Supplementary Report:
Social and Economic Implications of a Channel Islands Marine Reserve Network

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ENVIRONMENTAL DEFENSE

finding the ways that work

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Executive Summary

This paper is intended to supplement prior and current analyses of the potential social and economic implications of marine reserves in the Channel Islands, California. For the proposed network of marine reserves, there exists to date only a comparison of the immediate effects of a marine reserve network on revenues and employment from consumptive fishing and recreational activities in the region around the CINMS. This analysis, conducted by the stakeholder working group's socioeconomic panel with support from NOAA's Special Projects Office (available as Leeworthy and Wiley, 2001a), computes the revenues lost due to various percentage reductions of areas available to consumptive uses, notably commercial and recreational fishing and diving. Importantly, the analysis only provides a before and after scenario for each of the boundary alternatives, including the "preferred alternative" submitted by the Sanctuary Advisory Council to the California Department of Fish and Game. ***Crucially, the current socioeconomic analysis rests on the assumption that current fishing efforts could continue at present rates into the future.***

In this analysis, the "preferred alternative" would reduce commercial fishing ex-vessel values by about 16% of the 1996-1999 baseline total ($28,111,179), or roughly $4.5 million, and charter/party boat fishing income by about 20% (of roughly $28.5 million), or roughly $5.3 million (Leeworthy and Wiley, 2001b). However, this is a loss only if it can indeed be assumed that current rates of exploitation, and thus revenues, could be maintained into the future. Yet over the past 20 years, sampler estimates for fish caught by marine recreational anglers show a decrease of 85% over that period (RecFIN, 2001), while commercial landings of all species but squid[1] decreased by 50% over the same period (NMFS, 2001). ***Given these declining trends, a more comprehensive socioeconomic assessment should take dynamic effects into account, and evaluate the costs and benefits of marine reserves over an extended time period, and in the context of other variables governing the fishing industry.*** These include the long-term socioeconomic viability of

[1] Although squid is the most important species, commercially, its life history characteristics make it an outlier among target species. Over the past 20 years, the squid fishery has experienced greater than average booms and busts than the rest of the commercial effort (Leeworthy and Wiley, 2001; Lutz and Pendleton, 2000).

declining target species populations in a no-reserve scenario, and the changing industry profile in response to longer-term ecological, economic, and regulatory trends.

In light of the emphasis often given to claims of immediate adverse economic impacts arising from the closure of fishing grounds, it is important to point out that the *socioeconomic benefits of marine reserves, both for fishers and for other user groups, have traditionally been overlooked by standard economic methods*. As many marine species decline to the brink of extinction, the long-term beneficial role of marine reserves in avoiding the need for more stringent management measures, such as ESA listings and outright species closures, is likewise hard to quantify. These challenges notwithstanding, **socioeconomic benefits are important and should be taken into account in evaluating the complete set of implications of establishing marine reserves in the Channel Islands.** Analytical tools for predicting these kinds of benefits do exist, and can be used to extrapolate economic and social benefits that are not usually apparent to decision-makers.

In what follows, we review socioeconomic benefits associated with marine reserves in the Channel Islands. These include:

<u>1. Direct use values.</u> ***Marine reserves clearly protect marine biodiversity and allow marine populations depleted by fishing to recover within their borders. Marine reserves are expected to result in an array of non-consumptive use benefits, including enhanced ecotourism, diving, underwater photography, and nature appreciation.***

Several case studies indicate that ecotourism returns can be large relative to the operating costs of a reserve. For example, gross revenues generated from dive-based tourism in the Bonaire Marine Park (BMP) were $23.2 million in 1991, while taxes levied on BMP divers amounted to only about $340,000 that year (Dixon et al., 1993). These taxes have been sufficient to cover the costs of managing the BMP. The Virgin Islands National Park generated about $23.3 million in benefits against annual costs of $2.1 million in the early 1980s. The Saba Marine Park is estimated to have generated about $1 to $1.5 million in local-economy expenditures by divers in 1988 (Dixon, 1993).

More and bigger fish and other organisms inside the reserve translate into a greater enjoyment of diving and other recreational experiences. For example, in a survey of divers in marine parks in the Caribbean, 47% of respondents said that they would be willing to pay an extra $10 or more for a trip that featured 12 grouper per dive than for a trip featuring one grouper; 20% of the respondents said that they would pay an extra $10 or more for a trip with larger grouper than for a trip with smaller grouper (Rudd and Tupper, 2000). A longtime marine refuge in Puget Sound is the most popular dive site in Washington state, with large lingcod and rockfish as watchable wildlife (Palsson, 2001).

Similar benefits can be expected for the Channels Islands, where diving is a popular recreational activity. No systematic studies of divers' willingness-to-pay or other proxies for the value they derive from healthier ecosystems and more abundant fauna have been conducted. The Channel

Islands are one of the most popular dive sites in California; continued declines in sea life populations resulting from current management may harm that reputation. Marine reserve designation could help to reverse those trends, increasing the value of the Channel Islands for uses such as diving and photography. Another popular activity in the waters around the CINMS, whale watching, is also likely to be enhanced by the designation of marine reserves. Over the past 50 years, whale watching has grown into a global industry that generates over $1 billion in revenues (Hoyt, 2001).

2. Indirect use values. ***Because marine reserves demonstrably allow marine organisms to build up large populations (by factors of 2 or more) and increase their reproductive capacity (by up to 55 times), reserves can be expected to export adult and juvenile fish to fished areas, enhancing catches. This stream of future benefits in the form of spillover into adjacent areas constitutes the considerable "capital value" of marine reserves.***

For example, the partial closure of large areas of Georges Bank in New England represents one of the very few "marine reserves" established for fishery management, specifically to reduce total fishing mortality in order to enhance the recovery of depleted fish populations. These closures have resulted in an increase in haddock abundance, and scallop biomass increased by 1400% within their borders. In 1999, after nearly five years of closure, Area II yielded scallop landings worth over $34 million. Furthermore, the closures may have enhanced scallop yields outside their borders by stabilizing recruitment and increasing numbers of harvestable scallops by about 113% (Murawski et al., 2000).

A study of sport catches adjacent to a marine reserve near Cape Canaveral in Florida showed that target fishes moved from the reserve to fishing grounds (Johnson et al., 1999). A recent paper quantifies this effect and shows that there is a higher concentration of game fish fishing records near these no-take zones (Bohnsack, in review). This illustrates the benefits to recreational fisheries from marine reserves. Anecdotal evidence suggests that marine reserves established in the Florida Keys National Marine Sanctuary just a few years ago may be having a positive economic impact by helping to increase lobster landings and recreational catches. In the Channel Islands, buoys tied to lobster traps line the boundary of the Anacapa reserve and serve as vivid illustration that fishermen appear to <u>expect</u> enhanced catches there.

A study of various species of rockfish in kelp forests inside and outside of three ecological reserves in Central California, however, illustrates the value of fish "saved" in a reserve and the potential "spillover". Using Paddack and Estes' survey of fish biomass and abundance for a number of rockfish species (2000), we can estimate the value of one of these as a function of the reserve area. In two of the reserves—Hopkins Marine Reserve and Point Lobos Ecological Reserve—that have been in existence for 12 and 23 years respectively (sufficient time, in other words, for any recovery effects to become visible), the value-per-area of black and yellow rockfish (Sebastes chrysomelas) was twice to three times as high as outside: about $\$30/km^2$ and $\$50/km^2$ respectively. Significantly, in this study of three small ecological reserves, the oldest one, Pt. Lobos, generated the higher values. While the study sites are too small, and spillover effects too life-history specific to allow any scaling up to larger areas or other species, this example illustrates the value embodied in marine reserves.

<u>3. Option value.</u> ***Marine reserves will safeguard future uses (consumptive and non-consumptive) of marine biodiversity and resources. These future uses may be compromised by failing to implement marine reserves, given the unsustainable nature of some current fisheries.***

Listing of any target or incidentally caught species under the state or federal Endangered Species Acts (ESAs) would be expected to constrain fisheries to a very great extent, as has been the case for salmon. Efforts to restore endangered coho salmon stocks, as well as a number of chinook salmon runs in the Klamath river system and central California, have resulted in a series of season and area closures over the last 20 years, during which the value of the commercial catch has fallen from over $24 million (in 2000 dollars) to just under $9 million per year (PFMC, 2001a). ESA listings as a result of inadequate fishery management or habitat damage are real possibilities in the Channel Islands region: white abalone has been listed already, and a petition to list bocaccio was recently made to the NMFS. Economic costs associated with listings under the ESA will depend directly on the specific nature of protective management measures that are taken, but these costs can be extraordinarily high, sometimes resulting in complete fishery closures. The Pacific Fisheries Management Council (PFMC) projects that the ocean salmon management measures adopted for 2001 will result in $12 million in ex vessel values, 76% lower than the pre-ESA 1976-1990 average of $48 million, and 26% less in income generated by recreational trips: some $32 million, compared to the 1976-1990 average of $43 million (PFMC, 2001b).

<u>4. Quasi-option value.</u> ***The quasi-option value of marine reserves derives from the future uses that might arise if we avert the further decline of fisheries and marine ecosystems —uses that may only be discovered in the future. Marine reserves can help reduce uncertainty and improve fisheries management, thereby enhancing long term fishery yields as well as providing numerous other ecosystem benefits. Reserves might also be a good hedge against decisions based on inadequate information.***

The biodiversity protected within marine reserves may also yield as yet unrealized economic benefits. For example, Bryostatin 1—a compound isolated from the bryozoan *Bugula neritina*, an organism that attaches itself to the bottom of boats off the coast of California—is currently in phase II clinical trials at the National Cancer Institute for treatment of melanoma, non-Hodgkin's lymphoma, and renal cancer (Rayl, 1999). Already on the market is an anti-inflammatory compound extracted from the seafan, *Pseudopterogorgia elizabethae*, which is generating millions of dollars in annual revenues in an Esté Lauder skin care product, Resilience. Twelve compounds from marine organisms had entered Phase I or II clinical trials as of 2000 (including anti-cancer, anti-inflammation, and an anti-schizophrenia/Alzheimer's compound) and many more are in preclinical evaluation (Fusetani, 2000). No one can predict the true value of unrealized economic benefits from marine reserves. However, the pharmaceutical potential of coral reefs alone, for example, has been estimated to range from $72,500 to $698,000 per hectare (Cartier and Ruitenbeek, 1999).

<u>5. Bequest value</u>. *The bequest value of marine reserves entails the belief that we have a responsibility for passing on our natural heritage to future generations.*

No studies are available that measure the bequest value of protecting the marine environment in monetary terms. However, a proxy measure is provided by the roughly $3.5 billions (Canadian dollars) that the Canadian government has paid in benefits to fishermen and other programs in response to the northern cod collapse in the 1990s (Auditor General, 1997). This figure is a lower bound because it only captures the government's expenditures to deal with the crisis—the actual costs borne by industry, communities and individuals are considerably higher. More importantly, because of overfishing, a 400 year old way of life on the Atlantic coast and the revenues it generated can no longer be bequeathed to future generations.

Commercial and sport fishing are an integral part of coastal life in the Channel Islands, and in 1999 generated roughly $190 million in income in the seven counties adjacent to the CINMS, according to a report by the socioeconomic panel of the marine reserve working group (Leeworthy and Wiley, 2001). The bequest value of a marine reserve, then, lies in the extent to which it supports these sorts of income streams in perpetuity, and the extent to which it protects a way of life in the Channel Islands that might be lost if fisheries continue to be fished to the brink of collapse.

<u>6. Existence (heritage) value</u>. *Existence value refers to the appreciation of the inherent value of marine wildlife and healthy marine ecosystems and can be held by people who live nowhere near the ocean.*

Just knowing that it is there and is preserved in a special, protected status potentially elevates the value of the Channel Islands to people who never intend to use the area. The existence (sometimes called heritage) value of marine reserves is one of the least tangible, and least immediate benefits associated with setting aside areas of the ocean for habitat regeneration and biodiversity protection.

In their review of benefits evaluation for marine reserves, Hoagland et al. (1995) found that the existence values measured in surveys of visitors to nationally important sites such as the John Pennekamp Coral Reef State Park and the Key Largo National Marine Sanctuary in Florida (Leeworthy, 1991), or international sites such as the Galapagos Islands or the Great Barrier Reef (Edwards, 1991; Hundloe, 1989), stand out by an order of magnitude when compared to values reported at state or local beaches. Mean values per visitor, per day in these sites range from $150 to $500, as compared to the tens of dollars reported for the other beaches. No such studies have yet been undertaken for the CINMS, nor is it clear where exactly on the spectrum of natural and attractive (to tourists) sites the sanctuary ranks.

