CALIFORNIA
MARINE PROTECTED AREAS
PAST & PRESENT

Deborah A. McArdle

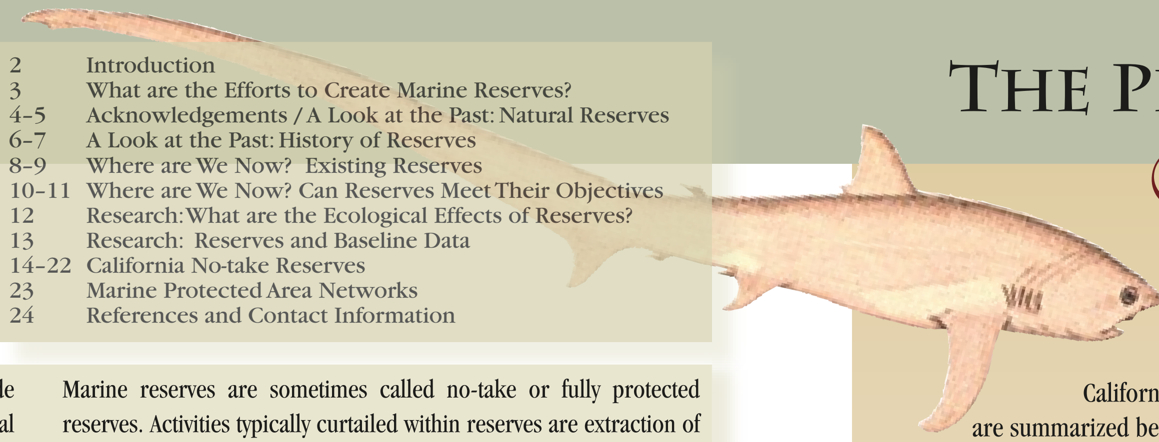
Santa Catalina Island in 1913

In 1913, concerns about many sea life population declines led to the designation of the waters surrounding Santa Catalina Island as a marine protected area. All fishing, except hook-and-line angling, was prohibited in the state waters (from the coastline to 3nmi seaward) surrounding the entire island. The protected area status was later revoked. The map was hand drawn by Harry Wilson in 1913 to provide a guide to the island's recreational activities including the locations of the fishing grounds surrounding the island.

CALIFORNIA MARINE PROTECTED AREAS PAST & PRESENT

Deborah A. McArdle, Editor
Marine Advisor, California Sea Grant Extension Program, U.C. Cooperative Extension

TABLE OF CONTENTS



Marine Protected Areas (MPAs) are sections of the ocean set aside to protect and restore habitats and ecosystems, conserve biological diversity, provide a sanctuary for sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the environment, and help rebuild depleted fisheries. There are a variety of types of MPAs, ranging from limited to full protection.

Marine Life Reserves are areas of the ocean completely protected from all extractive activities. They are a special category of MPAs. Marine reserves are sometimes called no-take or fully protected reserves. Activities typically curtailed within reserves are extraction of organisms (e.g., commercial and recreational fishing, kelp harvesting, commercial and private collecting), mariculture, and activities that can alter oceanographic or geologic attributes of the habitat (e.g., mining, intake and discharges of seawater and effluent).

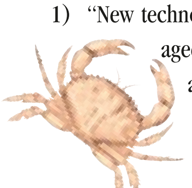
Networks of MPAs or Marine Life Reserves are sets of protected areas within a biogeographic region, connected by larval dispersal and juvenile or adult migration.

INTRODUCTION

There is a present interest in the establishment of new marine protected areas (MPAs), no-take marine life reserves and networks of MPAs in California, and throughout the world, to conserve and manage marine resources. Concern about the status of California's marine ecosystems, and dissatisfaction with existing MPAs, led the Legislature to pass the Marine Life Protection Act (MLPA) in 1999. The MLPA requires that the California Department of Fish & Game (CDFG) develop a plan to improve the array of MPAs and design an alternative network that includes fully protected marine life reserves (http://www.dfg.ca.mrd.mlpa). Goals of the MLPA include protection of marine life populations and ecosystems for their recreational, commercial and intrinsic value, protection of marine natural heritage, and provision of recreational, educational, and research opportunities. Therefore, the purposes for creating MPAs are much broader than providing a management tool solely to help sustain fisheries (CDFG 2002). To meet these multiple objectives the Legislature determined that new and existing MPAs must be redesigned and managed, to the extent possible, as a network.

MPAs and marine life reserves are being considered in California for multiple reasons. The Legislature stated some of these reasons when it declared a set of "findings" supporting the MLPA. (Fish & Game Code § 2851). They include:

1) "New technologies and demands have encouraged the expansion of fishing and other activities to formerly inaccessible marine areas that once recharged nearby fisheries (i.e. natural reserves). As a result, ecosystems throughout the state's ocean are being altered, often at a rapid rate."



2) "Only 14 of the 220,000 square miles of combined state and federal waters off California, or 6 thousandths of one percent, are set aside as genuine no-take areas."

3) The existing collection of MPAs is ineffective because it was ". . . established on a piecemeal basis rather than according to a coherent plan and sound scientific guidelines. As a result, the array of MPAs creates the illusion of protection while falling far short of its potential to protect and conserve living marine life and habitat. Moreover, many of them lack clearly defined purposes, effective management measures and enforcement."

4) Since there is increasing evidence of a wide range of benefits associated with fully protected marine life reserves, they are "an essential element of an MPA system." "[T]hey protect habitat and ecosystems, conserve biological diversity, provide a sanctuary for fish and other sea life, enhance recreational and educational opportunities, and may help to rebuild fisheries."

5) "Understanding of the impacts of human activities and the processes required to sustain the abundance and diversity of marine life is limited. The designation of certain areas as sea life reserves can help expand our [e.g., managers, researchers and the general public] knowledge by providing baseline information and improving our understanding of ecosystems where minimal disturbance occurs."

The purpose of "California Marine Protected Areas: Past and Present" is to present examples of the historical, anthropological, ecological science-based information underlying each of these findings. This additional background will provide managers, decision makers, stakeholders and the general public involved or interested in the MLPA process with a broader understanding of the fundamental concepts and rationales underpinning the MLPA.

The objective of this publication is to increase the availability of science-based information for public policy debate, not to advocate for or against the formation of marine life reserves. This publication does not interpret the MLPA or provide an exhaustive analysis of the information available to the Legislature at the time the Bill was enacted. Additionally, the publication focuses primarily on ecological parameters. Decisions about the implementation of marine reserves may also need to incorporate social and economic factors.

This analysis is limited to California state waters and state designated MPAs and excludes areas comprised of only federal waters or designated by federal agencies. National Marine Sanctuaries, National Parks and State Areas of Special Biological Significance are excluded because they currently do not restrict fishing activities in California. As a result of these exclusions, there are only 53 MPAs mentioned in this publication as opposed to the 103 in McArdle (1997).

— Deborah A. McArdle

THE PRESENT: *What are the Efforts to Create Fully Protected Marine Reserves?*

Current interest in the development of marine protected areas (MPAs) and fully protected marine reserve networks stems from global, national, state, regional and local initiatives. Several initiatives that may influence California state and federal marine resource management are summarized below.

At a national level, on May 26, 2000, President Clinton signed Executive Order 13158 on MPAs to strengthen the protection of U.S. ocean and coastal resources. On June 4, 2001, U.S. Secretary of Commerce Donald Evans announced that President Bush's Administration intended to retain and proceed with the Executive Order (EO). The EO directs the Departments of Commerce and the Interior, and other federal agencies, to strengthen and expand a national system of MPAs representing diverse U.S. marine ecosystems, and the Nation's natural and cultural resources by working closely with state, territorial, local, tribal, and other stakeholders. Ultimately, this network might include new MPA sites established under existing management authorities, and enhanced existing sites (http://mpa.gov/welcome.html).

At a regional level, the Pacific Fisheries Management Council has been examining the potential applicability of MPAs. The Council's primary interest in MPAs is related to problems in the groundfish fishery. The Council adopted six fishery management objectives that might be addressed by marine reserves as a supplemental tool for management of groundfish fisheries; (1) Stock Rebuilding (2) Biological Productivity (3) Economic Productivity (4) Insurance (5) Habitat Protection and (6) Research and Education. To date, the Council has established two MPAs off southern California to help rebuild cowcod. These two MPAs cover 4,700 square miles. In those areas, all fishing for Federal groundfish species is prohibited and the state has prohibited prawn trawling and other recreational and commercial fishing except in shallow waters (less than 20 fathoms). The Council is also interested in the process for considering marine reserves for the Channel Island National Marine Sanctuary (CINMS) (http://www.pcouncil.org).

At a local level, in 1998, the California Department of Fish & Game (CDFG) and the Channel Islands National Marine Sanctuary (CINMS) developed a partnership to consider establishing fully protected marine reserves in the CINMS. The community discussion of marine reserves was conducted through a 17-member Marine Reserves Working Group (MRWG) that included state and federal managers, commercial and recreational fishermen, divers, environmentalists, and local community members. In August 2001, CDFG submitted to the Fish & Game Commission their preferred network of reserves that protect valuable ecological attributes while limiting the potential short-term social and economic impacts. The Commission will consider the preferred alternative in the context of other designs that vary in size and location of reserves (http://www.cinms.nos.noaa.gov/cimpa2.html).

One hours catch, 1587 lbs. Albacore at Imperial Beach, California. Caught September 2, 1909. Courtesy The San Diego Historical Society Photograph Collection. www.sandiegohistory.org

This publication was funded by a grant from the David and Lucile Packard Foundation and by the National Sea Grant College Program of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration under NOAA Grant #NA06RG0142, Project number A/P-1, through the California Sea Grant College Program. The views expressed herein do not necessarily reflect the views of any of those organizations.

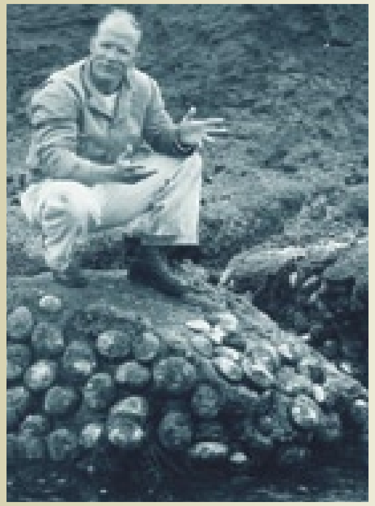
University of California, La Jolla 92093-0232.
http://www.csgc.ucsd.edu
Publication No. T-050, ISBN 1-888691-10-7

ACKNOWLEDGEMENTS

I would like to thank the following people for their significant and specific contributions:

- ***Satie Arimae***, Marine Science Institute, UCSB for contributing significant information and reviews.
- ***Robert Gerson***, www.book*designing*.com, for the publication design and digital effects production.
- ***Paul Gregory***, California Department of Fish and Game, for providing several historic photographs.
- ***Joe Milton***, Staff Counsel Department of Fish and Game, for locating historic legal information.
- ***Georgia Ratcliffe***, Programmer/Analyst CA Sea Grant College, for assisting in historic map, journal article and photograph aquisition.
- ***Natalie Senyk***, UCSB Interdisciplinary Marine Science Program
  Will McClintock, Marine Science Institute, UCSB,
  Michael Glassow, Department of Anthropology, UCSB
  Scott Pletka, UCLA
  for providing help in the production of the page 5 maps.
- ***Richard Starr***, CA Sea Grant UC Cooperative Extension for providing insightful comments and reviews.
- ***Michael M. Youngdahl*** for assisting with editorial review.
- ***Catalina Island Museum*** for donating two historic photographs.
- ***National Ocean And Atmospheric Association (NOAA) Digital Library*** for making many of the historic maps and fish sketches in this publication easily accessible and available.
- ***The David and Lucile Packard Foundation***, for the funding of this project.
- I would also like to thank the following reviewers:
  Dave Bard, Sea Web, Washington, DC
  Marsha Gear, CA Sea Grant College Program
  Paul Olin, CA Sea Grant UC Cooperative Extension
  Paul Reilly, California Department of Fish & Game
  Brooke Simler, Oregon State University

Pole fishing for tuna. Courtesy The San Diego Historical Society Photograph Collection. www.sandiegohistory.org



Parke Young and black abalone at Santa Cruz Island, 1948. By John Fitch, California Department of Fish and Game.

Party boat (CPFV) "Sunshine II" with a catch of bluefin tuna. San Pedro, September 20, 1937. Photo by R. S. Croker, California Dept. Fish and Game

A Big Hammerhead, caught with a rod and reel by Mr. Paine, Mexican Joe, boatman. In (Holder 1910).

A Look at The Past: *Natural Reserves*

CA Legislative Finding

"New technologies and demands have encouraged the expansion of fishing and other activities to formerly inaccessible marine areas that once recharged nearby fisheries (i.e., natural reserves). As a result, ecosystems throughout the states ocean are being altered, often at a rapid rate." Fish and Game Code, §2851 (c).

The "formerly inaccessible marine areas" identified by the Legislature above are described by researchers as "natural reserves" or places too deep, too remote, too dangerous or too rough to fish. It is difficult to determine where these "natural reserves" may have been located because most of them probably have not existed for hundreds, or perhaps thousands of years. One possible way to define their boundaries is to use anthropological and archeological evidence of the probable limitations on fishing during these times.

For example, anthropologists and archeologists have gathered data from which one can approximate the boundaries of fishing grounds around Santa Cruz Island, California between 1300 and 1782 AD. This evidence consists of population size and mobility, fishing gear and vessels used, habitat of fish caught, diet, site location, and social customs (Pletka 2001; Glassow 2002). Anthropologists and archeologists believe that during this prehistoric time period there was intensive fishing of the island's nearshore waters and concentrated fishing of a few species in mid and deep waters. The map of Santa Cruz Island below shows a simplified representation of the approximate limits of the prehistoric fishing grounds. The map was created using Pletka's (2001) data analysis and definitions. Areas outside the highlighted fishing grounds may have been prehistoric "natural reserves" because the evidence suggests that the island inhabitants did not take resources from these locations. Note one exception, swordfish were caught in deep waters during human transit to the mainland, but this area was not represented as a fishing ground. All waters surrounding the island (from the coastline to 11km) are fished today (Leeworthy et al. 2002).

PREHISTORIC (1300–1782 AD) & PRESENT DAY FISHING GROUNDS AT SANTA CRUZ ISLAND

During the 1800s, the growth of coastal populations subjected California marine resources to increased pressure. Moreover, improvements in fishing vessels and gear enabled fishermen to venture farther from port into areas that were previously inaccessible natural reserves. These factors contributed to the decline of many marine species. By the turn of the century, reports on the status of marine resources requested by the Fish and Game Commission often documented these declines. Excerpts from a few of those reports are shown below.

FISH REPORTS FROM THE EARLY 1900s

OVERVIEW

1917 The comparatively recent and enormous development of our fisheries, the prospect of a far more extensive utilization of their products, and the perfection of the machinery of exploitation, has brought sharply to our focus the question of the capacity of the species of fish to withstand the strain. The introduction of power vessels, the enormous improvement in transportation facilities, the use of ice and refrigerating plants, the introduction of the otter trawl, and the great increase in population have taken place within the last thirty-five years. Instances of overfishing are already well known, both on our own coast and in the Atlantic, and the stability of the supply is a real question everywhere.

Those intimately concerned with the fisheries are having as a rule decided opinions regarding the species in which they are particularly interested, frequently ask why the world should not accept at once and act upon their belief that the fish are becoming less in number, or their contradiction of such an assertion. However, proof that seeks to modify the ways of commerce or of sport must be overwhelming and unfortunately the statements of those who know the truth are too readily contradicted by the assured arguments of those who regard the resources of the sea as inexhaustible, or of those who see in everything evidence of depletion.

. . . it has become the function of the government, not only to aid in procuring the greatest possible use, but to insure its continuance, because it is the only agency uniting all factions and successive generations." (Thompson 1919)

ABALONE

1913 "I have seen the diver send the net up, filled with about fifty green and corrugated abalones, every six or seven minutes. During his shift below the diver gathers from thirty to forty basketfuls, each containing one hundred pounds of meat and shell, or altogether one and a half to two tons.

. . . Much has been recently in the newspapers concerning the threatened extermination of the abalone. For instance, near Avalon, Santa Catalina Island, not more than twenty years ago, the green abalones were so thick that they rested upon one another four or five deep, all over the rocks. After much searching in this locality, I was unable to find a single specimen. The same thing is true of many other places where the abalone was formerly abundant. The large individuals of legal size are taken and it is probably true…that in this manner the most prolific breeders are sacrificed." (Edwards 1913)

1913. Big wooden tubs hold the abalone meat which is par-boiled. It's then placed in the sun, smoked for three hours and again boiled and dried several times. Fish Bulletin, v.1 1913.

CRAB

1913 "To the Californian who purchases his crab (Sausalito/Eureka) at twenty to thirty-five cents, it is a hint of the possible fate in store for his delicacy, that through depletion of the supply, the price is already about three times what it was in 1880. Unless protected, the future history of the crab may be but a repetition of that of the lobster of New England . . .

It is evident that since the development of the fishery, a period of perhaps fifteen or twenty years, there has been a marked decrease in the abundance of the crab, though by intensive fishing both as regards a greater amount of gear and a greater number of men, the catch has not only been maintained but greatly increased. The growing scarcity is further shown by the increase in price. In 1880 the average wholesale price was 60 cents a dozen; in 1912, $1.50 and $2.00. ..we cannot afford to relax any of the protection now given to the crab.

. . . We are still in the position of conserving a natural resource, a task of comparative ease when contrasted with that of restoring it after it has been exhausted. Let us maintain our favorable position." (Weymouth 1913)

LOBSTER

1913 "Four years ago the spiny lobster supply of our waters had become so seriously depleted that the legislature passed a measure prohibiting the capture of spiny lobster for a period of two years . . . Interesting accounts are given of their former abundance. The supply has become greatly depleted, this being especially evident in some places. Santa Catalina Island furnishes a good example of how a coast splendidly adapted as a habitat for these crustaceans, and formerly abounding in them, has become so depleted by intensive fishing that the fishery is no longer profitable there.

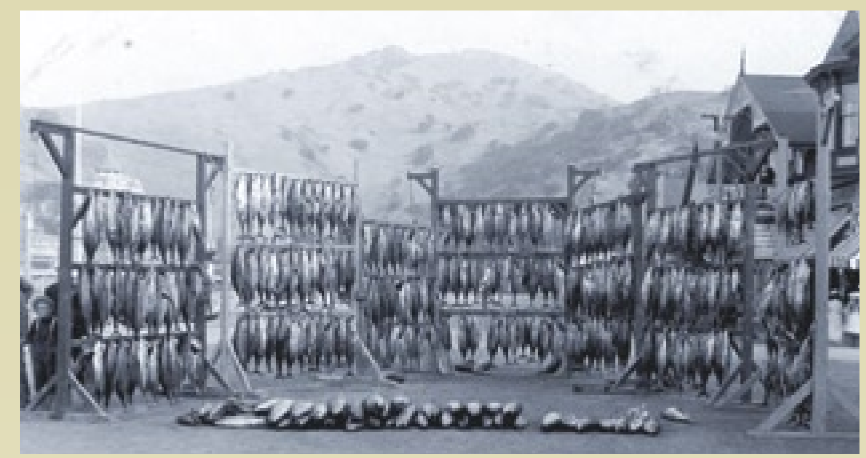
Wise consistent conservation of the supply will, in the long run, benefit the consumer. Exactly the same principles apply to the conservation of our fish as to the conservation of our forests." (Bennett 1913)

A LOOK AT THE PAST: *History of Reserves Prior to 1950*

Shortly after the turn of the last century, the California Legislature passed several laws to stem overexploitation. Marine protected areas were one of the strategies the Legislature used to manage and conserve marine resources. Like now, a public policy debate regarding whether these protected areas were an appropriate marine resource management strategy took place. The support and opposition to the 1913 Santa Catalina Fish Reserve described below provides an example of that initial debate. The first six MPAs established in California are listed below. All of them were repealed by 1950.*

- **1913 Monterey Shellfish and Invertebrate Reserve** designated to prohibit the take of all invertebrates except squid and devilfish (i.e. octopus) by commercial fishermen. (CA Statute 1913, Chapter 569)
- **1909 Humboldt and Trinidad Bays Preserves** created to prohibit the take of crab by commercial and recreational fishermen. (CA Statute 1909, Chapter 192)
- **1909 Santa Cruz and False Bay Fish Reserves** established to prohibit most forms of recreational and commercial fishing. (CA Statute 1909, Chapter 431, CA Statute 1909, Chapter 429)
- **1913 Santa Catalina Island Fish Reserve** established to prohibit all but hook-and-line fishing within three miles of the entire shoreline. (CA Statute 1913, Chapter 193)

1913 Abalone Story In the late 1800s, a productive abalone fishery existed off of the north and south coast of California. The fishery off the north coast of Mendocino collected as many as 2300 abalones a day (Ward 1903). In 1889, it was said that 300 tons were shipped from the southern California coast in one year, 50 tons being handled by one man in a month's time (Williamson 1894). However, by the early 1900s, the north coast fish camps had been closed, or were about to close due to depletion of the abalone and a marine reserve was established in 1913 at Monterey Bay. That same year, recognized declines along the south coast triggered a proposal to establish a network of reserves to protect abalone: "It would be advantageous to establish a number of protected reservations at regular intervals along the coast. In these places, colonies of abalones would be established, which would not only insure us against future extermination, but would afford greater opportunity for the study of their life history and commercial utilization" (Edwards 1913).



Catalina Island Museum Collection

Catalina Fishing, 1902

STORY OF 1913 SANTA CATALINA ISLAND FISH RESERVE

In 1913, Professor Charles Frederick Holder was asked to make a report to the Fish & Game Commission on the status of island fisheries (Holder 1913). Based on observations from 30 years, Holder concluded in 1913, ". . . the supply has dropped off to a menacing extent, due to lack of laws, lack of protection and over-fishing…The angling at Santa Catalina Island in 1886 to 1900 was the most remarkable in the world, and I say this advisedly; but with the coming of power boats the seines, trawls and other nets, the fisheries began to decrease. . ." These and additional findings were made the basis of a bill framed into a law which made Santa Catalina a fish reserve in 1913. The bill called for absolute cessation of netting of all sorts within three miles of shore, but allowed both commercial and recreational fishing by hook-and-line.

For several years, Holder had taken various experts over the fishing grounds surrounding Santa Catalina Island- Dr. Van Dyke, Gifford Pinchot, Dr. David Starr Jordan and others. Many of those experts provided their opinion on the proposed fish reserve; one letter of support is summarized to the right. Opposition to the reserve is also described.

RESERVE OPPOSITION

By 1913 from 50 to 100 commercial fishermen had established themselves at Avalon, representing an investment of three quarters of a million dollars. The fishermen invested in power boats and a variety of gear including seines, gillnets, trawls and hook-and-line to catch a variety of species such as abalone, sardine, tuna, sea bass, halibut, yellowtail, etc. The fish reserve designation was opposed by the "marketmen" (i.e. commercial fishermen), and various fish industries such as sardine and albacore canneries. The San Pedro "marketmen" (500 in number) asked the authors of the bill to annul the reserve, in 1913, but were unsuccessful. Some of the commercial fishermen of Avalon and representatives of the canning interests requested a provision to haul seines for sardines and were successful. Shortly thereafter the fish reserve designation was removed.*

RESERVE SUPPORT

December 5, 1912
Dr. Chas. F. Holder
Throop College of Technology,
Pasadena, Cal.

Dear Sir:

I trust that you may be successful in having Santa Catalina and San Clemente islands set aside as game preserves. . . . The netting carried on in shore disturbs these fishes at spawning time, and it is said that there has been a very marked falling off of these species. It is desired to prohibit the use of seines and all nets for market purposes within three miles of the shores of these islands. I trust that you and our friends will be successful in getting the statute passed which shall protect these islands and set them apart as spawning grounds for the great game fishes of southern California.

Very truly yours,
David Starr Jordan

*Information on why the MPAs were repealed could not be located by the author in the available timeframe.

WHERE ARE WE NOW? *Existing Marine Reserves*

CA Legislative Finding

"Only 14 of the 220,000 square miles of combined state and federal waters off California, or 6 thousandths of one percent, are set aside as genuine no-take areas." Fish and Game Code, §2851 (g).

