roberts 1998a; Pauly et al. 1998; Palumbi 1999; Murray et al. 1999). Still other marine scientists have touted considerable ancillary benefits, including education, diving, photography, tourism, and conservation of marine biodiversity (Bohnsack 1993; Sobel 1993). All of these benefits are thought to lead to and enhance the long-run sustainability of the fishery.

Traditionally, fishery managers have controlled fishing effort through the use of restrictions on vessel size and power, total allowable catches, types of gear, time and area closures, and size and sex of the catch. In the United States, eight regional management councils—comprised of inshore and offshore commercial fishermen, scientists, conservationists, recreational fishing interests, and national,

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1 According to the World Conservation Union (IUCN), a marine protected area (MPA) is "any area of intertidal or subtidal terrain, together with its overlying waters and associated flora, fauna, historical and cultural features, which has been preserved by legislation or other effective means to protect all or part of the enclosed environment." While the IUCN establishes a forward-looking agenda for setting aside areas, the current sanctuary system within the United States is based on more traditional goals and the use of set-aside areas. In the United States, the National Marine Sanctuary Act defines a sanctuary as an area of the marine environment of special national significance due to its resource or human-use values, designated as such to ensure its conservation and management.

regional, and local government officials—set these practices. It is in this policy environment that the expanded use of marine protected areas will be debated and explored. Closing part of the fishing grounds will almost inevitably lead to the perception, at least, that the current consumptive users of the grounds will be directly and immediately impacted. Given the inclusion of a diverse set of potential stakeholders in the U.S. fishery policy process, the claims of the affected parties will have a potential legitimacy and compromises over the degree of protection (types of uses allowed), scale and location of MPAs are inevitable.

Because of the potential political difficulty in siting MPAs, the regional councils could benefit from a nationally defined framework with which to decide if MPAs are an appropriate management tool. To help develop a set of such guidelines, numerous biological, economic, and regulatory arguments both for and against MPAs are presented. The hypotheses are placed into a traditional benefit and cost structure. The list covered here is not intended to be exhaustive, but rather to provide a set of criteria by which MPAs can be assessed. Of course, the policy question should not simply be whether MPAs are beneficial relative to the status quo, but are they the best possible policy tool available.[2] While the latter calculus is arguably more general and policy relevant, the hope here is to provide some structure to the former by highlighting biological and economic issues inherent in the siting of protected areas.

The focus of this article differs from other review articles on MPAs in three main ways (Davis 1989; Roberts and Polunin 1991; Carr and Reed 1993; Farrow 1996; Carr and Raimondi 1998; Thomson 1998; Palumbi 1999; Murray et al. 1999; Boersma and Parrish 1999). First, the biological and economic impacts both within and beyond the borders of the protected areas are highlighted. This runs contrary to the emphasis on the benefits *within* the boundaries of the closed area. Second, the article places the current debate within a cost-benefit framework while at the same time illuminating some of the indirect or induced changes that could occur after MPAs are sited. Finally, the susceptibility of MPAs to both environmental shocks and the uncertainty of using MPAs as a means to control effort are highlighted. The emphasis on the expected costs and benefits is not intended to downplay the potentially large moral, ethical and cultural benefits of MPAs. In a political-economy framework, all values are important and need to be considered, and the lack of discussion here is not meant to signal otherwise.

The discussion is structured by first presenting the general economic principles that can be used to assess whether MPAs are a beneficial investment of resources. In doing so, some distributional issues at the center of the MPA debate are highlighted. The costs and benefits regarding the use of no-take zones—which are a particular type of MPA and ban all consumptive uses (e.g., mineral extraction,

[2] Within the debate surrounding the use of MPAs, the subtle differences between determining if protected areas are worthwhile and if so, what type of protection is needed, are often blurred. The confusion is fueled by the interchangeable use of the terms MPA, marine reserve, harvest refugia, no-take zones, closed areas, and marine sanctuaries, whereby each designation could imply different levels of protection and very different goals. For example, a marine sanctuary might be proposed to protect an endangered species or unique habitat. On the other hand, a harvest refugia or no-take zone might ban commercial or recreational harvest within the area with the intent of increasing harvest levels in the surrounding areas.

fishing)—are presented next where the focus is on ecological and economic forces that can potentially affect net returns. Then potential risks stemming from induced changes in behavior of the users and changing environmental conditions are discussed to assess the degree to which MPAs insure the sustainability of our marine resources. Finally, the paper concludes with a discussion on the potential role of MPAs in fishery policy and in the future of marine stewardship.