While less tangible than the other values reviewed here, existence values have in fact been measured. In the aftermath of the Exxon Valdez oil spill, researchers surveyed households throughout the United States (excluding Alaska) and found that, on average, people were willing to pay about $30 to prevent another oil spill (Carson et al. 1992), thus putting a "price" on the spectacular Alaska shoreline that had been despoiled. These estimates were used to determine the range of damages awarded by the jury in the Exxon case, $5.3 billion (NRC, 2001). Of another 18 studies in which non-use economic values were estimated reviewed by Desvouges et al. (1992), 16 reported values of $10 or more per household, per year for a variety of natural resource protection efforts, one reported values between $3.80 and $5.20 and the remaining one reported values ranging from $6.50 to $75.

We can only speculate on the existence value of marine reserves in the Channel Islands. If we (conservatively) assume that 1% of US households would be willing to pay $3, $5, or $10 per year just for knowing that some portion of the marine ecosystems around the Channel Islands were protected within marine reserves, marine reserves would have existence values of $3.39 million (low estimate), $5.65 (middle), and $11.3 million (high). This is nearly as much or more than the total "consumer surplus"[2] of $5.56 million generated by recreation (consumptive and non-consumptive) in the 1999 baseline year. This estimate of existence value is conservative, since these willingness-to-pay values are in the lower range of the published figures (see overviews in NRC, 2001 and Hoagland et al., 1995), and the assumption that only 1% of U.S. households would be willing to pay for a marine reserve is also a conservative lower bound. A 1990 survey found that 8% of U.S. households made financial contributions to environmental organizations (Roper, 1990; cited in Leeworthy and Wiley, 1999). In the United States, a survey commissioned by SeaWeb found that 76% of respondents are in favor of ocean protected areas.

Conclusion

An easy, straightforward cost-benefit analysis to inform decision-making with regard to establishing marine reserves in the Channel Islands is as elusive as it is desirable. We have argued that in order to make a public investment of the kind entailed by marine reserves, all costs and benefits should be accounted for—even though some might be difficult to quantify. If expected net returns can be shown to be positive using available data and knowledge, then it may be concluded that society as a whole is better off as a result of the public investment.

Even a cursory review of the kinds of indirect and non-use values associated with marine reserves strongly suggests that the value of such a public investment into marine reserves (to reduce fishing mortality and protect marine biodiversity) will generate more value than the costs of <u>not</u> reducing fishing mortality and <u>not</u> protecting biodiversity.

These values increase as the timeframe under which they are considered is extended—natural resources, like those that stand to be protected by a network of marine reserves—do not fare well on the short timeframe of many economic decisions. The more we treat the debate about the costs and benefits of marine reserve like a public investment into the future of our oceans and the

[2] Consumer surplus is the difference between the price actually paid, in this case for recreational activities, and what consumers would have been willing to pay.

livelihoods they support, the more likely we are to make wise decisions that reflect the full spectrum of costs and benefits to society, present and future.

Recommendations for the analysis of the CINMS marine reserve options

- Marine reserves should be implemented in the Channel Islands. The reserves should be designed to meet science-based conservation and fishery enhancement goals and criteria, while minimizing both immediate and longer term socioeconomic costs.

- A benefit-cost assessment should be conducted to inform decision-making processes, addressing quantitative and qualitative aspects of the ecological and economic benefits and costs associated both with marine reserves and no-reserves management alternatives.

- Conduct or, if necessary, commission, more research on the total socioeconomic value of marine reserves, to enable baseline and comparative measurements of the implementation effects of marine reserves.

- Include the public in strategies to reach consensus on management objectives, location and design, and the uses and values of marine reserves, now and for future generations.

Introduction

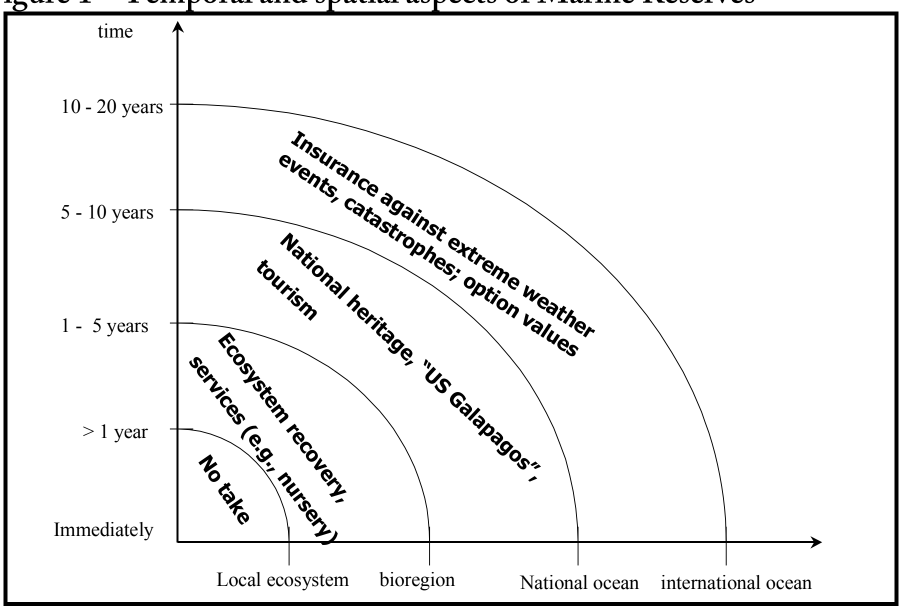
Marine reserves are areas in the ocean in which fishing and other extractive activities are banned completely. Marine reserves can generate many benefits to society, especially if fishing or other types of human activities are having significant adverse impacts on biological diversity, ecosystem health, or marine resources held in the public trust. A process is currently underway to consider the development of a network of marine reserves in the Channel Islands of California.

Previous studies of socioeconomic impact have emphasized adverse economic impacts of marine reserves on consumptive uses, such as sport and commercial fishing. While fishing and other consumptive uses are most easily quantifiable due to ready availability of data, they are by no means the only—or necessarily most significant—values associated with a marine reserve or a particular patch of ocean habitat. It is critical to consider all of the components of total economic value of a reserve, which include use and non-use, consumptive and non-consumptive values. In the remainder of this paper, we discuss some of the costs and benefits associated with these values, which heretofore have not been considered adequately. It is our hope that this discussion will help round out the picture on the economic values associated with marine reserves. Other important values—such as ethical, cultural, and spiritual values—should also influence marine resource decisions, but are beyond the scope of this paper. By focusing on a more complete picture of the economic values in this paper, we do not mean to deny or minimize the importance of these non-economic values.

When a natural resource management measure is proposed, a socioeconomic analysis is generally conducted to help decision-makers and stakeholders understand the social and economic impacts of the proposed measure. Many such analyses, however, focus almost exclusively on the short-term costs of the measure. This is not least due to issues raised by stakeholder groups that tend to be concerned with economic losses they sustain when their customary access to a marine area is curtailed. Many benefits such as the intrinsic value of biological diversity, various ecosystem services, and the value of passing on intact and healthy ecosystems to future generations are difficult to quantify and are therefore ignored or de-emphasized in these analyses, and consequently, in the decision-making process. Even some economic values associated with natural resource management measures are difficult to quantify. These include the value of biodiversity and healthy ecosystems as nursery grounds for commercial and sports fisheries, as destinations for dive-tourism and other water sports, and the contribution of healthy ecosystems to the general quality of life in an area. A study published in the journal Nature illustrates these hard-to-quantify yet significant values of ecosystems: based on their survey of published studies of a variety of ecosystem services, the authors estimate the global annual flow of a variety of marine ecosystem services and the attendant indirect, functional benefits to society to be on the order of $20 trillion annually, or the equivalent of the entire global economic output (Costanza et al., 1997).

At a smaller scale, the marine reserve network proposed in the Channel Islands can be expected to have significant biological and socioeconomic effects. Marine reserves constitute a public investment into the health of ocean ecosystems, and stand to generate a stream of tangible biological and economic dividends. Marine reserves could potentially result in an array of non-consumptive use benefits, including ecotourism, diving, underwater photography, nature appreciation, research and educational uses, and considerable "existence value" as the marine analogs of the Nation's publicly owned parks and wilderness areas. While some non-consumptive benefits may be difficult to quantify, they are no less important than losses of fishing opportunity as factors to be weighed in considering whether or not to establish a marine reserve. These difficulties in adequately capturing all the costs and benefits associated with the proposed marine reserve are characteristic of the temporal and spatial complexity involved in natural resource management issues in general. As shown in Figure 1, both the biological and the socioeconomic implications of designating a marine reserve have different effects over time and space.

Figure 1 – Temporal and spatial aspects of Marine Reserves



Typically, the initial costs of establishing a marine reserve are perceived to disproportionately affect commercial and recreational fishers and other consumptive users of the marine resources in the reserve area. For example, an immediate opportunity cost associated with designating a marine reserve is the loss of fishing revenues due to the closure of habitual fishing grounds. With fishing constituting an integral part of the coastal way of life, these costs are at the forefront of local stakeholders' concerns about implementing a reserve network. By the same token, there is also an immediate benefit: species at the brink of depletion or extinction gain an instant reprieve, and the ecosystem begins to recover. Immediate benefits also accrue to non-consumptive users of the reserve area, such as divers and other recreationalists. In addition, there are potential beneficial effects on fishable stocks outside the reserve area. Over the first few years of the reserve's existence, behavioral responses can be expected to result in relocation of fishing efforts to other parts of the ocean, and operators exiting the already overcapitalized industry. Over the same period, more regional benefits such as an increase of tourism revenues begin to be felt. Taking a long-run perspective, marine reserves act as "insurance" against natural and human-made accidents and disasters, while leaving intact ecosystems to future generations of coastal dwellers and visitors to enjoy. A full assessment of costs and benefits of the reserve designation, therefore, has to take into account these various trade-offs between biological and socioeconomic effects of the reserve, as well as the allocation of costs and benefits to different socioeconomic groups, over geographical areas and over time.

In this paper, we describe the rationale for establishing marine reserves in the Channel Islands and explain some of the biological and socioeconomic benefits that would likely accrue from these marine reserves, both immediately and over time. We also discuss socioeconomic costs associated with establishing marine reserves. We hope that this discussion of the various benefits and costs, both socioeconomic and ecological, will help stakeholders, decision-makers, and the general public to make informed decisions about whether to establish a marine reserve network in the Channel Islands. We also hope that this discussion contributes to the identification of research and monitoring needs, to make possible the best possible management of a reserve network in conjunction with other fisheries management measures already in effect.

The Channel Islands are a Local and a National Treasure

The Channel Islands hug the coast of Central California, sheltering a lush and diverse marine ecosystem that has earned this place a reputation as "The American Galapagos." The islands of San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara rise from the sea, attracting thousands of visitors to nearby coastal communities each year. The Islands and their marine ecosystems are an integral part of these coastal communities.

A diverse array of marine habitats is found in the deep submarine canyons, among the rocky reefs, and within the Santa Barbara Channel that separates the islands from the mainland. The varied and nutrient-rich ecosystem supports a diversity of marine species that rivals that of any place on the planet.

The Channel Islands: a vibrant marine environment

Natural forces come together around the Channel Islands to create a vital ocean environment teeming with life. Seasonal winds push warm surface water out to sea, enabling cold, nutrient-rich water to rise from the deep ocean. In these waters, millions of microscopic marine plants called phytoplankton bloom. Tiny marine animals called zooplankton feed on the plant life, creating the base of a productive food web.

Biological diversity on this part of California's coast is further enhanced as cooler ocean waters from the north mix with warm currents from the south. In this ocean "mixing zone," a diverse array of species find just the right conditions to make a home. Massive ocean currents called "gyres" circulate the highly mobile eggs and larvae of many species throughout this ecosystem. Hundred-foot-high giant kelps shelter a lively marine community.

First granted official federal recognition as a national monument by Franklin D. Roosevelt in 1938, the Channel Islands were declared a national park in 1980. Also in 1980, in response to federal proposals to expand offshore oil and gas drilling, local residents and elected officials secured designation of 1,658 square miles (all waters within six miles of the islands) as the Channel Islands National Marine Sanctuary. This status affords permanent protection from new offshore oil rigs, and also bans ocean mining operations. Traditionally, fishing privileges have been granted to support a local fishing industry, under the jurisdiction of the California Fish and Game Commission and the California Department of Fish and Game. While fishermen and fishery managers attempted to manage fisheries in good faith, based on the best available science, it has become clear that current levels of some fishing activities are unsustainable in view of reduced ocean productivity in recent decades and new information about the life histories and population dynamics of marine organisms. Thus, the overfishing of some species now constitutes a major threat to biodiversity and ecosystem health in the Channel Islands, as well as a threat to fishing as a way of life.

Marine Life in Decline

Present fishing regulations in the Channel Islands, established during the last three decades, have been based on the conventional wisdom that populations of fish and shellfish can sustain fairly high levels of fishing mortality, because they produce thousands of eggs. Despite the application of the best available science at the time, and despite the good intentions of managers and fishermen, fished populations of abalone, red sea urchins, and rockfish declined dramatically over the past 2 decades.