MPA Designation Timeline

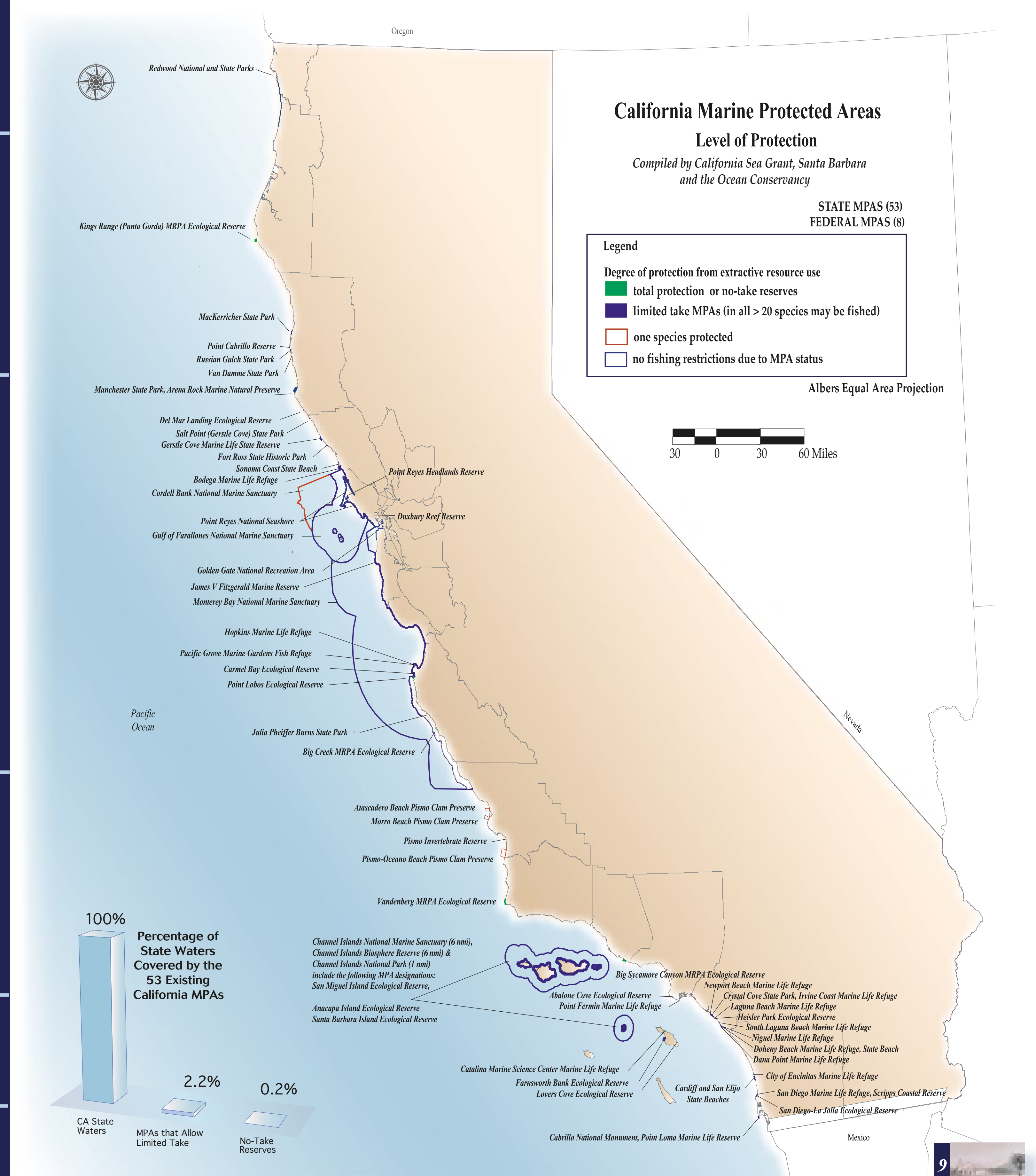
Many management strategies were implemented since 1950 to protect and rebuild marine animal populations. One strategy that received renewed interest was marine protected areas. After 1950, state administrative agencies, the Legislature, and the public through the initiative process created 53 state MPAs in the state waters off California's coast. There are 18 refuges, 13 state parks, 10 ecological reserves, 7 reserves, 4 marine resource protection act (MRPA) ecological reserves and 1 U.C. natural reserve. The 53 state MPAs cover 2.2% of state waters; 10 are fully protected or no-take marine life reserves and cover 0.2% of state waters.

Unfortunately, many of the MPAs established after 1950 were poorly designed, placed and managed. Recognition of these inadequacies caused the Legislature to pass the Marine Life Protection Act in 1999 to improve the array of MPAs in California. This Act has generated public policy debates similar to those that occurred nearly a century ago when the Legislature created the first MPAs.

Seiner "Richmond" with 43 tons of sardines approaching the dock at San Pedro. Feb. 13, 1934. The boat successfully unloaded and did not sink. Photo by Don Fry, California Dept. Fish and Game

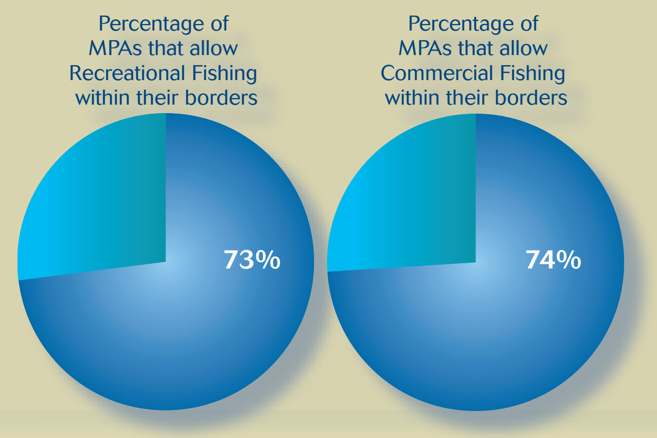
1900–1950	1909	Humboldlt and Trinidad Bays Crab Preserves
		Santa Cruz Bay Fish Preserve
		False Bay Fish Preserve
	1913	Monterey Shellfish and Invertebrate Reserve
		Santa Catalina Island Fish Reserve
		All reserves were repealed.
1950–1970	1957	San Diego Marine Life Refuge
	1963	Point Lobos Reserve (State Park)
	1965	U.C. Scripps Natural Reserve
		Bodega Marine Life Refuge*
	1968	Laguna Beach Marine Life Refuge
		South Laguna Beach Marine Life Refuge
	1969	James V. Fitzgerald Reserve (Marine Life Refuge)
		Point Fermin Marine Life Refuge
		Dana Point Marine Life Refuge
		Doheny Beach Marine Life Refuge
		CA Fish and Game Commission given authority to create no-take ecological reserves
1970–1980	1970	Nine Underwater Parks
	1971	Gerstle Cove Reserve
		Duxbury Reef Reserve
		Irvine Coast Marine Life Refuge
		Niguel Marine Life Refuge
		San Diego-La Jolla Ecological Reserve
	1972	Del Mar Landing Ecological Reserve
		Point Reyes Headlands Reserve
		Farnsworth Bank Ecological Reserve
	1973	Point Lobos Ecological Reserve*
		Heisler Park Ecological Reserve*
	1974	Lovers Cove Reserve, Santa Catalina Island
	1975	Point Cabrillo Reserve
	1976	Carmel Bay Ecological Reserve
	1977	Pismo Invertebrate Reserve
		San Miguel Island Ecological Reserve
		Abalone Cove Ecological Reserve
	1978	Anacapa Island Ecological Reserve Natural Area*
		Santa Barbara Island Ecological Reserve
		Point Loma Reserve
1980–1990	1981	Newport Beach Marine Life Refuge
	1982	Crystal Cove State Park
	1984	Pacific Grove Marine Gardens Fish Refuge
		Hopkins Marine Life Refuge*
	1985	Atascadero Beach Pismo Clam Preserve
		Morro Beach Pismo Clam Preserve
		Pismo Oceano Pismo Clam Preserve
	1987	Arena Rock Natural Preserve (State Park)
	1988	Santa Catalina Island Marine Life Refuge*
	1989	City of Encinitas Marine Life Refuge
		Cardiff and Elijo State Beaches
1990–2000	1994	Kings Range MRPA Ecological Reserve*
		Big Creek MRPA Ecological Reserve*
		Sycamore Canyon MRPA Ecological Reserve*
		Vandenberg MRPA Ecological Reserve*
	1999	**Marine Life Protection Act Passed**
2000–present	2002	**Marine Life Protection Act master plan being developed**

* No-take reserves



CA Legislative Finding
"The array of MPAs creates the illusion of protection while falling far short of its potential to protect and conserve living marine life and habitat." Fish & Game Code, § 2851(a).

The quoted legislative declaration is understandable because MPA regulations often appear to be inconsistent with the objectives stated in the initial legislation authorizing their creation. For example, since the vast majority of California MPAs have few commercial or recreational fishing restrictions, it is questionable whether these areas are meeting their intended objective of resource protection. This inconsistency is potentially dangerous because it produces an "illusion of protection." This false sense of security could endanger the resources the MPA was designed to protect.



Fishing can have significant impacts on marine ecosystems (Jackson 2001, Pauly 1998). Since most existing MPAs allow both commercial and recreational fishing, it is important to consider the effect that fishing may have on the potential success of MPAs. Moreover, those involved in the present MLPA discussions will need to decide what the appropriate levels of restrictions are for new MPAs. One recent study summarized below examined whether recreational fishing could prevent an MPA from achieving its goals (Schroeter and Love, in press).

The combined effect of millions of anglers on fish abundance, size, and species composition can be substantial. As a result, areas that exclude commercial but not recreational fishing may not generate the outcomes associated with fully protected marine reserves.

In California, for example, 1.7 million recreational fishers take some 6 million ocean fishing trips per year. For some shallow-water species, they accounted for 75 percent or more of the total landings, far exceeding landings by commercial fishers.

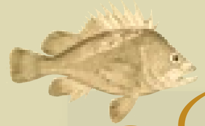
Currently, most recreational saltwater fishing is catch-and-release due to regulations on size and number of fishes taken. Even so, the stress from capture leads to the death of many fishes after release. Estimates of mortality after release average 20 percent but could be higher. By elevating the death rate, catch-and-release fishing increases the influence of recreational fishing on populations.

Effects of recreational angling on fish abundance can be tremendous for certain species of fish. Along the California coast, cowcod and bocaccio, two federally listed overfished species, were 32 times and 408 times more abundant, respectively, in an area where no fishing occurs than in a recreational fishing area. Fish in the unprotected area were also smaller because anglers primarily remove large fishes. This change in average size can lead to a decline in reproduction.

The data on recreational fishing indicate that it warrants consideration in management planning for marine protected areas.

Catch of Sea Bass from Pier, Hotel Del Coronado, December 4, 1905. Courtesy The San Diego Historical Society Photograph Collection.

Do the Restrictions Enable the MPAs to Meet Their Goals?

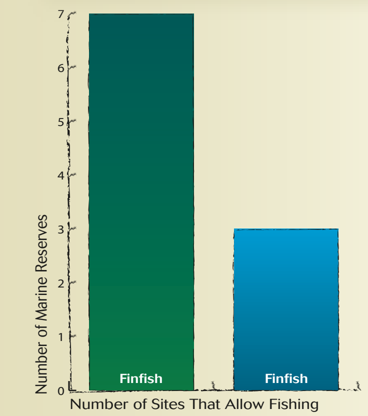


In some cases, it is clear why certain types of fishing are allowed within an MPA's borders. In many cases, however, it is not clear how the permitted fishing activities enable the MPA to achieve it's goals. Primarily because many MPAs lack clear objectives and MPA regulations are often inconsistent within a classification, the Legislature enacted the Marine Managed Areas Improvement Act (AB 2800) in 2000. One goal of the Act is to simplify the existing classification system of the state's marine managed areas (which include MPAs) and provide categories with clear objectives and consistent degrees of regulation. Existing MPAs will be re-classified and their regulations will not change as a result of this legislation. However, the MLPA process will likely result in changes to some of the existing MPA regulations as well as create new MPAs. The new MPA classifications will be:

- State Marine Reserve (no-take reserve): Prohibits all commercial and recreational fishing
- State Marine Park: Prohibits commercial fishing and allows recreational fishing although some restrictions may apply
- State Marine Conservation Area: Prohibits specific commercial and/or recreational activities on a case-by case basis

Comparisons of fishing restrictions to the objectives of the six state MPA classifications that existing MPAs currently fall into are illustrated. It is important to note that the restrictions described are only those imposed by the MPA designation. Other types of regulations (e.g. temporary closures, gear restrictions, etc.) may prohibit the take of certain species within the MPA as well. However, these restrictions are often only temporary and/or subject to change.

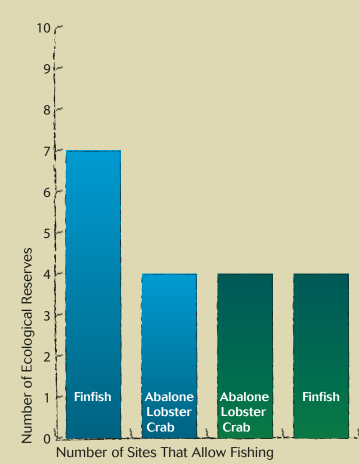
Where Do Restrictions Seem Appropriate for the Objectives?



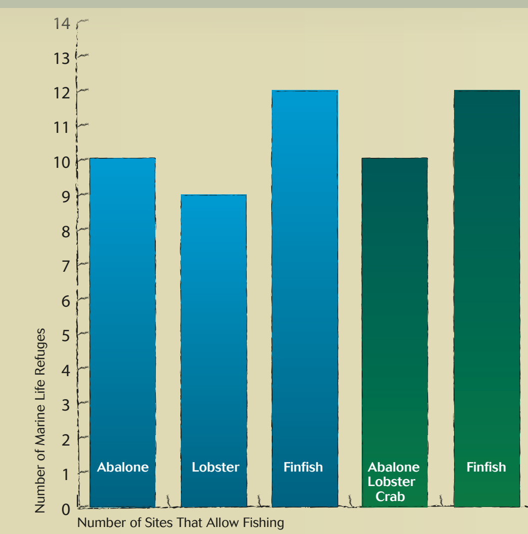
The seven **Marine Reserves** were established to give the California Fish and Game Commission additional authority over recreational fishing. Therefore it is understandable why all of these sites allow commercial fishing.

The four **MRPA Ecological Reserves** were designated, by the state Legislature to provide "natural" areas for scientific research. Appropriately, they all prohibit extractive uses including commercial and recreational fishing.

Where is it Unclear if Restrictions are Appropriate for the Objectives?

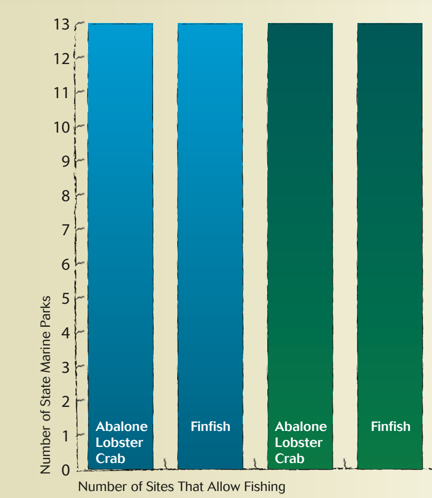


The ten state Fish and Game Commission designated **Ecological Reserves** have the partial objective of protecting aquatic organisms for the future of mankind. To this end, the classification's general regulations prohibit all fishing activities. However, many of the ten ecological reserves allow extensive commercial and recreational fishing. Two of the ecological reserves prohibit all fishing.



Fourteen **Marine Life Refuges** were created by the state Legislature to protect only invertebrates. However, ten of these allow abalone, crab and lobster to be taken, among other invertebrates.

Recreational Fishing | Commercial Fishing



The **State Parks** (established by the State Parks and Recreation Commission) include thirteen small underwater sites with varying objectives. All allow extensive commercial and recreational fishing even though one classification's objective is to maintain areas of outstanding natural or scenic aspects in undisturbed integrity.

The one **U.C. Natural Reserve** allows all fishing even though its objective is to provide relatively undisturbed environments to serve as experimental stations.

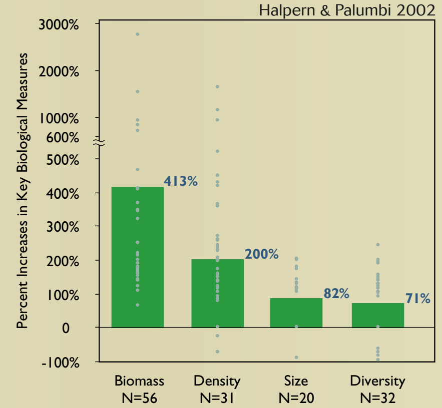
RESEARCH: *What are the Ecological Effects of Reserves?*

CA Legislative Finding
"Marine life reserves are an essential element of an MPA system because they protect habitat and ecosystems, conserve biological diversity, provide a sanctuary for fish and other sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the marine environment, and may help rebuild depleted fisheries." Fish & Game Code § 2850(f).

There is strong evidence of the positive effects of fully protected reserves on the number, diversity and size of sea life within reserves. Reserves may also enhance fisheries outside their boundaries (i.e., spillover), however fewer research studies have investigated this effect (Roberts et al. 2001, Murawski et al. 2000). Two reviews of studies on reserve effects on sea life are summarized below. For a more comprehensive review of the scientific literature on the effects of reserves on marine life see (PISCO 2002).

Reserve Effects in the World's Oceans

A comprehensive review of over 80 separate studies of reserves worldwide provides insight into the effects no-take reserves can have on sea life (Halpern, in press). The review shows that protection from fishing leads to rapid increases in biomass, abundance, and average size of exploited organisms and to increased diversity within reserves. The results include findings across a range of partially to fully protected reserves- studies of the best-protected reserves show that they can more than triple biomass of exploited species, and some species may increase by orders of magnitude. Nearly half of the study sites were in temperate oceans like California's.



Reserve Effects in the World's Temperate Oceans

Studies of marine reserves in temperate ecosystems suggest that it is reasonable to anticipate increases in densities (numbers) of lobster, finfish and other species in California marine reserves. The effects of reserves on sea life in temperate ecosystems were summarized by M. Carr in (Starr 2002). Examples from the review are listed below.

1 Puget Sound:

Surveys at seven sites show that reserve effects can vary among species, largely corresponding to fishing intensity. The more heavily a species was fished before the reserve was created, the greater the effect of the reserve. For example, heavily and moderately fished species like copper and black rockfish were more abundant and larger within than outside reserves. In contrast, the number of lightly fished species (e.g., Brown and Puget Sound rockfish) did not differ significantly between reserve and fished sites (Palsson 1998). Lingcod abundance was three times greater in a reserve then in fished areas outside of the reserve (Palsson & Pacunski 1995).

2 Straits of Georgia:

The abundance of spawning lingcod was significantly greater in two reserves than in adjacent fished areas (Martell et al. 2000).

3 New Zealand:

The abundance of the fish red moki, was six times higher in a reserve than at adjacent sites (McCormick & Choat 1987). Snapper were six to nine times more abundant and 50% longer within reserves. Lobster were two to four times more abundant and had an average of two centimeters longer shell length (Babcock et al. 1999).

4 Chile:

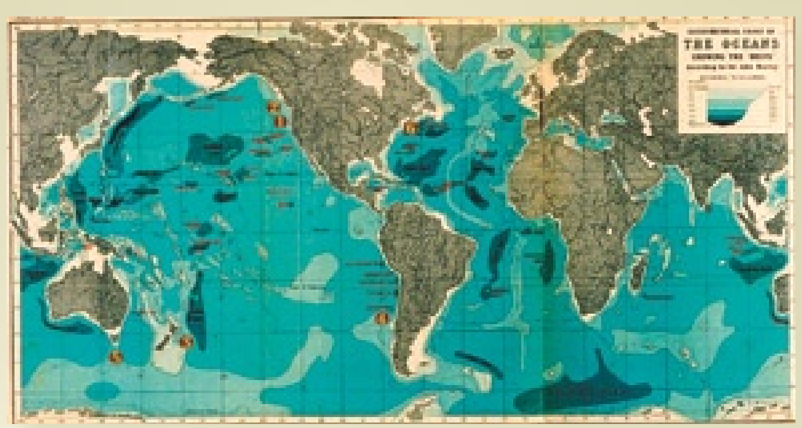
Commercially taken snails increased in abundance five to 14 times and doubled in body size in reserves compared to fished areas (Castilla & Duran 1985).

5 Tasmania:

Rock lobster and reef fish abundance increased by one and two orders of magnitude on temperate rocky reefs within reserves (Edgar & Barrett 1999).

6 Georges Bank and Southern New England:

In three large closed areas total and harvestable scallop biomasses (weights) were nine and 14 times greater than in adjacent open fished areas (Murawski et al. 2000).



Bathymetric Map of the World's Oceans, Showing The "Deeps." Produced by Sir John Murray, 1911

NOAA Digital Library

RESEARCH: *Reserves and Baseline Data*

CA Legislative Finding
"Understanding of the impacts of human activities and the processes required to sustain the abundance and diversity of marine life is limited. The designation of certain areas as sea life reserves can help expand our knowledge by providing baseline information and improving our understanding of ecosystems where minimal disturbance occurs." Fish & Game Code § 2850(e)

GATHERING BASELINE DATA ON CALIFORNIA'S FULLY PROTECTED RESERVES

To determine the effectiveness of a reserve, baseline information is first needed to determine the abundance and sizes of fish populations and the types of habitats within reserves. To that end, in 1996, the California Sea Grant College Program was selected by the Fish and Game Commission to design and administer a competitive peer-reviewed research program focusing on the four new fully protected ecological reserves, the Marine Reserves Research Program (MERRP). The goal of the program was to learn how marine reserves might be used as a management tool and to enable managers to make better decisions about their placement and design.

For example, one study characterized the benthic habitats and fish species that occur in deep water areas in and around Big Creek MRPA ecological reserve. This characterization provides a valuable baseline data set that can be used for future monitoring. To learn more about the MERRP studies visit: www.csgc.ucsd.edu.

CAN RESERVES PROVIDE MANAGERS WITH BASELINE DATA?

Summarized by J. Casselle in (Starr 2002)

Many studies have shown that fully protected reserves are able to protect populations of sea life within their borders. However, fully protected reserves may also provide baseline data that can be used to more accurately assess what changes are occurring in fish stocks. A recent study at the Channel Islands off Santa Barbara, California, compared the long-term population fluctuations of the warty sea cucumber (*Parastichopus parvimensis*) within the Anacapa Island Natural Reserve with several fished areas outside of the reserve (Schroeter et al. 2001).

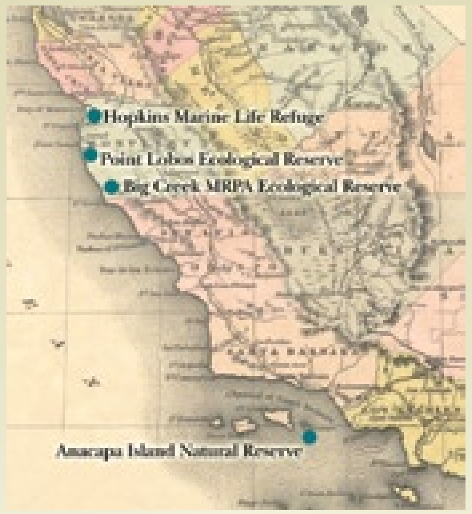
Sea cucumber abundance was measured both inside the reserve and outside at fished sites both before and after the onset of fishing. These data were then compared to stock assessments obtained from traditional catch per unit effort- fishery dependent data (i.e., the amount of a time it takes to catch a specific number of animals in a specific amount of time) often used by managers.

Following the onset of the fishery, the abundance of warty sea cucumber decreased, (33% to 83%), at seven fished sites throughout the islands. In contrast, sea cucumber abundance at the two unfished sites in the reserve showed no significant change. Moreover, their populations tended to increase in the reserves.

Interestingly, it did not take longer to catch sea cucumbers at any of the fished sites after the onset of fishing despite the general decline in abundance at the sites. This implies that the traditional method of using the amount of time it takes to catch fish (catch per unit effort) as an indicator of population health may not be a true estimate. Areas that are not fished, fully protected reserves, may be able to assist managers in determining what the true standings of fish stocks are.

Reserve Effects in California's Temperate Oceans

A review of the effectiveness of the three fully protected marine reserves in central California, and one in southern California was conducted in 2001 (Starr et al. 2002). The review concludes that reserve effects are apparent and are briefly summarized below.



J.H Colton & Company, 1855

Pt. Lobos Ecological Reserve and Hopkins Marine Life Refuge

Fish abundance, size, and species composition were modestly greater inside the reserves relative to adjacent areas with similar habitat.

Big Creek MRPA Ecological Reserve

The number, size and diversity of fishes were similar inside and outside the reserve. This is not surprising given that this reserve was only recently established. Moreover, most fish species there are rockfishes, which grow slowly and have low reproductive success so it may take many years for them to grow bigger and produce large numbers of young. Some rockfish species take over 30 years to reach maturity. The reserve does serve as a rearing ground for rockfish or at least an area to which rockfish young (recruits) can arrive and settle (Yoklavich et al. 2002).

Anacapa Island Natural Reserve

Harvested species were in greater abundance inside the reserve than in areas fished outside the reserve. The abundance of species that were not commonly harvested, however, were similar or greater outside the reserve.

Review of Research on Fully Protected California No-take Reserves

CA Legislative Finding

"Marine life reserves (no-take areas) are an essential element of an MPA system because they protect habitat and ecosystems, conserve biological diversity, provide a sanctuary for fish and other sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the marine environment, and may help rebuild depleted fisheries. Fish & Game Code, § 2851(f). *However . . . despite the demonstrated value of marine reserves, only 14 of the 220,000 square miles of combined state and federal water off California or 6 thousandths of one percent, are set aside as genuine no take areas."* Fish & Game Code, § 2851(g).

A map of the locations of the ten California no-take marine life reserves, which cover 0.2% of state waters, is shown here. Summaries of the research conducted within each reserve and conclusions about reserve effectiveness follow. The summaries were compiled by the California Department of Fish and Game.