II. Marine Protected Areas as an Investment

From an economic perspective, MPAs represent a public investment. With any investment, the decision to invest is guided by whether the expected benefits, adjusted to account for the risks, outweigh the expected costs. As stated in the introduction, the potential biological benefits include increased stock abundance, healthier fish stocks, and spillover effects into the nonprotected areas. MPAs are also touted as a hedge against potential management failures, such as setting the total catch levels too high, and are seen as very useful tool in the recovery of overdepleted fish stocks. Potential benefits also include increase in harvests, increase in catch of older (more valuable) fish, and increases in nonconsumptive use values. Costs stem directly from the reduction in fishable waters and the resulting displacement of fishing effort.

With all investments, there are risks. The main biological risks stem from the fact that MPAs are fixed in space even though fish stocks are mobile and the ocean environment is susceptible to broad environmental shocks (e.g., ENSO events, run-off, oil spills, etc.). For example, if an area is selected for closure due to its unique role in the lifecycle of the fish stocks, there is no guarantee that this habitat will continue to provide the necessary ecological services if affected by pollution or environmental change. Other risks are due to the likely induced changes in fishing operations following post siting. For example, in response to area closures, skippers might alter the configuration or design of their vessels to employ multiple gear types or the skippers might increase the number of trawls. In this example, increased effort or more detrimental practices could drive nonprotected area fish stocks to dangerously low levels. In the end, the councils will need to weigh the risks of using MPAs along with the benefits and costs.

Even though the underlying economic principles involved are rather simple, calculation of the expected net returns from MPAs are not. Like most public investments, the expected benefits of MPAs will be realized at some future date whereas the majority of the costs are incurred initially, implying that closing off areas also results in an intertemporal tradeoff, perhaps even across generations (Holland and Brazee 1996; Sanchirico 1998; Sanchirico and Wilen 1998; Hannesson 1999; Pezzey et al. 2000). Difficulties also stem from the complexity and the corresponding degree of imprecision when trying to predict the impact of policy changes on the biological and economic systems. Along with intertemporal tradeoffs and uncertainties, MPAs could potentially affect one user group disproportionately, implying that there are potential distributional issues among the stakeholders in the process (Holland 2000). For example, if an MPA is sited within the near-shore environment, the inshore fleet could potentially incur the highest cost (i.e., direct loss of fishable waters), while the offshore fleet could receive some of the benefits.

Another difficulty for fishery managers is quantifying the potential nonconsumptive use values associated with the closure. It is generally understood that these values are an important factor in resource allocation decisions. And, in fact, many recent calls for MPAs have cited the potentially large returns from ecotourism (e.g., scuba, snorkeling) activities and conservation values associated with biodiversity preservation. However given the current lack of research on the magnitude of these benefits for marine resources, the regional councils will find it difficult in the near future to incorporate these values into their decisions.

Further complicating matters is that current research has shown that the magnitude of the impacts from protected areas depend in an important way upon the location, scale, and number of areas. If, as some claim, protected areas need to encompass 50% of the population to be effective (Lauck et al. 1998), then one would expect these impacts to be large and significant. On the other hand, if the areas do not represent a significant portion of the relevant fishing grounds, then the impacts on the fishing sector might be lower.

III. Expected Benefits in the Protected Area

In the debate on the benefits from MPAs, it is clear that biologists and ecologists view protected areas as an instrument that will broadly improve biological conditions within their boundaries. Also nested within this hypothesis is the conjecture that MPAs will provide protection for and conservation of marine biodiversity. Another argument for creating protected areas is that they will provide much-needed control areas to study the impact of fishing on marine ecosystems. Stated economic benefits include potential increases in tourism and nonconsumptive use recreation along with the notion that MPAs will stem the tide of overfishing and therefore, provide sustainable long-run returns to the stakeholders.

In the following section, we discuss four potential benefits.

MPAs will improve broadly the health of the ecosystem within the boundaries including increases in stock abundance, age/size composition, spawning stock biomass, yield per recruit, and restoration of healthy trophic levels.