Recent scientific studies have revealed that abalone, rockfish, and other species are especially vulnerable to fishing due to certain life history characteristics. For example, contrary to previous assumptions, abalone need to be quite close to others of their species to fertilize their eggs. Fishing reduced the density of these animals to levels too low for successful reproduction. Rockfish live much longer than previously thought (up to 140 years for some species), reproducing for many years. Older, larger rockfish tend to produce many more eggs than younger rockfish; for example, a blue rockfish (*Sebastes mystinus*) that is 25 cm long produces 50,000 eggs, while a blue rockfish that is 32.5 cm long produces 300,000 eggs (6 times more). A female Pacific ocean perch (*Sebastes alutus*) that is 23 cm long generates 10,000 eggs, while one that is 45 cm long generates 300,000 eggs (30 times more) (Casillas, et al., 1998). Fishing reduces the lifespan of individual rockfish and has reduced the average size of rockfish (Ralston, 1998), greatly reducing their reproductive potential. Rockfish also tend to mature relatively late, further adding to their vulnerability to fishing.

Changes in natural ocean productivity (resulting from climate change, El Ninos, and perhaps the Pacific Decadal Oscillation), pollution, and disease have had impacts on the region's marine life in general. However, it is clear that fishing has been the major cause of the decline in several exploited species. Recent population models suggest that fishing mortality has exceeded the "surplus production" of several rockfish species (now depleted) for many years (Parrish, 2001). A study of long-term marine refuges in the Puget Sound found that the reproduction per acre in a long-term marine protected area is 20 or more times greater than in nearby fishery sites. This suggests, among other things, that even under the currently available "best science", the reproductive potential of fished populations has been greatly depleted (Palsson, 2001).

Some of the most compelling evidence that fishing has caused the observed population declines and attendant shifts in ecosystem balance comes from the tiny East Anacapa Island no-fishing reserve, the only such reserve in the Channel Islands. Densities of large red sea urchins were about 12,000 per hectare[3] when the fishery began targeting them in the early 1970s. While overall urchin densities do not differ substantially today between the reserve and the fishing grounds, there are now about 15,000 to 20,000 large red sea urchins per hectare in the no-take reserve at East Anacapa Island (called the Natural Area). In contrast, most kelp forests in the Channel Islands National Park support fewer than 2,000 large red urchins per hectare where fishing is allowed. Key urchin predators such as spiny lobsters and sheephead have declined dramatically in fished areas, while over the same time period they have been 10 and 1 1/2 times more abundant inside the reserve (Sladek Nowlis, 2001). Unexploited species remain abundant in both fished areas and in the reserve. Clearly, fishing caused the observed declines in exploited species. Otherwise, one would expect to see no major differences between areas within the no-take reserve and areas of equivalent habitat that are open to fishing. In addition, both unexploited and exploited species would tend to decline in fished areas and in the reserve if factors such as climate change or El Niños were primarily responsible for the declines.

Fishing can impact entire ecoystems and foodwebs, not just the target species or bycatch species, by removing predators and competitors, thus allowing other species to become more abundant. Spiny lobsters and sheephead are key purple sea urchin predators in southern California kelp bed ecosystems (Tegner and Levin, 1983; Cowen, 1983). While non-targeted purple urchin densities have grown by only a factor of four within the reserve, they have increased by a factor of over 15 in adjacent fished areas since 1983 (Sladek Nowlis, 2001). Where purple urchins have thrived, giant kelp has suffered from heavy grazing by the urchins. Kelp has actually increased inside the reserve since 1983 by more than 10% while it disappeared entirely from survey sites in adjacent fishing areas (Sladek Nowlis, 2001), depriving the ecosystem of important primary energy production and physical structure (Dayton et al. 1998). The very dense purple sea urchin populations that built up in the absence of predators like lobsters and sheephead, which have been depleted by fishing, tend to have high frequencies of disease, while purple sea urchin populations in the Anacapa Natural Area are much less diseased (Kushner and Lafferty, 2000).

Why Marine Reserves?

There is very strong empirical evidence supporting the use of marine reserves to protect biodiversity and to help rebuild depleted fish and shellfish populations. A recent scholarly survey of 89 scientific papers on marine reserves revealed that: (1) 90% of the reserves studied had higher fish biomass than fished areas or the same area prior to reserve establishment; (2) fish density was higher in 63% of the reserves; (3) 83% of the reserves had larger carnivorous fish and

[3] A hectare is about the size of two soccer fields.

invertebrates; and (4) 59% of the reserves had higher biodiversity (Halpern, 2001). This survey showed that the average size of fish and shellfish within reserves are between 20 and 30% higher relative to fished areas or pre-reserve conditions; densities are roughly double in reserves; and biomass levels are nearly triple in reserves.

There is strong evidence from both temperate and tropical waters, including areas off California, Washington, and British Columbia (Canada) that fish populations increase in abundance (by factors of 2 to 13), size, and reproductive capacity (by factors of 20 to 55) in marine reserves, in which fishing is banned (Paddack and Estes, 2000; Palsson and Pacunski, 1995). Species that respond well to marine reserve management include lingcod and rockfish, both of which have suffered steep declines in abundance due to fishing. Marine reserves help to restore the size and age distributions of exploited fish populations, which are often altered by fishing. In a 30-year old marine refuge near Edmonds, in Puget Sound, copper rockfish numbers are 15 times greater than in the comparison sites where fishing takes place. Most common, in the refuge, were large copper rockfish exceeding 16 inches in length. Similarly, lingcod are more than twice as abundant in the refuge, where they averaged almost three feet in length. By comparison, lingcod were only about two feet long in the fished sites (Palsson, 2001). There are also some indications that marine reserves can help protect and restore other ecosystem attributes, such as kelp cover, by allowing a more diverse set of trophic (food web) relationships, competitive relationships, and symbiotic relationships to develop (Sladek-Nowlis, 2001; Lafferty et al., in review).

There is now scientific consensus that sufficient information exists to justify the implementation of marine reserves to help protect biodiversity. Reviewing research on marine reserves from all over the world, an international working group of scientists convened by the National Center for Ecological Analysis and Synthesis (NCEAS) found that creating marine reserves leads to rapid increases in abundance, animal body size, biomass, and diversity of marine communities. Those changes translate into much higher rates of reproduction, and ocean currents are able to move offspring from reserves to fishing grounds. In February 2001, a group of 161 leading marine scientists issued a consensus statement at the annual meeting of the American Association for the Advancement of Science supporting the use of marine reserves as a conservation and fisheries management tool (NCEAS, 2001).

As a result of the good performance of marine reserves and the relatively poor performance of conventional fisheries management in protecting marine populations and ecosystems, there is growing federal and state interest in marine reserves. In May 2000, former President Clinton issued an Executive Order on Marine Protected Areas (MPAs), which orders federal agencies to establish a comprehensive national network of strengthened MPAs throughout US marine waters, and to prevent or ameliorate any activities that harm MPAs. The Bush Administration recently reaffirmed its interest in carrying out this executive order. Marine Protected Areas are defined by the World Conservation Union (IUCN) as "any area of intertidal or subtidal terrain, togeher 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" (Roberts and Hawkins, 2001). A fully-protected marine reserve, often called simply marine reserves, are MPAs in which all extractive uses, such as fishing, mining, and oil drilling, are banned. A recent report by the National Research Council concludes that on the basis of existing evidence, "marine reserves and protected areas will be an effective tool for addressing conservation needs as part of an integrated coastal and marine area" (NRC, 2001).

The vast majority of Marine Protected Areas, such as the National Marine Sanctuaries, allow fishing and other uses to continue throughout all or most of their waters. Only a very tiny fraction of US ocean waters are fully protected from all extractive uses—less than 0.2% of California waters are fully protected (McArdle, 1997). Almost all scientific studies of the effects of marine reserves on fish and shellfish populations have been done in fully protected marine reserves. A few studies have been conducted in reserves in which enforcement was poor, or in which some extractive activities have been allowed; these studies suggest that full protection is required for good results (e.g., Klima et al., 1986). In addition, understanding of how marine ecosystems work and what roles individual species play is increasing rapidly. Full protection from all extractive uses, including all forms of fishing, is essential for understanding the impacts of fishing and other uses on marine ecosystems.

Conventional fishery management has been based on many untested assumptions, including the idea that pelagic (free-swimming) species such as salmon and tuna do not use specific sites. Many of these assumptions have turned out to be unwarranted, and contributed to the failure of fishery management to sustain many marine populations and fisheries. We simply do not know how pelagic species interact with benthic (bottom-oriented) ecosystems. There are several possible types of interaction: (1) Pelagic species may transport nutrients from deeper waters to habitats protected within nearshore marine reserves (the large contribution that salmon make to freshwater habitats was unknown until recently); (2) many pelagic species appear to use special sites such as convergence zones, which may in turn depend on the effects of bottom structures on vertical and horizontal currents, for feeding, rearing, and other important life history activities; (3) pelagic species may prey on significant numbers of species resident within marine reserves, prey on species that are particularly important in structuring marine ecosystems, or prey on life history stages that have disproportionately large impacts on population dynamics. Controlled experiments using fully protected marine reserves and marine conservation areas where certain kinds of fishing are allowed will be necessary to test these and other hypotheses.

The National Oceanic and Atmospheric Association (NOAA) has also demonstrated a commitment to consider MPAs as part of the management review process for all National Marine Sanctuaries, and several Sanctuaries (including the Channel Islands Marine Sanctuary) have taken the lead. In 1997, the first planned marine reserve network was instituted in the Florida Keys National Marine Sanctuary (FKNMS) and provides important lessons for the reserve design process in the Channel Islands. Local communities, fishermen, and administrators developed a more inclusive and participatory decision-making process that resulted first in the designation of several small reserves, and then in a recent expansion of the reserve area by 151 square nautical miles. In the Florida Keys, after initial skepticism and opposition to the reserve idea, commercial and recreational fishermen have come to support reserves, as they have begun to notice benefits (Dobrzynski and Nicholson, 2001). In the North

East of the United States, fishermen are supportive of the closed areas on the Georges Bank and attribute the recovery of the groundfish stocks to these and other measures.[4]

Momentum behind fully protected marine reserves is especially strong on the Pacific Coast. While there are 101 marine protected areas in California, occupying 18.2% of state waters, only a small portion of this area (0.2%) is closed to fishing (McArdle, 1997). The state of California adopted a new law in January 2000—the Marine Life Protection Act (MLPA)—aimed at creating a comprehensive network of MPAs and fully protected marine reserves to safeguard ocean biodiversity and habitats. The Pacific Fisheries Management Council (PFMC) concluded that marine reserves can be a useful tool for rebuilding groundfish populations in September 2000, and is moving forward to develop options for design and location of specific reserves. The California Department of Fish and Game (CDFG) is also expanding its use of marine reserves and closed areas as a fisheries management tool. In December 2000, the California Fish and Game Commission (CDFG) adopted a 4,300 square mile zone banning the take of rockfish. CDFG has also proposed "Nearshore Finfish Conservation Areas" that would close 30-50% of the habitat to nearshore finfish take as one of its management alternatives.

The Channel Islands National Marine Sanctuary and the California Fish and Game Commission have been engaged in a process to scope the potential for marine reserves around the Channel Islands since July 1999. They established a Marine Reserves Working Group (MRWG), consisting of a diverse array of stakeholder representatives. The MRWG set forth the following goals for a marine reserve network around the Channel Islands: (1) to protect representative and unique marine habitats, ecological processes, and populations of interest; (2) to maintain long-term socioeconomic viability while minimizing short-term socioeconomic losses to all users and dependent parties; (3) to achieve sustainable fisheries by integrating marine reserves into fisheries management; (4) to maintain areas for visitor, spiritual, and recreational opportunities which include cultural and ecological features and their associated values; (5) to foster stewardship of the marine environment by providing educational opportunities to increase awareness and encourage responsible use of resources.

The MRWG was advised by a Science Panel and a Socioeconomic Panel. The MRWG identified a number of different reserve boundary alternatives that would set aside between 10 and 28% of the existing CINMS. The Socioeconomic Panel prepared a report on the immediate effects on commercial and recreational users of sanctuary waters that each scenario would have (see Leeworthy and Wiley, 2001a). These alternatives were presented to the Sanctuary Advisory Council of the CINMS, which forwarded them to staff of the California Department of Fish and Game and the CINMS who had co-chaired the MRWG process. The Department and the CINMS subsequently developed a number of variations on these alternatives and put forward a "preferred alternative" in July (see http://wwwcinms.nos.noaa.gov/cimpa.html), which will be considered by the California Fish and Game Commission for a final decision in August. This

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[4] See the testimonials of fishermen at http://www.habitatmedia.org/transcripts.html).

preferred alternative for a network of marine reserves would set aside 25 percent of the CINMS area in a network of marine reserves.[5]

[5] In addition to the marine reserves network, a tiny marine park and a small marine conservation area are also part of the proposal, bringing the total to 26% (Satie Airame, CINMS science advisor, personal communication 16 August 2001).