The original map was produced by J.H Colton & Company, 1855

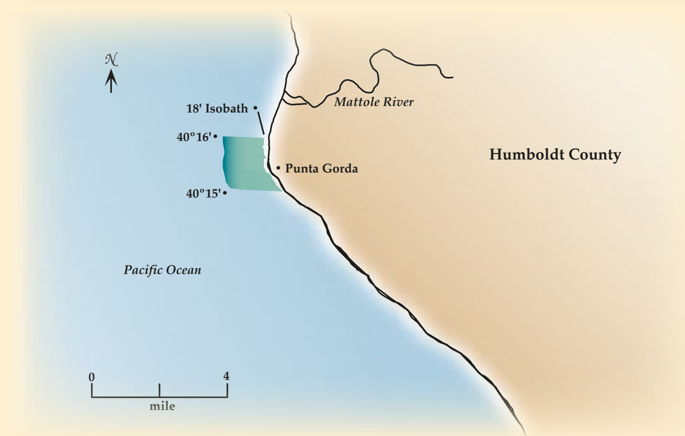
Site Name:

King Range (Punta Gorda) Marine Resources Protection Act Ecological Reserve*

* As of January 1, 2002 the name of this site was officially changed by the Marine Managed Areas Improvement Act to: ***King Range State Marine Reserve***.

MLPA Region: North (Humboldt County)

- Year established: 1994 • Area: 1.97 nm^2
- Shoreline length: 1.74 nm • Depth range (feet): 18 to 180



Habitat types: Dominated by sand with some hard bottom; in a vigorous upwelling zone. Large wash rock (Gorda Rock) and a few subtidal pinnacles offshore.

Surrounding habitat types: Larger rocky habitat areas to the north of the reserve near Cape Mendocino. Mattole Submarine Canyon is 2 miles north of the reserve boundary. Spanish and Delgada Submarine Canyons are south of the reserve. Canyon habitats are rocky with soft substrate on their slopes.

Baseline and ongoing monitoring and research studies:

Anonymous. 1979b California Marine Waters Areas of Special Biological Significance Reconnaissance Survey Report, King Range National Conservation Area. California State Water Resources Control Board, Division of Planning and Research, Surveillance and Monitoring Section. Water Quality Monitoring Report No. 79-18

Karpov, K.A., et al. (In Prep.) Quantitative inventory of habitat and species of management importance at Punta Gorda Ecological Reserve. MERRP Sea Grant Report. Proj. PG-1, Marine Eco. Reser. Res. Prog.

Basic Evaluation: The reserve currently protects a small amount of rocky habitat which is unique in its encrusting invertebrate assemblage. Suitable habitat for nearshore finfish species of management concern is sparse within the reserve. The reserve also has low algal abundance due to high turbidity and sand scour. Karpov et al. (in prep.) observed no red abalone within the reserve and very few red sea urchins. This report also recommended relocation of the reserve to an area with habitats more suitable for species of management concern, and to allow better access to the reserve for research and enforcement.

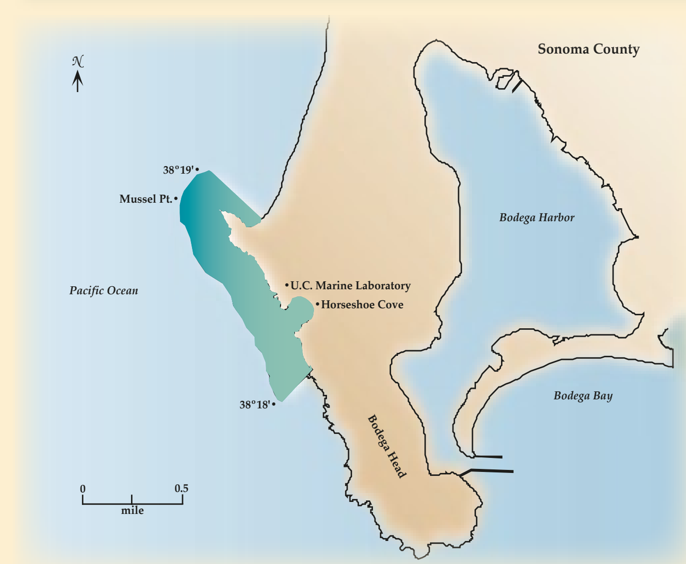
- Published references related to effectiveness of this MPA: Karpov, et al. (In Prep.)
- Unpublished references related to effectiveness of this MPA: None found.
- Published references related to use of this MPA as a research tool: Karpov, et al. (In Prep.)
- Unpublished references related to use of this MPA as a research tool: None found.

Site name:

Bodega Marine Life Refuge

MLPA Region: North Central (Sonoma County)

- Year established: 1965 (full protection established in 1999)
- Area: 0.20 nm^2 • Shoreline length: 1.0 nm
- Depth range (feet): 0 to 36



Habitat types: Rocky outcrops in sandy bottom.

Surrounding habitat types: Exposed coastline, wash rocks, rocky bottom interspersed with sand.

Baseline and ongoing monitoring and research studies: Bodega Marine Laboratory utilizes this refuge on a regular basis for research projects and observation.

Basic Evaluation: This refuge is relatively small and is the only existing MPA in the North Central region which is entirely marine and which has complete protection for all marine organisms. Complete protection has only been afforded to this reserve since 1999, a relatively short time period in which to access its function as a no-take reserve. However, several studies utilize the reserve as a comparative baseline for species protected from the effects of fishing (i.e., urchins, crab, and abalone). The current boundaries of the refuge are honored and generally accepted by users groups. Any proposed enlargement of the boundaries likely will be met with opposition.

- Published references related to effectiveness of this MPA: Botsford, L.W., et al. 1999
- Unpublished references related to effectiveness of this MPA: None found.
- Published references related to use of this MPA as a research tool: Botsford, L.W. 2001; Botsford, L.W., et al. 1994. MacFarlane, R.B. and E.C. Norton. 1999; Morgan, L.E., et al. 2000(1); Morgan, L.E., et al. 2000(2); Norton, E.C. and R.B. MacFarlane. 1995; Norton, E.C. and R.B. MacFarlane. 1999; Norton, E.C., et al. 2001; Quinn, et al. 1993; Rogers-Bennett, L., et al. 1995; Rogers-Bennett, L. and J.S. Pearse. 2001; Smith, B.D., et al. 1998; Wing, et al. 1995(1); Wing, S.R., et al. 1995(2); Wing, S.R. and M.R. Patterson 1993

Text provided by California Department of Fish and Game.
Maps created by McArdle & Gerson 2002.

Site name:
Hopkins Marine Life Refuge
MLPA Region: South Central (Monterey County)
- Year established: 1984
- Area: 0.15 nm²
- Shoreline length: 0.95 nm
- Depth range (feet): 0 to 60

Habitat types: Mostly granite reef; smaller portions of sand, especially on outside edge

Surrounding Habitat types: Similar

Baseline and ongoing monitoring and research studies: Numerous studies of algae, invertebrates, and fish have taken place in the HMLR. Long-term monitoring of the intertidal zone dates back to the 1930's. The Department carried out relatively intensive fish counts, and some re-monitoring of those counts has taken place. A recent study was completed comparing counts and sizes of benthic fishes in and adjacent to the refuge. In addition, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) has had permanent intertidal and subtidal monitoring sites here for several years.

Basic Evaluation: The area contains one of the oldest fully-protected marine research sites in the state and contains a variety of shallow habitat types within a relatively small area. It is a classic example of how a small but fully protected MPA can function well by providing a multitude of research opportunities with populations of marine organisms occurring at natural densities and size frequencies. While it is relatively small, studies have documented significantly greater biomass and size frequencies of nearshore fishes compared with adjacent fished areas.

There is a great deal of public support for establishing some form of MPA to the east of and adjacent to HMLR, using 60 feet as the offshore depth boundary. Establishing an MPA from the eastern boundary of HMLR to the base of the Coast Guard Breakwater (in the Cannery Row area) would provide increased protection for marine fishes and invertebrates in an area that is frequently utilized by dive classes, recreational divers, and recreational anglers but would leave the area west of HMLR (the existing Pacific Grove Marine Gardens Fish Refuge) available for recreational fishing. However, there is also considerable local support for increasing the degree of protection within the existing and adjacent Pacific Grove Marine Gardens Fish Refuge. Extension of HMLR offshore would place deeper-water reef areas under protection but would impact fisheries such as commercial passenger fishing vessel (CPFV) and squid. This site is also overlapped by an Area of Special Biological Significance designation.

Published references related to effectiveness of this MPA: Cooper, J., et al. 1977; Lowry, L.F. and J.S. Pearse. 1973; Miller, D.J. and J.J. Geibel. 1973; Paddack, M.J. and J.A. Estes. 2000; Pearse, J.S. and A.H. Hines. 1987; Sagarin, R.D., et al. 1999; Schaeffer, T.N., et al. 1999; State Water Resources Control Board. 1979.

Unpublished references related to effectiveness of this MPA: Paddack, M.J. 1996

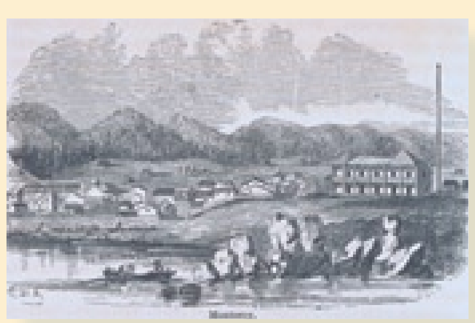
Published references related to use of this MPA as a research tool: Brawley, S.H. 1989; DeBevoise, A.E. 1975; Fadlallah, Y.H. 1982; Holts, L.J. and K.A. Beauchamp. 1993; Lyman, B.W. 1975; Russo, A.R. 1984; Seiff, S.R. 1975; Smith, A.M. 1992; Tomanek, L. and G.N. Somero. 1997; Tomanek, L. and G.N. Somero. 1998; Watanabe, J.M. and Cox, L.R. 1975; Williams, R. 1975

Unpublished references related to use of this MPA as a research tool: Ammann, A. J. 2001; Fadallah, Y.H. 1981; Holyoak, A.R. 1992;

The Hopkins Marine Station web site presently lists more than 150 student papers dating back to 1964, most of which involved at least some field work or collection or organisms with HMLR. The web site address is: http://www.marine.stanford.edu/HMSweb/marine-indexes.html.

Many others have used the HLMR as a site for research both before and after its establishment as an MPA. The library at HLMR maintains an extensive list of abstracts of dissertations by Hopkins Marine Station Ph.D candidates. Dr. Freya Sommner provided the Department with a list of 34 completed or ongoing research projects at HMS since 1994.

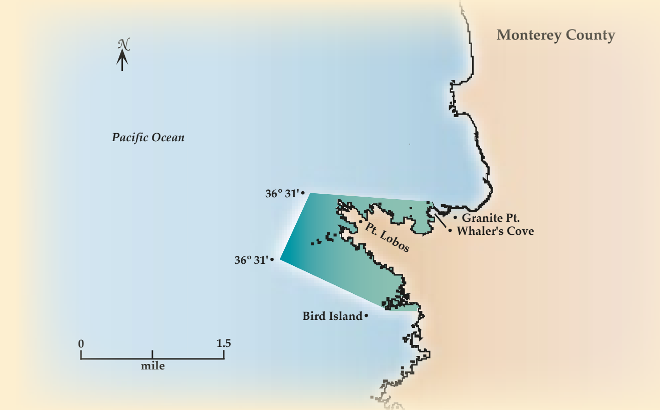
Text provided by
California Department of Fish and Game.
Maps created by McArdle & Gerson 2002.



View of Monterey from offshore. 1855

NOAA Digital Library

Site name:
Point Lobos Ecological Reserve
MLPA Region: South Central (Monterey County)
- Year established: 1973
- Area: 0.8 nm²
- Shoreline length: 6.7 nm
- Depth range (feet): 0 to 195



Habitat types: Mostly granite reef dropping form shore to sand bottom. Reef habitat with many crevices and pinnacles. Extensive kelp beds

Surrounding habitat types: Carmel submarine canyon is nearby. Extensive hard bottom offshore, as determined from submersible studies.

Baseline and ongoing monitoring and research studies: UC Santa Cruz student found slightly greater abundances of benthic fish in the reserve than in adjacent areas. Department has conducted habitat-based surveys of fish abundance within the reserve. Submersible surveys have been carried out offshore of the reserve. In addition, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) has had permanent intertidal and subtidal monitoring sites here for several years.

Basic Evaluation: This site contains a complex variety of habitats, primarily hard bottom, and contains high densities of large, adult bottom fishes such as rockfishes and lingcod. Although relatively small, the reserve functions well as a fully protected area because of its high species diversity and variety of habitat, and it is effectively enforced.. Studies by the Department and others have documented high population densities and large sizes of economically important nearshore fish species, in particular rockfishes, lingcod, cabezon, and greenlings, with population densities and size frequencies significantly greater than in adjacent and more distant fished areas. In addition, the site is a prime destination for non-extractive scuba divers, and use is limited by local policy.

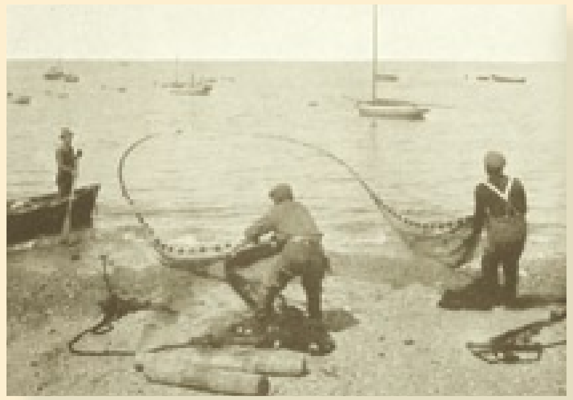
This site would be an excellent candidate for expansion from the point of view of habitat protection, but it could cause significant impacts to users groups. The region is approximately 10 miles from a major central coast port (Monterey). Expansion to the north in the area west of the Carmel Bay Ecological Reserve would include part of the Carmel Submarine Canyon but would impact existing commercial fisheries such as spot prawn and hook-and-line finfish, as well as recreational CPFV fisheries. Expansion to the south (to Yankee Point or beyond) would add additional area extensive rock reef habitat but would impact commercial and recreational finfish fisheries. Offshore extension of the reserve would add deeper reef habitat but would impact existing commercial fisheries such as spot prawn and hook-and-line finfish, as well as recreational CPFV fisheries. As an alternative to expanding this site, a more suitable location in terms of less socioeconomic impact might be possible to the south between Point Lobos and Point Sur. In addition to the above rationale, this site is also overlapped by an Area of Special Biological Significance designation (which will be re-named State Water Quality Protection Area).

Published references related to effectiveness of this MPA: Baldridge, A. and L.L. Rogers. 1991; Hanggi, E.B. and R.J. Schusterman. 1994; Long, D.J. 1992; Paddack, M.J. and J.A. Estes. 2000; Riedman, M.L. and J.A. Estes. 1988; VenTresca, D.A., et al. (In prep.)

Unpublished references related to effectiveness of MPAs: Cazanian, G.V., et al. 1979; DeMartini, J.D. and W.J. Barry. 1977; Drury, A. 1970; Lea, R.N. 1978; Lea, R.N. 1979; Lea, R.N. 1979; Lea, R.N. 1982; Lea, R.N. 1993; Nichols, D.R., et al. 1974; Paddack, M.J. 1996; Reilly, P.N., et al. 1998; Reilly, P.N., and D.A. VenTresca. 1999; Thompson, T. 1974

Published references related to use of this MPA as a research tool: Gingras, M.L., et al. 1998; Johansen, H.W. and L.F. Austin. 1970

Unpublished references related to use of this MPA as a research tool: Castleton, M. R. 2000



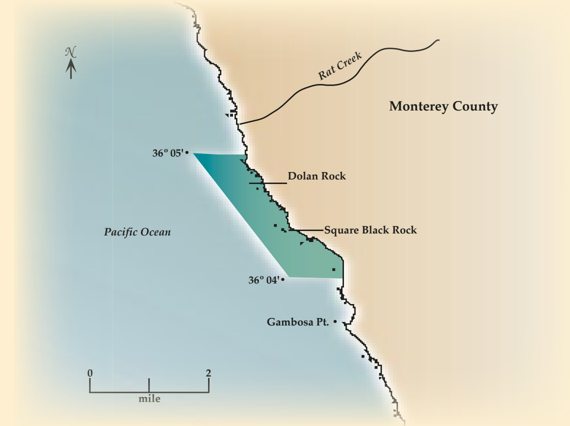
Vincente, the Venetian, hauling seine for bait.
In (Holder 1910).

Text provided by
California Department of Fish and Game.
Maps created by McArdle & Gerson 2002.

Site name:
Big Creek Marine Resources Protection Act Ecological Reserve*

*As of January 1, 2002 the name of this site was officially changed by the Marine Managed Areas Improvement Act to: ***Big Creek State Marine Reserve.***

MLPA Region: South Central (Monterey County)
- Year established: 1994
- Area: 1.9 nm²
- Shoreline length: 2.7 nm
- Depth range (feet): 0 to 300



Habitat types: Soft intertidal: est. 10%; Hard intertidal: est. 90%; Soft subtidal: est. 18%; Hard subtidal: est. 82%; Soft shelf: est. 88%; Hard shelf: 12%; Kelp beds; many wash rocks and pinnacles.

Surrounding habitat types: To the north and south a mixture of hard and soft bottom with scattered kelp beds. Several heads of submarine canyons adjacent on seaward side.

Baseline and ongoing monitoring and research studies: Benthic habitat mapping and characterization: baseline information for entire reserve (Yoklavich, VenTresca). Mapping ocean currents and related hydrographic studies: ongoing research (C. Collins, F. Schwing). Benthic fish surveys: baseline research; deep (Yoklavich), subtidal (VenTresca, Paddock). Benthic Invertebrates; some baseline; intertidal (Pearse); subtidal (Mira Parks). Local Fishery (social aspects; Pomeroy, Smiley). PISCO long-term subtidal monitoring site (Carr).

Basic Evaluation: This site contains a variety of habitats with hard and soft substrates, including kelp beds, and is one of the few existing MPAs which extend to 50 fathoms depth. This site functions well as a completely protected area while allowing research, particularly the documentation of population densities of nearshore and offshore fishes. Studies by the CDFG, National Marine Fisheries Service, and others have quantified density and size frequency of populations of rockfishes, lingcod, cabezon, and other economically important finfishes within and outside the reserve boundaries, and have found significant numbers of large, reproductively mature fishes within as well as adjacent to this site. Populations of fishes in adjacent areas are of higher density than within fished areas closer to ports, primarily due to the remoteness of the areas and their difficult access from shore. If fishing pressure increases in the future in adjacent areas, the reserve will continue to serve as a baseline for indices of natural populations. The reserve benefits from the presence of an on-site manager and has excellent enforcement.

This site could benefit from extending boundaries offshore for the purpose of maintaining a larger portion of an intact ecosystem. There are presently no State Marine Reserves in California which extend to 3 miles offshore, and the existing array of MPAs does not include adequate representation of deep-water habitat, particularly in depths exceeding 50 fm. This area would be a likely candidate because it already has full protection inshore, is relatively remote for central California standards, and would include a wider variety of habitat within an MPA. An expanded SMR at this site would allow the natural ecological functions to occur in this area and would enhance economically important species, including lingcod and rockfishes such as bocaccio, yelloweye, canary, vermilion, and yellowtail.

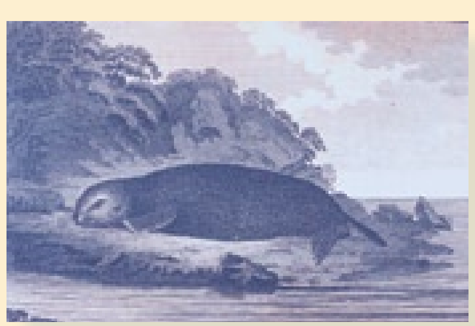
Published references related to effectiveness of this MPA: Ferguson, A. (ed.) 1984; Paddack, M.J. and J.A. Estes. 2000; Pomeroy, C. 1999; VenTresca, D.A., et al. (in prep); VenTresca, D.A., et al. 1998; Yoklavich, M., et al. 1997; Yoklavich, M. et al. (In prep).

Unpublished references related to effectiveness of this MPA Gingras, M.L. 1997; Gingras, M.L. 1998; Gingras, M.L. 1998; Houk , J.L. 1994; Lea, R.N., et al. 1982; Lea, R.N. 1982; Lea, R.N. 1993; Lea, R.N. and P.N. Reilly. 1999; Malone, C. 1994; Paddack, M.J. 1996; Pattison, C.A. 1995; Pomeroy, C. 1996; Reilly, P.N., et al. 1994; Reilly, P.N., et al. 1995; Reilly, P.N., et al. 1996; Reilly, P.N., et al. 1997; Reilly, P.N., et al. 1998; Reilly, P.N., and D.A. VenTresca. 1999; Reilly, P.N., et al. 2000; Smiley, J. 2000; VenTresca, D., et al. 1999; VenTresca, D.A., et al.; Wilson, C.E. 1996; Yoklavich, M., et al. 1997.

Published references related to use of this MPA as a research tool: Pomeroy, C. 1999; Pomeroy, C. and J. Beck. 1998

Unpublished references related to use of this MPA as a research tool: None found.

Text provided by
California Department of Fish and Game.
Maps created by McArdle & Gerson 2002.



NOAA Digital Library

A Sea Otter discovered in Capt. Cook's last voyage. 1790

Site name:
Vandenberg Marine Resources Protection Act Ecological Reserve*

*As of January 1, 2002 the name of this site was officially changed by the Marine Managed Areas Improvement Act to: ***Vandenberg State Marine Reserve.***

MLPA Region: South Central (Santa Barbara County)
- Year established: 1994
- Area: 2.0 nm²
- Shoreline length: 4.5 nm
- Depth range (feet): 0 to 60

Habitat types: The area contains a mixture of hard and soft bottom. This is a high energy area that is likely heavily scoured.

Surrounding habitat types: Fairly similar to north, south, and offshore, although a higher percentage of soft bottom to the north.

Baseline and ongoing monitoring and research studies: Benthic habitat mapping (Cochrane USGS). Mapping ocean currents and related hydrographic studies: ongoing research (Russ Vetter, NMFS). Eggs and larval fish surveys: research (Vetter, NMFS). Abalone enhancement, growth studies (Friedman, Haaker). Intertidal invertebrate surveys (PISCO-Pete Raimondi, UCSC; Steve Murray). Evaluation of effects of oil spill on intertidal (Pete Raimondi, UCSC; Andy Lisner, MMS). Some baseline data on fish abundance in the adjacent Purisima Point area exists from a CDFG research cruise in 1998.

Basic Evaluation: This site contains primarily shallow soft-bottom substrate but includes some low-relief subtidal reef. Based on Department surveys in the late 1990s, the site and the immediately adjacent area appear to function well in protecting high population densities of black abalone. The adjacent area, while not within an MPA, benefits from military-imposed restricted access. No other sites along the southern California mainland contain high densities of black abalone.

A significantly larger MPA, in the form of a State Marine Conservation Area, could be created without causing any additional negative socio-economic impact on users, who are already excluded from Military Zone 4 and Zone 5 with few exceptions. Zone 4 is enforced as a no-stopping area by the Air Force. Some fishing does occur if it does not require stopping or loitering (i.e., salmon trolling), so a logical option would be to create a SMCA with all fishing prohibited except for salmon trolling in the area outside the existing Vandenberg Ecological Reserve, while retaining the complete no-take provisions of Vandenberg Ecological Reserve. Resources within this site could benefit from extending boundaries to north and westward. Expanding the existing MPA would incorporate brown rockfish (an important nearshore species) habitat, which is not adequately represented within existing MPAs, and would enhance other economically important species, particularly lingcod, cabezon, greenlings, and rockfishes such as gopher, yellowtail, blue, vermilion, canary, bocaccio, and copper. There is some diving that goes on in Zone 4, but this activity is by permission only and the military estimates that they have 1-2 dive requests per year, largely at the southern end of zone 4 near Destroyer Rock

Published references related to effectiveness of this MPA: None found.

Unpublished references related to effectiveness of this MPA: Friedman, C. S., et al., 2001.

Published references related to use of this MPA as a research tool: Watson, W., et al., 1999

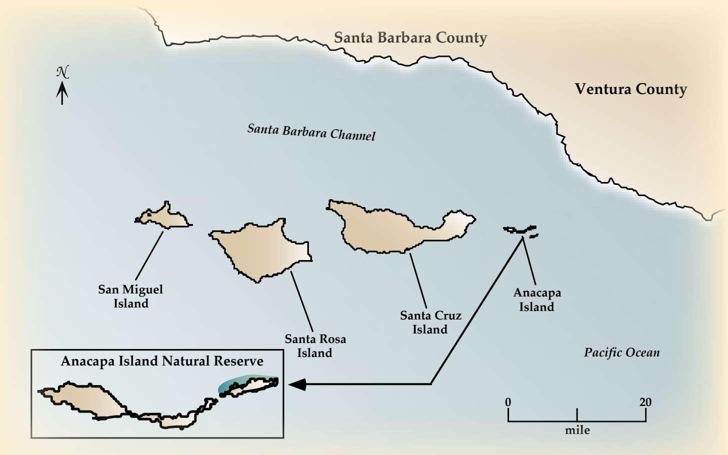
Unpublished references related to use of this MPA as a research tool: None found.