There is growing anecdotal and empirical support for the realization of the ecological benefits within the protected area. Approximately, 60% of the case studies and empirical analyses on the impacts of protected areas found them to have varying degrees of significant positive effects on abundance, size, and density.[3] For instance, McClanahan and Safir (1990) found that total fish densities increased 3.6 times in protected lagoons over those in the unprotected ones.

Because many empirical studies rely on sampling techniques with high degrees of imprecision and/or lack the necessary controls to determine cause and effect relationships, the reliability of the magnitude of the effects remains uncertain. For example, the Polunin and Roberts study (1993), which uses a visual sampling technique to get an estimate of abundance and age/size distributions, reports that a 45-59% increase occurred in abundance, size, or biomass in shallow protected areas. However, as the study mentions, water clarity problems, lack of measurement of movements within and outside the protected area, and the absence of a control to determine if the closed area always had

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[3] For comprehensive analysis of the literature on the impacts from protected areas, see Davis 1989; Roberts and Polunin 1991; Dugan and Davis 1993; Palumbi 1999; Murray et al. 1999; Boersma and Parrish 1999.

higher biomass density imply that the results attributing these changes to the MPA are not definitive. Regardless, there appears to be a growing consensus among ecologists and fishery biologists that ecosystem health within the protected area will improve in one form or another.

MPAs will provide in situ conservation of marine biodiversity.

Protected areas have been widely used in conserving terrestrial biodiversity throughout the world. Enthusiasm for this approach is spilling over into the marine conservation movement, especially with regard to species-rich coral reefs, which are being targeted for protection around the world. A case in point is President Clinton's recent executive order that established an 84-million-acre MPA in Hawaii that encompasses nearly 70% of the U.S. coral reef habitat. If species richness (number of species) is an appropriate measure of biodiversity, then there are some visual conformations that biodiversity can increase after an area is closed (Sobel 1993).

MPAs will provide opportunities for increased nonconsumptive use values.

Like their counterparts on land, protected areas have the potential to increase coastal communities' revenue from nonconsumptive uses, such as diving and photography. Depending on the share of the tax base dependent on fishing, this could prove to be a substantial benefit. Furthermore, some have argued that the potential increases in revenue from tourism could even offset potential losses due to lower commercial or recreational catches as a result of the closure.[4] However, if the gainers and losers differ and/or the losers are not compensated (Caldor-Hicks criteria), then siting an MPA for tourism revenues potentially could be politically difficult. Obviously, the location and setting of a particular MPA would play a critical role in the magnitudes of these benefits. For example, a protected area offshore that is mainly occupied by bottom-dwelling species will most likely not have a significant tourism potential while a coral reef closure might.

MPAs will provide 'undisturbed' areas for scientific research.

Scientists who have promoted MPAs typically note the enormous research potential in having study areas that are free from exploited uses. Many argue that these areas can be used as controls to monitor and study the recovery of fish populations. Fishery biologists contend the benefits will be in revised empirical estimates of population parameters (e.g., growth and natural mortality rates) that will greatly improve stock assessments, which currently rely heavily on catch-effort data. Reducing the current level of uncertainty and improving the science in stock abundance forecasts can only improve the long-run economic and biological outlook of fisheries.

IV. Expected Benefits Outside the Protected Area

Many marine scientists point out that potential effects both within and outside the protected area are biologically linked; the link is a complex composite of the ecological structure, oceanographic

[4] It could very well be that a catch-and-release recreational fishery will be allowed to operate within the no-take zone and therefore, there is the potential for some recreational fishing occurring. Along these same lines, Bohnsack (1993) argues that protected areas, which only prohibit commercial catches, could actually reduce potential conflicts between commercial and recreational fishers.

patterns, fish migrations, and the scale and location of the no-take zone.[5] For example, if the fish stocks residing within the proposed MPA interact through migrations with the remaining open areas, then there is a possibility of the biological benefits spilling over. In this case, there is the potential for broad ecosystem improvements. On the other hand, if the majority of the stocks are sessile or the area is so large as to encompass the entire range of the more mobile species, then there is little export of the benefits to the open areas. Lastly, there is some theoretical work demonstrating that even if the adult population is sessile, the potential for increased exports of larvae from an MPA and subsequent increased recruitment could potentially improve the biological populations residing outside the MPA (Hastings and Botsford 1999; Pezzey et al. 2000). In general, the nature of the biological linkages are critical determinants of the potential biological and economic benefits that occur outside an MPA (Sanchirico and Wilen 1998).