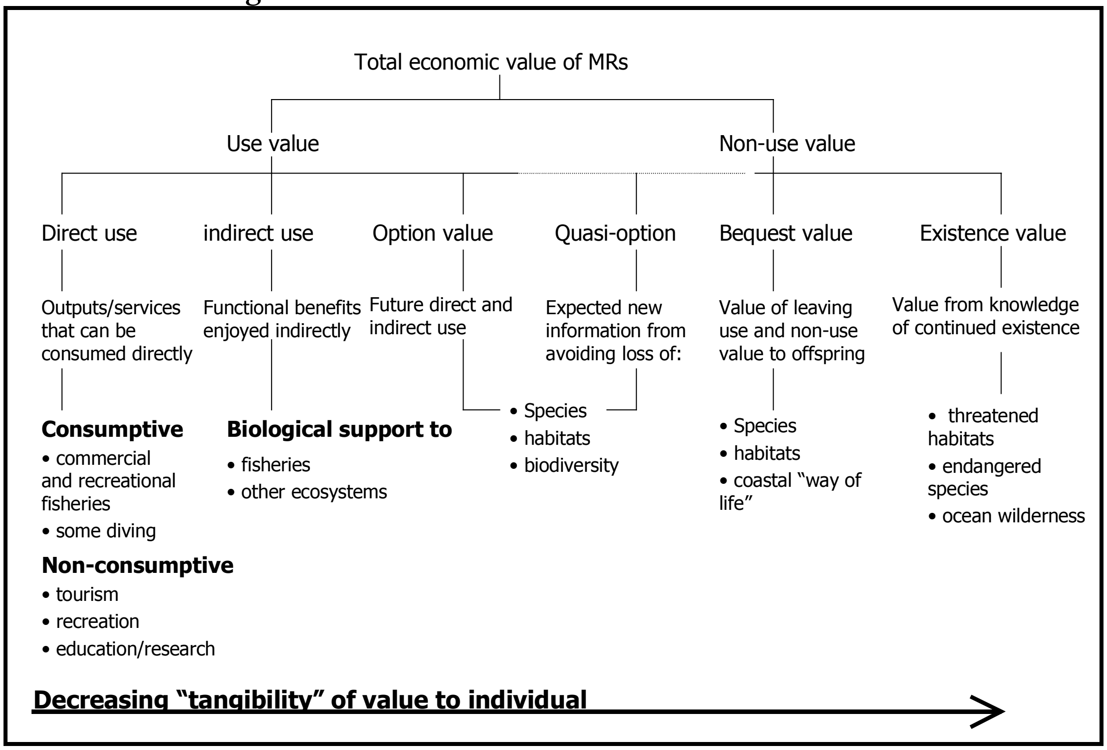
Social and Economic Implications of Marine Reserves

The scientific case for marine reserves is strong, and well documented in an expanding body of literature on the biological and ecological benefits of marine reserves on surrounding ecosystems and ocean habitats. The attendant gains in biodiversity conservation, recovery of fish and other populations, and general ecosystem health typically exact a cost in the short term, in the form of lost revenues from fishing and other consumptive activities. Ideally, these short term losses are minimized through careful reserve design and siting, while overall benefits from a marine reserve network, which include support functions for continuing fishing efforts outside the reserve, are maximized. In contrast to the biological and ecological aspects of marine reserves, the socioeconomic aspects of reserves have not garnered much analytical attention and consequently are a lot less well understood. They are, however, as critical to the reserve design process as they are elusive. Studies confirm what common sense would suggest—that in addition to community involvement in the design process, socioeconomic considerations determine the success or failure of a proposed marine reserve (Kelleher and C. Recchia, 1998; Dobrzynski, forthcoming).

The biological and socioeconomic costs and benefits of a marine reserve are closely related. It is therefore useful to keep in mind the components of total economic value of a reserve, which include use and non-use, consumptive and non-consumptive values (Figure 2). While fishing and other commercial, consumptive uses are most easily quantifiable due to ready availability of data, they are by no means the only—or necessarily most significant—values associated with a marine reserve or a particular patch of ocean habitat. In the remainder of this paper, we discuss some of the costs and benefits associated with all the values captured in Figure 2. These will help round out the picture on the economic values associated with marine reserves. Other important values—such as ethical, cultural, and spiritual values—also influence marine resource decisions, but are beyond the scope of this paper. By focusing on a more complete picture of the economic values, we do not mean to deny the importance of these non-economic values. Rather, we propose that a more comprehensive consideration of economic values provides an avenue for considering the biological, ecological, and socioeconomic aspects of conservation measures such as marine reserves across a variety of spatial and temporal scales.

Marine reserves have considerable socioeconomic implications because, by setting aside ocean areas from extractive uses, they change patterns of human use of marine resources (Hanna, 2000). Effectively, they allocate ocean resources from one set of uses and users to another, just as the absence of marine reserves allocates resources. Without marine reserves, ocean resources are by default allocated to consumptive users. Marine reserves would allocate some portion of the ocean resources of the Channel Islands from fishermen and other consumptive users to non-consumptive users such as boaters, divers, and people who value the existence of these resources in a relatively unperturbed state. Another complexity implicit within the marine reserve design process is that some benefits accrue to future generations, or to constituencies farther afield geographically—neither of whom tend to be represented at the local negotiating table. In the case of the CINMS, for example, decision-makers should account not just for the local fishing and tourism industry, but for the broader U.S. public, in whose trust terrestrial and marine ecosystems are managed.

Figure 2 - Total economic value of Marine Reserves



(Adapted from Barton, 1994)

While the scientific literature documenting the biological performance of marine reserves is large, a smaller but steadily growing body of literature examines the social and economic implications of marine reserves (e.g., Dixon, 1993; Dixon et al., 1993; Farrow, 1996; Hanneson, 1998; Hoagland et al., 1995; Thomson, 1998; Holland and Brazee, 1996; Milon, 2000; Pomeroy, 1999; Cocklin et al., 1998; Sumaila, 1998). Resource economists study human behavioral responses to the establishment of marine reserves, such as changes in fishing operations and other commercial activity, and estimate changes in values to determine if the conservation gains attributed to marine reserves provide net returns to society. They seek to account for both the biological and socioeconomic benefits of increased spatial protection as well as the costs associated with the reduction in available fishing area and subsequent shifting of fishing effort to other grounds and species. The assessment of costs and benefits of marine reserves is helpful in efforts to integrate human uses of marine resources with the ecological rationale for their protection, and for guiding public and private decision-making.

From an economic perspective, marine reserves represent a public investment (Sanchirico, 2000). For the cost of setting aside an area of the ocean and closing it to consumptive uses, we gain a host of biological and—as we elaborate in this paper—economic benefits. As with any investment, the decision to commit resources to a marine reserve is guided by whether the potential benefits of protection, adjusted to account for risks, outweigh potential costs. Here it is important to note that economic methods tend to most reliably measure the costs and benefits associated with direct uses, such as fishing (consumptive) or recreation (consumptive and non-consumptive). This is facilitated by the ready availability of data on commercial landings, the market value of various edible fish species, and expenditures on recreational activities such as boating, diving, or sport fishing.

In order to make a decision on a public investment such as a marine reserve that will have far-reaching temporal and spatial consequences, however, it is important not only to provide the most complete measurement of direct use values possible; all of the other components of economic and non-market values must be considered as well. The following sections provide an overview of the state of the art analysis of the biological and socioeconomic implications of marine reserves.

Potential Benefits of Marine Reserves

Significant ecological and socioeconomic benefits can be expected from marine reserves. Considerable ecological benefits are associated with the protection and enhancement of marine biodiversity within MPA borders. Most case studies and empirical analyses report effects ranging from overall higher fish populations including larger and older fish with higher fecundity rates to improvements in habitat within the boundaries of marine reserves (Halpern, 2001; Polacheck, 1990; Dugan and Davis, 1993; Roberts and Polunin, 1993; Allison et al., 1998; inter alia). An analysis of 89 studies of marine reserves (Halpern, 2001) indicates that, compared with fished areas or the same areas prior to reserve designation: 63% of the reserves had higher densities of organisms; 90% of the reserves had higher biomass levels; 80% of the reserves had larger organisms; and 59% of the reserves had higher species diversity. On average, organism density was 1.91 times higher in reserves; biomass was 2.92 times higher; organism size was 1.31 times higher; and diversity was 1.23 times higher. There is consensus among ecologists and fishery biologists that ecosystem health within protected areas will improve (NCEAS, 2001).

It seems clear that marine reserves established within the Channel Islands will result in similar good ecological performance. The small no-take reserve on Anacapa Island harbors much higher densities of lobsters, game fish, and large red sea urchins[6] than fished areas. The socioeconomics of marine reserves and protected areas are considerably less well understood. To date, the Socioeconomic Panel advising the stakeholder process in the Channels Islands has only produced estimates of the immediate costs associated with the closure of fishing grounds associated with the various boundary alternatives under consideration (Leeworthy and Wiley, 2001a), and with the "preferred alternative" currently before the Fish and Game Commission. In the remainder of this section, we discuss a variety of immediate and longer-term benefits that comprise the total economic value of marine reserves, and that should be considered by decision-makers and stakeholders in conjunction with any costs.

[6] Overall urchin density is about the same within and outside the reserve.

1. Direct use values

As shown in Figure 2, direct use values are those outputs and services that can be used directly. They are typically divided into consumptive and non-consumptive uses, which we consider in turn.

1.a. consumptive uses

Marine reserves in the Channel Islands will entail adverse economic impacts on current sport and commercial fisheries there, in part because these fisheries are very active and valuable. For example, the rockfish fishing effort in California is highly concentrated, with over 90% of the commercial harvest and more than 85% of the recreational harvest taking place in just 63 fishing blocks off the coast of California, i.e., only about 10% of the total (Thomson, 1999). T hree of these blocks are located in CINMS waters, and correspond to some key habitats earmarked for protection, including the north side of West Anacapa Island, waters north of Santa Cruz Island, and the western tip of San Miguel Island.

By definition, there are no consumptive benefits associated with marine reserves, since all fishing and other extractive activity within them is curtailed. Correspondingly, just as biological and economic productivity are correlated in fisheries, so are the success of recovery measures and the location of reserves. The benefits from this public investment will eventually benefit commercial and recreational fishing activities, as well as a host of other user groups. Just as it is beneficial for a private investor to set aside money and reap the interest, it makes economic sense to set aside some natural capital and, instead of mining marine resources until they are depleted, skim off the "dividend" provided by healthy ecosystems and enhanced stocks. This is discussed in more detail under the indirect use values below.

When considering a marine reserve in a spatial context, there are some direct use benefits that begin to materialize almost immediately. These benefits are revealed in the "edge effect" that can be observed at the border around marine reserves. This effect has occurred, for example, outside a marine reserve located off the coast of Kenya, where the number of fish traps increased dramatically in the immediate vicinity of the protected area (McClanahan and Kaunda-Arara, 1996). Trap catches closer to the reserve are 25% higher than those obtained further away, and local fishermen have come to an agreement that the most senior of them get the choicest fishing spots (Roberts and Hawkins, 2001). While edge effects also entail enforcement costs and other problems that we will turn to below, they reveal that catch per unit effort typically increases approaching reserve boundaries. In the United States, edge effects have been observed along no-fishing zones in the Georges Bank and outside a Sanctuary Protected Area in the Florida Keys National Marine Sanctuary, where boats "fish the line" (marked by buoys) separating fishing grounds from no-take areas (Jim Bohnsack, NMFS, electronic communication, 10 August, 2001).

In the Channel Islands, there is anecdotal evidence that this phenomenon can be observed annually at the start of the lobster season, when boats line up along the boundary of the Anacapa reserve. Recreational fishing fleets stand to benefit the most from marine reserves because of spillover effects and increased demand for trips near reserves. For example, scientists found that fish tagged inside aquatic areas closed to all public access for security purposes at the Kennedy Space Center at Cape Canaveral in Florida swim across the boundary (Johnson et. al., 1999), where they contribute to the area's reputation as one of the best places for sport fishing in the region. A recent paper quantifies this effect and shows that there is a higher concentration of game fish fishing records near these no-take zones (Bohnsack, in review). This illustrates the benefits to recreational fisheries from marine reserves.

In the longer term, it is reasonable to expect marine reserves to export larvae and mobile juvenile and adult fish to fishing grounds, thus enhancing fishery yields or helping to rebuild depleted populations. These "spillover effects" constitute indirect use values (reviewed below), since they support economic activities, but are not directly measurable by market parameters.