Text provided by
California Department of Fish and Game.
Maps created by McArdle & Gerson 2002.

Record rod and reel swordfish catch, 339 lbs.
Mr. C.G. Conn, prior to 1910.

Site name:
Anacapa Island Ecological Reserve Natural Area

MLPA Region: South (Ventura County)
- Year established: 1978
- Area: 0.04 nm^2
- Shoreline length: N/A
- Depth range (feet): 0 to 60



Habitat types: Nearly 100% rocky shoreline and intertidal zone with rocky reef to 20 m depth and rock reef scattered below that. Approximately 80% hard substrate overall. There are kelp beds and surfgrass areas through the area.

Surrounding Habitat types: Nearshore kelp forest and reef habitat with interspersed sandy areas.

Baseline and ongoing monitoring and research studies: Channel Islands National Park has two fixed sites for the Kelp Forest Monitoring program, (est. 1982) within the natural area. Comparisons of fish inside and out of the reserve were made by Larson (2000). Tetreault (2000) made independent assessments of fish inside and out of the reserve. Schroeter et al. (2001) used a BACI analysis of Channel Islands National Park data to look at fishery effects on sea cucumbers. There is a pink abalone enhancement study site (density enhanced through transplants to increase reproduction), a joint CDFG and Channel Islands National Park project. In addition, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) has had a permanent subtidal monitoring site here for several years.

Basic Evaluation: Provides complete protection of marine life in a limited area in the warmer water region of the Northern Channel Islands. Provides an opportunity to evaluate effects of complete protection on resident species. This site has a diversity of habitat and species, but encompasses a relatively small portion of the habitat in the area extending only to a depth of 20m and may be affected by intense edge fishing for finfish and lobster. Nevertheless, kelp bass and sheephead were found in higher densities and larger sizes in this MPA than in nearby areas open to harvest indicating that this MPA is protecting these desirable species to a greater extent than general fishery regulations elsewhere. Sea cucumber abundances were stable or increased here compared to other sites at the Channel Islands open to harvests of that species. Lobster populations were higher and lobster and sea urchin populations more stable in this MPA as well. It is within an ecological reserve, National Park, National Marine Sanctuary, International Biosphere Reserve, and Area of Special Biological Significance. Current proposals to establish two new MPAs at Anacapa Island include a no-take reserve encompassing and greatly expanding the area this MPA. A wide range of habitats and resources present in this warmer water region will be represented by this proposed MPA. It is also designed to provide connectivity with other MPAs and open areas at the Channel Islands through movements of adult and juvenile organisms and transport of larvae.

Published references related to effectiveness of this MPA: Schroeter, et al. 2001. Laferty, K.D. and D.J. Kushner. 2000

Unpublished references related to effectiveness of this MPA: Tetreault, I. and R.F. Ambrose. (in prep.); Larson, R. J. 2000

Published references related to use of this MPA as a research tool: Richards, D.V. and G.E. Davis. 1993; Schroeter, S. C., et al. 2001

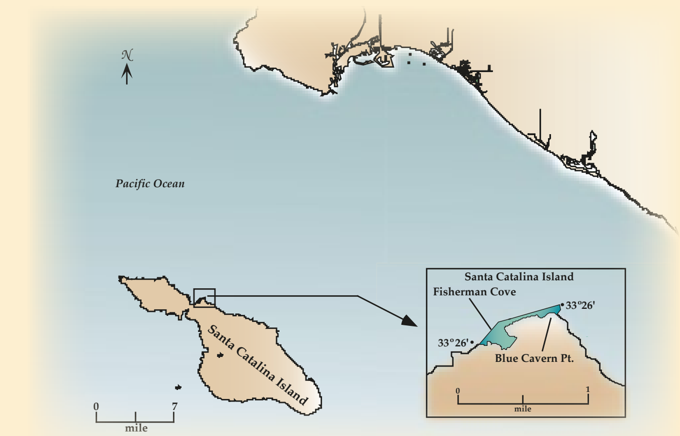
Unpublished references related to use of this MPA as a research tool: Davis, G. E. 1985; Davis, G. E. 1986; Kushner, et al. 1995a; Kushner, et al. 1995b; Kushner, D. J., et al. 1997a; Kushner, D. J., et al. 1997b; Kushner, D. J., et al. 1998; Kushner, D. J., et al. 2000; Kushner, D. J., et al. 2001; Richards, D. V. 1986; Richards, D. V. 1988; Richards, D. V. 1994; Richards, D. V., et al. 1997; Richards, D.V., et al. 1993a; Richards, D.V. and D. Kushner. 1994; Richards, D.V., et al. 1993b; Richards, D. V. 1998; 2001; Larson, R. J. 2001

Text provided by California Department of Fish and Game. Maps created by McArdle & Gerson 2002.

White Sea Bass. Mr. C.G. Conn, prior to 1910.

Site name:
Catalina Marine Science Center Marine Life Refuge

MLPA Region: South (Los Angeles County)
- Year established: 1988
- Area: 0.06 nm^2
- Shoreline length: 1.08 nm
- Depth range (feet): 0 to 120



Habitat types: Overall this site has about 50% hard and 50% soft substrates. Southwest of the pier is a soft-bottom cove with approximately 20 moorings for large boats. Southeast is a small soft-bottom cove. Within the small cove there are approximately 8 moorings for small research craft. Further southeast are rocky walls and hard bottom (to 30 m) and deeper soft bottom (to 100 m). The hard bottom habitat supports kelp forests.

Surrounding habitat types: Rocky shoreline, kelp forest and reefs adjacent to site. Some soft bottom areas offshore and in nearby coves. Extensive reef systems in nearby general area.

Baseline and ongoing monitoring and research studies: There have been numerous studies by scientific, volunteer and student researchers. The Catalina Conservancy Divers have long-term studies, especially for giant kelp. Published and gray literature in the Southern California Academy of Sciences Bulletin. Dr. Jack Engle of UCSB has conducted roving diver fish surveys during the last 3 or 4 years and is working with others to monitor rocky intertidal populations at Bird Rock. Mark Littler and Steve Murray established a site near Fisherman Cove as part of the BLM-sponsored studies in the mid-1970s. Steve Murray of CSU Fullerton has recently re-assessed the distributions and abundances of rocky intertidal populations to examine decadal scale changes in intertidal systems. Irene Tetreault has on-going fish and habitat surveys.

Basic Evaluation: Provides complete protection to all marine life in a semi-sheltered island habitat in the warm water region of the southern Channel Islands. It was established as a research site under control of the adjacent Wrigley Institute for Environmental Studies (WIES). WIES has become a popular educational and outreach center. It now subsidizes graduate student work and continues to support university researchers. The no-take MPA is vital to those operations. In addition, this site has strong research and monitoring potential to assess the effectiveness of no-take MPAs on resources since surrounding areas receive heavy recreational fishing pressure. Kelp bass and sheephead were found in higher densities and larger sizes in this MPA compared with nearby areas open to harvest indicating that this MPA is protecting these desirable species to a greater extent than general fishery regulations elsewhere. Expansion of this site, either along the shoreline or to include nearby offshore reef systems, could increase its usefulness as a research tool.

Published references related to effectiveness of this MPA: None found

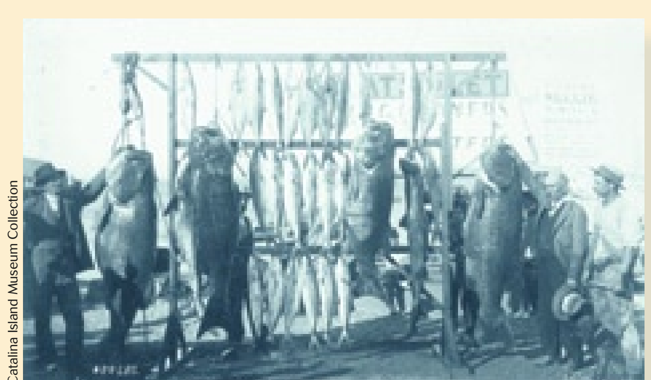
Unpublished references related to effectiveness of this MPA: Tetreault, I. and R.F. Ambrose. (in prep.)

Published references related to use of this MPA as a research tool: McAlary, F.A. 1987; Murray, S. N. and M. M. Littler. 1979a; Murray, S. N. and M. M. Littler. 1979b; Murray, S. N. and M. M. Littler. 1978a; Murray, S. N. and M. M. Littler. 1978b; Murray, S. N. and M. M. Littler. 1977

Unpublished references related to use of this MPA as a research tool: Tetreault, I. and R.F. Ambrose. (in prep.)

Text provided by California Department of Fish and Game. Maps created by McArdle & Gerson 2002.

Catalina Island Museum Collection



Weight of entire catch in 3 hours, 1745 lbs, Santa Catalina Island

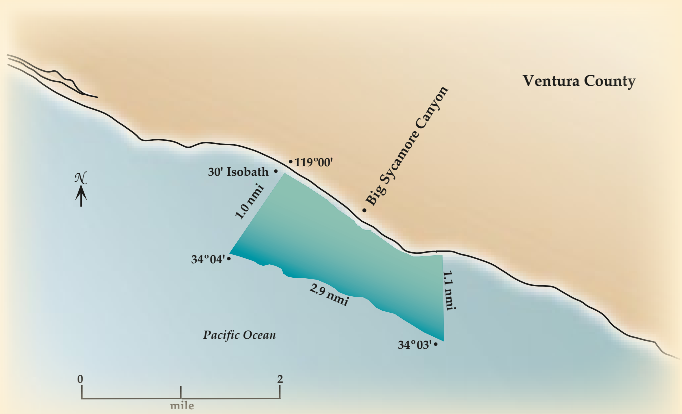
Site name:

Big Sycamore Canyon State Marine Reserve*

* As of January 1, 2002, this site's designation was officially changed by the Marine Managed Areas Improvement Act from an "Ecological Reserve" to a State Marine Reserve.

MLPA Region: South (Ventura County)

- Year established: 1994
- Area: 1.67 nm^2
- Shoreline length: 1.84 nm
- Depth range (feet): 30 to 120



Habitat types: Sandy bottom 100%

Surrounding habitat types: Mostly sandy areas. Kelp forest and reef habitat at Deer Canyon to the east. Mugu Submarine Canyon to the west.

Baseline and ongoing monitoring and research studies: Habitat mapping surveys (sonar) conducted as part of MERRP research projects.

Basic Evaluation: This site was chosen as an MPA location because it was least objectionable to users during the MRPA process. Habitat here is almost entirely sand with no reef structure. As such, this site does not contain the large diversity of species and habitats that are present in many other MPAs. Despite these limitations, it is the only MPA which provides protection to an extensive area of this type of wide spread habitat in southern California. Halibut, a highly sought after species, are protected here, as well as a potential spawning area for market squid. Expansion of this site to the east would include kelp/reef habitats providing a more diverse habitat representation in the reserve.

Published references related to effectiveness of this MPA: None found

Unpublished references related to effectiveness of this MPA: Cochrane, G.R., et al;. 2001; Watson, W., et al. 2001

Published references related to use of this MPA as a research tool: None found

Unpublished references related to use of this MPA as a research tool: Cochrane, G.R., et al. 2001; Watson, W., et al. 2001

Site name:

Heisler Park Ecological Reserve

MLPA Region: South (Orange County)

- Year established: 1973
- Area: 0.04 nm^2
- Shoreline length: 0.39 nm
- Depth range (feet): 0 to 60

Text provided by California Department of Fish and Game.
Maps created by McArdle & Gerson 2002.

Habitat types: Rocky platforms and sandy beaches. Extending out into the subtidal zone. As for most of this section of the coast, rocky benches are heavily sand influenced with rocky platforms and headlands separated by intermittent pocket sandy beaches. Main Beach in Laguna is very heavily used by tourists.

Surrounding habitat types: Similar to the site. Rocky points and benches, sandy coves with scattered offshore reefs.

Baseline and ongoing monitoring and research studies: Historic algae surveys were performed in 1957-59 by E. Yale Dawson at a site inside Heisler Park. These surveys were repeated in the late 1960s by T. Widdowson and in the 1970s and early 1980s by Ronald Thom. Steve Murray resurveyed Dawson's transects at Laguna Beach during Fall 1998. Irene Tetreault surveyed the nearshore fish populations at Heisler Park as part of a study of the effects of Ecological Reserve designations on extracted populations.

Basic Evaluation: Provides complete protection to all marine life in a southern California coastal nearshore reef habitat. The site's small size and heavy public use within the site and nearby areas appears to limit the effectiveness of protection. Despite these factors, barred sand bass and kelp bass had higher densities and larger sizes in this MPA than in areas nearby subject to harvesting pressure indicating that this site is protecting these desirable species to a greater extent than general fishery regulations alone in areas elsewhere. Combining the adjacent Laguna Beach Marine Life Refuge with this site and providing for the same higher level of resource protection would eliminate public confusion over allowable activities and simplify enforcement while providing a larger area of habitat for undisturbed ecosystem functions and biodiversity maintenance.

Published references related to effectiveness of MPAs: None found

Unpublished references related to effectiveness of MPAs: Tetreault, I. and R. F. Ambrose. (in prep.)

Published references related to use of this MPA as a research tool: Dawson, E. Y. 1959; Dawson, E. Y. 1965; Thom, R. M., and T. B. Widdowson. 1978; Widdowson, T. B. 1971

Unpublished references related to use of this MPA as a research tool: Tetreault I. and R.F. Ambrose. (in prep.)

CA Legislative Finding

The state's MPAs should be designed and managed, to the extent possible, as a network. Fish & Game Code, § 2853(6). *"The MPA network… should be of adequate size, number, type of protection, and location to ensure that…the network as a whole meets the goals and guidelines of this chapter."* Fish & Game Code, § 2857(5)

A network is a set of protected areas within a biogeographic region, connected by larval dispersal and juvenile or adult migration. The ecological criteria or factors that should be considered in network design include, among other things, habitat, species or populations of special concern, ocean circulation patterns, ecosystem health and reserve size (PISCO 2002, Roberts et al., in press). The California Legislature has declared that MPA networks should be based on the criteria listed below. The social and scientific values defining these criteria need to be set so that the network has a chance of meeting its goals. Removal of any criterion could reduce the degree of protection provided by the network (Roberts et al., in press).

Legislative Code	Legislative Criteria	Legislative Requirements	Scientific Definition (PISCO 2002)
Fish & Game Code, §2851	Biogeographic representation	Areas characterized by particular sets of environmental conditions, habitats, and species shall be included.	The inclusion of different regions characterized by particular sets of habitats, environmental conditions, and species.
Fish & Game Code, §2851	Habitat representation	A variety of representative habitat types shall be included.	The inclusion of different types of habitats (e.g., estuary, rocky shore, kelp forest, sandy bottom).
Fish & Game Code 1580-1585; 1907	Vulnerable habitats	The state must protect threatened and endangered aquatic organisms & specialized habitat types through the creation of ecological reserves.	Rare or threatened habitats susceptible to stresses.
Fish & Game Code, §2851 & Code 1580-1585; 1907	Species or populations of special concern	Enhancement of specific species or groups of species shall be included.	Species that are of economic or recreational value, are globally rare, or live in small geographic ranges.
Fish & Game Code, §2851	Size	The network… shall be of adequate size to meet the goals of the network.	The area covered by a single reserve or a network of reserves.
Fish & Game Code, §2851	Replication	Similar types of habitats and communities shall be replicated…in more than one reserve in each biogeographical region.	More than one reserve in the same critical habitat type (e.g., estuary, rocky shore, kelp forest, sandy bottom).
Fish & Game Code, §2851	Ecosystem functioning	Reserves . . . should ensure that activities do not upset the natural functions of the protected area.	Beneficial services that people use directly, such as removal of pollutants from the water, and climate control.

SELECTED REFERENCES

Allen. B.N. 1913. The Problem of the Spiny Lobster. California Fish & Game Commission. Fish Bull. No.1. Sacramento.

California Department of Fish & Game. 2002. Clarification Guidelines for the MLPA. June 2002.

Edwards, C.L. 1913. The Abalone Industry in California. California Fish and Game Commission. Fish Bull. No.1. Sacramento.

Glassow, M. A. 2002. Personal Comm. Department of Anthropology, U.C.S.B.

Halpern, B. H. In press. The impact of marine reserves: Do reserves work and does reserve size matter? Ecological Applications.

Holder, C.F. 1914. Attempts to protect the sea fisheries of southern California. California Fisheries Laboratory. Contribution No. 157. Vol.1. California Fish & Game. San Francisco.

Holder, C.F. 1910. *The Channel Islands of California.* A.C. Clurg & Co. Chicago.

Jackson, J.B.C. et al. 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems. Science. 293: 629–637.

Leet et al. 2001. *California's Living Marine Resources: A Status Report.* The Resources Agency, California Department of Fish & Game.

Leeworthy, V. R. & P.C Wiley 2002. "Socioeconomic Impact Analysis of Marine Reserve Alternatives for the Channel Islands National Marine Sanctuary." NOAA, NOS, Special Projects, Silver Spring, Maryland.

McArdle, D. 1997. *California Marine Protected Areas.* Publication No. T-039. California Sea Grant College Program, La Jolla, CA.

Murawski, S. A. et al. 2000. Large-scale closed areas as a fishery-management tool in temperate marine systems: The Georges Bank experience. Bull. of Marine Science 66(3):775–798.

Pacific Fisheries Management Council. 2000. Overcapitalization of the west coast groundfish fishery: background, issues, and solutions. Prepared by the Economic Subcommittee and the Scientific and Statistical Committee for the Pacific Fisheries Management Council. March 2000.

Pauly, D, V. et al. 1998. Fishing down marine food webs. Science 279:860–863.

PISCO. 2002. *The Science of Marine Reserves.* Partnership for Interdisciplinary Studies of Coastal Oceans: OSU, UCSC, Stanford University, and UCSB. www.piscoweb.org

Pletka, S. 2001. The Economics of Island Chumash Fishing Practices. In *The Origins of a Pacific Coast Chieftom*. J.E. Arnold (ed). Univ. of Utah Press.

Roberts, C. M. & J. P. Hawkins. 2000. *Fully-protected marine reserves: A guide.* WWF Endangered Seas Campaign, NW, Wash. DC. and Environment Department, University of York, UK. 134 pages. www.panda.org.

Roberts, C. M. et al. 2001. Effects of marine reserves on adjacent fisheries. Science 294:1920–1923.

Roberts,C.M. et al. In press. Application of ecological criteria in selecting marine reserves and developing reserve networks. Ecological Applications.

Schroeder, D. M. & M. S. Love. In press. On recreational fishing and marine fish populations. In California Cooperative Oceanic Fisheries Investigations Report.

Schroeter et al. 2001. The use of marine reserves in evaluating the dive fishery for the warty sea cucumber (*Parastichtichopus parvimensis*) in California. Can. J. Fish. Aquat. Sci. Vol. 58.

Starr, R.M. et al. 2002. *A Review of the ecological effectiveness of subtidal marine reserves in Central California. Part I. Synopsis of scientific investigations.* A report to the Monterey Bay National Marine Sanctuary. Monterey, CA. 133 pp.

Thompson, W.F. 1919. The scientific investigations of marine fisheries, as related to the work of the Fish & Game Commission in Southern California. California Fish & Game Commission. Fish Bull. No.2. Sacramento.

Ward, S. 1903. The Abalone. The Overland. P.534.

Weymouth, F.W. 1913. Investigation of the life history of the edible crab (*Cancer magister*). California Fish & Game Commission. Fish Bull. No. 1. Sacramento.

Williamson, M.B. 1894. Abalone or *Haliotis* Shells of the Californian Coast, Amer. Nat., Vol. XXVII.

For additional information about CA Sea Grant or to download a PDF version of this report, go to the Publications link at www.csgc.ucsd.edu.

The editor, Deborah McArdle, can be contacted at: damcardle@ucdavis.edu

For additional print copies, contact Sea Grant at: 858-534-4446 or gfrederick@ucsd.edu.

Meeresalgen (kelp) in "Das Meer" (The Sea) in MJ Scheiden, p. 168. 1888. NOAA Digital Library

Publication Design by
Robert Gerson
www.bookdesigning.com
robertgerson@bookdesigning.com

18. DEPARTMENT PRESENTATION RE: DRAFT POLICY ON LIMITED ENTRY COMMERCIAL FISHERIES. (Informational item only. Public testimony will be accepted at future meetings.)

Summary of Issue

This item is scheduled to receive the Department's proposed draft Commission policy regarding limited entry commercial fisheries. The Department will be making its presentation on April 2 and will provide the draft policy at that time. Commissioners were provided with a copy of a news article related to this issue.

Action

The Department did not complete its draft policy and will provide its report at a future meeting.

19. INFORMATIONAL DISCUSSION OF MANAGEMENT OPTIONS FOR MARINE RESOURCES IN AND AROUND THE CHANNEL ISLANDS NATIONAL PARK.

Summary of Issue

At the Commission's August 1997, meeting in Santa Barbara, Mr. Tim J. Setnicka, Superintendent, of the Channel Islands National Park requested the Commission consider discussing available management options for marine resources in and around the Channel Islands National Park. The Commission agreed with Mr. Setnicka's request and instructed its staff to work with Mr. Setnicka to facilitate this discussion. This "discussion" will be a workshop (information gathering) format to receive input from a number of speakers with various points of view. Each speaker will be given approximately 10 minutes and then it will be opened up to the public for their comments.

No action is required at this time, but the Commission could decide to conduct additional "workshops" on marine resource management and/or request the Department to review the information presented and report to the Commission at a future meeting. This would be a first step in gathering information on a large policy issue which the Commission needs to address. Commissioners were provided with a copy of a report provided by the Sea Urchin Harvesters' Association and background information from the Channel Islands Marine Resource Restoration Committee.

Action

Executive Director Treanor introduced the item.

Tim Setnicka stated that many species in the waters surrounding the Channel Islands are declining. He recommended that the State consider zonal fishery management. He stated that species by species management is not effective. He suggested closures to fishing of 20 percent of the waters within the National Park.

Gary Davis presented slides comparing densities of various species in 1975, 1983, and

1996 in fished and unfished areas within the Channel Islands National Park. He stated that there should be areas in the ocean that are left in a natural state, creating a marine wilderness.

James Donlon was in agreement with the National Park Service regarding protection of the zones surrounding the Channel Islands. He stated that his organization also recommended that 20 percent of the Channel Islands National Park be established as a no take zone.

Bob Fletcher objected to the proposed no-fish zones and stated that the zonal management tool has not been tried in California. He maintained that more scientific study needed to be completed before implementing this proposal.

Tom Raftican indicated that United Anglers of Southern California also opposed the zonal management plan proposed. He agreed with Mr. Fletcher that more scientific knowledge is necessary before establishing additional marine protected areas.

Peter Halmay provided a handout regarding the sea urchin fishery. He also opposed the National Park's proposal.

Eric Hooper and John Guth opposed creation of a marine refuge around the Channel Islands National Park.

Deborah McArdle made a slide presentation and provided a handout regarding marine protected areas/refuges in California.

Zeke Grader suggested that the Department review the current marine reserves to evaluate their benefits; that for marine reserves to work, there needs to be good enforcement; and that there needs to be a scientific process for establishing marine reserves.

Locky Brown recommended a scientific plan for developing reserves instead of the piecemeal method currently employed.

Steve Rebuck opposed the proposed reserve. He stated it would lead to poaching. He stated that scientists should not become advocates.

Dr. Craig Barilotti stated there is no crisis in management of red sea urchin and there is no need for creation of a refuge.

Chris Miller stated that the proposed refuge would create a hardship for fishermen and create more pressure in other areas.

The following also opposed the proposed refuge: Harry Liquornik, Mike McCorkle, Sam Shrout, Gordon Cota, Bob Hay, Ken Bortolazzo, Jerome Betts, Bruce Harvey, Charles Igawa, James McClelland, Don Thompson, Bruce Steele, Steve Stickney, and Mark Manning.

President Thieriot thanked the National Park Service for its presentation.

Commissioner Boren pointed out that there are others besides users of the resources whose interests should be considered. He urged more dialogue on the issue and recommended a status report at a future meeting.

CONSENT CALENDAR

Items 20 through 24 have been placed on the Commission's consent calendar. Your staff knows of no opposition to these proposals at this time, other than as specified in this analysis. The Department has provided a recommendation on each of these items which calls for approval or modified approval by the Commission. Any item may be removed from the consent calendar by the Commission or upon the request of the Department or someone in the audience who would like to speak to that item. Your staff has prepared a summary of consent items which will be made available to the audience. One overall motion is appropriate for approval of these items.

Action

Executive Director Treanor introduced the consent calendar and asked if anyone in the audience wished to speak on any item. There was no response.

It was then:

MOVED BY MR. MCGEOGHEGAN, SECONDED BY MR. CHRISMAN, THAT THE FISH AND GAME COMMISSION HEREBY APPROVES ITS APRIL 2, 1998, CONSENT CALENDAR, ITEMS 20 THROUGH 24.

PASSED UNANIMOUSLY.

20. CONFIRMATION OF COMMISSION'S DECEMBER 4, 1997, EMERGENCY ACTION TO AMEND SECTION 7.50(b)(30), TITLE 14, CCR, TO REOPEN FISHING IN BUTT CREEK AND BUTT VALLEY RESERVOIR POWERHOUSE OUTFALL, PLUMAS COUNTY.

