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Why Don't Parks and Sanctuaries Protect Marine Fish Too?

Introduction

Many people believe that marine wilderness—i.e., areas of the sea where human influences are minimized and no extractive uses are allowed—protects biodiversity, restores and sustains fisheries, provides insurance for management errors, and produces tourism industries. In spite of the apparent benefits, and in stark contrast to the proliferation of wilderness designations in the terrestrial environment, very little marine wilderness has been designated worldwide. Marine protected areas (MPAs) abound, but we afford few portions of the sea enough protection from fisheries harvest and other extractive activities to function as wilderness. Why?

The title of this essay may seem facetious or cynical. It is not. Serious, thoughtful people still ask, "Why should parks and sanctuaries protect marine fish?" Many believe the sea is inexhaustible and deny that human activities, particularly fishing, damage ocean resources. These people believe that wilderness designations in the sea unnecessarily restrict economic development and reduce profitability of fisheries.

Conflicts between competing beliefs such as these cannot be resolved without additional knowledge and understanding. Science can provide the required knowledge and facilitate understanding. Here, I will explore the role of science in marine protected area designation and management, identify the theoretical values of marine wilderness, describe scientific documentation of these potential values, and discuss why we need new approaches to marine conservation.

Science, as a way of knowing, began challenging people's beliefs about their environment and natural resources as early as the 16th century, when Galileo, to his detriment at the hands of church inquisitors, championed Copernicus' heliocentric description of the universe in defiance of prevailing Ptolemaic beliefs. Beliefs still dominate resource allocation and management issues, but we have made some progress in the intervening 400 years, most of it in the last century. When Yellowstone National Park was designated in 1872, people came to the park to see forests and herds of elk and deer, and to catch trout. Virtually everyone believed fires threatened the forests, wolves and coyotes threatened the elk and deer, and white pelicans threatened cutthroat trout populations in Yellowstone Lake. Appropriate management of these situations therefore required fire suppression and predator control, i.e. killing wolves, coyotes, and pelicans. Today those beliefs seem remarkably naïve because, during the past 75 years, science has elucidated the essential role of fire in forest ecosystems and the vital importance of predator–prey relationships in maintaining healthy fish and wildlife populations. If science similarly shows essential functions of unimpaired, untrammeled, marine ecosystems, perhaps those holding beliefs of the sea's inexhaustibility and denying human culpability for collapsed fished populations can embrace new knowledge and modify their beliefs to everyone's benefit. Simply challenging one set of untestable beliefs with another is futile. Only new information, knowledge, can break the deadlock. Science as a process for learning can do that. Science as a source of light in the darkness of ignorance can help us change the way we allocate, restore, maintain, and protect marine resources to assure that future generations will still have options to exercise.

Conservation of Marine Resources

People have little empathy for fishes, invertebrates, and algae, even in national parks. More than 30 units of the United States National Park System and the 12 national marine sanctuaries contain some of the nation's finest marine resources, 85 park units support salmonid fisheries, and many more harbor warm-water aquatic ecosystems of national and international significance. All of these places, widely recognized as the nation's heritage and most protected, allow and even encourage killing and removal of marine and aquatic plants and animals from within their 'protected' boundaries. The difference in treatment of aquatic and marine resources from terrestrial resources in these special places is not an accident. I found that simply informing people of the disparity didn't change their beliefs. Early in my career I naïvely thought, "If the public knew what I did about the policies and practices and what they did to native populations and ecosystems, they'd agree with me that we need to change how parks are managed." That is not true.

In the 1970s, with many colleagues, I explored ways to enhance the integrity of park ecosystems by showing the contributions no-take areas in parks could make to adjacent fisheries. We labored in the coral reefs, seagrass meadows, and mangrove-lined estuaries of Everglades, Biscayne, Virgin Islands, and Dry Tortugas National Parks. We sought to discover how spiny lobsters, stone crabs, snappers, seatrout, drum, and shrimp fisheries depended on these parks, and to determine the fishery benefits of creating no-take areas in the parks (Jones et al. 1978; Costello and Davis 1979; Davis 1977, 1979, 1981, 1982a, 1982b; Davis and Dodrill 1980, 1989).