1.b. non-consumptive uses

Non-consumptive users of marine reserves benefit from the protection and enhancement of marine biodiversity within the borders of a marine reserve. We discuss some equity issues associated with the distribution of costs and benefits in the last section of the paper. Non-consumptive uses provide one of the best glimpses into tangible economic benefits associated with marine reserves.

Marine reserves and protected areas have resulted in a wide array of non-consumptive use benefits, including ecotourism, diving, underwater photography, and nature appreciation. ***While some non-consumptive benefits may be difficult to quantify, they are no less important than losses of fishing opportunity as factors to be weighed in considering whether or not to establish an MPA.*** Estimates of ecotourism benefits associated with MPAs will be highly site-specific, depending on the nature of the habitats and marine resources protected within the MPA, proximity to shore, available infrastructure for ecotourism, the mix of regulations and incentives to prevent overcrowding and damage, and other factors.

Several case studies indicate that ecotourism returns can be large relative to the operating costs of a reserve. For example, Dixon et al. (1993) estimate that gross revenues generated from dive-based tourism in the Bonaire Marine Park (BMP) were $23.2 million in 1991. Taxes levied on BMP divers amounted to about $340,000 in 1991 (Dixon et al., 1993). A dive fee of $10 has been sufficient to pay for BMP operating expenses; however, expenses are now outpacing these revenues (MPA News, 2001). Dixon (1993) estimated that the Virgin Islands National Park generated about $23.3 million in benefits (e.g., payroll, taxes, and local purchases at resorts; visitor expenditures; boat charters; increased land values) against annual costs of $2.1 million in the early 1980s. The Saba Marine Park is estimated to have generated about $1 to $1.5 million in local-economy expenditures by divers in 1988 (Dixon, 1993). While it is not entirely clear what the marginal increase in economic value is due to the establishment of marine reserves in these cases, it seems clear that these marine parks have enhanced the value of marine resources and will probably continue to do so as long as the carrying capacity for tourists is properly set and not exceeded.

Increased numbers and size of fish and other organisms inside the reserve translate into a greater enjoyment of diving and other recreational experiences, which in turn can generate higher revenues for non-consumptive activities. For example, in a survey of divers in marine parks in the Caribbean, researchers found that 47% of respondents would be willing to pay an extra $10 or more for a trip that featured 12 grouper per dive than for a trip featuring one grouper; 20% of the respondents said that they would pay an extra $10 or more for a trip with large grouper than for a trip with smaller grouper (Rudd and Tupper, 2000). A longtime marine refuge in Puget Sound is the most popular dive site in Washington state, with large lingcod and rockfish as watchable wildlife (Palsson, 2001).

Similar benefits can be imagined for the Channels Islands, where diving is a popular recreational activity. However, no systematic studies of divers' willingness-to-pay or other proxies for the value they derive from healthier ecosystems and more abundant fauna have been conducted. The Channel Islands are on of the most popular sites for diving in California. Continued declines in sea life populations resulting from current management may harm that reputation. Marine reserve designation could help to reverse those trends, increasing the value of the Channel Islands for uses such as diving and photography. The proposed network of marine reserves in the Channel Islands comprises physical and biological characteristics that are as aesthetic as they are crucial to habitat protection. Indeed, the designation of the marine reserve itself constitutes a benefit. For example, the designation of the Florida Keys National Marine Sanctuary allowed the Monroe County Tourist Development Council to mount a successful advertising campaign using the slogan "protect and they will come".

According to the Socioeconomic Panel's assessment, whale watching is the most significant non-consumptive recreational activity in the waters of the CINMS. In 1999, there were 25,984 person-days of whale watching in the sanctuary, generating between $4 and $5 million in total income in the adjoining counties (Leeworthy and Wiley, 2001a). While an informal survey of whale watching operators in the sanctuary revealed that few of them expect any impacts (positive or negative) on their business, the tourism potential of whale watching is considerable and growing. Marine reserves might draw more tourists in general to the Channel Islands, which in turn may generate more whale-watching revenue. A recent report documents that over the past 50 years, whale watching has grown into a global industry that generates over $1 billion in sales (Hoyt, 2001). This report also estimates that commercial whale watching tours in California generate about $65 million in annual sales, with 762,700 people participating in boat-based tours. The future tourism potential of California remains strong, with the marine reserve designation likely enhancing the attractiveness of the area to tourists and other visitors.

2. Indirect use values

Marine reserves generate a number of indirect use values by providing biological support to fisheries as well as other ecosystem goods and services. Here we focus on the former, and provide an overview of studies suggesting that there is a "double dividend" from setting aside areas and allowing them to recover. Healthy ecosystems may not only increase the biomass inside marine reserves, but may also result in increasing catches in adjacent fishing areas. Both the environment and human users of marine resources gain in the long run.

Marine reserves provide important ecosystem services to economic activities, largely by providing nursery grounds and safe havens for exploited species. Fish tend to grow larger in marine reserves, since reproductive capacity (e.g., egg production) increases exponentially with size in many fish species, and since many species have extended pelagic larval phases resulting in the export of larvae from marine reserves to fishing grounds. Indeed, modeling studies suggest that marine reserves do have the potential to enhance catches and accelerate the rebuilding of depleted populations outside their borders (Bohnsack, 1990; Sladek Nowlis and Roberts, 1999; Sladek Nowlis, 1999; Sladek Nowlis and Yoklavich ,1998; DeMartini, 1993; Polachek, 1990). Models of the potential impacts of marine reserves on fisheries outside their borders are limited by inadequate data and some theoretical gaps. However, they can be useful tools for planning and for identifying research needs.

In one recent model, for example, Sladek Nowlis and Roberts (1999) investigate the response of queen trigger fish (*Balistes vetula*), red hind (*Epinephelius guttatus*), white grunt (*Haemulon plumieri*), and spiny lobster (*Panulirus penicillatus*) to reserves. They conclude that reserves enhance productivity, especially in heavily fished areas. They also find that reserves reduce annual catch variation, thereby promising to simplify management and improve fish abundance projections (Sladek Nowlis and Roberts, 1999). In a related study, Sladek Nowlis and Roberts (1999) compare the effect of different management techniques in a model of red hind, white grunt, and spiny lobster fisheries. They conclude that for the red hind and white grunt, which mature prior to entering the fishery, reserves produce few short-term costs beyond those created by temporary closures or size limits, and that reserves generate the highest stable catch levels. For the spiny lobster, which enters the fishery while still immature, minimum size limits best aid the fishery (Sladek Nowlis and Roberts, 1999). The model does not consider the effects that marine reserves apparently have on other ecosystem components, such as kelp cover. Marine reserves appear to protect or enhance kelp cover and prevent the formation of "urchin barrens" produced by population explosions of purple sea urchins in the Channel Islands by protecting urchin predators like spiny lobsters and sheephead fish (Sladek Nowlis, 2001).

Few models focus specifically on the effects of marine reserves on enhancing yields in fisheries for species found around the Channel Islands, such as bocaccio (*Sebastes paucispinis*) and other rockfish species. Sladek Nowlis and Yoklavich (1998) explored the effects of marine reserves on larval export and catches of bocaccio rockfish by modeling the supply of recruits as a function of adult population size. They show that marine reserves could enhance fishery yields whenever the fishery was overfished (as it is today), and that optimal reserve size increases with fishing pressure, while yields are maintained at close to maximum sustainable yield levels. When larval survival was varied from year to year, catch variability generally decreased with increasing reserve size. The results of this study also indicate that "natural" reserves (where fishing was limited due to depth and/or inaccessibility) might have enhanced bocaccio catches off central and northern California consistently since the late 1970s. Current catch levels by contrast have been sharply reduced in response to severe population decline and regulatory catch constraints.

Few empirical studies of the effects of marine reserves on catches outside the reserve are available, and the number of marine reserves specifically designed for fishery management is smaller still. Catches increased significantly near marine reserves in 5 of the 8 field studies (Russ and Alcala, 1996; Johnson et al., 1999; Polunin and Roberts, 1993; McClanahan and Kaunda-Arara, 1996; Schlining, 1999; Klima et al., 1986; Heslinga et al., 1984; Yamasaki and Kuwahara, 1990) reviewed by Fujita et al. (2000). Total catch may increase over time, as fish density and reproductive capacity builds up within the reserve. The partial closure of large areas of Georges Bank in New England represents one of the very few "marine reserves" established for fishery management, specifically to reduce total fishing mortality in order to enhance the recovery of depleted fish populations. These closures have resulted in an increase in haddock abundance, and scallop biomass increased by 1400% within their borders. Furthermore, the closures may have enhanced scallop yields outside their borders by stabilizing recruitment and increasing numbers of harvestable scallops by about 113% (Murawski et al., 2000). In the past two years—after nearly five years of closure and in conjunction with management measures in adjacent waters—the closed areas in the Georges Bank yielded scallop landings worth rough $35 million each year. Not only do these areas now contribute the lion share of New England's scallop landings, scallops there are considerably bigger and fetch higher than average prices (NMFS fisheries statistics database, www.st.nmfs.gov and Dvora Hart, NEFSC, electronic communication, August 2001).

The fact that most of the marine reserves that have been studied appear to enhance fish catches—despite the fact that none were designed to do so—suggests that the catch enhancement by marine reserves may be quite robust. These results are consistent with the results of modeling studies, which project that marine reserves should increase fish catches and accelerate rebuilding of depleted populations. Recommendations for reserve size to enhance fish catches in the scientific literature range from 25% to more than 50% of the fished area, depending on which assumptions are used for unknown or poorly studied parameters such as fish mobility, the relationship between fish abundance and recruitment, and the effects of habitat quality. In the specific case of the Channel Islands, the Science Panel of the Marine Reserves Working Group has recommended that 30% to 50% of the major habitat types characteristic of the Channel Islands be set aside within marine reserves.

It is clear that large red sea urchins, kelp bass, and male sheephead are more abundant within the East Anacapa Island marine reserve than in fished areas around the Channel Islands (Irene Tetreault Beers, personal communication, August 2001; Larson, 2000). In addition, not only are targeted species within this marine reserve larger, in general, than in fished areas; in the case of large (>12 inches) sheephead, they are more than four times more abundant inside the reserve than outside (Irene Tetreault Beers, personal communication, August 2001). Hence, it is logical to expect that fisheries adjacent to marine reserves in the Channel Islands will be enhanced through the export of larvae from the marine reserves, and perhaps through the "spillover" of adult and juvenile fishes. No empirical studies of larval export or spillover from the East Anacapa Island marine reserve have been conducted as yet. A study of various species of rockfish in kelp forests inside and outside of three ecological reserves in Central California, however, illustrates the value of fish "saved" in a reserve and the potential "spillover". Using Paddack and Estes' survey of fish biomass and abundance for a number of rockfish species (2000), we can estimate the value of one of these as a function of the reserve area. In two of the reserves—Hopkins Marine Reserve and Point Lobos Ecological Reserve—that had been in existence for 12 and 23 years respectively (sufficient time, in other words, for any recovery effects to become visible), the value-per-area of black and yellow rockfish (*Sebastes chrysomelas*) was twice to three times as high as outside: about $30/km^2 and $50/km^2 respectively. This gives a measure of the capital value of the reserves, in terms of the market value of black and yellow rockfish: Depending on the discount rate,[7] this translates into a "capital value" of between $300/km^2 (at 10%) and $1,667/km^2 (at 3%). In other words, by virtue of the biomass produced (and thus potential revenues) within its boundaries, marine reserves have value much in the same way as other forms of capital are valuable for the revenues they generate. Interestingly, in this study of three small ecological reserves, the oldest one, Pt. Lobos, generated the higher values. This, together with the sensitivity of the value of reserves to "time preferences" (i.e., money now versus money later), exemplifies that marine reserve decisions have to take into account a number of different concerns at different time scales. While the study sites are too small, and spillover effects too life-history specific to allow any scaling up to larger areas or other species, this example gives an impression of the value embodied in marine reserves. Furthermore, the differential of the per-area-value in the reserve and in adjacent fishing sites—about $22/km^2 for the one species in our example, *S. chrysomelas*—is potentially available as "spillover" into adjacent fishing areas.

It is important to note that the existence of positive biological spillovers does not guarantee enhanced fish catches after a marine reserve is sited. The net impact on catch probably depends on the relative importance of the MPA in the total catch prior to the closure and the status of the fish stock. For example, if the area contributed a significant share of total catch, it is less likely that total catch could increase, because the threshold level that the biological spillover effects must overcome is higher. On the other hand, if the catch from the area to be designated a MPA is an insignificant share of total catch, possibly as a result of over-exploitation of the stock prior to the closure, then the probability of increasing the total catch is 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). The benefits to the fishery will also depend, in part, on how fishermen respond to the marine reserve as will be discussed in a later section.

3. Option values

One of the most important, and difficult to conceptualize or measure, effects of marine reserves is that they safeguard the future uses (consumptive and non-consumptive) of marine resources.