Summary of Issue

As background, on May 21, 1996, the Commission took emergency action to amend Section 7.50(b)(30), Title 14, CCR, to close fishing in Butt Creek and its estuary, Plumas County. The Department provided a status report on August 29, 1996, regarding PG&E's seismic work on Butt Creek Dam. PG&E indicated that the seismic work would take longer than originally planned; therefore, the Commission confirmed its emergency closure to make "permanent" the fishing closure. PG&E had received authorization to close access to Butt Creek Reservoir; and therefore, this fishing closure to the creek and "estuary" was necessary.

PG&E finished that seismic work on the dam in early December 1997 and indicated it would reopen public access on December 6. On December 4, 1997, the Commission took emergency action to amend Section 7.50(b)(30), Title 14, CCR, to reopen fishing in Butt Creek and Butt Creek Estuary, Plumas County. This item is to confirm that emergency action.

Commissioners were provided with a copy of the Department's Initial Statement of

FISH AND GAME CODE
SECTION 200-220

200. There is hereby delegated to the commission the power to regulate the taking or possession of birds, mammals, fish, amphibia, and reptiles to the extent and in the manner prescribed in this article.

No power is delegated to the commission by this article to regulate the taking, possessing, processing, or use of fish, amphibia, kelp, or other aquatic plants for commercial purposes, and no provision of this code relating or applying thereto, nor any regulation of the commission made pursuant to such provision, shall be affected by this article or any regulation made under this article.

201. Nothing in this article confers upon the commission any power to regulate any natural resources or commercial or other activity connected therewith, except as specifically provided.

202. The commission shall exercise its powers under this article by regulations made and promulgated pursuant to this article. Regulations adopted pursuant to this article shall not be subject to the time periods for the adoption, amendment, or repeal of regulations prescribed in Sections 11343.4, 11346.4, 11346.8, and 11347.1 of the Government Code.

203. Any regulation of the commission pursuant to this article relating to resident game birds, game mammals and furbearing mammals may apply to all or any areas, districts, or portions thereof, at the discretion of the commission, and may do any or all of the following as to any or all species or subspecies:

(a) Establish, extend, shorten, or abolish open seasons and closed seasons.

(b) Establish, change, or abolish bag limits and possession limits.

(c) Establish and change areas or territorial limits for their taking.

(d) Prescribe the manner and the means of taking.

(e) Establish, change, or abolish restrictions based upon sex, maturity, or other physical distinctions.

203.1. When adopting regulations pursuant to Section 203, the commission shall consider populations, habitat, food supplies, the welfare of individual animals, and other pertinent facts and testimony.

204. The commission has no power under this article to make any regulation authorizing or permitting the taking of:

(a) Any bird or mammal in any refuge heretofore or hereafter established by statute, the taking or possession of which shall be regulated pursuant to Sections 10500 to 10506, inclusive.

(b) Elk, the taking or possession of which shall be regulated pursuant to Section 332.

(c) Antelope, the taking or possession of which shall be regulated pursuant to Section 331.

(d) Any spike buck or spotted fawn. "Spotted fawn" means a young deer born that year which has spotted pelage. "Spike buck" means a male deer with unbranched antlers on both sides which are more than three inches in length.

Any regulation establishing a season to compensate for closure of an area due to extreme fire hazard shall be made pursuant to Section 306.

Any regulation setting a special hunting season for mammals, except deer, or game birds which have increased in number to such an extent that a surplus exists or which are damaging property or are overgrazing their range shall be made pursuant to Section 325.

205. Any regulation of the commission pursuant to this article which relates to fish, amphibia, and reptiles, may apply to all or any areas, districts, or portion thereof, at the discretion of the commission, and may do any or all of the following as to any or all species or subspecies:

(a) Establish, extend, shorten, or abolish open seasons and closed seasons.

(b) Establish, change, or abolish bag limits, possession limits, and size limits.

(c) Establish and change areas or territorial limits for their taking.

(d) Prescribe the manner and the means of taking.

206. (a) In addition to, or in conjunction with, other regular or special meetings, the commission shall, at least every three years, hold meetings in the first 10 days of August, October, November, and December for the purpose of considering and adopting revisions to regulations relating to fish, amphibians, and reptiles. The commission shall alternate the locations of the August and December meetings between Los Angeles or Long Beach and Sacramento, and the October and November meetings between San Diego and Redding or Red Bluff.

(b) At the August meeting, the commission shall receive recommendations for regulations from its own members and staff, the department, other public agencies, and the public.

(c) At the October and November meetings, the commission shall devote time for open public discussion of proposed regulations presented at the August meeting. The department shall participate in this discussion by reviewing and presenting its findings regarding each regulation proposed by the public and by responding to objections raised pertaining to its proposed regulations. After considering the public discussion, the commission shall announce, prior to adjournment of the November meeting, the regulations it intends to add, amend, or repeal relating to fish, amphibians, and reptiles.

(d) At the December meeting, the commission may choose to hear additional public discussion regarding the regulations it intends to adopt. At, or within 20 days after, the meeting, the commission shall add, amend, or repeal regulations relating to any recommendation received at the August meeting regarding fish, amphibians, and reptiles it deems necessary to preserve, properly utilize, and maintain each species or subspecies.

(e) Within 45 days after adoption, the department shall publish and distribute regulations adopted pursuant to this section.

207. (a) In addition to, or in conjunction with, other regular or special meetings, the commission shall hold meetings in the first 10 days of the months of February, March, and April at least once every three years for the purpose of considering and adopting revisions to

regulations relating to mammals. The commission shall alternate the location of the February meeting between Sacramento and Los Angeles or Long Beach. The commission shall alternate the location of the March meeting between San Diego and Redding or Red Bluff. The commission shall alternate the location of the April meeting between Sacramento and Los Angeles or Long Beach.

(b) At the February meeting, the commission shall receive recommendations for regulations from its own members and staff, the department, other public agencies, and the public.

(c) At the March meeting, the commission shall devote time for open public discussion of proposed regulations presented at the February meeting. The department shall participate in this discussion by reviewing and presenting its findings regarding each regulation proposed by the public and by responding to objections raised pertaining to its proposed regulations. After considering the public discussion, the commission shall announce, prior to adjournment of the March meeting, the regulations it intends to add, amend, or repeal relating to mammals.

(d) At, or within 20 days after, the April meeting, the commission may choose to hear additional public discussion regarding the regulations it intends to adopt. At, or within 20 days after, the meeting, the commission shall add, amend, or repeal regulations relating to any recommendations received at the February meeting regarding mammals that it deems necessary to preserve, properly utilize, and maintain each species or subspecies.

(e) Within 45 days after adoption, the department shall publish and distribute regulations adopted pursuant to this section.

208. (a) In addition to, or in conjunction with, other regular or special meetings, the commission shall hold meetings in June and August at least once every three years for the purpose of considering and adopting revisions to regulations relating to resident game birds.

(b) At the June meeting, the commission shall receive recommendations for regulations from its own members and staff, the department, other public agencies, and the public.

(c) At, or within 20 days after, the August meeting, the commission shall devote time for open public discussion of proposed regulations presented at the June meeting. The department shall participate in this discussion by reviewing and presenting its findings regarding each regulation proposed by the public and by responding to objections raised pertaining to its proposed regulations. After considering the public discussion, the commission, at, or within 20 days after, the August meeting, shall add, amend, or repeal regulations relating to any recommendation received at the June meeting regarding resident game birds that it deems necessary to preserve, properly utilize, and maintain each species or subspecies.

(d) Within 45 days after adoption, the department shall publish and distribute regulations adopted pursuant to this section.

209. (a) The commission shall determine and give notice of the date and location of the first meeting required to be held during a year by Sections 206, 207, and 208 at least 60 days prior to that first meeting. The commission shall give notice of any change in the date or location of that first meeting at least 30 days prior to the meeting date.

(b) The commission shall cause to be published the notice required in subdivision (a) in each newspaper of general circulation, as defined in Section 6000 of the Government Code, with an average daily circulation of 50,000 or more.

(c) The commission shall set the dates of its meetings in order to provide maximum time for public review of proposed regulations consistent with the proper management of the species or subspecies affected. All meetings required by Sections 206, 207, and 208 shall be open to the public and, to the extent feasible, held in state facilities.

210. (a) The commission shall provide copies of the regulations added, amended, or repealed pursuant to subdivision (e) of Section 206, subdivision (e) of Section 207, and subdivision (d) of Section 208 to each county clerk, each district attorney, and each judge of the superior court in the state.

(b) The commission and the department may do anything that is deemed necessary and proper to publicize and distribute regulations so that persons likely to be affected will be informed of them. The failure of the commission to provide any notice of its regulations, other than by filing them in accordance with Section 215, shall not impair the validity of the regulations.

(c) The department or the license agent may give a copy of the current applicable published regulations to each person issued a license at the time the license is issued.

(d) Notwithstanding any other provision of law, the commission and the department may contract with private entities to print regulations and other regulatory and public information. Printing contracts authorized by this subdivision and for which no state funds are expended are not subject to Chapter 2 (commencing with Section 10290) of Part 2 of Division 2 of the Public Contract Code, except for Article 2 (commencing with Section 10295) of Chapter 2.

211. (a) Material printed pursuant to subdivision (d) of Section 210 that contains advertisements shall meet all specifications prescribed by the department. The printed material shall not contain advertisements for tobacco products, alcohol, firearms and devices prohibited pursuant to Sections 12020, 12220, and 12280 of the Penal Code, or firearms not authorized by the commission as a legal method of sport-hunting, political statements, solicitations for membership in organizations, or any other statement, solicitation, or product advertisement that is in conflict with the purposes for which the material is produced, as determined by the commission. The printing contract shall include criteria to ensure that the public information provided in the publication is easy to reference, read, and understand.

(b) Neither the department nor the commission shall contract with private entities to print the materials described in subdivision (d) of Section 210 if the letting of those contracts will result in the elimination of civil service positions.

215. Every regulation of the commission made pursuant to this article shall be filed with the Secretary of State, and shall become effective at the time specified therein, but not sooner than the date of the filing.

217.5. (a) The department shall identify property it owns or manages that includes areas for sport fishing which are accessible to disabled persons.

(b) Commencing with the booklet of sport fishing regulations published by the commission in 1986, the availability of sport fishing areas, identified by the department as accessible to disabled persons under subdivision (a), shall be noted in the booklet of regulations, together with telephone numbers and instructions for obtaining a list of those areas from regional department offices.

217.6. Commencing with the booklet of sportfishing regulations published in 1987, the booklet shall also contain any human health advisories relating to fish which are formally issued by the State Department of Health Services or summaries of those human health advisories. The summaries shall be prepared in consultation with the State Department of Health Services.

218. Any regulation of the commission made pursuant to this article shall be subject to review in accordance with law by any court of competent jurisdiction.

219. Any regulation adopted pursuant to this article may supersede any section of this code designated by number in the regulation, but shall do so only to the extent specifically provided in the regulation. A regulation which is adopted pursuant to this section shall be valid only to the extent that it makes additions, deletions, or changes to this code under one of the following circumstances:

(a) The regulation is necessary for the protection of fish, wildlife, and other natural resources under the jurisdiction of the commission.

(b) The commission determines that an emergency exists or will exist unless the action is taken. An emergency exists if there is an immediate threat to the public health, safety, and welfare, or to the population or habitat of any species.

A regulation which is adopted pursuant to this section shall be supported by written findings adopted by the commission at the time of the adoption of the regulation setting forth the basis for the regulation.

A regulation adopted pursuant to this section shall remain in effect for not more than 12 months from its effective date.

220. (a) Any regulation of the commission added or amended pursuant to this article shall remain in effect for the period specified therein or until superseded by subsequent regulation of the commission or by statute.

(b) Notwithstanding this article, the commission may add, amend, or repeal regulations at any regular or special meeting if facts are presented to the commission which were not presented at the time the original regulations were adopted and if the commission determines that those regulations added, amended, or repealed are necessary to provide proper utilization, protection, or conservation of fish and wildlife species or subspecies.

Ecological Applications, 13(1) Supplement, 2003, pp. S117–S137

THE IMPACT OF MARINE RESERVES: DO RESERVES WORK AND DOES RESERVE SIZE MATTER?

Benjamin S. Halpern

Department of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara, California 93106 USA

Abstract. Marine reserves are quickly gaining popularity as a management option for marine conservation, fisheries, and other human uses of the oceans. Despite the popularity of marine reserves as a management tool, few reserves appear to have been created or designed with an understanding of how reserves affect biological factors or how reserves can be designed to meet biological goals more effectively (e.g., attaining sustainable fish populations). This shortcoming occurs in part because the many studies that have examined the impacts of reserves on marine organisms remain isolated examples or anecdotes; the results of these many studies have not yet been synthesized. Here, I review the empirical work and discuss the theoretical literature to assess the impacts of marine reserves on several biological measures (density, biomass, size of organisms, and diversity), paying particular attention to the role reserve size has in determining those impacts. The results of 89 separate studies show that, on average, with the exception of invertebrate biomass and size, values for all four biological measures are significantly higher inside reserves compared to outside (or after reserve establishment vs. before) when evaluated for both the overall communities and by each functional group within these communities (carnivorous fishes, herbivorous fishes, planktivorous fishes/invertebrate eaters, and invertebrates). Surprisingly, results also show that the relative impacts of reserves, such as the proportional differences in density or biomass, are independent of reserve size, suggesting that the effects of marine reserves increase directly rather than proportionally with the size of a reserve. However, equal relative differences in biological measures between small and large reserves nearly always translate into greater absolute differences for larger reserves, and so larger reserves may be necessary to meet the goals set for marine reserves.

The quality of the data in the reviewed studies varied greatly. To improve data quality in the future, whenever possible, studies should take measurements before and after the creation of a reserve, replicate sampling, and include a suite of representative species. Despite the variable quality of the data, the results from this review suggest that nearly any marine habitat can benefit from the implementation of a reserve. Success of a marine reserve, however, will always be judged against the expectations for that reserve, and so we must keep in mind the goals of a reserve in its design, management, and evaluation.

Key words: *marine reserves; reserve design; reserve effect; reserve size; trophic cascades.*

Introduction

Marine reserves (also called marine protected areas, no-take zones, marine sanctuaries, etc.) have recently become a major focus in marine ecology, fisheries management, and conservation biology. Interest stems in part from the realization that traditional forms of fisheries stock management are inadequate, as evidenced by the historical and recent collapse of many fisheries. In addition, traditional management methods such as maximum sustainable yield estimates are inadequate for addressing the multiple types of anthropogenic impacts on marine life such as over-fishing, certain fishing methods, pollution, coastal development, and other human-derived impacts. Marine reserves have been proposed as an efficient and inexpensive way to maintain and manage fisheries while simultaneously preserving biodiversity and meeting other conservation objectives as well as human needs (Plan Development Team [PDT] 1990, Ballantine 1992, Dugan and Davis 1993, Bohnsack 1996, Nowlis and Roberts 1997, Allison et al. 1998, Lauck et al. 1998).

Despite the popularity of marine reserves as a management tool, decisions on the design and location of most existing reserves have largely been the result of political or social processes (Jones et al. 1992, Agardy 1994, McNeill 1994); until very recently, little work has been done to understand or include biological considerations in reserve placement or design. A fair amount of recent work has attempted to try to understand and quantify the biological impact of marine reserves. However, these efforts have been scattered around the world and in the scientific literature, so the results are often not easily accessible to people trying to design marine reserves. Relatively little work has been done to assess the success of reserves in general (Roberts and Polunin 1991, 1993, Jones et al. 1992,

Manuscript received 27 September 1999; revised 1 March 2001; accepted 30 March 2001; feature accepted 21 February 2002. For reprints of this Special Issue, see footnote 1, p. S3.

Dugan and Davis 1993), and all of it has been anecdotal in nature. In an attempt to draw together all of these results, I have reviewed and synthesized the findings of marine reserve evaluations in order to assess the effectiveness of marine reserves. In particular, I evaluated how marine reserves have affected four biological measures (density, biomass, size, and diversity of organisms) within the reserves, and examined if reserve size influences the magnitude of these reserve effects. Specifically, I asked:

1) What are the impacts of marine reserves on the above four biological measures?

2) Is the magnitude of the effect of a reserve on biological measures related to the size of the reserve (i.e., does size matter)?

3) Does trophic structure change with the implementation of a reserve?

4) Does the goal of a reserve (e.g., fishery management vs. biodiversity conservation) influence how large a reserve needs to be?

5) What biases or problems exist in the current literature regarding reserve assessment and/or reserve design, and what can be done to remedy these problems?

Theoretical endeavors have produced some predictions for a few of these questions. Modeling efforts aimed at fisheries management have suggested that biomass of reproductively active fish (spawning stock biomass) should generally increase as a result of reserve protection (Polacheck 1990, DeMartini 1993, Quinn et al. 1993, Attwood and Bennett 1995, Man et al. 1995). Concomitantly, reserves are predicted to increase spillover of fishes to areas outside of the reserve, an effect that is likely to be positively correlated with higher density of fishes inside the reserve (Russ et al. 1992, Hockey and Branch 1994). Organism size and diversity are generally assumed to follow these trends as well, since reserve protection should allow for individual organisms to grow larger (i.e., not be fished out of the system once they reach a certain size) and may also provide protection for species that are normally fished to local extinction. This review will help assess the validity of these predictions.

No direct efforts have been made to evaluate how reserve size itself affects the impact of reserves on any of these biological measures, although it is usually assumed that bigger reserves will always be ''better.'' The literature on the theory of island biogeography (MacArthur and Wilson 1967; reviewed by Diamond and May 1976) predicts that species diversity should increase with area, and so larger reserves should contain more species. However, the theory of island biogeography does not address how reserve protection might influence species diversity at a particular location, and so few predictions can be made about how reserve size might affect the impact marine reserves have on species diversity. This review in particular addresses if reserve size affects the impact marine reserves might have on all four biological measures (density, biomass, size, and diversity).

Marine reserves are also predicted to lead to trophic cascade effects, in that protection from fishing may allow top predators to become more abundant in a reserve, which may in turn reduce the abundance of prey, releasing the subsequent trophic level from predation pressure, etc. (Steneck 1998; see also Sala et al. 1998). If this general pattern holds across reserves, then large increases in carnivore abundance and/or size should be associated with smaller differences or even reductions in prey populations.

Independent of the many predictions of the above models, most people simply assume that marine reserves provide the functions expected of them (such as increasing numbers of fish within and outside a reserve). Reserve success stories end up serving as the primary evidence for these assumptions, even though many examples exist where reserves did not provide the necessary functions. The main goal of this review is to evaluate the success of marine reserves in a quantitative way, and to assess what role reserve size plays in determining the magnitude of the reserve effect.

Methods

Source selection

This review addresses the biological impacts of marine reserves and the implications of these impacts for reserve design. I limited my literature search, therefore, primarily to ecological journals. Policy and management journals, which deal with issues such as cost-efficient design, selection criteria, prioritization schemes, etc., do not include biological data and so are not relevant to this review.

I searched for empirical research in which reserves were actually surveyed. Criteria for inclusion of a study in this review were that (1) data from both before and after the creation of the reserve or from inside and outside of a reserve were reported, (2) no known harvesting occurred within the marine reserve, and (3) the observations measured at least some of the biological variables of interest. Studies examining processes only inside a reserve were not included because they did not have a control site. Similarly, I omitted surveys concerning the impact of marine reserves on fishing effort because they did not address biological measures. Finally, I looked only at no-take reserves because it allowed me to exclude fishing effort as a possible factor affecting the impact of reserves. I included work from gray literature (e.g., conference proceedings, reports, lab bulletins, etc.) if it met my criteria. Using these criteria, I found 89 empirical studies of marine reserve effect that made 112 independent measures of marine reserves (i.e., some studies examined several reserves, and some reserves were examined by several different studies). Of these 89 studies, I was able to use 81 for qualitative analyses and 69 for quantitative analyses.

I also examined theoretical articles for predictions about how biological measures should respond to reserve protection, but only if a significant portion of the article addressed biological issues of marine reserve design. These articles often proposed models or offered reviews of specific issues (many of these I discussed in *Introduction*). Most management and policy literature addresses logistical, economic, or sociological aspects of marine reserves and was not included in this review.

Data extraction and formatting

To determine the size of a reserve, I considered only the part of the reserve that was fully protected (i.e., a no-take zone; in two cases it was a zone of no spearfishing). If the source paper did not mention the reserve size specifically, I used the World Conservation Monitoring Center's web site,[1] McArdle (1997), or communication with the authors of the studies to determine reserve size. I was unable to find sizes for five reserves and therefore only include them in my analyses of general reserve effect. The appendix lists the reserve sizes I was able to find.

Although the way in which data were reported varied among the studies of reserve effect, the type of data reported was fairly consistent. Studies examined the effect of marine reserves on the density, biomass, mean size, and diversity (measured as species richness) of organisms within the reserves, although few studies examined all four of these biological variables. The effect of the marine reserves on these measures was reported either as a qualitative trend (e.g., ''fish density was higher in the marine reserve'') or a quantitative difference (e.g., ''lobster biomass increased 250% since the date of inception of the marine reserve''). I recorded both of these types of data as a trend of the reserve having higher values than nonreserve areas. The latter example I also recorded as a numerical difference of 3.5 (i.e., 250% equals a 3.5-fold increase).

An overall trend and the mean for all numerical values were calculated for all species examined in a given study, regardless of the number of species in each study. In five cases (Moreno et al. 1984, 1986, Castilla and Duran 1985, Cole et al. 1990, MacDiarmid and Breen 1992), several species were examined but results were presented for only one or a few species. Overall values in these cases represent only the species with reported data. Since many studies only examined a single species, overall values can represent anywhere from one to several hundred species.

In separate analyses, I examined data by functional group when it was provided. The functional groups were invertebrates, herbivorous fishes, planktivorous/invertebrate-eating fishes, and carnivorous fishes (see Table 1 for fish family classifications). Data for families or species that did not fall into one of these functional groups (such as omnivores) were omitted since there were too few of these data to allow for separate statistical analyses. I treated each family (or species if the study only looked at a single or a few species) as a separate data point for analysis. This method avoided redundancy; many studies collected data for only one functional group, and if I were to sum all data for a functional group from a study and then calculate a mean, the functional group results would look very similar to the overall values. Calculating grand means of the functional-group data allowed for a more accurate picture of the effect reserve protection can have on a particular family or species, since each family or species value was recorded as a separate datum and not summed across all organisms within the same functional group within a study.

I extracted qualitative and quantitative data from the text, tables, and bar graphs presented in the articles. While data extraction from text and tables was straightforward, data extracted from graphs were slightly less precise, since these values were estimated by measuring the height of the bars against the *y*-axis. I tabulated data regardless of the reported significance values. Overall values of differences between reserve and nonreserve areas were often provided, or I calculated them

TABLE 1. Fish families and their functional group classifications.

Herbivores	Planktivores/ invertebrate eaters	Carnivores
Acanthuridae	Anthiidae	Batrachoididae
Kyphosidae	Apogonidae	Bothidae
Pomacentridae	Atherinidae	Carangidae
Scaridae	Balistidae	Carcharhinidae
Siganidae	Belonidae	Centracanthidae
Zanclidae	Caesionidae	Centropomidae
	Chaetodontidae	Coracinidae
	Clupeidae	Gadidae
	Dasyatidae	Haemulidae
	Diodontidae	Letherinidae
	Gerreidae	Lutjanidae
	Gobiidae	Muraenidae
	Holocentridae	Pomatomidae
	Labridae	Sciaenidae
	Lagocephalidae	Scombridae
	Myliobatidae	Scorpaenidae
	Mullidae	Serranidae
	Nemipteridae	Soleidae
	Pomacanthidae	Sparidae
	Syngnathidae	Sphyranidae
	Tetraodontidae	

Notes: These classifications are natural groupings based on those made in the reviewed literature. Mugilidae, Elopidae, Ariidae, Ephippidae, Cichlidae, and Blennidae, which were observed in a few of the studies reviewed here, do not fit well into a single category and so are not included in functional group analyses. They are included in overall values and analyses.

[1] URL: 〈http://www.wcmc.org.uk:80/marine/data/〉

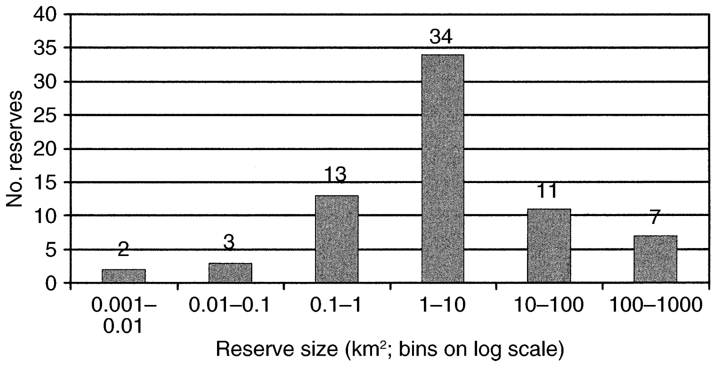


FIG. 1. Sizes of the reserves reviewed in this study. Reserve size is in square kilometers and is binned on a log scale. The range of reserve sizes is 0.002–846 km^2.

as the mean of the summed values for all groups or species listed. For example, Roberts (1995) lists the overall density and biomass for fish inside and outside the marine reserve in Saba, Netherland Antilles, as well as density values for several families of fish. I used the overall totals to calculate differences in biological measures as a result of reserve protection, and then calculated values for each family and averaged those to give functional group differences.