In the 1980s I returned to my home in California to discover that some coastal fisheries could not be sustained without no-take areas to act as refugia, de facto or designated (Davis 1989). The many long-lived, slow-growing, late-maturing residents of kelp forests and deep rocky reefs were particularly susceptible. Now in the 1990s, we must not only discover new models to sustain fishery harvests, we must first stop exhausting populations and find ways to rebuild depleted populations (Davis in press). Research into refugia design needed to discover optimum sizes, shapes, and distributions to protect ecosystem integrity and to sustain fisheries takes on a real sense of urgency as some fished populations slouch toward extinction (Davis et al. 1998).

Why Create Marine Wilderness?

I can think of at least three reasons to set aside, or restore to natural conditions, areas of the sea. First, it's simply the right thing to do—to save some unimpaired marine areas as wilderness for future generations. As Aldo Leopold told us in *Round River* (1953), the first rule of intelligent tinkering is to save all the pieces. We are beginning to lose pieces, both habitats and species, of coastal marine ecosystems and have no way to recover them, once lost. Second, we need to protect biodiversity and ecosystem structure to serve as control areas for the numerous environmental management experiments we conduct, such as fishing. Finally, adequately protected marine wilderness can serve as refugia to rebuild and sustain fished populations by assuring survival of adequate spawning stock and enough habitat to perpetuate harvests.

If marine wilderness is such a good idea and essential for human well-being, why aren't the coasts littered with it? Tradition, denial, and apathy are powerful impediments to creating marine wilderness. Traditionally, everyone has had unrestricted access to the sea. This open access, combined with a frontier approach to management, led to serial depletions that sustained fisheries, but not fished populations. Denial that fishing alters populations and ecosystem structure or threatens future productivity produced a general euphoria and impression that everything's fine. Public apathy, confusion, and ignorance regarding the status of fished populations and other publicly owned resources allowed fishing industries to profitably deplete the ecological equivalent of capital assets needed to generate annual yields. Now the public must invest in rebuilding depleted populations before they can again produce any yield.

Serial depletion is a natural strategy for hunter-gatherers with unlimited resources. Human societies have practiced this strategy successfully for millennia. It is a short-term solution for sustaining economic development of virgin resources, and it is a common resource management practice worldwide. Unfortunately, because humans have now saturated the Earth for the first time, we need a new strategy. Without new territories or new resources, the serial depletion strategy is fatally flawed.

The California diving fleet provides a good example of the serial depletion problem. Commercial abalone landings increased and appeared stable for 30 years after World War II, and then declined dramatically in the 1970s. A common industry explanation for the 1970s landings decline is sea otter predation and a shift of harvest effort to more profitable red sea urchins. An examination of the evidence reveals a different story for southern California, where otters have played no significant role in the twentieth century. Here we see a sequence of five abalone species supplying the apparently stable landings. First the harvest consisted primarily of pink abalone, the most common southern California species. When pink abalone landings began to decline, the difference was made up by red abalone, a large, valuable, species more common to the north. When both pink and red abalone landings began to decline, harvest efforts shifted to shallower regions for green abalone, and for a short time to deep reefs for white abalone. By the early 1970s, even adding new species and habitats was not sufficient to sustain abalone landings, so the fleet shifted some effort to red sea urchins and began harvesting intertidal black abalone, previously considered undesirable in the market. In the 1980s, red sea urchins replaced abalone as California's most valuable coastal fishery. But southern California reefs could not sustain the annual 20,000 mt harvest required to replace the value of 2,000 mt of abalone, and the fishing effort expanded into new territory in northern California to sustain the fleet's income. The income to the diving fleet remained roughly the same through this transition from abalone to urchin, which obscured the severely depleted condition of abalone populations. The ecological cost of serial depletion was high. It left abalone populations collapsed, with white abalone on the brink of extinction, and will require expensive and risky rebuilding to restore abalone populations to productive levels again. The lower market value of red sea urchins required removal of ten times the biomass to secure the same financial income.