[7] When faced with a decision whether to have money now or money later, the more highly one values the present, the higher any interest paid will have to be to make it worth my while to get the money later, i.e., the higher the interest rate has to be on a saving/investment. Typical values range from 3% to 10%, and any positive value entails a preference of the present over the future.

This is referred to as "option value" because the knowledge that there is a future stream of revenues from fishing and other uses already has value in the present, much like bonds or stock options have a value today based on the future pay-off their owners are guaranteed to receive. In the case of marine reserves, both present and future users—as well as the American public at large, as owners of natural resources in U.S. waters—stand to benefit from the option on future uses protected and engendered by marine reserves.

Given the downward trends of certain target fish and shellfish populations in California, as in other coastal waters, current catch rates in some fisheries appear to be unsustainable. This makes their use as a benchmark against which to compare the effects of marine reserves problematic. Current fishing practices, with existing fisheries management tools and regulations in place, also have considerable costs. The avoidance of some of those costs are a potential benefit of marine reserves, and pertains to the future value for fishing and other uses. Option values can be thought about in terms of other costs avoided, for example revenues that would otherwise be lost through management measures to improve the no-reserve state of affairs, or in terms of the replacement value of a fishery once it has been depleted. A recent National Research Council (National Academy of Sciences) study of marine reserves and protected areas observes that "since the Magnuson-Stevens Fishery Conservation and Management Act mandates that [stock] rebuilding plans be implemented, user groups will be required to incur the upfront costs associated with whatever methods are chosen to rebuild the fishery. [...] It is only a question of whether fishery reserves will be more effective than other management methods" (NRC, 2001, p. 61).

The benefits of marine reserves associated with averting costly management measures or outcomes are illustrated by a recent experience in waters near the CINMS. As populations of exploited and incidentally caught species dwindle, multispecies fisheries (which catch a number of different species) are adversely affected by management measures designed to protect less productive populations. For example, cowcod rockfish is caught with several other rockfish species, but has declined to low levels. In response, the California Department of Fish and Game has closed a large area (4,300 square nautical miles) to protect cowcod by preventing directed and incidental catch of this species. Similarly, bocaccio rockfish has declined to low levels and is being protected by restricting direct and incidental catch, resulting in reduced overall catches of still-productive populations such as chilipepper rockfish. In addition, reduced allowable catch levels often result in higher discards and economic waste.

Listing of any target or incidentally caught species under the state or federal Endangered Species Acts (ESAs) would be expected to constrain fisheries to an even greater extent, as has been the case for salmon. In the past 20 years, a series of sequentially more restrictive area and season closures have been implemented along the Pacific coast as part of management efforts to restore dwindling chinook and coho stocks. It is difficult to isolate the effect of federal and state Endangered Species Acts (ESAs) listings of a number of evolutionarily significant units (ESUs), such as winter chinook, coho, Klamath River fall chinook, and Central Valley spring chinook, on commercial and recreational fisheries. Other constraints are renegotiated in-river harvests to fulfill Indian-treaty obligations, the ecological conditions of the river systems supporting salmon runs, and market forces (especially the competition with farmed and imported salmon). It is also unclear whether anything would be different in the absence of the ESA listings, as some measures originating in provisions of the 1996 Magnuson-Stevens act are as restrictive as the ESA. Over the past twenty years, however, salmon ocean fishing has declined considerably, with the size of the California commercial fleet reduced to roughly 700 boats in 2000, from nearly 5,000 in 1980, and the value of salmon landed sharply reduced from over $24 million to just under $9 million, in 2000 dollars (PFMC, 2001a).

One case illustrating the connection between an ESA-listing and the potential effect on the fishery is the recreational winter chinook fishery. Before the 1989 listing of the Sacramento River winter-run chinook, the California recreational ocean salmon season was wide open, lasting from Mid-February to mid-November. After the listing, the seasons along the coast were delayed, effectively cutting out the month of February. In a second step, after the National Marine Fisheries Service (NMFS) issued a biological opinion resulting in a more stringent "jeopardy standard" of increasing the adult escapement (fish escaping the fishery to spawn) to 31% of the baseline, the month of March was effectively eliminated from the season. Most recently, in response to spring chinook management concerns, the season opening was delayed further, to mid-April for the stretch of coast between Point Arena and Pigeon Point (PFMC, 2001a). Assuming that the historical rate of harvest during the month of February could have been maintained, then the 5,000 chinooks, on average (PFMC, 2001a), that were historically landed in San Francisco during the month of February represent annual lost fishing opportunity due to ESA-induced management measures.

ESA listings as a result of inadequate fishery management or habitat degradation are real possibilities in the Channel Islands region: white abalone has been listed already, and a petition to list bocaccio was recently made to the NMFS. Economic costs associated with listings under the ESA will depend directly on the specific nature of protective management measures that are taken. However, the potential economic impacts of one or more ESA-listings on Santa Barbara and Ventura can be illustrated by the loss of fishing opportunity and ex-vessel revenue associated with the cowcod closure. Declining stocks made necessary the closure of an area over <u>twice</u> the size of the <u>entire</u> area that comprises the CINMS, resulting in decreased landings of rockfish. In other words, there are benefits from marine reserves—which account for only 25% of the CINMS area—being the "lesser evil" when it comes to management and legal tools for protecting endangered marine organisms.

<u>4. Quasi-option values</u>

Even less tangible than option value of marine reserves is the quasi-option value that derives from delaying irreversible decisions and awaiting future information. In the case of marine resources, such information might arise in the form of new socioeconomic or environmental information that might reduce the uncertainty of resource management decisions (Freeman, 1993). In the case of fisheries, however, there is now little doubt that many fish stocks are fully exploited or overexploited and in need of urgent conservation and management measures (FAO, 1999; NRC, 2001). Hence, no benefits are likely to arise from postponing the decision to implement a reserve. For practical purposes, therefore, the quasi-option value of marine reserves refers to the future uses that might arise if we prevent the further decline of fisheries and marine ecosystems, about which we may only find out in the future. Perhaps the most concrete way to think about quasi-option value is in terms of the scientific research and potential applications that a network of marine reserves could yield.

Reducing the current level of uncertainty and strengthening the science of stock abundance forecasts can only improve the long-run economic and biological outlook of fisheries well beyond a given marine reserve study area. Marine reserves will provide relatively undisturbed areas, creating new opportunities for scientific research and offering a hedge against management decisions based on inaccurate assumptions or information. Marine scientists argue that these areas can be used as controls (reference areas) to monitor the recovery of fish populations and rigorously study the production ecology of fish, and the impacts of fishing on fish populations and other ecosystem components and processes. They contend the benefits will be realized 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 (NRC, 2001). If poor stock assessments or lack of persuasive scientific information to set total allowable catches at sustainable levels are important causes of overfishing, then marine reserves might not only be a good hedge against decisions based on inadequate information; marine reserves are also likely to reduce or prevent overfishing.

The biodiversity protected within marine reserves may also yield what are currently unrealized economic benefits. For example, Bryostatin 1—a compound isolated from the bryozoan *Bugula neritina*, an organism that attaches itself to the bottom of boats off the coast of California—is currently in phase II clinical trials at the National Cancer Institute for treatment of melanoma, non-Hodgkin's lymphoma, and renal cancer (Rayl, 1999). Already on the market is an anti-inflammatory compound extracted from the seafan, *Pseudopterogorgia elizsabethae*, which is generating millions of dollars in annual revenues in an Esté Lauder skin care product, Resilience. Twelve compounds from marine organisms have entered Phase I or II clinical trials as of 2000 (including compounds against cancer, inflammation, schizophrenia, and Alzheimer's) and many more are under preclinical examination (Fusetani, 2000). No one can predict the true value of unrealized economic benefits from marine reserves. However, the pharmaceutical potential of coral reefs alone, for example, has been estimated to range from $72,500 to $698,000 per hectare (Cartier and Ruitenbeek, 1999).

5. Bequest values

Perhaps one of the most devastating consequences of declining fish stocks globally has been the destruction of the coastal way of life. People living in coastal communities derive considerable value from the knowledge that this way of life is passed on to their children and future generations. When fish populations collapse, the economic and psychological cost to the communities who depended on fishing for their livelihood can be high.

However, a proxy measure is provided by the roughly $3.5 billions (Canadian dollars) that the Canadian government has paid in benefits to fishermen and other programs in response to the northern cod collapse in the 1990s (Auditor General, 1997). This figure is a lower bound because it only captures the government's expenditures to deal with the crisis—the actual costs borne by industry, communities, and individuals are considerably higher. Because of overfishing, a 400 year old way of life on the Atlantic coast and the revenues it generated can no longer be bequeathed to future generations. Since the northern cod collapse, new fisheries for crabs and shrimps have developed, with equivalent or greater landed values than the cod fishery. This has not been socially beneficial, however, because the income has been very unevenly distributed. The cod fishery provided adequate livelihoods for many people, with only modest variation in income. Nowadays, there are some very rich fishermen due to a limited number of fishing licenses for crab and shrimp, and many poor, former cod fishermen who found no alternative employment and continue to live off welfare (Martin Willison, electronic communication, 31 May 2001).

It is uncertain whether a network of marine protected areas and reserves could have prevented the collapse of the North Atlantic cod fishery, and no studies have been conducted to address this issue. It is clear, however, that the collapse occurred concurrently with the use of conventional fisheries management tools that were relying on best available scientific knowledge and stock assessments at the time. Indeed, if there is one lesson from the cod collapse it's that stock assessments are inherently uncertain (Walters and Maguire, 1996; Ludwig et. al., 1993). A recent study by the National Research Council specifically recommends the use of marine reserves and protected areas as a means for mitigating the uncertainty inherent in conventional management tools (NRC, 2001), and to avoid potentially catastrophic collapses and their detrimental effects on fishing communities.

Commercial and sport fishing are an integral part of coastal life in the Channel Islands, and in 1999 generated roughly $190 million income in the seven counties adjacent to the CINMS, according to a report by the socioeconomic panel of the marine reserve working group (Leeworthy and Wiley, 2001a). The bequest value of a marine reserve, then, lies in its capacity to support these income streams in perpetuity, and in the way of life in the Channel Islands that might be lost if fisheries continue to be fished to the brink of collapse can only be estimated.

6. Existence (heritage) values

The existence (sometimes called heritage) value of marine reserves denotes an appreciation of the inherent value of marine wildlife and healthy marine ecosystems, and can be held by people who live nowhere near the ocean. Just knowing that it is there and is preserved in a special, protected status potentially elevates the value of the Channel Islands to people who never intend to use the area. The existence value is one of the least tangible and least immediate benefits associated with setting aside areas of the ocean for habitat and biodiversity protection, but it is very important to many people.

Putting a dollar value on the (continued) existence of living marine resources is contentious and technically challenging. Resource economists have, however, derived reasonable values for living marine resources. Such estimates are a way of figuring the public good provided by marine reserves into political decision-making processes, which tend to be biased towards the private goods or adverse consequences associated with a conservation measure. Studies have found, for example, that beach visitors derive greater value (as measured by their willingness to pay for improved quality in a hypothetical market scenario) from their visits to less polluted beaches or better protected intertidal habitats (Hall et. al., 2001 and literature reviewed therein). In their review of benefits evaluation for marine reserves, Hoagland et al. (1995) found that the existence values measured in surveys of visitors to nationally important sites such as the John Pennekamp Coral Reef State Park and the Key Largo National Marine Sanctuary in Florida (Leeworthy, 1991), or international sites such as the Galapagos Islands or the Great Barrier Reef (Edwards, 1991; Hundloe, 1989), stand out by an order of magnitude when compared to values reported at state or local beaches. Mean values per visitor per day in these sites range from $150 to $500, as compared to the tens of dollars reported for the other beaches. No such studies have yet been undertaken for the CINMS, nor is it clear where exactly on the spectrum of natural and attractive (to tourists) sites the sanctuary ranks.

Of the non-use economic values reviewed here, indirect-use, option, and quasi-option values are functions of the inherent biological properties of the resource and cannot be conclusively elicited. Existence and bequest values (sometimes called "passive use values"), however, have garnered scholarly and public attention since they were first quantified in the aftermath of the Exxon Valdez oil spill. Researchers surveyed households throughout the United States (excluding Alaska) and found that, on average, people were willing to pay about $30 to prevent another oil spill (Carson et al. 1992), thus putting a "price" on the spectacular Alaska shoreline that had been despoiled. These estimates were used to determine the range of damages awarded by the jury in the Exxon case, $5.3 billion (NRC, 2001). Of another 18 studies in which non-use economic values were estimated reviewed by Desvouges et al. (1992), 16 reported values of $10 or more per household, per year for a variety of natural resource protection efforts, one reported values between $3.80 and $5.20 and the remaining one reported values ranging from $6.50 to $75.