Next, we discuss three potential biological and economic benefits.

MPAs will provide positive biological spillovers into the remaining non-protected areas.

As Carr and Reed (1993) and Allison et al. (1998) have pointed out, improvements within the protected area are neither a necessary nor a sufficient condition that MPAs will be a successful tool in improving the health of the fisheries outside their boundaries. To have improvement beyond the boundaries of MPAs, there must be a biological link between the closed and open areas. If there is no link, then the areas are independent, and closing off areas will only have direct local ecological impacts. If the link is too strong (e.g., a highly migratory pelagic species) the within and outside effects might be insignificant, because the fish stock will likely spend most of its lifecycle outside of the MPA. Some argue however, that with appropriately targeted locations, such as nursery habitat, even highly mobile species could benefit from MPAs. But even if the adults are sessile, it is possible for biological spillover to occur from larvae dispersal. In fact, if the age/size of the stock residing within the protected areas increases and fecundity increases with age/size, then it is possible that the level of larvae in the system can dramatically increase post-siting (Hastings and Botsford (1999) and Pezzey et al. (2000)). It is important to note however that even the existence or potential for positive biological spillovers does not guarantee that the biological health of the nonprotected areas will improve post siting. As discussed in the following sections, the biological health of the nonprotected areas will also depend on the impacts and response of the users to the MPA.

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[5] The importance of connectivity issues for siting decisions is controversial as there is some evidence that these ecological structures might not be as well defined in practice. For example, in a study looking at the dispersal of larvae in the Caribbean, Roberts (1998b) used surface current patterns to map dispersal trajectories. Roberts found that for the most part "sources" and "sinks" are transitory classifications, and that "low" replenishment areas have the most potential for beneficial effects associated with closures. The transitory status of sources and sinks is also found in a theoretical bioeconomic analysis where the result is not due to surface current patterns, but to the levels of fishing effort being applied across the areas (Sanchirico and Wilen 1999). In essence, they found that in an exploited system whether an area is a source or sink depends on economic factors and not just biological ones.

MPAs will increase aggregate catch levels in the fishery.

The objections to protected areas typically stem from the belief by fishermen that they are bearing the costs from policies that, to them, offer questionable benefits. Consequently, an important question in the policy debate is under what conditions might aggregate catch from a fishing ground increase after a closure.[6] As numerous authors have shown, there are circumstances when aggregate catch levels can increase or remain unchanged after a protected area is sited.[7] It can be shown that there are at least three necessary conditions for this to occur. First, it is necessary for a biological link to exist between the closed and open areas. For example, Hastings and Botsford (1999) and Pezzey et al. (2000) have shown (theoretically) that if transmission of larvae is broad and uniform across all areas, then aggregate catch levels might not decrease due to the higher levels of recruitment resulting from the increased levels of larvae in the system from the protected area.[8] Second, it is necessary (and rather obvious) that catch outside of the MPA increase from the status quo. Finally, the relative share of total catch that the area contributed prior to closure must be relatively small.

In the end, the net impact on catch depends on the relative magnitudes of these factors. For example, if the area contributed a significant share of total harvest, it is less likely that total harvests could increase, because the threshold level that the biological spillover effects must overcome is higher. On the other hand, if the catch level is an insignificant share of total catch, possibly as a result of over-exploitation, then probability of increasing catch levels is probably higher. In an over-exploited system and when fish stocks are neither too sessile nor too mobile, total catch levels have been shown (theoretically) to increase after an area is set-aside from harvesting (Sanchirico and Wilen 1998).

MPAs will enhance market value by altering the composition of the catch.

One of the uses of traditional area and time closures has been to provide protection to stocks to enhance market value by altering selectivity (OECD 1997). Selectivity could be altered, for example, if a closure is implemented in an area where a high proportion of the stock is young. In this case, effort will be displaced to areas with greater frequencies of older (i.e., larger) stocks, and catches comprised of larger individuals could receive higher market prices per unit of weight.[9] Within the

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[6] Another theoretical benefit of protected areas not addressed here is that an MPA might stabilize population levels both inside and outside the area, causing reduced variations in catch levels (Lauck et al. 1998).