This story also reveals the danger of relying entirely on fishery landings data to understand the status and trends in populations. Fishery-independent surveys and ecological monitoring were needed to interpret resource status, and to separate the influences of natural environmental factors, such as El Niño events, and fishing-induced depletion. Only with independent data could fishery managers confirm population status with enough certainty to close fisheries, as they finally did in the mid-1990s.

The consequences of serial depletion and the general lack of fishery-independent resource assessments may be catastrophic. As populations collapse, fisheries remain open and stocks may never recover. The abalone fishery along the Orange County coast of southern California was closed in 1977, and abalone populations there show no signs of recovery more than 20 years later.

Refugia as Fishery Management Strategies

Searching for resource management strategies that would avoid the consequences of serial depletion and recruitment overfishing led to a review of fisheries-related experiences with marine protected areas. This revealed a burgeoning literature that identified several potential refugia effects on target species and on ecosystem structure and function. Briefly summarized, these hypotheses suggest:

- Abundance in no-take MPAs increases
- Individual size and age in no-take MPAs increases
- Reproductive output from no-take MPAs increases
- Recruitment in and adjacent to no-take MPAs is enhanced
- Genetic diversity of stocks is maintained
- Fishery yields are enhanced in areas adjacent to no-take MPAs
- Species diversity increases in no-take MPAs
- Habitat complexity and quality is enhanced in no-take MPAs
- Community stability increases in no-take MPAs

Several years ago, we found 31 studies that actually tested some of these hypotheses (Dugan and Davis 1993). The best-documented effect was an increase in abundance of target species in no-take MPAs. Fisheries-targeted species were 2 to 25 times more abundant in no-take MPAs than in surrounding areas for fish, crustaceans, and mollusks on coral and temperate reefs in Australia, New Zealand, the Philippines, Japan, Kenya, South Africa, the Mediterranean Sea, Venezuela, Chile, and the United States (California, Florida, Rhode Island). Mean sizes of fished species protected in no-take MPAs were 12-200% larger than those in surrounding areas for all fishes studied and in 75-78% of the invertebrates. Increases in size in MPAs is best documented in large predators, e.g., serranids, lobsters and crabs. Only 4 of the 31 studies measured reproductive output from no-take MPAs. All four studies found increased reproductive output for lobster, conch, and abalone. The well-documented increases in sizes of individuals is strong evidence that reproductive products must also increase, even though few empirical data exist. We found little empirical evidence that no-take MPAs increased juvenile or adult recruitment outside the protected area, only 3 studies attempted to measure recruitment adjacent to the MPA. Only one found evidence of increased recruitment (Shepherd 1990). Recruitment is clearly a key parameter to measure empirically to demonstrate the efficacy of no-take MPAs and to determine optimum no-take MPA design. This topic needs more research before conclusions can be reached.

We found no studies that attempted to compare genetic diversity in no-take MPAs and equivalent fished areas. Nevertheless, the circumstantial evidence of fishing as a selection pressure favoring small, early-maturing, slow-growing fish and invertebrates is intriguing, e.g., the size of lobster maturity is smaller in the heavily fished Florida Keys than in adjacent unfished Dry Tortugas (Davis 1975). The theoretical mechanisms for no-take MPAs to protect larger, faster growing individuals are clear. Clearly, we need more empirical research on this topic.

The "bottom line" for fishery managers is whether fishery yields increase near no-take MPAs. Empirical evidence of this is scarce, but consistent. Nearly all (86%) of the studies that tested fishery yields found catches within 3 km of the MPAs were 46-50% higher than before no-take MPAs were created. It is clear that fishers all over the world believe no-take MPAs increase yields, because they fish as close to no-take MPA boundaries as they can. Perhaps the best example of an effective fisheries refugium is Sumilon Island in the Philippines (Russ and Alcala 1996). Mean catch was 0.8 kg per day before a small no-take MPA was designated. Catch rate tripled within five years of MPA creation, and remained high for nearly ten years. Harvest in the no-take MPA rapidly reduced catch rate to the original subsistence low level.