In a socioeconomic assessment for the Dry Tortugas reserve initiative in the Florida Keys National Marine Sanctuary that is currently awaiting final approval by the State of Florida, Leeworthy and Wiley conduct a thought experiment that illustrates that the non-use values of the marine reserve are larger than commercial and recreational uses taken together (Leeworthy and Wiley, 1999). The authors assume that 1% of U.S. households would have some positive non-use value for the marine reserve, and that this 1% of households would be willing to pay either $3, $5, or $10 per year and household. Multiplying by the number of households in the United States (113 million as of 1997), they arrive at annual non-use values of $3.39 million, $5.65 million, and $11.3 million, respectively. For the final boundary alternative decided upon in the Tortugas, this is between 3 and 10 times the amount of the total economic value generated annually by recreational and commercial fisheries.

Using these same assumptions and repeating the thought experiment for recreational uses in the CINMS (due to a lack of econometric studies on demand and supply of commercial fishing products), it turns out that the same is true for the Channel Islands and non-use values are comparable or more than the use values (Bob Leeworthy, electronic communication, 12 June 2001). In the 1999 baseline year, recreation (consumptive and non-consumptive) generated a total consumer surplus of $5.56 million. By comparison, non-use values generated consumer surpluses of $3.39 million (low), $5.65 (middle), and $11.3 million (high) for the three household willingness-to-pay values used ($3, $5, and $10 per year and household). Notice, however, that these willingness-to-pay values are in the lower range of the published figures, and that the assumption that only 1% of U.S. households would be willing to pay for a marine reserve is also a conservative lower bound—a 1990 survey found that 8% of U.S. households made financial contributions to environmental organizations (Roper, 1990; cited in Leeworthy and Wiley, 1999). The actual stake of the American public in a network of marine reserves may be many times than that: a recent survey commissioned by SeaWeb found that 76% of respondents are in favor of ocean protected areas. Correspondingly, ocean protection activities and programs have expanded, with public interest organizations spending on millions of dollars annually on marine resource research, advocacy, and conservation.

Potential Costs of Marine Reserves

As with all investments, public or private, there are costs associated with establishing marine reserves. In contrast to the benefits, most of which accrue over time, the costs tend to be short-term in nature. They also tend to disproportionately affect consumptive users, or at least are perceived to do so by such user groups as commercial and recreational fishers (NRC, 2001). Below we examine some of the historical and cultural factors behind the perceived and real equity issues associated with marine reserves, as well as mechanisms for making the implied reallocation of user rights over marine resources more palatable to all groups involved. In this section, we focus on the state of the knowledge about socioeconomic costs associated with the establishment of marine reserves.

1. Lost revenues

In the Channel Island process, there exists to date only a comparison of the immediate effects of a marine reserve network on revenues and employment from consumptive fishing and recreational activities in the region around the CINMS. This analysis, conducted by the stakeholder working group's socioeconomic panel with support from NOAA's Special Projects Office (available as Leeworthy and Wiley, 2001a), computes the revenues lost due to various percentage reductions of areas available to consumptive uses, notably commercial and recreational fishing and diving. Importantly, the analysis is static in the sense that it only provides a before and after scenario for each of the boundary alternatives, including the "preferred alternative" submitted by the Sanctuary Advisory Council to the California Fish and Game Commission in July 2001. This analysis uses only a relatively simple multiplier to estimate ripple effects on the regional economy, notably on employment. Furthermore, the current socioeconomic analysis rests on the assumption that current fishing efforts could continue at present rates into the future.

Under these conditions, the "preferred alternative" would reduce commercial fishing ex-vessel values by about 16% of the 1996-1999 baseline total ($28,111,179), or roughly $4.5 million, and charter/party boat fishing income by about 20% (of roughly $28.5 million), or roughly $5.3 million (Leeworthy and Wiley, 2001b). Given that it is likely that the political process will focus on ways to mitigate these immediate "losses" to consumptive users, it is important to remember the assumptions of this analysis. It is a loss only if it could be assumed that current rates of exploitation, and thus revenues, could be maintained into the future. Yet the network of marine reserves have become necessary precisely because many of California's fishing stocks are severely depleted. Over the past 20 years, sampler estimates for fish caught by marine recreational anglers show a decrease of 85% over that period (RecFIN, 2001), while commercial landings of all species but squid[8] decreased by 50% over the same period (NMFS, 2001). Given these declining trends, a more comprehensive socioeconomic assessment would thus have to take dynamic effects into account, and evaluate the costs and benefits of marine reserves over an extended time period, and in the context of other variables governing the fishing industry. These include the longterm socioeconomic viability of declining target species populations in a no-reserve scenario, and the changing industry profile in response to longer-term ecological, economic and regulatory trends.

While the overall impact of any of the marine reserve boundary alternatives, including the "preferred alternative" on local county economies is relatively minor, according to the report (Leeworthy and Wiley, 2001a), there are considerable impacts on particular user groups and locations. For example, 90% of all consumptive recreational activities in the region take place in Ventura County, resulting in the largest share of revenues and jobs being located there. Consequently, Ventura County stands to be considerably impacted by any change in use patterns (notably a decline of consumptive activities) associated with a marine reserves network. By contrast, Ventura is also associated with the largest income from commercial fishing and kelp activities, yet will not be as adversely affected as other counties. For example, the biggest reserve alternative originally considered by the Marine Reserves Working Group, alternative "A", diminished overall commercial fishing and kelp revenues (for all counties) by 24%, and by 46% in Santa Barbara County alone—but only by 19% in Ventura. This example illustrates that the effects of marine reserves are very different for recreational and commercial consumptive activities. Costs for their implementation are also allocated unevenly across the seven counties in the region. Together, these phenomena point to a need to consider carefully who benefits and who pays the price of establishing each reserve alternative, and perhaps the importance of considering mechanisms of compensating those disproportionately affected under the final reserve design.

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[8] Although squid is the most important species, commercially, its life history characteristics make it an outlier among target species. Over the past 20 years, the squid fishery has experienced greater than average booms and busts than the rest of the commercial effort (Leeworthy and Wiley, 2001; Lutz and Pendleton, 2000).

Since the existing short-term analysis is static, there are considerable uncertainties as to what the actual effects will be on individual target species catches and revenues. These are affected by meteorological, biological and ecological factors that may have little to do with the size or location of marine reserves in the Channel Islands. Consider squid, for example, which in 1999 accounted for 72% of the commercial ex vessel value, or $26,558,813. Responding to signals from the increasing export market for squid in the early 1990s (especially increased exports to China), the fleet increased from around 85 vessels during the 1970s to currently around 200 (Lutz and Pendleton, 2000). Is it reasonable to expect that these levels could be sustained, even if there were no marine reserve? The scientific evidence provides no clear answer to that question. According to one recent study, little is known about the Pacific squid resource over and beyond recent catch data and the historical record from which the biomass of squid is inferred to be quite large—though highly variable (Lutz and Pendleton, 2000). Seasonal spawning grounds are located in shallow inshore areas, and since the commercially viable squid are the pre-spawning biota (ibid.), it is not surprising that these authors find that between 65% and 85% of California squid is caught off the Channel Islands.

From an ecological perspective, squid are a vital part of the marine ecosystem, as a food source for many fish, birds, and marine mammals (Lowery and Carretta, 1999). Indeed, many other fish that are essential to Southern California's commercial and recreational fisheries also rely on squid as a critical food source (Morejohn et al., 1978, cited in Lutz and Pendleton, 2000). Although we know of no studies of the ecological impact of squid harvest, it seems clear that removal of such an important food source should have significant impacts on the food web. Historically, the squid fishery has seen large fluctuations in landings, often from year to year, in response to fluctuating ocean temperatures. After experiencing a big decline during the 1997/98 El Niño, the 2000/2001 season has yielded bumper landings (Lutz and Pendleton, 2000).

Clearly marine reserves are neither causes of nor protection against the vagaries of the weather, or the size or directions of market incentives from export markets and other economic signals (however, there are indications from models that marine reserves could stabilize yields from some fisheries). For a more complete picture of the socioeconomic effects of marine reserves on the squid fishery, therefore, the analysis has to take into account these other factors, as well as the circumstances that have led to the current levels of capitalization of commercial fisheries and behavioral responses to marine conservation measures.

2. Changing variable costs of fishing effort

Setting aside marine reserves will have several implications for the variable costs of fishing. In addition to the revenue foregone from reductions in fishable area, other effects might include the displacement of fishing effort, increased congestion on the fishing grounds that remain open (if nothing is done to reduce fishing capacity), higher cost of reaching a different fishing location, and costs associated with enforcing and/or monitoring the protected areas. These costs are likely to be incurred immediately, but may decline over time as fishermen find ways to adapt their use patterns.

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 remaining open fishing grounds. Congestion effects could result in increases in fuel usage, crew employment, and higher capital costs (e.g., fish finding equipment). In addition, congestion could lead to increased conflicts between fishermen concerning appropriate gear or catch allocations between commercial and recreational fishing. Yet another congestion effect could potentially occur if the establishment of an MPA shifts fishing pressure from one target species to another, thereby increasing the competition for the catch of that second species. These effects are exacerbated when considered in conjunction with existing constraints on the fisheries, such as the 4,000 square mile cowcod closure area, or the management measures to protect listed salmon runs. No research has as yet been done to determine the size and synergies of these effects, and the implementation of a marine reserve network in the Channel Islands would provide important opportunities to study these actual and anticipated effects of a mixed portfolio of management measures. However, there is general recognition of the need to reduce fishing capacity in several Channel Island fisheries, whether or not marine reserves are established. Reduced fishing capacity could greatly ameliorate or eliminate increased congestion (and potential local depletion of fish stocks) associated with the displacement of fishing effort.

Marine reserves will increase the variable costs associated with the choice of fishing location. A fisherman's decision of where to fish depends on 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. Following siting of a marine reserve, vessels could spend more time steaming to and from the fishing grounds, which could increase fuel use and reduce the amount of time that vessels will spend with fishing gear in the water. The increase in fuel costs and the increase in steam-time costs can create incentives for skippers to invest in additional capacity such as larger hold size, improvements in handling technology, and more horsepower. There is thus the potential for behavioral responses to marine reserves to exacerbate the problem of over-capacity in commercial fisheries. In this context it is also interesting to note that one study found that some management measures, notably the weekend closure of the squid fishery, had significantly higher impacts on out-of-state vessels than local ones (CCR, 2001). Effort or capacity controls, along with measures to reduce capacity such as limited entry, can be used to prevent these effects. Individual Fishing Quotas for fish harvest privileges can reduce capacity (if the IFQ is transferable) and prevent "capital-stuffing" (the addition of more fishing capacity per vessel) by providing an assured percentage of the allowable catch to individual fishermen, who can then match their capital investment to this percentage, rather than increasing capacity to compete for an unspecified catch (NRC, 1999b).

In many fisheries, a significant component of total variable harvesting costs is the time and fuel spent searching for the fish. In modeling fishing costs, a basic assumption is that higher fish population levels result in lower search costs, everything else being equal. This effect is commonly referred to as the stock effect. If marine reserves are established in a fishery where the stock effect is significant, then they could potentially reduce this component of harvesting costs. For instance, if the biological spillover effects of marine reserves are large and far-reaching, then the possibility exists that stock levels will increase throughout the fishery. In this case, one would expect searching costs to decrease. On the other hand, if the positive spillover effects are only local in nature, then searching costs might actually increase after marine reserves are established. For example, 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.

3. Monitoring and Enforcement Costs

Marine reserves will likely result in additional monitoring and enforcement costs. Some experienced fishermen fear that marine reserve boundaries simply cannot be enforced given the strong incentive to poach in protected areas and limited resources dedicated to enforcement. The fact that existing California marine reserves exhibit dramatically larger populations of fish and shellfish within their borders compared to fished areas suggests that enforcement has been adequate at these sites. Monitoring and enforcement costs are likely to depend on factors such as the size, location and use restrictions of MPAs, as well as local fishing practices and customs. Furthermore, if fishermen are displaced and crowding of fishing grounds results, then additional regulations and enforcement costs may be necessary outside of the MPA. New technology allows use of the global positioning satellite (GPS) network to automatically monitor the location of fishing vessels and detect violations. This technology (termed Vessel Monitoring Systems, or VMS) is being used around the Great Barrier Reef in Australia, in the Northern Pacific (to monitor Hawaiian longline vessels), and the Georges Bank off the coast of Maine, and it has reduced spending on fishery patrol vessels (The Economist, 2001) and is regarded as a highly effective enforcement tool.

MPAs influence fishing effort directly by restricting the location where fishing can occur and indirectly by altering the potential profitability of a fishing enterprise. Properly enforced, MPAs control effort within their boundaries, but they have no effect on the causes of excess effort that will continue to plague the rest of the fishing grounds. These factors (e.g., competition for unspecified amounts of catch, overcapitalization, subsidies, etc.) must be controlled with other kinds of measures, such as limited access, effort controls, IFQs, or buyouts.