Because overall values integrate across all species studied, an extremely abundant species can disproportionately influence these overall values. For example, Cole et al. (1990) report that all but one species had higher density inside the reserve compared to outside. The one species that was very abundant, however, was much more numerous outside the reserve, and so the mean overall value ends up indicating lower density levels as a result of reserve protection. Analysis of the data at the functional group level as well as for overall values allowed this sort of ''single-species'' influence to be isolated. Although total density for all fish was lower inside the reserve (the entire community value), functional group analysis showed that most species had higher values inside the reserve.

Data from relevant work were occasionally described in articles that I could not obtain (Ayling and Ayling 1986, as cited in Jones et al. 1992; Spanier 1984 and Hunt et al. 1991, both cited in Childress 1997); I included these data as separate entries in my database, but only as trends (except for one datum). All studies and data used in my analyses are listed in the appendix.

Most studies compared inside vs. outside a reserve at a single point in time, and so I report these data as the ratio of these values (inside divided by outside). Several studies were able to survey an area before and after a reserve was put in place; I present these data as the ratio of after divided by before. A few studies had both before/after and inside/outside (for reference) data (Alcala 1988, Russ and Alcala 1989, 1996, 1998*a*, *b*, Alcala and Russ 1990, Bennett and Attwood 1991, Dufour et al. 1995, Edgar and Barrett 1999). For these cases, I report values as the ratio of after to before, adjusted by the difference in the reference (outside) values over the same time period. Occasionally data were collected after protection of a marine reserve broke down (Davis 1977, Russ and Alcala 1996, 1998*a*). To standardize these results with the rest of the data, I report these values as if the effect were reversed. In other words, if density of a fish dropped with the loss of protection, I recorded the reserve as increasing the density of that fish.

Ratios greater than 1 represent higher levels of a biological measure within a reserve relative to nonreserve areas, while ratios between zero and one represent lower levels. If a biological measure began at or went to zero, I was unable to create a ratio and was therefore unable to use these data. To normalize the distribution of the ratios, I log-transformed the values. I use these log ratios for all analyses. In the end I back transformed ratios to aid in interpretation of the results. A reported ratio of 2.5 means that the value inside a reserve or after the establishment of a reserve was 2.5 times (or 150%) higher relative to outside (or before) the reserve.

In a few cases the trend was reported as not statistically significant, but I still used the data provided to calculate ratios. In these cases I recorded the trend as no difference but used the ratio for calculations of reserve and size effects on biological measures. For the majority of these cases the nonsignificant difference is in a negative direction; therefore, using these values can only add a slight bias against finding a positive reserve effect.

In seven cases (see Appendix), data from several noncontiguous reserves were presented as a single value. I treated these values as representing a single reserve of the summed sizes of the reserves. In only one case was the total size >30 km^2, and so this method should not create a bias for large reserves in my analyses of reserve size effects.

Several studies made multiple measurements in categories I did not consider in this review, such as by season (n = 2), depth (n = 3), habitat (n = 2), size classes (n = 1), or for several sites within a reserve (n = 6). In these cases, I averaged the values into a single value. When data for multiple years were presented, I

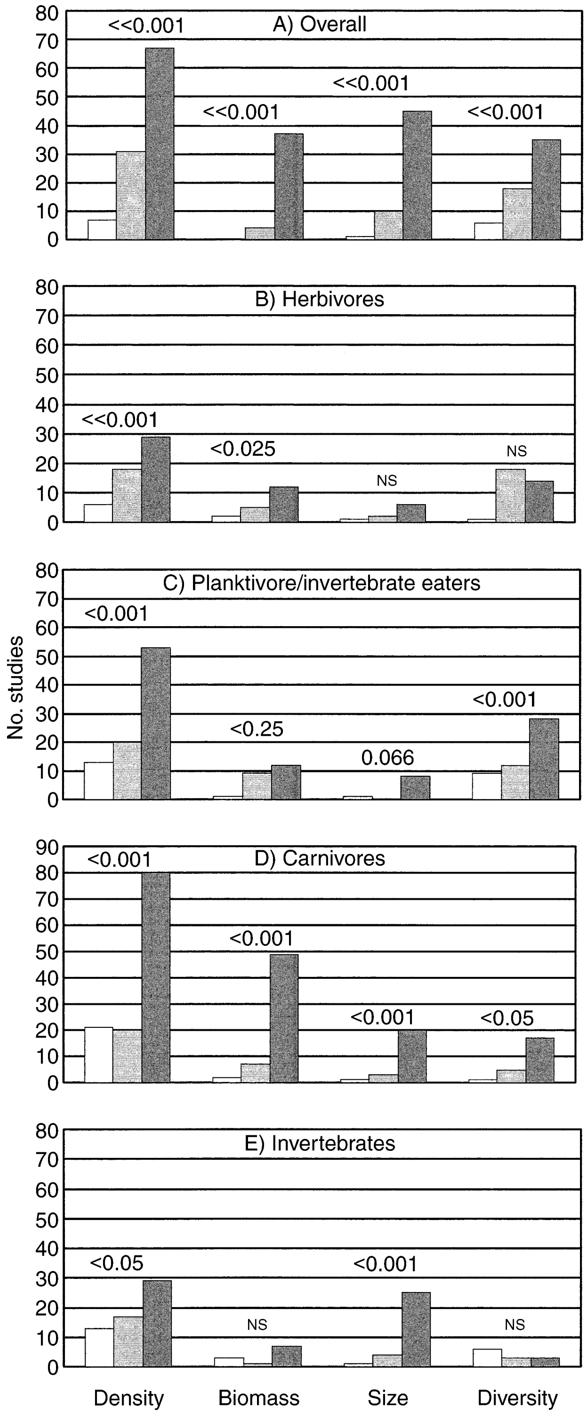


FIG. 2. Differences in biological measures (density [no./area], biomass [mass/area], mean size of organism, and diversity [total species richness]) between inside a reserve and outside a reserve (or after vs. before) for all organisms (A) and for each functional group (B–E). The numbers of independent reserve measurements that were associated with each trend are plotted for each biological measure: white bars represent lower values inside the reserve, gray bars represent no difference between reserve and nonreserve areas, and dark bars represent higher values inside the reserve. *P* values above the bars are significance values for chi-square tests values for chi-square tests of differences between frequencies among observations (null hypothesis: no difference in frequency); NS, not significant.

used only the data for the final year to allow for the longest time of protection and minimize the likelihood of a time effect (see *Discussion*). If reserve protection was initiated during the course of a study, then the data were treated as a before/after case.

In a few cases I needed to make minor calculations to make reported data congruent with the other studies. For example, if only a range of differences in some value was reported, I used the median of this range to approximate the mean difference. In two cases, only abundance values were given, with no reference to the area surveyed or the effort expended (Hunt et al. 1991; cited in Childress 1997, and Grigg 1994). I used these data to create ratio values, even though they might not accurately reflect the actual density of fish within the reserves. All other density values are per area or per effort.

A final difficulty arose in cases where only trends were reported and some species or families showed one trend while others showed a different trend. This occurred only three times (Duran and Castilla 1989, Bennett and Attwood 1991, Watson and Ormond 1994). In these cases, I used the trend for the majority of the species or families for overall values. For example, Watson and Ormond (1994) reported that 15 species had greater density inside the reserve, 34 showed no difference, and two showed lower density. I recorded this as a trend of no difference for overall density, even though many species did have greater numbers inside the reserve.

RESULTS

General descriptions of reserves studied

Reserve size varied over six orders of magnitude (see Fig. 1). Mean reserve size was 44.1 km^2, although half of the reserves were between 1 and 10 km^2 and the median reserve size was 4.0 km^2. The largest reserve (which was actually a collection of reserves) was 846 km^2; the smallest reserve was 0.002 km^2.

The number of species surveyed in each study also varied widely, but the majority of studies fell into one of two categories: almost half of the measurements were of five or fewer species, and almost half were of 50 or more species.

The distribution between studies conducted in tropical climates and those conducted in temperate climates was fairly equal. Forty-one percent of studies were conducted in temperate regions and the rest were conducted in tropical areas. However, nearly all of the studies looked at organisms associated with reefs—coral reefs for tropical regions and rocky reefs and intertidal zones for temperate areas (although other

←

TABLE 2. Mean squares and F ratios for one-way ANOVA tests of the association of mean reserve size and the three trend categories (less than, no difference, greater than) for each biological measure in each functional group.

	O			C		
Effect	df	MS	F	df	MS	F
Density	2, 97	2528.1	0.179	2, 116	2821.9	0.817
Biomass	2, 38	204 465.0	11.084	2, 53	610.8	0.044
Organism size	2, 49	594.8	0.068	2, 24	1520	0.205
Diversity	2, 56	3798.3	0.291	2, 23	119.3	1.342

Notes: P values for all cases are >0.07, except for overall biomass ($P = 0.002$), suggesting that there is no effect of reserve size in qualitative changes associated with reserve establishment. Abbreviations: O = overall, C = carnivores, H = herbivores, P/I = planktivores/invertebrate eaters, and I = invertebrates.

†Only two trend categories were available for these tests.

habitats such as seagrass beds existed within these reserves).

Qualitative results

Effect of marine reserves on biological measures.—Overwhelmingly, reserves were associated with higher values of density, biomass, organism size, and diversity of species for overall trends and for all four functional groups (Fig. 2). Invertebrate biomass and size were the only exceptions. Moreover, few reserves showed lower levels for any biological measure. This pattern is particularly striking for the analysis of all species combined (overall group; Fig. 2A): 63% of reserves had higher density (Chi-square test, $P \ll 0.001$), 90% of reserves had higher biomass ($P \ll 0.001$), 80% of reserves had larger organisms ($P \ll 0.001$), and 59% of reserves had higher diversity ($P \ll 0.001$). Only a small minority of reserves had lower values for these biological measures (7%, 0%, 2%, and 10% of reserves had lower density, biomass, organism size, and diversity, respectively). Reserves in general, therefore, usually had higher values, less often had no effect, and rarely were associated with lower values of the four biological measures.

Results are similarly striking when analyzed by functional group. For carnivorous fishes (Fig. 2D), 66% of reserves had higher density ($P \ll 0.001$), 84% of reserves had higher biomass ($P \ll 0.001$), 83% of reserves had larger organisms ($P < 0.001$), and 74% of reserves had higher diversity ($P < 0.05$). Reserves rarely were associated with lower values for any measure for carnivores; lower values occurred in only 3–17% of the cases (Fig. 2D). For planktivorous and invertebrate-eating fishes (Fig. 2C), 62% of reserves had higher density ($P \ll 0.001$), 55% of reserves had higher biomass ($P < 0.025$), 55% of reserves had higher diversity ($P < 0.005$), and 89% of reserves had larger organisms ($P = 0.066$). Although the difference in the trend for size of planktivorous fishes is not quite statistically significant, all but one of the reserves were associated with larger such organisms. For the other biological measures, only 5–18% of the reserves had lower values (Fig. 2C).

Herbivorous fishes showed similar patterns (Fig. 2B): 53% of reserves had higher density ($P < 0.01$) and 63% of reserves had higher biomass ($P < 0.05$). No difference existed between reserves and nonreserves for herbivore size or diversity; however, there was only one case of a lower value for both variables within reserves and six of nine cases showed positive differences in herbivore size. Therefore, herbivore size and diversity are usually higher or unchanged as a result of reserve protection. Herbivore density and biomass were lower in only 13% and 11% of the reserves, respectively.

Finally, for the invertebrate functional group (Fig. 2E), 50% of the reserves had higher density ($P < 0.05$) and 83% had larger organisms ($P < 0.001$), but biomass and diversity were not statistically different between reserve and nonreserve areas. Sample size for these latter two categories was fairly small ($n = 11$ for biomass and $n = 12$ for diversity), and so it is difficult to draw robust conclusions.

In summary, most of the biological measures were higher inside reserves. The next most common result was no difference from the non-reserve conditions. Rarely did reserves have lower values for density, biomass, size, or diversity, both overall and within functional groups.

The role of reserve size in determining reserve effect

I also used the qualitative data to investigate whether reserve size influences the trends seen in the previous section. For instance, were reserves that showed the largest differences more likely to be larger reserves? In all cases but one, the mean size of reserves for each of the three trend categories (less than, no difference, and greater than) for both overall and functional group categories were statistically indistinguishable (one-way ANOVA, $P \leq 0.08$ for all cases; see Table 2). This result implies that the proportional effect of a reserve is independent of reserve size.

The only case where reserve size appeared to have an effect was for overall biomass. In this case, reserves were never associated with lower biomass levels (a trend of ''less than''). The mean size of a reserve in the no difference category was larger than the average reserve size in the ''greater than'' category (Tukey test, $P < 0.05$), but one of the three reserves in the no

TABLE 2. Extended.

P/I			H			I		
df	MS	F	df	MS	F	df	MS	F
2, 81	30.9	0.180	2, 51	67.2	0.501	2, 53	12 327	1.525
1, 17	170	2.601†	2, 17	92.3	1.456	1, 10	360.3	2.068†
1, 9	24.3	1.193†	2, 9	140.6	3.995	2, 28	256.3	1.156
2, 44	377.6	2.177	2, 30	157.5	0.792	2, 11	14 282	0.733

difference category was nearly an order of magnitude larger than all other reserve sizes.

Quantitative results

Functional group response to reserve establishment.—As expected, mean values of ratios for all biological measures in each functional group, except invertebrate biomass and size, are significantly greater than zero (two-tailed Student's t test, $P < 0.025$ for all cases) indicating a consistently positive effect of reserve establishment on density, biomass, size of organism, and diversity (Table 3). This pervasive positive effect can be seen clearly in Figs. 3–7, where results for each reserve are plotted against reserve area. Nearly all points in all figures lie above the log ratio = 0 line, indicating that values are almost always higher inside of reserves (or after reserve protection).

The two exceptions to this are invertebrate size and biomass. Invertebrate size inside reserves is significantly less than zero (two-tailed Student's t test, $P < 0.005$), and invertebrate biomass is indistinguishable from zero (two-tailed Student's t test, $P = 0.053$), indicating that reserves may lower invertebrate size and have little effect on invertebrate biomass. However, invertebrate biomass values were highly influenced by extremely bimodal data and invertebrate size values were skewed by a single low datum (see Fig. 7). Removal of this single datum leads to higher mean size values roughly equal to those for all other functional groups, ~20% (a 1.2-fold increase). I discuss these factors in greater detail in the *Discussion.*

To determine if marine reserves affect functional groups differently, I tested if ratio values for density, biomass, size of organism, and diversity were different from each other. In all cases but two, ratio values of the functional groups were not statistically different from each other or from overall values (one-way ANOVA, $P > 0.13$ for all cases excluding the two excep-

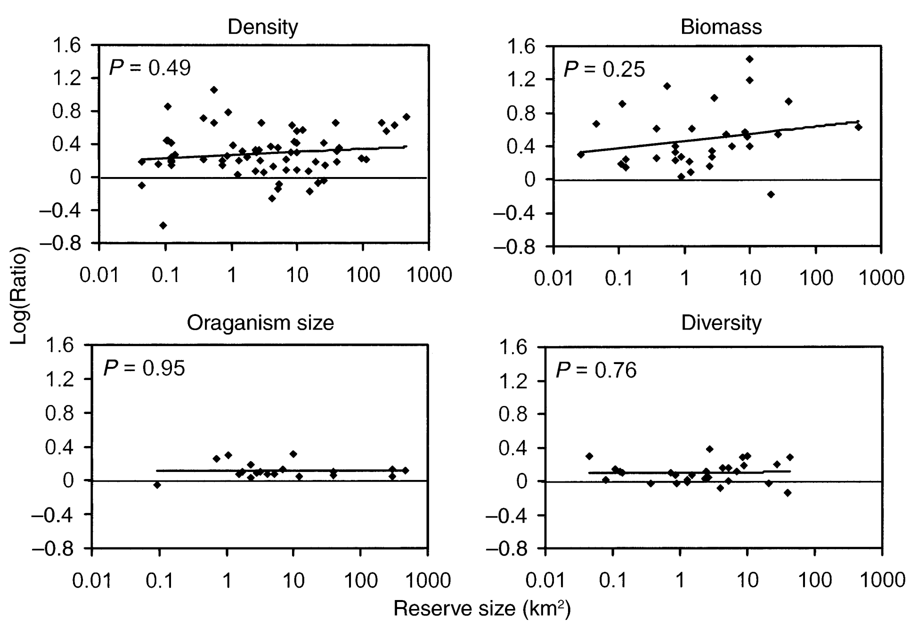


FIG. 3. Log difference ratios (inside a reserve vs. outside, or after a reserve vs. before) for each biological measure for overall values as a function of reserve size. Data are plotted as the log of the ratio vs. the log of reserve size. Because the ratio is log-transformed, lines drawn at log ratio = 0 show where reserves had no effect. Points above this line represent values greater than zero for the biological measure; points below the line represent values less than zero. In all cases except invertebrate biomass, log ratio values were significantly different from zero (Table 2). The slopes of all regression lines are not significantly different from zero (P values for linear regression analyses are in the upper left corner of each plot), indicating that reserves of all sizes showed similar proportional differences to nonreserve areas.

TABLE 3. Mean ratios of each biological measure (value inside the reserve divided by the value outside of the reserve or before the creation of the protected area), for each functional group and for all trophic groups together.

	O	C	P/I	H	I
Density	1.91 ± 0.28***	2.21 ± 5.63*	1.85 ± 0.56***	2.39 ± 2.67**	2.04 ± 6.15*
Biomass	2.92 ± 0.92***	3.12 ± 1.23***	2.38 ± 2.19**	3.33 ± 4.82**	0.25 ± 2.23
Organism size	1.31 ± 0.07***	1.31 ± 0.10***	1.23 ± 0.13***	1.52 ± 0.36**	0.80 ± 0.17***
Diversity	1.23 ± 0.07***	2.40 ± 0.43***	1.35 ± 0.37***	1.39 ± 0.27***	1.08 ± 0.22**

Notes: Values are presented as the mean (calculated from the log-transformed data, then back transformed), plus or minus the standard error (calculated from the nontransformed data). Invertebrate biomass and organism size and herbivore organism size all have six or fewer cases. Abbreviations: O = overall, C = carnivores, H = herbivores, P/I = planktivores/invertebrate eaters, and I = invertebrates. P values for two-tailed Student's t tests, testing if the mean values are equal to zero, are as follows: * $P < 0.05$, ** $P < 0.025$; *** $P < 0.001$. For invertebrate biomass, $P = 0.053$.

tions). The two exceptions are invertebrate biomass, which had lower mean values inside (or after) reserves (one-way ANOVA, $P < 0.025$), and carnivore diversity, which had much higher values than other groups (one-way ANOVA, $P < 0.0001$).

Interestingly, these results do not show a consistent pattern indicative of trophic cascades, where higher densities or biomass of carnivores would be matched by decreases in prey functional groups. In the discussion, I offer possible explanations for why trophic cascades were not obviously present here.

Effects of reserve size

Figs. 3–7 show the log of the ratio for each biological measure plotted against reserve size for overall values and for each functional group. The slopes of the regressions for all measures in all functional groups vs. reserve size are not significantly different from zero (linear regression analysis, $P > 0.12$ for all cases; see figures for exact P values), indicating that reserve size has no apparent impact on proportional differences. There were only four data points for herbivore size, and so regression analysis was not possible for this case. Thus, the relative impact of reserves on all biological measures in each functional group was significantly positive, and this relative impact appears to be independent of reserve size. I discuss the implications of this in the *Discussion.*

DISCUSSION

These results demonstrate that reserves are associated with higher values of density, biomass, organism size, and diversity for overall values as well as for all functional groups. This is strong support for the many claims made that marine reserves ''work.'' The results of this study also support the predictions of many fisheries models; reserve protection should increase bio-

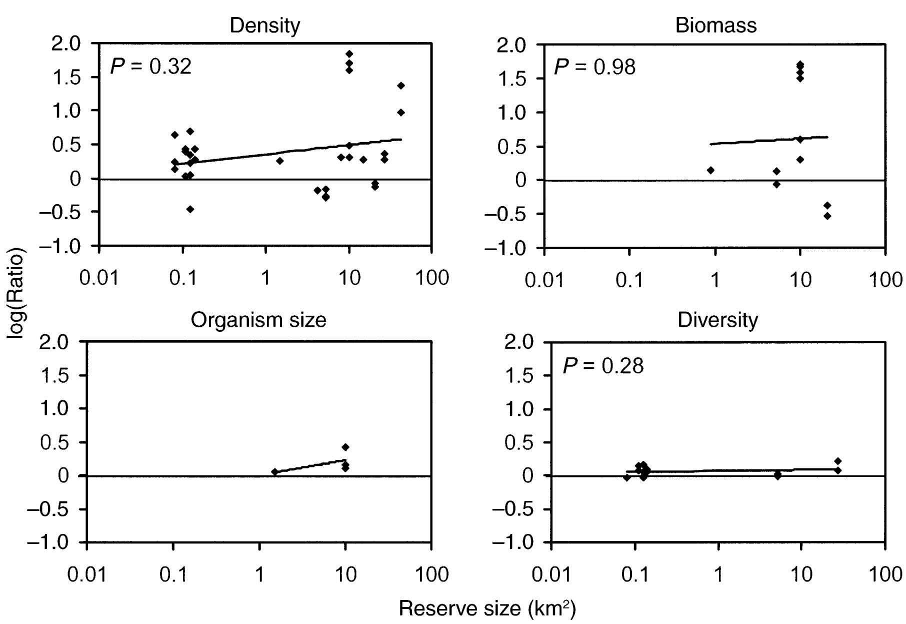


FIG. 4. Log difference ratio of each biological measure for herbivores as a function of reserve size. See Fig. 3 legend for explanation of the graphs. No P value is reported for organism size since there were too few data to perform a regression analysis.

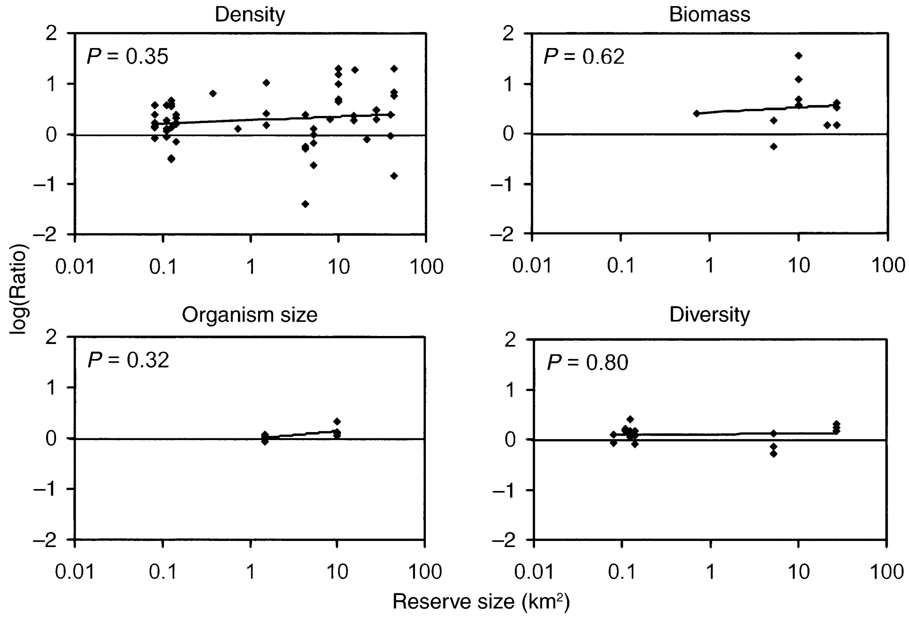


FIG. 5. Log difference ratio of each biological measure for planktivore/invertebrate eaters as a function of reserve size. See Fig. 3 legend for explanation of the graphs.

mass (Polacheck 1990, DeMartini 1993, Quinn et al. 1993, Man et al. 1995) and density (which is probably correlated to the spillover of fish to nonreserve areas; Russ et al. 1992, Hockey and Branch 1994) within a reserve. This is an encouraging conclusion in that at least some of the fishery and conservation expectations for current and future marine reserves have been met and can be realized.