Another example demonstrates the odd relationship of belief-based management and knowledge-based management. Research predicted that protection of juvenile lobster in nursery habitats would increase fishery yield on adjacent reefs (Davis 1980). While fishers, both sport and commercial, supported MPA creation, they would not invest in research to measure the increase or test the prediction (hypothesis). Once the fishers accepted the research results (knowledge) they *believed* the MPA would work, therefore testing their belief would have been a waste of time and money. The concepts of adaptive management and the scientific method are not widely known or used outside the scientific community, not even in many natural resource-based industries.

Measuring ecological effects of no-take MPAs is even more complex than detecting population-level effects. Ecological theory predicts that key species—especially top consumers and species providing habitat for others—maintain diversity and community structure, at least in some kinds of ecosystems (Dayton et al. 1995). Evidence of this effect was reported for fishes in New Zealand, Corsica, and the Philippines, and with invertebrates in Chile and Kenya (Dugan and Davis 1993). In California, fisheries removal of urchin predators and competitors has allowed unharvested urchin populations to increase and create urchinbarrens.

As we explore the limits of MPAs as refugia and search for evidence of their efficacy to restore and sustain fisheries and to protect biodiversity, we do well to remember the late Carl Sagan's admonition that "absence of evidence is not evidence of absence." Many no-take areas are too small to effectively protect wide-ranging species. California waters contain no less than 104 MPAs that collectively include 46% of the state's coastal ocean. Nevertheless, only 11 of them contain no-take areas, which total only 0.1% of the coastal ocean. The mean size of each no-take area is less than 300 ha, four of them are less than 40 ha, and the largest by far is only 845 ha. This is in a coastal ocean of 3.7 million hectares (see Table 1). Many no-take MPAs were estab-ished in marginal habitat for most fished species, the result of a 'not-in-my-back-yard' political selection process. Some no-take areas were established on historical fishing grounds in hopes that depleted populations would spontaneously recover. Most studies of ecology and MPAs are less than three years in duration, not long enough to detect changes in long-lived species or capture infrequent recruitment events. Rarely have designed systems of MPAs been created, let alone tested or evaluated to see if they met design criteria or expectations (Balantine 1995).

Conclusions

Humans dominate coastal ecosystems and threaten their stability and continued productivity (Vitousek et al. 1997). Many coastal fisheries are unsustainable with current management strategies. We are simply taking more from them than can be replaced by natural reproduction. Designated no-take MPAs can protect fished populations from recruitment and ecosystem over-fishing. No-take MPAs may protect genetic diversity and high reproductive capacity of fished populations. Existing no-take MPAs are generally too small to test their conservation efficacy.

Table 1. California's marine protected areas: Are they?

- Total fishing area = 9.2 million acres
- Number of MPAs = 104
- Extent of MPAs = ~ 4.4 million acres (46% of total fishing area)
- No fishing is allowed in parts of 11 MPAs, totaling 10,000 acres (<0.1% of total fishing area)
- The basic discrepancy: less than one-tenth of one percent (0.1%) of California's ocean is truly protected, yet nearly half of California's ocean *appears* protected by being under MPA status

Machiavelli (1525) described the dangers of advocating change in social systems. He warned that those profiting by the *status quo* would defend it vigorously, whereas those who might benefit from a new order would only defend the changes with lukewarm enthusiasm until they had personal experience that it would benefit them. In such situations advocates of change will find themselves in great peril, opposed by zealots and supported by skeptics. The information age has perversely given new respectability to uninformed opinion.

As a society, we need to get past the denial that fishing has caused problems and accept that traditional marine conservation has not worked as well as we need it to. Moving beyond denial toward acceptance and commitment to new ways of managing marine resources is a long and difficult passage. We need to start soon. Persistence is essential for success.

We need unharvested marine wilderness as insurance against our collective ignorance and the uncertainty of untested management schemes. We need such areas to protect the integrity of marine ecosystems so we can learn how they work and how to make them more productive for people. Finally, we need them to rebuild depleted populations, restore the productivity of coastal fisheries, and sustain that productivity into the future.