4. Increasing and shifting fishing efforts

In a regulated open-access fishery such as the one in the CINMS, overfishing results in part because fishermen lack rights to protect and conserve the fish stocks for future harvests. Without rights, fishermen perceive that a fish not caught today is someone else's fish tomorrow. So they invest in larger boats and more gear in order to catch more fish without realizing the social opportunity cost of their actions. That is, they over-fish the stock and ultimately impose a cost on other fishermen in the way of lower future benefits from the fishery (OECD, 1997). For decades, subsidies for vessel construction and operation have signaled artificially low costs of entering and staying in the industry (Hanna, 1999). Current fisheries management efforts have overlooked the problems of open access and skewed market signals, and instead focused on effort controls, such as trip limits, to restore stocks. But these measures ignore the fact that signs of a recovery often attract additional effort, as the perception of lower costs and greater than actual net benefits attract new entrants in to the fishery and induce existing fishermen to apply more effort to maintain their profitability.

While MPAs provide spatial refugia for fish stocks, they do not address the causes of excess effort. Fishermen will respond to MPAs as they do to other open-access regulations, such as input controls or trip limits—by trying to maintain their profitability without taking into account the social opportunity costs of their actions. At the same time, conservation measures alone will not generate the market signals to correct the excess effort. In practice, this means that short-run gains in net revenues due to increases in catch, or shifts in the catch composition, may not be sustainable as the industry quickly increases effort to capture the benefits of an MPA (Hannesson, 1998).

However, some studies have shown that MPAs may be a feasible alternative to conventional fishery management tools when dealing with complex, multispecies fisheries or when there is a lack of resolve to control fishing effort (Holland and Brazee, 1996; Lauck et al., 1998; Roberts, 1997). Multispecies fisheries are often difficult to manage because management controls or market demand may shift effort from one species to another or result in greater discards. If designed and sited properly, MPAs may offer a second best solution to stem overfishing in multispecies fisheries, such as the reef fishes off California, in the Gulf of Mexico, and the Southeastern United States. Economists have shown, using in simulation models, that MPAs can be effective in sustaining yields or increasing fishery yields for moderate to heavily fished reef fish fisheries where single species effort reductions are not possible (Holland and Brazee, 1996). Mortality due to incidental catch (bycatch) often makes single species catch reductions very difficult or impossible in multispecies fisheries, where species with low productivity mix with highly productive species. In such cases (typical of California rockfishes, for example), valuable catch of the productive species (e.g., chilipepper rockfish) is often forgone to protect low productivity species (e.g., bocaccio and cowcod).

In two studies investigating the implications of marine reserves, which include behavioral models of the fishing industry, the models predict that harvesting pressure outside and especially along the boundaries of the marine reserve will increase (Sanchirico, 1998; Walters, 1999), causing "edge effects". There is some anecdotal evidence that this has occurred outside a marine reserve located off the coast of Kenya, where the number of 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 marine reserve have been quickly dissipated. In the U.S., however, one study shows that recreational catches near the Florida keys reserves have been increasing near reserves at increasing rates and more game fish fishing records have been set the closer one gets to a de facto marine reserve, a security zone near the Kennedy Space Center (Bohnsack, in review), suggesting sustainable fishery enhancement as an outcome of marine reserves.

5. Synchronization of management tools

From the foregoing discussion of costs, it is clear that marine reserve measures necessitate a review of, and integration with other fisheries management tools—both to offset any increases in fishing pressures associated with the reserve designation, and to mitigate the perceived costs of “double jeopardy." This potentially occurs when, after a reserve goes into effect, fishing pressures increase in adjacent fishing grounds and necessitate further or new restrictions on those areas. Although this has not been documented for any of the existing marine reserves, the fear to get “punished” repeatedly might well factor into the opposition of stakeholders to marine reserves. Federal, state and regional fisheries management agencies will therefore have to incur some costs of synchronization and integration of traditional and the new, spatially based, management tools such as marine reserves and protected areas.

The most effective way to reduce the potential for increased fishing pressure on remaining fishing grounds resulting from the establishment of marine reserves is to introduce management measures that control fishing capacity. Such measures should address the fundamental causes of excess effort and capacity. This can be achieved by replacing incentives to over-invest in fishing capacity and to compete for fish with incentives for investment appropriate to sustaining fish populations. Public or private tenure arrangements (i.e., a unified directing power) are necessary to prevent the resources of the community-at-large from being destroyed by excessive exploitation. Individual Fishing Quotas (IFQs) are being used in many different fisheries and countries to regulate fishing effort to the advantage of fishermen and the environment (NRC, 1999b). Other management measures, such as limited entry, can be useful to control effort if implemented early in the evolution of a fishery and if they are coupled with other measures, such as gear and vessel restrictions, to prevent “capital stuffing” (whereby fishermen increase fishing power by enhancing equipment or changing fishing practices, while keeping the number of vessels constant). Fishing cooperatives, Community Development Quotas, vessel buybacks, and other management measures may also serve to reduce the dislocation of fishing effort from marine reserves into the remaining fishing grounds.

Marine reserves and MPAs create an opportunity to maximize ecosystem health by synchronizing water quality control efforts with a ban on extractive uses. MPAs appear to increase efforts to protect water quality, which can be important both in maintaining ecological integrity within the MPA and in maintaining healthy fisheries outside the MPA. While marine reserves are not automatically protected from external threats, like nutrient pollution, coastal erosion, diversion of freshwater, and broad shocks, such as those caused by El Niño, the designation of an MPA or marine reserve brings with it the connotation that it is a “special place” worth protecting from all threats. This connotation has helped create constituencies to work together to reduce nutrient pollution and other environmental threats. The Florida Keys National Marine Sanctuary (FKNMS), for example, includes a comprehensive water quality protection program that is strongly supported by both local citizens and national groups. The designation of the FKNMS enabled water quality protection advocates to successfully obtain millions of dollars in appropriations for improved wastewater treatment and water quality research in the Florida Keys.

Political economy of Marine Reserves

When marine resources owned by all Americans and managed by federal and state governments are dedicated to a particular use, like marine reserves, a public investment has been made. The desirability of such an investment is found by weighing potential benefits and costs as described above, along with moral, ethical and cultural values. While the latter values are largely beyond the scope of this paper, they often play a major role in shaping decisions in our democracy. Studies have found that people in many nations value the quality of the environment. In a poll regarding the perceived trade-off between environment and the economy, more than 50% of respondents in each of 24 nations chose environmental protection over economic benefits (Dunlap et al., 1993). In the United States, a survey commissioned by SeaWeb found that 76% of respondents are in favor of ocean protected areas, but only 34% had any awareness of the National Marine Sanctuaries Program's existence (NRC, 2001). Often, these public values are not translated into regulatory decision-making processes for lack of institutional and organizational avenues.

This raises important issues about the distribution of benefits and costs (both real and perceived) between different user groups, local stakeholders and the American public, and across time. While resource economists can systematically identify, describe, and quantify potential benefits and costs of marine reserves, a precise calculation of expected net returns (expressing all benefits and costs in dollar terms) may prove to be difficult. Like other public investments, many benefits of marine reserves will be realized at some future date, whereas many costs are incurred initially, implying that closing off areas also results in an intertemporal tradeoff, perhaps even across generations (Holland and Brazee, 1996; Sanchirico and Wilen, 1998; Hannesson, 1998; Pezzey et al., 2000). Difficulties also stem from the complexity and degree of imprecision when trying to predict the impact of a new management tool on biological and economic systems. Along with intertemporal tradeoffs and uncertainties, marine reserves—as was discussed above—affect user groups differently and perhaps disproportionately, revealing that there are equity issues among the stakeholders in the process (Holland, 2000). For example, if a marine reserve 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 most of the benefits. A recent report found that 10% of commercial fishing operations account for 70% of ex-vessel revenues, suggesting that there are considerable distribution issues between larger and smaller operations (Lutz and Pendleton, 2000).

The stakeholder process in the CINMS case was intended to be representative of the different user groups and the public at large, and appears to have integrated scientific and economic analysis with decision-making in a unique and valuable way. However, an evaluation of it remains to be done to see if the process might be improved in any way. In Europe, good results have been obtained with novel forms of participatory processes such as citizen juries that combine communication, deliberation and a broad set of socioeconomic considerations (see for example the review in O'Connor, 2000). In the United States, the National Research Council and the Environmental Protection Agency have taken the lead in developing analytical deliberative processes for participatory decision-making, and are actively promoting it for environmental resource management issues (NRC, 1996 and 1999a; EPA, 2000).

Conclusions

As our review of the various costs and benefits associated with marine reserve has shown, an easy, straightforward cost-benefit analysis to inform decision-making is as elusive as it is desirable. We have argued that in order to make a public investment of the kind entailed by marine reserves, all costs and benefits should be accounted for—even though some might be difficult to quantify. If expected net returns can be shown to be positive using available data and knowledge, then it may be concluded that society as a whole is better off as a result of the public investment. On the other hand, if the analysis concludes that expected returns are negative, it means society would be worse off with a marine reserve. Such outcomes are powerful, but may be difficult to arrive at in practice. Even a cursory review of the kinds of indirect and non-use values associated with marine reserves strongly suggests that the value of such a public investment in marine reserves (to reduce fishing mortality and protect marine biodiversity) will generate more value than the costs of <u>not</u> reducing fishing mortality and <u>not</u> protecting biodiversity.

Every public investment has equity or fairness implications. Another way of stating this is that MPAs could potentially affect one user group disproportionately, revealing that there are equity issues among the stakeholders in the process (Holland, 2000). People do not necessarily have an incentive to reveal their true benefits from marine reserves, nor do they necessarily have the means to pay for them, even if they wanted to. These facts are very important in the political realm of decision-making. And, they may be especially important for marine reserves, particularly if reserves are viewed as undesirable by some members of the local community affected by their siting. Concern about fairness and equity emphasizes the importance of a public outreach strategy to reach general consensus on management objectives, location and design, and use of marine reserves.

Commercial and recreational fishermen often fear that they will bear the costs of closing areas but will not be the recipients of the benefits. For example, a leading sport fishing group recently announced that it will oppose all MPAs that prohibit recreational fishing unless it can be determined that recreational anglers are the cause of a specific conservation problem and that traditional conservation measures are inadequate to correct the problem.[9] Such a change in the distribution of costs and benefits—real or perceived—is inevitably the subject of considerable

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[9] For details see the August 6, 2001 press release issued by the American Sportsfishing Association, http://www.asafishing.org/newsroom/pressreleases/asapr_freedom.htm

dispute. Better understanding of the benefits and costs may reveal ways to compensate fishermen and allow the marine reserve to go forward. Otherwise, one could reasonably expect political actions that limit management options. Sen. John Breaux (D-LA), co-sponsor of the Freedom to Fish Act, recently said, "restricting public admission to our coastal waters should not be our first course of action but rather our last." This statement goes to the heart of the shift in attitudes towards the ocean that is required by the ecosystem-based, spatial approach to fisheries management and conservation entailed by the Marine Life Protection Act and marine reserves: precisely because the oceans are held in public trust, it is imperative that decisions regarding the marine environment consider all rights and potential uses of it equally. Traditionally, the presumption has been that customary uses like fishing entail rights over the resource that supercede others. An important goal of a complete socio-economic analysis of marine reserves is to bring all claims to the table, and have all parts of the public heard.

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Table 1 – Summary of costs and benefits of marine reserves

Issue	Benefit	Cost
Habitat	Ecosystem recovery	Potential impact on open areas
Consumptive uses	Enhanced fecundity; increased future yields and recruitment ("spillover" via larval export and adult emigration); lower bycatch	Decreased revenues, at least temporarily; increased variable costs (due to displacement and/or crowding)
Non-consumptive uses	Increased consumer surplus from diving among more abundant and/or larger fish; higher potential for ecotourism and recreational opportunities	Potential crowding
Relation to other management measures	Option value: Avoiding other, more costly measures such as ESA listings or large area closures (e.g. cowcod closure)	"Double jeopardy" if marine reserves and other measures (gear, effort regulation, capacity reduction) are not synchronized
Uncertain future	Safeguard way of life (bequest value), future revenues from fishing and other uses; insurance against stock collapses from natural fluctuations or overfishing	Loss of customary fishing areas and access
Enforcement	Potentially efficient, using remote geographic systems or aerial monitoring.	Requires additional area-based enforcement in addition to fishery regulations in open area
Non-market values	Protection of scenic habitats, rare species, and the public's interest in special places and natural heritage (existence value)	Considerable public investment into designation, monitoring, and enforcement of reserves; potential litigation
Research	Provision of scientific information for fisheries management; potential new sources of revenues, e.g., drugs from marine organisms (quasi-option value)	Integration and consolidation with existing data-bases and research efforts.
Management	Spatially explicit management allows better allocation and use of marine areas and resources	New requirements for monitoring and research; costly establish baseline measures

Source: Results from this paper, and table 4.3 (National Research Council, 2001, p. 59)