These results also provide some guidelines for the magnitude of change in biological measures we can expect as a result of marine reserve protection. On average, creating a reserve appears to double density, nearly triple biomass, and raises organism size and diversity by 20–30% relative to the values for unprotected areas (see overall values in Table 3). It is important to remember, however, that these values have

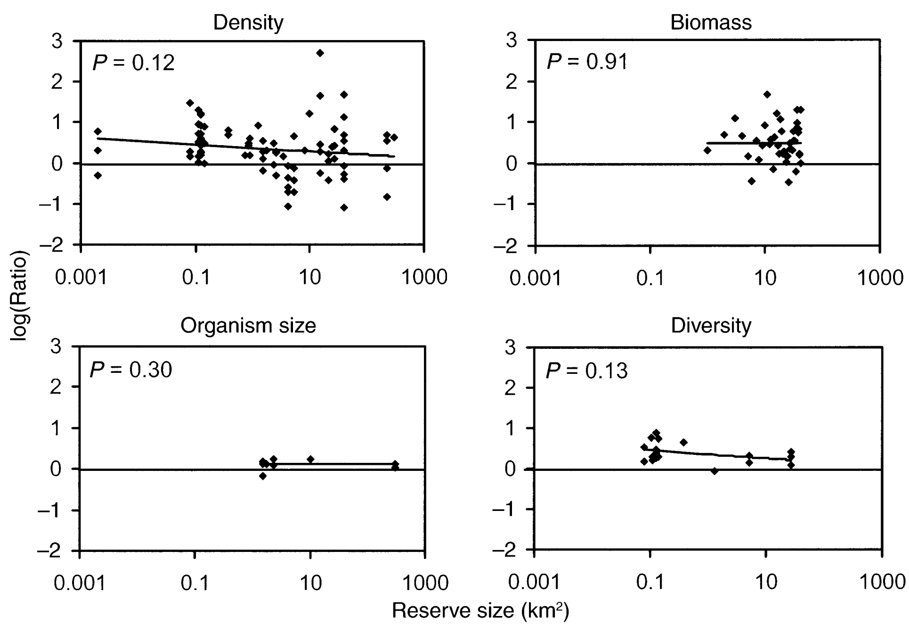


FIG. 6. Log difference ratio of each biological measure for carnivores as a function of reserve size. See Fig. 3 legend for explanation of the graphs.

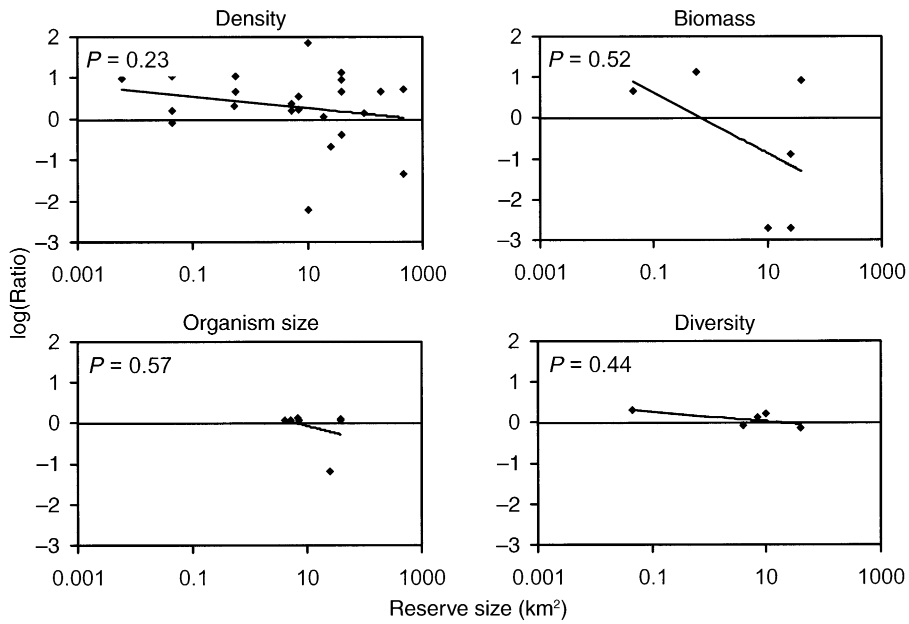


FIG. 7. Log difference ratio of each biological measure for invertebrates as a function of reserve size. See Fig. 3 legend for explanation of the graphs.

considerable variance and cannot be used to predict how a specific reserve will affect particular organisms and communities.

The results for invertebrates are less clear than for the other functional groups, but nevertheless do not detract from the general results. Invertebrate density trends and numerical values were predominantly positive, as was the case for the other functional groups. The invertebrate size results might at first glance appear to be contradictory; qualitative results showed that a vast majority of reserves held larger organisms while quantitative data imply that invertebrates are generally smaller in reserves. As was mentioned in the *Results*, however, the quantitative data were highly influenced by a single datum; removal of that datum led to new mean size values roughly equal to those for all other functional groups, about 20% higher inside the reserves. For invertebrate diversity, analysis showed that reserves were equally likely to be associated with lower, no difference, or higher trend values. However, sample size was small and the quantitative value was significantly positive, indicating that, on average, diversity will be higher inside reserves. Invertebrate biomass was lower within reserves, but as already described, these data were extremely bimodal, with reserves leading to either much higher or much lower levels of biomass. For the most part, the high values came from studies on lobsters and exploited intertidal invertebrates, while the lower values were from measurements of urchin biomass levels, which dropped within a reserve when numbers of urchin-feeding fishes increased. The implication here is that, for invertebrate biomass in particular, the effect of reserve protection will depend in part on the exploitation level of the invertebrate and its position in the food chain. I discuss below other ways in which the organisms being studied might impact the way in which reserves are perceived to perform.

It is also important to distinguish between how diversity is affected by reserve protection as distinct from the other three biological measures. Diversity in this review is actually species richness, which is not measured per unit area or effort, as are density and biomass. While it is quite possible for both small and large reserves to have the same initial values of density or biomass (e.g., 2 fish/m^2), larger reserves almost always initially contain more species than smaller reserves. Therefore, finding equal proportional increases in diversity for small and large reserves actually indicates a greater absolute increase in species numbers for the larger reserve. Furthermore, a single individual of a new species has a large impact on species richness measures, whereas a single individual has little impact on overall density, biomass, or organism size. Larger reserves are more likely to contain rare species simply because they encompass a greater area. In addition, diversity values will be somewhat dependent on the effort used to measure them; a long search will more likely produce a rare species than a short search. However, effort was not standardized in any way between studies.

A surprising result of this review is that the relative magnitude of the effect of a reserve on a biological measure appears to be independent of reserve size. A small reserve can double biomass per unit area just as likely as a large reserve can. This result holds even for extremely small reserves; for example, reserves in both St. Lucia (0.026 km^2) and Chile (Las Cruces: 0.044 km^2) were associated with significantly larger values in the biomass and size of the organisms within the reserve compared to nonreserve areas (Castilla and Bustamante 1989, Roberts and Hawkins 1997). The reserve in St. Lucia is particularly noteworthy because even large, mobile fishes seemed to benefit from the small reserve, suggesting that small reserves can work even for mobile organisms. Furthermore, many of the small reserves were located haphazardly, yet still positively affected the organisms within them. If small reserves are more strategically placed, for example on spawning grounds or along migratory routes, their impact may be even greater.

When considering the results of this review it is extremely important to keep in mind the distinction between absolute and relative effects of reserve protection. Even small reserves appear to be able to increase density, biomass, size, and diversity of organisms, and small and large reserves can show the same proportional differences relative to nonreserve areas, but the absolute impacts of small and large reserves will be very different. For example, doubling fish numbers in a small reserve from 10 to 20 fish is substantially different from doubling the fish numbers in a large reserve from 1000 to 2000 fish, even though the relative change in density might be the same for both reserves. The goals of reserve and fishery managers often include some minimum benefit level from reserves (e.g., total catch outside the reserve, all species present and abundant enough to be self-sustaining, etc.), goals that may not be achieved if only proportional differences are considered.

Small reserves may also be insufficient for several other reasons. Alone, small reserves may not be able to provide significant export functions. This review does not examine the possibility that reserves serve as sources for unprotected areas (sensu Pulliam 1988), even though it is often assumed and expected that they provide this service. Models have addressed how current regimes might influence dispersal (e.g., Roughgarden et al. 1988, Roberts 1997), but only a few studies have tried to infer or measure the impact of reserves on reproductive output (Davis 1977, Davis and Dodrill 1980, Polacheck 1990, Stoner and Ray 1996, Sluka et al. 1997, Edgar and Barrett 1999; all suggest that reproductive output can be higher in reserves). An increase in numbers or size of organisms in a reserve will obviously increase reproductive output, but small reserves will only be able to increase reproductive output a small amount relative to target areas. For reserves to serve as larval sources they must be large enough to sustain themselves as well as supply the rest of the target areas.

Another potential drawback of small reserves is their susceptibility to catastrophic events. For example, if an oil tanker runs aground near a small reserve, it is likely that the entire reserve will be impacted by the spill. If the accident occurred near part of a large reserve, on the other hand, it is possible that some of the reserve would escape harm. The unaffected part of the reserve could considerably, then, aid in the recovery process of the damaged region.

It is also possible that very large reserves (e.g., $>$500 km^2) might provide proportionally larger values when evaluated by density, biomass, etc. If fish within a reserve use several habitats throughout their life histories, it may require a very large reserve to encompass and protect all life stages adequately. This review would most likely not be able to detect a size threshold effect such as this, since only seven of the reserves studied covered $>$50 km^2, and the only one $>$460 km^2 came from pooled data from a collection of seven smaller reserves. Furthermore, nearly three quarters of all the reserves studied covered $<$10 km^2 (see Fig. 1). Such shortcomings in the data leave open the possibility that large reserves affect biological measures in a way not detectable here. While it would be desirable to test how such a large reserve would affect such measures, the logistics of such studies would be very difficult.

An important variable not analyzed here is the role that the length of protection plays in determining the magnitude of a reserve effect. Examples exist where the magnitude of the reserve effect increased over time (e.g., Watson et al. 1996, Russ and Alcala 1998*a*, *b*). Conan (1986) described how lobster biomass initially increased over several years but then receded to original levels. In all of these cases, results would have been different had population surveys been made at a single point in time (or over a relatively brief period of time), as they were in most of the studies I reviewed here. It is difficult to determine, therefore, if the populations had actually reached equilibrium at the time of measurement. Furthermore, the impact of a reserve is certainly not instantaneous, but little is known about how long it takes for a population to reach equilibrium, or even if it ever does. I address in depth the role that length of protection plays in determining the effect of marine reserves elsewhere (Halpern and Warner 2002).

Many other variables could also influence the impact of reserves on the biological resources contained within them. Species composition (PDT 1990, Carr and Reed 1993, Ballantine 1992, 1995, 1997, Dugan and Davis 1993, Tegner 1993, Rowley 1994), the fishing intensity around the reserve (Polacheck 1990, Russ et al. 1992, Carr and Reed 1993, Rowley 1994, Nowlis and Roberts 1997), adult mobility or home range size of fish within the reserve (Kramer and Chapman 1999), and the types and quality of habitats both inside and outside the reserve (Salm and Clark 1989, Hockey and Branch 1994, Agardy 1995, Nilsson 1998) have all been proposed as variables that could be important in determining how an organism responds to reserve protection. These sorts of observations were usually not reported in the empirical studies on marine reserves I used, and so I was unable to evaluate them here. However, these other factors should certainly be considered when setting goals and expectations for marine reserves.

Despite that many empirical studies found trophic cascade effects as a result of marine reserve protection (Kenya: McClanahan and Muthiga 1988, McClanahan and Shafir 1990, McClanahan 1994, 1995, 1997, Watson and Ormond 1994; Chile: Castilla and Duran 1985, Duran and Castilla 1989; Mediterranean: Sala et al. 1998*a*), this pattern did not emerge from my large-scale analyses. Instead, the densities of invertebrates, herbivorous fishes, planktivorous/invertebrate eating fishes, and carnivorous fishes all increased almost exactly the same amount (see Table 3). A possible explanation for this is that trophic cascades appear to be more likely to occur when only a small subset of a community is observed (Polis and Strong 1996). For example, in Kenya (e.g., McClanahan and Shafir 1990) the trophic cascade occurred between humans, triggerfish (Balistidae) and a few species of sea urchins, and was not evident in other families of fish and species of urchins that were studied. Similarly, in Chile (Castilla and Duran 1985, Duran and Castilla 1989) the cascade occurred between humans, a single gastropod, a single mussel, and algae. Thus trophic cascades may be masked when entire communities are measured. In the study by McClanahan and Shafir (1990), total fish densities as well as densities for four fish families (Labridae, Balistidae, Diodontidae, and Lagocephalidae) and urchins were measured. Urchin densities were nearly 200 times higher outside the reserve, while Balistid density was nearly 10-fold greater inside the reserve, exemplifying a classic trophic cascade. When all four fish families were considered (all are planktivorous fishes/invertebrate eaters), fish densities dropped to only 28% higher inside the reserve, obscuring the trophic cascade. When family or species results are incorporated into an entire functional group, as was the case here, trophic cascade effects can often become muted.

Empirical tests of the effect of reserve size are needed to test the robustness of the results suggested here. To date, only one study (Edgar and Barrett 1999) has tried to assess empirically the potential effects of marine reserve size on biological attributes of species contained within the reserves. They studied four reserves in Tasmania, three of which were $\sim$0.6 km^2 and a fourth that was about 7 km^2. The largest reserve showed many significant differences relative to nonreserve areas, while the smaller reserves had only a few notable differences. For example, in the large reserve, overall fish size, density of large fish, abalone size, size of crayfish, mean plant cover, and species diversity of fish, invertebrates, and algae all increased significantly compared to control sites. In the other three sites, significant differences were found only for density and diversity of large fish in one reserve and density of algae in another. Although the observations from the large reserve were not replicated, these results offer some empirical evidence suggesting that large reserves can provide biological functions not possible in small reserves. This conclusion is in stark contrast to the results of this review, in which even small reserves appeared to have a positive impact on most biological measures. In order to assess adequately the role of area in reserve function, a real need exists for studies that make observations in reserves of many sizes within the same biogeographic region.

Success in the design and function of a marine reserve is closely tied to the goals of the reserve. For example, fishery reserves need to increase abundance, biomass, and organism size within the reserve in order to sustain the reserve populations as well as supply the harvested areas. Conservation reserves, on the other hand, focus more exclusively on the maintenance of diversity and abundance of organisms within the reserve itself. Fortunately, marine reserves appear to lead to higher values of all of these biological measures, implying that both goals can be met with the same reserve.

The impact of marine reserves on the organisms contained within them will never be completely predictable. Variation among reserves and a level of uncertainty will always exist when examining how marine reserves affect specific biological measures. Goals set for marine reserves should account for this variation (Walters and Holling 1990, Clark 1996, Hall 1998, Lauck et al. 1998). Ultimately, though, it is encouraging to know that reserves of any size appear to function well, in terms of producing higher densities, sizes, and diversity of organisms.

Inherent problems and necessary caveats

The enormous variation in type and quality of the observations from marine reserves made it difficult to compare or analyze the results of the studies I reviewed (see also Jones et al. 1992). The primary problems include:

1) results are more likely to be reported for species that are actually affected by reserves (either positively or negatively) than for unaffected species, especially for single-species studies;

2) methodologies often differ drastically among different observations and among scientists within a study;

3) characteristics of reserves being studied (such as location, habitat type, current regimes, temperatures, etc.) are not the same;

4) observations are rarely replicated temporally or spatially (usually because there is only one reserve available for study);

5) reserves are not always adequately protected from poaching;

6) the length of protection varies among reserves;

7) numbers and types of organisms studied vary between experiments;

8) the intensity of fishing outside of the reserve may enhance or even create the perceived affect on biological measures of reserve protection.

As many have argued, the intensity of fishing occurring outside a reserve (or where a reserve is before it becomes a reserve) can have a large impact on the perceived effects of reserve protection (Polacheck 1990, Russ et al. 1992, Carr and Reed 1993, Rowley 1994, Nowlis and Roberts 1997). If an area is nearly completely fished out, the ratio of postprotection to preprotection values of abundance, biomass, etc. will be much higher than for an area that had been lightly fished (assuming all else is equal, and that new fish can be imported to the fished areas from elsewhere). It is difficult to compare fishing intensities in different parts of the world, and this can lead to inaccuracies when combining data.

The confidence in the results from any one study depend on the quality and breadth of the sampling involved, and thus can complicate comparisons across studies. As an example, conclusions drawn when comparing results from a single-species study with results from a study on 250 species suffer obvious comparison problems. Furthermore, studies that looked at only one or a few species may have missed how other species responded to reserve protection; rarely do all species respond in the same way. Future studies, therefore, should include at least a few species from all trophic levels in order to assess reserve effect accurately.

Another problem many studies face is the lack of consistency in protection level for the reserves. Even fully protected reserves often suffer some poaching (e.g., Klima et al. 1986). This potential problem was rarely quantified, largely due to difficulties in monitoring a clandestine act. Because information on actual protection level is lacking, it is difficult to know exactly how long and to what degree a reserve has been protected. Reserve effects can change over time (see Russ and Alcala 1998*a*, *b* for examples of this), so knowing the length of time protection has been in place can be a critical part of analysis. To be able to make more accurate predictions of the effect of marine reserves, actual fishing effort within reserves must be measured and accounted for (Polacheck 1990, Russ et al. 1992, Carr and Reed 1993, Rowley 1994, Nowlis and Roberts 1997) and the length of complete protection identified.

The lack of temporal and spatial replication in many of the studies further complicates interpretation of the results. Snapshots in time and space can provide clues to the effects of reserves, but it is very difficult to eliminate the possibility that observed effects were not simply a result of spatial or temporal differences, especially with inside/outside reserve studies. Before/after studies offer a possible solution to these problems and should be coupled with control observations in non-reserve areas over the same time period, across several spatial scales within a biogeographic region. However, such studies are often logistically difficult to implement.

One of the largest problems with the empirical literature on marine reserve effects is that methodologies used for different studies and the characteristics of reserves and control sites (such as substrate rugosity, depth, current regime, etc.) differ dramatically. Few people make efforts to accommodate the problems mentioned above, let alone measure the same variables in the same way. For example, sample sizes in many studies were not large enough to draw statistically significant conclusions. Other studies did not report the statistical significance of their results, even though this might have been possible. Empirical work on marine reserves needs to reflect the rigorous standards of the rest of the scientific literature.

Finally, results are often only reported when a reserve actually had an effect on an organism, whether negatively or positively. This was unlikely to be a problem for studies that looked at entire communities, but was potentially a large factor influencing single-species studies. Single-species studies can often be useful, especially for fisheries management, but it is important to remember that not every species will respond to reserve protection.

Despite these potential sources of error, my analyses uncovered clear and significant positive effects of reserve establishment on the organisms dwelling within reserve boundaries. Even the inclusion of gray literature, where many of these interpretation problems discussed above are exacerbated, did not obscure these results.

Conclusions

The most important lesson provided by this review is that marine reserves, regardless of their size, and with few exceptions, lead to increases in density, biomass, individual size, and diversity in all functional groups. The diversity of communities and the mean size of the organisms within a reserve are between 20% and 30% higher relative to unprotected areas. The density of organisms is roughly double in reserves, while the biomass of organisms is nearly triple. These results are robust despite the many potential sources of error in the individual studies included in this review.

Equally important is that while small reserves show positive effects, we cannot and should not rely solely on small reserves to provide conservation and fishery services. Proportional increases occur at all reserve sizes, but absolute increases in numbers and diversity are often the main concern. To supply fisheries adequately and to sustain viable populations of diverse groups of organisms, it is likely that at least some large reserves will be needed.

Finally, it is paramount that we explicitly state our goals when creating marine reserves. These goals help guide the design of reserves and are critical for assessing whether or not a reserve has functioned successfully.

Acknowledgments

I thank Bob Warner for the many insightful comments he offered on drafts of this paper. Thanks also to George Branch, Callum Roberts, Heather Leslie, Jenny Dugan, Kevin Lafferty, Deborah McArdle, Rodrigo Bustamante, Kim Selkoe, Kurt Anderson, Steve Palumbi, and two anonymous reviewers for the helpful comments they provided. This is contribution number 26 from the Working Group on the Science of Marine Reserves of the National Center for Ecological Analysis and Synthesis. NCEAS is funded by NSF, UC–Santa Barbara, and the State of California.

Literature Cited

Agardy, T. E. 1994. The science of conservation in the coastal zone: new insight on how to design, implement, and monitor marine protected areas. A marine conservation and development report. IUCN, Gland, Switzerland.

Alcala, A. C. 1988. Effects of marine reserves on coral fish abundances and yields of Philippine coral reefs. Ambio **17**: 194–199.

Alcala, A. C., and G. R. Russ. 1990. A direct test of the effects of protective management on abundance and yield of tropical marine resources. Journal Du Conseil **47**:40–47.

Allison, G. W., J. Lubchenco, and M. H. Carr. 1998. Marine reserves are necessary but not sufficient for marine conservation. Ecological Applications **8**:S79–S92.

Attwood, C. G., and B. A. Bennett. 1995. Modelling the effect of marine reserves on the recreational shore-fishery of the south-western cape, South Africa. South African Journal of Marine Science; Suid-Afrikaanse Tydskrif Vir Seewetenskap **16**:227–240.

Ballantine, W. J. 1992. The practicality and benefits of a marine reserve network. Submitted to the Workshop on Managing Marine Fisheries by Limiting Access. Center for Marine Conservation and the World Wildlife Fund. Annapolis, Maryland, USA.

Ballantine, W. J. 1995. Networks of ''no-take'' marine reserves are practical and necessary. Pages 13–20 *in* N. L. Shackell and J. H. M. Willison, editors. Marine protected areas and sustainable fisheries. Science and Management of Protected Areas Association, Wolfville, Nova Scotia, Canada.

Ballantine, W. J. 1997. Design principles for systems of ''no-take'' marine reserves. Pages 1–19 *in* The design and monitoring of marine reserves. Fisheries Center, University of British Columbia, Vancouver.

Beinssen, K. 1989. Results of the Boult Reef replenishment area study. Great Barrier Reef Marine Park Association, Townsville, Australia.

Bell, J. D. 1983. Effects of depth and marine reserve fishing restrictions on the structure of a rocky reef fish assemblage in the north-western Mediterranean sea. Journal of Applied Ecology **20**:357–369.

Bennett, B. A., and C. G. Attwood. 1991. Evidence for recovery of a surf-zone fish assemblage following the establishment of a marine reserve on the southern coast of South Africa. Marine Ecology Progress Series **75**:173–181.

Bohnsack, J. A. 1981. Effects of piscivorous predator removal on coral reef fish community structure. Pages 258–267 *in* G. M. Cailliet and C. A. Simenstad, editors. Gutshop '81: fish food habits studies. Washington Sea Grant Publication, Seattle, Washington, USA.

Bohnsack, J. A. 1996. Maintenance and recovery of reef fishery productivity. Pages 283–313 *in* N. V. C. Polunin and C. M. Roberts, editors. Fish and fisheries series, 20. Reef fisheries. Chapman and Hall, London, UK.

Bustamante, R. H., and J. C. Castilla. 1990. Impact of human exploitation on populations of the intertidal southern bull-kelp *Durvillaea antarctica* (Phaeophyta, Durvilleales) in central Chile. Biological Conservation **52**:205–220.

Buxton, C. D. 1993. Life-history changes in exploited reef fishes on the east coast of South Africa. Environmental Biology of Fishes **36**:47–63.

Buxton, C. D., and M. J. Smale. 1989. Abundance and distribution patterns of 3 temperate marine reef fish (Teleostei, Sparidae) in exploited and unexploited areas off the southern cape coast. Journal of Applied Ecology **26**:441–451.

Carr, M. H., and D. C. Reed. 1993. Conceptual issues relevant to marine harvest refuges: examples from temperature reef fishes. Canadian Journal of Fisheries and Aquatic Sciences **50**:2019–2028.

Carter, J., and G. R. Sedberry. 1997. The design, function and use of marine fishery reserves as tools for the management and conservation of the Belize barrier reef. Pages 1911–1916 *in* H. Lessios and I. G. Macintyre, editors. Proceedings of the Eighth International Coral Reef Symposium. Volume 2. Smithsonian Tropical Research Institute, Balboa, Republic of Panama.

Castilla, J. C., and R. H. Bustamante. 1989. Human exclusion from rocky intertidal of Las Cruces, central Chile: effects on *Durvillaea antarctica* (Phaeophyta, Durvilleales). Marine Ecology Progress Series **50**:203–214.

Castilla, J. C., and L. R. Durán. 1985. Human exclusion from the rocky intertidal zone of central Chile: the effects on *Concholepas concholepas* (Gastropoda). Oikos **45**:391–399.

Childress, M. J. 1997. Marine reserves and their effects of lobster populations: report from a workshop. (Fifth International Conference and Workshop on Lobster Biology and Management, Queenstown, New Zealand; February 10–14, 1997). Marine and Freshwater Research **48**:1111–1114.

Clark, C. W. 1996. Marine reserves and the precautionary management of fisheries. Ecological Applications **6**:369–370.

Clark, J. R., B. Causey, and J. A. Bohnsack. 1989. Benefits from coral reef protection: Looe Key Reef, Florida. Pages 3076–3086 *in* O. T. Magoon, H. Converse, D. Minor, L. T. Tobin, and D. Clark, editors. Coastal Zone '89: Proceedings of the Sixth Symposium on Coastal and Ocean Management. Charleston, N.C., July 11–14, 1989. American Society of Civil Engineers, New York, New York, USA.

Cole, R. G., T. M. Ayling, and R. G. Creese. 1990. Effects of marine reserve protection at Goat Island, northern New Zealand. New Zealand Journal of Marine and Freshwater Research **24**:197–210.

Conan, G. Y. 1986. Summary of session 5: recruitment enhancement. Canadian Journal of Fisheries and Aquatic Science **43**:2384–2388.

Craik, G. J. S. 1981. Underwater survey of coral trout *Plectropomus leopardus* (Serranidae) populations in the Capricornia section of the Great Barrier Reef Marine Park. Proceedings of the Fourth International Coral Reef Symposium **1**:53–58.

Davis, G. E. 1977. Effects of recreational harvest on a spiny lobster, *Panulirus argus*, population. Bulletin of Marine Science **27**:223–236.