[7] These studies are found both within the marine biology and fishery economics literature and can be placed into two broad categories. The first group (Polacheck 1990; Man et al. 1995; Lauck et al. 1998; Hastings and Botsford 1999) focuses on modeling the ecological implications and therefore, for the most part, relegates the economics to a background role. Models that incorporate more realistic harvesting processes fall into the second category, and include Holland and Brazee (1996), Sanchirico (1998), Sanchirico and Wilen (1998), Hannesson (1998), Pezzey et al. (2000), and Holland (2000).

[8] Whether the Hastings and Botsford (1999) result will continue to hold if the larvae only reach a fraction of the remaining open grounds is unclear.

[9] Pezzey et al. (2000) argues that the potential exists for positive economic welfare (both consumer and producer surplus gains) from MPAs. Essentially, the argument is that the increase in the average size of the catch will result in an increase in demand, and the MPA will reduce production costs due to the higher stock levels in the fishery (a positive fishery effect with respect to stock levels is assumed). In his example, the price

protected area debate, Pezzey et al. (2000) provides a heuristic argument for possible short-run, revenue-generating impacts from closures due to increased average catch sizes, which in many fisheries is a proxy for quality. Another possible increase in revenues could occur if the changes in catch composition are accompanied by a shift to a more valuable product form. Revenues could increase, for example, if the larger sizes are more likely than smaller sizes to enter the fresh market. Because MPAs do not address the regulated-open access institutional characteristics found in many U.S. fisheries, any revenue gains due to changes in catch compositions are most likely not sustainable in the long run as industry effort races to capture these benefits.

V. Expected Costs

Although there is a considerable amount of literature investigating the benefits from MPAs, there are potential costs that have not received much attention. In general, fishing is a complex process that depends on many factors including: the type of vessel and gear used, target species, stock density levels, time spent fishing, areas fished, and fishing effort levels operating in the fishery. The inputs into this process all affect the costs associated with fishing and therefore, impact the activity level. One can imagine, for instance, that less congestion at a given fishing ground could lower the cost per unit of catch. Costs could also differ across fishing grounds due to oceanographic conditions, such as stronger currents that increase fuel use and/or geographic features that prohibit the use of certain gear types. Within the current debate, an important question is how could closing areas directly affect these types of costs. We next address the costs associated with congestion on the fishing grounds and location choice of fishing operations.

MPAs will increase congestion on the remaining open grounds.

Reducing the amount of area open to fishing implies that, at least in the short-run, vessels could experience higher levels of congestion on the grounds. Congestion effects could result in increases in fuel usage, crew employment, and higher capital costs (e.g., fish finding equipment). In addition, congestion effects could lead to increased conflicts between users of the resource (i.e., inshore/offshore allocation disputes). Congestion effects could also lead to gear conflicts on the grounds. For example, a potential conflict could arise from a trawler displaced by an MPA venturing into an area mainly occupied before the MPA was established by fixed-gear fishermen. In this example, the costs of harvesting do not only go up for the displaced trawler, but also for the fixed-gear fishermen, who otherwise might not have been affected directly by the closures. Still another congestion effect could potentially occur if establishment of an MPA shifts fishing pressure from one species to another, thereby increasing the competition for the catch of that second species.

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of fish remains constant after the MPA is sited, but increases in consumer and producer surplus result from the increases in the demand and supply schedules.

MPAs will increase the variable costs associated with the choice of fishing location.

A fisherman's decision of where to fish is a function of many factors including time of year, targeted species, expected time at sea, expected catch rates, transportation costs, search costs, location-specific costs, expected (ex-vessel) prices, and weather-related events. With respect to how these factors might change after a closure, we focus on transportation costs (steaming and searching costs). The direct impact on transportation costs is rather obvious. Following siting of an MPA, vessels could spend more time steaming to and from the fishing grounds, which could increase fuel use. In fisheries where the time steaming to and from the grounds increases as a result of MPAs, the amount of time that the vessels will spend with the gear in the water—the opportunity cost associated with location choice—will decrease. The increase in fuel costs and the increase in steam-time opportunity cost can create incentives for skippers to invest in capacity enhancements such as larger hold size, improvements in handling technology, and more horsepower. This increase in capacity could occur even though MPAs are a policy tool designed to control (albeit indirectly) the amount of capacity and the location of effort being applied in the fishery.