We are entering a new era— humans dominate the Earth for the first time. We have no new frontiers left—only the last frontier in the Far North. Can we learn from the past, or must we repeat it and wait until fished populations collapse before we initiate a new order of business? The cost of restoration is much greater than that required to sustain extant populations. Can we save that cost? Only if we act now and recognize this as a new beginning, with new rules.

References

Ballantine, W. J. 1995. Networks of 'no-take' marine reserves are practical and necessary. Pp. 13-20 in *Marine Protected Areas and Sustainable Fisheries,* N. L. Shackell and J. H. M. Willison, eds. Wolfville, Nova Scotia: Science and Management of Protected Areas Association.

Costello, T. J., and G. E. Davis (team leaders). 1979. Fishery management plan for the stone crab fishery of the Gulf of Mexico. Gulf of Mexico Fishery Management Council, U. S. Department of Commerce. *Federal Register* 44(85), 19445-19496.

Davis, G. E. 1975. Minimum size of mature spiny lobsters, *Panulirus argus,* at Dry Tortugas, Florida. *Transactions of the American Fisheries Society* 104(4), 675-76.

——. 1977. Effects of recreation harvest on a spiny lobster, *Panulirus argus*, population. *Bulletin of Marine Science* 27(2), 223-236.

——. 1979. Changes in the red drum and spotted sea trout fisheries in Everglades National Park: Natural cycle, environmental perturbation or fishery harvest? Pp. 81-87 in *Proceedings of the Colloquium of the Gulf States Marine Fisheries Commission.*

——. 1980. Effect of injuries on spiny lobster, *Panulirus argus*, and implications for fishery management. *Fisheries Bulletin* 78(4), 979-984.

——. 1981. On the role of underwater parks and sanctuaries in managing coastal resources. *Environmental Conservation* 8(1), 67-70.

——. 1982a. A century of natural change in coral distribution at the Dry Tortugas: A comparison of reef maps from 1881 and 1976. *Bulletin of Marine Science* 32(2), 608-623.

——. 1982b. Fishery management conflicts in Everglades National Park. Pp. 65-75 in *Proceedings of the Seventh Annual Marine Recreational Fisheries Symposium, Ft. Lauderdale, Florida*, R. H. Stroud ed. Washington, D.C.: Sport Fishing Institute.
——. 1989. Designated harvest refugia: The next stage of California marine fishery management. *California Cooperative Oceanic Fisheries Investigation Reports* 30, 53-58.
——. In press. Refugia-based strategies to restore and sustain depleted abalone populations in southern California. *Canadian Journal of Fisheries and Aquatic Science.*
Davis, G. E., and J. W. Dodrill. 1980. Marine parks and sanctuaries for spiny lobster fisheries management. *Proceedings of the Annual Gulf and Caribbean Fisheries Institute* 32: 194-207.
——. 1989. The recreational fishery and population dynamics of spiny lobsters, *Panulirus argus*, in Florida Bay, Everglades National Park, 1977-80. *Bulletin of Marine Science* 44(1):, 78-88.
Davis, G. E., P. L. Haaker, and D. V. Richards. 1998. The perilous condition of white abalone, *Haliotis sorenseni*. *Journal of Shellfish Research* 17(3), 871-875.
Dayton, P. K., S. F. Thrush, M. T. Agardy, and R. J. Hofman. 1995. Environmental effects of marine fishing. *Aquatic Conservation: Marine and Freshwater Ecosystems* 5, 205-232.
Dugan, J. E. and G. E. Davis. 1993. Application of marine refugia to coastal fisheries management. *Canadian Journal of Fisheries and Aquatic Sciences* 50(9), 2029-2042.
Jones, A. C., J. E. Cato, T. J. Costello, A. Craig, A. E. Dammann, G. E. Davis, F. J. Prochaska, M. Rolon, and D. C. Simmons. 1978. *Fishery Management Plan for Spiny Lobsters (Puerto Rico and U. S. Virgin Islands).* San Juan, Puerto Rico: Caribbean Fishery Management Council.
Russ, G. R., and A. C. Alcala. 1996. Marine reserves: rates of recovery and decline in abundance of large predatory fish. *Ecological Applications* 6, 947-961.
Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth's ecosystems. *Science* 277, 494-499.

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