In many fisheries, a significant component of total variable harvesting costs is the time and fuel spent searching for the fish. In modeling harvesting costs, a basic assumption is that higher stock levels imply that search costs are lower, everything else being equal. This effect is commonly referred to as the stock effect. If MPAs are being considered in a fishery where the stock effect is significant, then the MPA could potentially reduce this component of harvesting costs. For instance, if the biological spillover effects of MPAs are large and far-reaching, then there is the possibility that stock levels will increase throughout the fishery. In this case, one would expect the searching costs to decrease, everything else being equal. On the other hand, if the positive spillover effects are only local in nature, then searching costs might actually increase after the MPA is established. For example, the displaced fishermen, who have local knowledge of fish concentrations, would need to spend time and effort learning about stock concentrations and oceanographic conditions that exist in the remaining non-protected areas.

VI. Management Uncertainties

There have been considerable discussions on the beneficial use of MPAs for managing fisheries. For example, many researchers point out that MPAs are a cheap and effective tool to control fishing effort, which has proved to be so elusive to fishery managers. MPAs are also thought to provide a hedge against management failures (Bohnsack 1993; Lauck et al. 1998; Murray et al. 1999) and to increase the resiliency of heavily exploited fisheries during times of environmental extremes (Carr and Reed 1993). These statements, along with those related to the associated benefits to the ecosystem, are behind the recent support for the use of protected areas as the centerpiece of the precautionary approach to management (Davis 1989; Polacheck 1990; Man et al. 1995; Lauck et al. 1998,Murray et al. 1999). If these hypotheses hold, then these are real benefits. But as discussed, relying on MPAs to accomplish all of these things is not without risk.[10] Potential risks stem from induced changes in industry behavior and practices and environmental factors (e.g., climatic shifts and pollution). How these risks are valued is critical in the decision to use MPAs, especially when MPAs are sited as a means of implementing the precautionary approach.

MPAs as a means of controlling fishing effort

MPAs attempt to control fishing effort by both directly restricting the location where fishing can occur and indirectly altering the potential profitability of a fishing enterprise. The long-run success of MPAs in controlling effort is uncertain however, as MPAs address a symptom and not the root cause of excess effort. Fisheries are common property resources and excess effort results from the users of the resource not internalizing the social costs of their activities. Any attempt to control effort without addressing the cause of excess effort is risky because commercial fishermen will attempt to remain profitable while still not internalizing the true social costs of their activities. In fact, there is a long history of fishermen responding to input controls on production by increasing the use of other inputs. For example, in the 1970s, the number of vessels in the British Columbia salmon fishery was restricted, and fisherman responded by increasing the size of their vessels. Canadian fishery managers then tightened controls on the size of vessels, and the fishermen responded by increasing the horsepower of their engines. Unfortunately, because MPAs control effort only within their boundaries, they have no effect on the causes of excess effort that will continue to plague the rest of the fishing grounds.

Two possible induced responses that could increase the uncertainty in using MPAs to control effort are potential changes in the concentration of fishing effort and vessels changing fishing gear and methods. Because establishment of an MPA does not necessarily coincide with other effort controls (i.e., restrictions on entry or a vessel buy-back program), some proportion of the effort operating in the closed area prior to closure will adjust by fishing in the remaining nonprotected areas. The increased amount of time spent fishing in the remaining open habitat could potentially reduce the nonprotected stocks to very low levels. In two studies investigating the implications of MPAs, which include behavioral models of the fishing industry, the models predict that harvesting pressure outside and especially along the boundaries of the MPA will increase (Sanchirico 1998; Walters 1999). There is some anecdotal evidence that this has occurred outside an MPA located off the coast of Kenya, where the number traps increased dramatically in the immediate vicinity of the protected area (McClanahan and Kaunda-Arara 1996). This increase in effort along the edge led the authors to conclude that the spillover benefits from that MPA have quickly been dissipated.

With respect to utilization methods, the costs associated with increased competition could induce the industry to adopt fishing practices that would yield the highest private return subject to the new

[10] Some proponents of MPAs have used the analogy that setting aside habitat is similar to an interest-bearing savings account. For several reasons, that statement is a little misleading. First of all, a savings account is insured (within the United States, by the Federal Deposit Insurance Corporation.) As this section will discuss, MPAs are neither insured nor risk-free investments. Second, the risk-free interest rate from a savings account is certain. As discussed throughout the paper, the magnitude of the spillover impacts from the closed areas is uncertain and will most likely not be a sure bet.

spatial constraint but would not necessarily be socially optimal. The ancillary social costs from the shift in fishing practices could, for instance, be a shift to modes that increased the levels of habitat destruction. In addition, any short-run revenue impacts in the fishery from, say, shifts in the catch composition or increases in aggregate harvests could generate increased levels of competition. As the vessels compete for these short-run revenue gains, the incentives to invest in more capacity increases.

MPAs as a hedge against poor stock assessments.

Many authors claim that a significant benefit of closures is that the stock residing in the protected area provides a hedge against stock collapse and the use of imperfect science in the regulatory process (e.g., Bohnsack 1993; Lauck et al. 1998; Allison et al. 1998; Murray et al. 1999). For example, one fisheries expert said that, "We've obviously screwed up [referring to management of stocks such as North Atlantic Cod]. The idea of closing off areas as a hedge against this imperfect science is a powerful one" (Schmidt 1997). In general, a hedge is an investment tool designed to offset a risky investment.[11] A good hedge has returns that are negatively correlated with any risky investment, so that its returns increase when the returns of the other investments decrease. Therefore, the appropriate policy question to ask is whether a protected area is a good hedge to imprecise estimates of abundance. If one assumes that a fishery will most likely collapse due to overfishing, then MPAs might be a good hedge against poor stock assessments. On the other hand, if there are other factors that could contribute to a fishery collapse, then a protected area might not be as valuable a hedge against poor stock assessments as first thought. In fact, the openness of marine environments, along with the susceptibility to broad oceanographic shocks call into question the usefulness of MPAs as a hedge. For example, suppose a climatic event (e.g., ENSO event) occurs, resulting in the protected area no longer being a suitable habitat for the species. If the fish respond to the changing conditions by migrating out of the area (i.e., by following the temperature gradient), the probability of being caught could increase as vessels are lined up along the edges of the protected areas. With respect to setting aside coastal habitat, MPAs cannot protect against the possibility of pollution run-off originating upstream. In both of these examples, putting all your eggs in one basket (investing in MPAs) could expose fishery managers to higher levels of risk. To account for this, fishery managers might want to diversify their holdings by closing off more areas and/or coupling MPAs with additional measures (e.g., water quality regulations, effort controls) that will help ensure the sustainability of fish stocks throughout the system.

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[11] In the debate on MPAs, the concepts of insurance and hedge are being used interchangeably. It is important to point out that insurance is a hedge against a specific risk, such as fire. But a hedge is not necessarily an insurance policy. For example, a portfolio manager might hedge against a risky asset (e.g., stocks) by investing in a less risky asset (e.g., bonds). But if the risky asset decreases in value, the less risky asset does not necessarily compensate for the loss. Furthermore, the use of the term insurance raises many questions each of which highlight potential issues in the design and implementation of MPAs. The most basic questions are, for example, who is taking out the insurance policy and who can claim on this policy when the fishery outside the protected area collapses? Formally, insurance is a method (institution) of pooling risks in a population and is a type of contingent asset that helps to reduce the potential high costs of accidents. It would be hard to argue that setting the total catch too high and incurring outright stock extinction does not fall into this case, but an insurance policy also pays out when accidents do happen.

Another issue that calls into question the quality of the hedge is the level and quality of the physical protection provided the fish stocks through compliance and monitoring of the area. If a protected area is sited, but there exists little or no enforcement and monitoring of the protected area, then the expected ecological benefits will probably not be realized, because the area remains effectively open to harvesting. In addition, MPAs that experience significant biological improvements could prove to be to tantalizing an opportunity for fishermen who are having a difficult time remaining profitable operating in the open fishing grounds. In both of these examples, the protected area, which in theory might provide a good hedge, in practice fails to provide the appropriate protection. These arguments provide heuristic support for the need to couple siting decisions with tools for ensuring that the area ends up being more than a protected area on paper (e.g., educating users, increases in monitoring budgets and personnel, siting with the support of the local communities, etc.).

MPAs improve the ecological health of the marine ecosystem.

Many claim that MPAs will reduce the unwanted catch of juveniles, reduce habitat degradation, and improve generally the quality of the marine ecosystem. These benefits are most likely realized within the protected area, but the overall impact, including areas protected and unprotected, is unclear. Unfortunately, there is very little empirical information on the magnitude of the impact MPAs will have on the health of nearby areas, not to mention the current uncertainties surrounding their long-range impacts. In general, the distance over which these potential benefits are realized will depend not only on the behavioral characteristics of the fish population and currents but also on the induced changes in fishing operations.

VII. Discussion

Given the current precarious state of some fisheries, the debate on how to restore or maintain healthy fisheries has recently focused on using temporal and spatial closures in a coordinated way to control overexploitation. The growing momentum behind protected areas as a management instrument follows directly from traditional policies focusing on reducing fishing mortality via implementation of controls on the fishing operation. And, while the use of area and time closures has a long history, the new momentum behind MPAs deviates from the traditional rationale by focusing on the need to provide protection beyond the spawning grounds and other areas identified as crucial to the life cycle of marine populations.

To society at large, MPAs are an investment that has some risks. There is growing evidence that within the boundaries the biological payoffs are positive and significant; improvements include increases in such biological measures as abundance, spawning stock, recruitment, and biodiversity. But whether these benefits will spillover and be sustained in the remaining areas is more uncertain. The answer to this question depends on the biological and economic linkages between the areas, which in turn depends upon the connectivity of the two systems and the response by the industry. In terms of the ecological structure, if the area sited for protection is biologically closed off from the remaining open areas or the area is too porous due to high dispersal rates of the fish stocks, then the benefits might not be fully realized. Even if the ecological and biological conditions are right for an MPA to provide spillover impacts, there is no guarantee that the effects will be realized. The state of the ecosystem outside the area post siting will depend on how the industry and the affected users respond to the closure and a possible scenario is one where the state could be worse. The health of the ecosystem outside the MPA could worsen, for example, if habitat quality is inversely related to the concentration of effort. Finally, it is not obvious how one should assess the overall impact from an MPA if only the ecology of the protected area improves.

Complicating any assessment of the potential returns from such an investment is that the benefits are broader in scope than simply fishery enhancement. At the same time, the fishing industry perceives that it will most likely bear the majority of the costs. Thus, inherent in the policy debate is the perceived transfer of resource rights from one group to another. Further complicating the debate is the fact that in many cases, the conditions supporting the highest biological returns correspond to the cases where the harvesting industry has the most to lose. Due to the presence of biological and economic trade-offs (in addition to the potential for altering perceived property rights) politically feasible siting may depend, in the end, less upon purely biological considerations and more on obtaining tacit approval from fishermen. This suggests, in turn, that economic factors should play an important role in siting decisions.

Within the policy debate over MPAs, many advocates for these policy instruments claim that they provide a hedge against management failures and therefore should be the centerpiece of the precautionary approach to fishery management. In fact, MPAs can provide a degree of spatial protection to a fraction of the total fish stocks. The degree of the protection depends on the openness of the system. If poor stock assessments and/or inadequate political will to set total allowable catches at biological and economic sustainable levels are the leading causes of fishery collapses, then MPAs might be a good hedge against management failures. However, the fact that marine environments are open and susceptible to broad oceanographic shocks may reduce the degree of protection provided the fish stocks and lowers the quality of the hedge. In addition, if little or no enforcement and monitoring of the protected area exist, then the expected ecological benefits will most likely go unrealized. While MPAs might provide short-term protection in certain settings, there still exist some fundamental long-run uncertainties associated with using MPAs as spatial protection measures for non-sedentary resources.

What role should protected areas play in fishery regulation of the new century? MPAs seem particularly important as an instrument to ensure that special treasures, like unique habitat and biodiversity, are preserved for posterity. MPAs also have the potential to provide a margin of safety and perhaps even enhance the productivity of some fisheries. But their usefulness as a fishery management tool to control effort and thereby mitigate the ills of overfishing is less clear. Fisheries are common property resources, and individual users of the resource do not face the proper incentives to conserve the stock. While MPAs might provide a safe buffer under certain circumstances, they are still addressing a symptom and not the fundamental cause of overfishing and waste in fisheries. Until institutions are designed that change the incentives fishermen experience, policymakers will continue to face the overcapacity problems that have given rise to the recent momentum for increasing the scale and scope of MPAs.

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