Davis, G. E. 1989. Designated harvest refugia: the next stage of marine fishery management in California. California Cooperative Oceanic Fisheries Investigations Report **30**:53–58.

Davis, G. E., and J. W. Dodrill. 1980. Marine parks and sanctuaries for spiny lobster fisheries management. Proceedings of the Gulf Caribbean Fisheries Institute **32**:194–207.

DeMartini, E. E. 1993. Modeling the potential of fishery reserves for managing pacific coral reef fishes. Fishery Bulletin **91**:414–427.

Diamond, J. M., and R. M. May. 1976. Island biogeography and the design of natural reserves. Pages 163–186 *in* R. M. May, editor. Theoretical ecology. Saunders, Philadelphia, USA.

Dufour, V., J. Y. Jouvenel, and R. Galzin. 1995. Study of a Mediterranean reef fish assemblage: comparisons of population distributions between depths in protected and unprotected areas over one decade. Aquatic Living Resources **8**:17–25.

Dugan, J. E., and G. E. Davis. 1993. Applications of marine refugia to coastal fisheries management. Canadian Journal of Fisheries and Aquatic Sciences **50**:2029–2042.

Duran, L. R., and J. C. Castilla. 1989. Variation and persistence of the middle rocky intertidal community of central Chile, with and without human harvesting. Marine Biology **103**:555–562.

Duran, L. R., J. C. Castilla, and D. Oliva. 1987. Intensity of human predation on rocky shores at Las Cruces in central Chile. Environmental Conservation **14**:143–149.

Edgar, G. J., and N. S. Barrett. 1999. Effects of the declaration of marine reserves on Tasmanian reef fishes, invertebrates, and plants. Journal of Experimental Marine Biology and Ecology **242**:107–144.

Ferreira, B. P., and G. R. Russ. 1995. Population structure of the leopard coral grouper, *Plectropomus leopardus*, on fished and unfished reefs off Townsville, Central Great Barrier Reef, Australia. U.S. National Marine Fisheries Service Fishery Bulletin **93**:629–642.

Francour, P. 1991. The effect of protection level on a coastal fish community at Scandola, Corsica. Revue D Ecologie-La Terre Et La Vie **46**:65–81.

Francour, P. 1994. Pluriannual analysis of the reserve effect on ichthyofauna in the Scandola natural reserve (Corsica, Northwestern Mediterranean). Oceanologica Acta **17**:309–317.

Francour, P. 1996. L'Ichthofaune de l'herbier a *Posidonia oceanica* dans la reserve marine de Scandola (Corse, Mediterranee Nord-Occidentale): influence des mesures de protection. Journal de Recherche Oceanographique **21**:29–34.

Garcia-Rubies, A., and M. Zabala. 1990. Effects of total fishing prohibition on the rocky fish assemblages of Medes Islands marine reserve (NW Mediterranean). Scientia Marina **54**:317–328.

Grigg, R. W. 1994. Effects of sewage discharge, fishing pressure and habitat complexity on coral ecosystems and reef fishes in Hawaii. Marine Ecology-Progress Series **103**:25–34.

Hall, S. J. 1998. Closed areas for fisheries management—the case consolidates. Trends in Ecology and Evolution **13**:297–298.

Halpern, B. S. and R. R. Warner. 2002. Marine reserves have rapid and lasting effects. Ecology Letters **5**:361–366.

Harmelin, J.-G. 1992. Economic impact of the Mediterranean coastal protected areas. Pages 21–25 *in* J. Olivier, N. Gerardin, and J. de Grissac, editors. Proceedings of the Ajaccio meeting. MEDPAN Secretariat Publications, Paris, France.

Harmelin, J.-G., F. Bachet, and F. Garcia. 1995. Mediterranean marine reserves: fish indices as tests of protection efficiency. Marine Ecology-Pubblicazioni Della Stazione Zoologica Di Napoli I **16**:233–250.

Hockey, P. A. R., and A. L. Bosman. 1986. Man as an intertidal predator in Transkei: disturbance, community convergence and management of a natural food resource. Oikos **46**:3–14.

Hockey, P. A. R., and G. M. Branch. 1994. Conserving marine biodiversity on the African coast: implications of a terrestrial perspective. Aquatic Conservation: Marine and Freshwater Ecosystems **4**:345–362.

Jennings, S., S. S. Marshall, and N. V. C. Polunin. 1996. Seychelles marine protected areas: comparative structure and status of reef fish communities. Biological Conservation **75**:201–209.

Jennings, S., and N. V. C. Polunin. 1996. Effects of fishing effort and catch rate upon the structure and biomass of Fijian reef fish communities. Journal of Applied Ecology **33**:400–412.

Johnson, D. R., N. A. Funicelli, and J. A. Bohnsack. 1999. Effectiveness of an existing estuarine no-take fish sanctuary within the Kennedy Space Center, Florida. North American Journal of Fisheries Management **19**:436–453.

Jones, G. P., R. C. Cole, and C. N. Battershill. 1992. Marine reserves: do they work? Proceedings of the Second International Temperate Reef Symposium. pp. 29–45.

Klima, E. F., G. A. Matthews, and F. J. Patella. 1986. Synopsis of the Tortugas pink shrimp fishery, 1960–1983, and the impact of the Tortugas Sanctuary. North American Journal of Fisheries Management **6**:301–310.

Koslow, J. A., F. Hanley, and R. Wicklund. 1988. Effects of fishing on reef fish communities at Pedro Bank and Port Royal Cays, Jamaica. Marine Ecology Progress Series **43**:201–212.

Lasiak, T. 1993. Temporal and spatial variations in exploited and non-exploited populations of the intertidal limpet *Cellana capensis*. Journal of Molluscan Studies **59**:295–307.

Lauck, T., C. W. Clark, M. Mangel, and G. R. Munro. 1998. Implementing the precautionary principle in fisheries management through marine reserves. Ecological Applications **8**:S72–S78.

Letourneur, Y. 1996. Reponses des peuplements et populations de poissons aux reserves marines: le cas de l'ile de Mayotte, Ocean Indien occidental. Ecoscience **3**:442–450.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, New Jersey, USA.

MacDiarmid, A. B., and P. A. Breen. 1992. Spiny lobster population change in a marine reserve. Pages 47–56 *in* Proceedings of the Second International Temperate Reef Symposium.

Man, A., R. Law, and N. V. C. Polunin. 1995. Role of marine reserves in recruitment to reef fisheries: a metapopulation model. Biological Conservation **71**:197–204.

McArdle, D. A. 1997. California marine protected areas. California Sea Grant College System, University of California–San Diego, La Jolla, Califonia, USA.

McClanahan, T. R. 1989. Kenyan coral reef-associated gastropod fauna: a comparison between protected and unprotected reefs. Marine Ecology Progress Series **53**:11–20.

McClanahan, T. R. 1994. Kenyan coral reef lagoon fish: effects of fishing, substrate complexity, and sea urchins. Coral Reefs **13**:231–241.

McClanahan, T. R. 1995. A coral reef ecosystem-fisheries model: impacts of fishing intensity and catch selection on reef structure and processes. Ecological Modelling **80**:1–19.

McClanahan, T. R. 1997. Primary succession of coral-reef algae: differing patterns on fished versus unfished reefs. Journal of Experimental Marine Biology and Ecology **218**:77–102.

McClanahan, T. R., and B. Kaunda-Arara. 1996. Fishery recovery in a coral-reef marine park and its effect on the adjacent fishery. Conservation Biology **10**:1187–1199.

McClanahan, T. R., and N. A. Muthiga. 1988. Changes in Kenyan coral reef community structure and function due to exploitation. Hydrobiologia **166**:269–276.

McClanahan, T. R., and S. H. Shafir. 1990. Causes and consequences of sea urchin abundance and diversity in Kenyan coral reef lagoons. Oecologia **83**:362–370.

McCormick, M. I., and J. H. Choat. 1987. Estimating total abundance of a large temperate-reef fish using visual strip-transects. Marine Biology **96**:469–478.

McNeill, S. E. 1994. The selection and design of marine protected areas: Australia as a case study. Biodiversity and Conservation **3**:586–605.

Moreno, C. A., K. M. Lunecke, and M. I. Lepez. 1986. The response of an intertidal *Concholepas concholepas* (Gastropoda) population to protection from man in southern Chile and the effects on benthic sessile assemblages. Oikos **46**:359–364.

Moreno, C. A., J. P. Sutherland, and H. F. Jara. 1984. Man as a predator in the intertidal zone of southern Chile. Oikos **42**:155–160.

Nilsson, P. 1998. Criteria for the selection of marine protected areas. Report 4834. Swedish Environmental Protection Agency, Stockholm, Sweden.

Nowlis, J. S., and C. M. Roberts. 1997. You can have your fish and eat it, too: theoretical approaches to marine reserve design. Pages 1907–1910 *in* H. Lessios and I. G. Macintyre, editors. Proceedings of the Eighth International Coral Reef Symposium Smithsonian. Volume 2. Tropical Research Institute, Balboa, Republic of Panama.

Oliva, D., and J. C. Castilla. 1986. The effect of human exclusion on the population structure of key-hole limpets *Fissurella crassa* and *F. limbata* on the coast of central Chile. Marine Ecology **7**:201–217.

Ortega, S. 1987. The effect of human predation on the size distribution of *Siphonaria gigas* (Mullusca: Pulmonata) on the pacific coast of Costa Rica. The Veliger **29**:251–255.

Palsson, W. A., and R. E. Pacunski. 1995. The response of rocky reef fishes to harvest refugia in Puget Sound. Pages 224–234 *in* Puget Sound Research '95. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

PDT (Plan Development Team). 1990. The potential of marine fishery reserves for reef fish management in the U.S. Southern Atlantic. Contribution No. CRD/89–90/04. NOAA Technical Memorandum NMFS-SEFC-261.

Polacheck, T. 1990. Year around closed areas as a management tool. Natural Resource Modeling **4**:327–353.

Polis, G. A., and D. R. Strong. 1996. Food web complexity and community dynamics. American Naturalist **147**:813–846.

Polunin, N. V. C., and C. M. Roberts. 1993. Greater biomass and value of target coral-reef fishes in two small Caribbean marine reserves. Marine Ecology Progress Series **100**:167–176.

Pulliam, H. R. 1988. Sources, sinks, and population regulation. American Naturalist **132**:652–661.

Quinn, J. F., S. R. Wing, and L. W. Botsford. 1993. Harvest refugia in marine invertebrate fisheries: models and applications to the red sea urchin, *Strongylocentrotus franciscanus*. American Zoologist **33**:537–550.

Rakitin, A., and D. L. Kramer. 1996. Effect of a marine reserve on the distribution of coral reef fishes in Barbados. Marine Ecology-Progress Series **131**:97–113.

Rice, M. A., C. Hickox, and I. Zehra. 1989. Effects of intensive fishing effort on the population structure of Quahogs, *Mercenaria mercenaria* (Linnaeus 1758), in Narragansett Bay. Journal of Shellfish Research **8**:345–354.

Roberts, C. M. 1995. Rapid build-up of fish biomass in a Caribbean marine reserve. Conservation Biology **9**:815–826.

Roberts, C. M. 1997. Connectivity and management of Caribbean coral reefs. Science (Washington D C) **278**:1454–1457.

Roberts, C. M., and J. Hawkins. 1997. How small can a marine reserve be and still be effective? Coral Reefs **16**:150.

Roberts, C. M., and N. V. C. Polunin. 1991. Are marine reserves effective in management of reef fisheries? Reviews in Fish Biology and Fisheries **1**:65–91.

Roberts, C. M., and N. V. C. Polunin. 1992. Effects of marine reserve protection on northern Red Sea fish populations. Proceedings of the Seventh International Coral Reef Symposium **2**:969–977.

Roberts, C. M., and N. V. C. Polunin. 1993. Marine reserves: simple solutions to managing complex fisheries? Ambio **22**:363–368.

Roughgarden, J. S. Gaines, and H. Possingham. 1988. Recruitment dynamics in complex life cycles. Science **241**:1460–1466.

Rowley, R. J. 1994. Marine reserves in fisheries management. Aquatic Conservation: Marine and Freshwater Ecosystems **4**:233–254.

Russ, G. 1985. Effects of protective management on coral reef fishes in the central Philippines. Pages 219–224 *in* C. Gabrie and M. Harmelin Vivien, editors. Proceedings of the Fifth International Coral Reef Congress. Volume 4. Antenne Museum-Ephe, Moorea, French Polynesia.

Russ, G. R., and A. C. Alcala. 1989. Effects of intense fishing pressure on an assemblage of coral reef fishes. Marine Ecology Progress Series **56**:13–27.

Russ, G. R., and A. C. Alcala. 1996. Marine reserves: rates and patterns of recovery and decline of large predatory fish. Ecological Applications **6**:947–961.

Russ, G. R., and A. C. Alcala. 1998*a*. Natural fishing experiments in marine reserves 1983–1993: community and trophic responses. Coral Reefs **17**:383–397.

Russ, G. R., and A. C. Alcala. 1998*b*. Natural fishing experiments in marine reserves 1983–1993: roles of life history and fishing intensity in family responses. Coral Reefs **17**:399–416.

Russ, G. R., A. C. Alcala, and A. S. Cabanban. 1992. Marine reserves and fisheries management on coral reefs with preliminary modelling of the effects on yield per recruit. Pages 978–985 *in* Proceedings of the Seventh International Coral Reef Symposium. Volume 2. University of Guam Press, Mangilao, Guam.

Sala, E., C. F. Boudouresque, and M. Harmelin-Vivien. 1998*a*. Fishing, trophic cascades, and the structure of algal assemblages: evaluation of an old but untested paradigm. Oikos **82**:425–439.

Sala, E., M. Ribes, B. Hereu, M. Zabala, V. Alva, R. Coma, and J. Garrabou. 1998*b*. Temporal variability in abundance of the sea urchins *Paracentrotus lividus* and *Arbacia lixula* in the northwestern Mediterranean: comparison between a marine reserve and an unprotected area. Marine Ecology Progress Series **168**:135–145.

Sala, E., and M. Zabala. 1996. Fish predation and the structure of the sea urchin *Paracentrotus lividus* populations in the NW Mediterranean. Marine Ecology-Progress Series **140**:71–81.

Salm, R. V., and J. R. Clark. 1989. Marine and coastal protected areas: a guide for planners and managers. IUCN, Gland, Switzerland.

Samoilys, M. A. 1988. Abundance and species richness of coral reef fish on the Kenyan coast: the effects of protective management and fishing. Pages 261–266 *in* J. H. Choat, et al., editors. Proceedings of the 6th International Coral Reef Symposium. Volume 2. Executive Committee, Townsville, Australia.

Sasal, P., E. Faliexs, and S. Morand. 1996. Population structure of *Gobius bucchichii* in a Mediterranean marine reserve and in an unprotected area. Journal of Fish Biology **49**: 352–356.

Siegfried, W. R., P. A. R. Hockey, and A. A. Crowe. 1985. Exploitation and conservation of brown mussel stocks by coastal people of Transkei. Environmental Conservation **12**:303–307.

Sluka, R., M. Chiappone, K. M. Sullivan, and R. Wright. 1997. The benefits of a marine fishery reserve for Nassau Grouper *Epinephelus striatus* in the central Bahamas. Pages 1961–1964 *in* H. Lessios and I. G. Macintyre, editors. Proceedings of the Eighth International Coral Reef Symposium. Volume 2. Smithsonian Tropical Research Institute, Balboa, Republic of Panama.

Steneck, R. S. 1998. Human influences on coastal ecosystems: does overfishing create trophic cascades? Trends in Ecology and Evolution **13**:429–430.

Stoner, A. W., and M. Ray. 1996. Queen conch, *Strombus gigas*, in fished and unfished locations of the Bahamas: effects of a marine fishery reserve on adults, juveniles, and larval production. Fishery Bulletin (Washington, D.C.) **94**: 551–565.

Tegner, M. J. 1993. Southern California abalones: can stocks be rebuilt using marine harvest refugia? Canadian Journal of Fisheries and Aquatic Sciences **50**:2010–2018.

Tupper, M., and F. Juanes. 1999. Effects of a marine reserve on recruitment of grunts (Pisces: Haemulidae) at Barbados, West Indies. Environmental Biology of Fishes **55**:53–63.

Wallace, S. S. 1999. Evaluating the effects of three forms of marine reserve on northern abalone populations in British Columbia, Canada. Conservation Biology **13**:882–887.

Walters, C. J., and C. S. Holling. 1990. Large-scale management experiments and learning by doing. Ecology **71**: 2060–2068.

Wantiez, L., P. Thollot, and M. Kulbicki. 1997. Effects of marine reserves on coral reef fish communities from five islands in New Caledonia. Coral Reefs **16**:215–224.

Watson, M., and R. F. G. Ormond. 1994. Effect of an artisanal fishery on the fish and urchin populations of a Kenyan coral reef. Marine Ecology Progress Series **109**:115–129.

Watson, M., R. F. G. Ormond, and L. Holliday. 1997. The role of Kenya's marine protected areas in artisanal fisheries management. Pages 1955–1960 *in* H. Lessios and I. G. Macintyre, editors. Proceedings of the Eighth International Coral Reef Symposium. Volume 2. Smithsonian Tropical Research Institute, Balboa, Republic of Panama.

Watson, M., D. Righton, T. Austin, and R. Ormond. 1996. The effects of fishing on coral reef fish abundance and diversity. Journal of the Marine Biological Association of the United Kingdom **76**:229–233.

Weil, E. M., and R. G. Laughlin. 1984. Biology, population dynamics, and reproduction of the queen conch *Strombus gigas* Linne in the archipelago de los Roques National Park. Journal of Shellfish Research **4**:45–62.

White, A. T. 1988. The effect of community-managed marine reserves in the Philippines on their associated coral reef fish populations. Asian Fisheries Science **2**:27–41.

Zeller, D. C., and G. R. Russ. 1998. Marine reserves: patterns of adult movement of the coral trout (*Plectropomus leopardus* (Serranidae)). Canadian Journal of Fisheries and Aquatic Sciences **55**:917–924.

APPENDIX

This appendix includes a summary of the data extracted from the literature reviewed, and the sources from where the data came.

Reserve	Size (km^2)	No. taxa	Functional group: C	H	P/I	I	Biological measure: D	B	S	Div	Reference
Caribbean											
St. Lucia	0.026						ND	+2	+	+	Roberts and Hawkins (1997)
Saba	0.9	40 species	×	×			ND	+1.9	+	+	Polunin and Roberts (1993)
Saba	0.9	26 species	×	×			ND	+1.09	ND	ND	Roberts (1995)
Belize	2.6	45 species	×	×			ND	+1.9	ND	+	Polunin and Roberts (1993)
Los Roques, Venezuela	4	1 species				×	+2.38		+1.17		Weil and Laughlin (1984)
Barbados	2.3	89 species					+1.16	+	+1.07	+1.06	Rakitin and Kramer (1996)
Barbados	2.3	7 species	×				+2.15		+1.53		Tupper and Juanes (1999)
Hol Chan, Belize	2.6							+2.21	ND		Roberts and Polunin (1993)
Hol Chan, Belize	2.6	19 fish families, 2 inverts	×	×	×	×	+2.1		+	+1.1	Carter and Sedberry (1997)
Half Moon Caye, Belize	39.25	19 fish families, 2 inverts	×	×	×	×	+2.07		+		Carter and Sedberry (1997)
Exhuma Sound, Bahamas	456	1 species	×				+	+4.19	+1.29		Sluka et al. (1997)
Exhuma Sound, Bahamas	456	1 species				×	+5.31				Stoner and Ray (1996)

APPENDIX. Continued.

Reserve	Size (km^2)	No. taxa	Functional group C	H	P/I	I	Biological measure D	B	S	Div	Reference
Manuel Antonio, Costa Rica	6.82	1 species					+1.65		+1.34		Ortega (1987)
SW Pedro Bank Jamaica		13 families	×	×	×		+1.22	+1.76	+	ND	Koslow et al. (1998)
Philippines											
Sumilon	0.125	102 species	×	×	×		+1.56			+1.3	Russ and Alcala (1989)
Sumilon	0.125	overall, 4 families	×				+2.6	+1.73		+	Russ and Alcala (1996)
Sumilon	0.125	102 species	×	×	×		+1.73		+	ND	Russ (1985)
Sumilon	0.125		×		×		+1.51			ND	Alcala (1988)
Sumilon	0.125	178 species					+1.4	+1.39		+1.31	Russ and Alcala (1998*a*)
Sumilon	0.125	178 species	×	×	×		ND				Russ and Alcala (1998*b*)
Apo	0.11	overall, 4 families	×				+7.1	+8.0			Russ and Alcala (1996)
Apo	0.11	126 species	×	×	×		+2.73			+1.4	White (1988)
Apo	0.11	178 species					ND	+1.54		ND	Russ and Alcala (1998*a*)
Apo	0.11	178 species	×	×	×		ND				Russ and Alcala (1998*b*)
Apo	0.11						+2.73				Clark et al. (1989)
Pamilican	0.14	126 species	×	×	×		+1.89			+1.25	White (1988)
Pamilican	0.14						+1.89				Clark et al. (1989)
Balicasag	0.08	126 species	×	×	×		+1.45			+1.03	White (1988)
Balicasag	0.08						+1.45				Clark et al. (1989)
Sumilon "outside"	0.375	overall, 4 families	×				+5.2	+4.1			Russ and Alcala (1996)
Sumilon "outside"	0.375	178 species					ND	+1.8		ND	Russ and Alcala (1998*a*)
Sumilon "outside"	0.375	178 species	×	×	×		ND				Russ and Alcala (1998*b*)
New Caledonia											
Amedee	2.8						+4.5	+9.5		+2.43	Wantiez et al. (1997)
Signal	4.3						+1.35	+3.5		+1.42	Wantiez et al. (1997)
Laregnere	8.5						+4.29	+3.7		+1.9	Wantiez et al. (1997)
Maitre	9						+2.71	+3.21		+1.5	Wantiez et al. (1997)
Bailly	2.4						+2.0	+1.44		+1.29	Wantiez et al. (1997)
All five reserves	27	214 species	×	×	×		+1.38	+3.47		+1.57	Wantiez et al. (1997)
Fiji											
Unnamed	9.4	83 species	×	×	×		+	+			Jennings and Polunin (1996)
Great Barrier Reef											
Lizard Island	9.9	1 species					+1.2				Zeller and Russ (1998)
Boult Reef	3.42	33 species	×				+		+		Beinssen (1989)
Glow and Yankee Reefs	25.15	1 species	×				+2.58		ND		Ferreira and Russ (1995)
Heron Island	12	1 species					+3.77		ND		Craik (1981)
Unamed on GBR							ND		+		Ayling and Ayling (1986) (in Jones et al. 1992)

APPENDIX. Continued.

Reserve	Size (km^2)	No. taxa	Functional group C	H	P/I	I	Biological measure D	B	S	Div	Reference
Red Sea											
Ras Mohamed, Sinai	21.1	45 species	×	×	×		ND (0.85)	ND (0.66)	ND	ND (0.93)	Roberts and Polunin (1992)
Ahkziv	1.5	1 species				×	+				Spanier (1994) (in Childress 1997)
Kenya											
Malindi						×	+16.57		+1.42		McClanahan and Muthiga (1998)
Malindi and Watuma	10			×	×	×	+3.58			+	McClanahan and Shafir (1990)
Malindi and Watuma	10	81 species + algae, coral	×			×	+2.6	+27.7			McClanahan (1997)
Kisite	15	51 species	×		×	×	ND	+			Watson and Ormond (1994)
Kisite	15		×	×	×		+1.19			ND	Watson et al. (1996)
Kisite	15	23 species	×								Watson et al. (1997)
Mombasa	10	10 families + others	×	×	×		+2.0	+15.5	+2.04	+2.0	McClanahan and Kaunda-Arara (1996)
Malindi, Watamu, and Kisite	25	127 species				×	ND (0.91)			+	McClanahan (1989)
Malindi, Watamu, and Kisite	25	118 species	×	×	×	×	+2.27			+1.92	McClanahan (1994)
Malindi, Watamu, Kisite, Mako Kokwe, Simambya, Arletts, and Kiwaiyu	846	188 species	×				ND	ND		+	Samoilys (1998)
Southeastern Africa											
Mayotte Island	5.25	239 species	×	×	×		ND (0.83)	+2.54		ND (1.01)	Letourneur (1996)
Cousin Island, Seychelles	1.2	115 species	×		×			+1.67		+	Jennings et al. (1996)
Sainte Anne	10	115 species	×		×			+2.5		+	Jennings et al. (1996)
South Africa											
De Hoop	230	10 species	×				+3.64		ND		Bennett and Attwood (1991)
Dwesa	39	8 species				×				−0.73	Hockey and Bosman (1986)
Dwesa	39	1 species				×	−		+1.16		Lasiak (1993)
Dwesa	39	1 species				×	+4.5	+8.5	+1.28		Siegfriend et al. (1985)
Hluleka	4					×				−0.83	Hockey and Bosman (1986)
Isi Laka		7 species				×	−0.74			−0.63	Hockey and Bosman (1986)
Tsitsikamma	300	2 species	×				ND		+1.12		Buxton (1993)
Tsitsikamma	300	3 species	×				+4.2		+1.33		Buxton and Smalle (1989)
North America											
Naranganset Bay, RI	1.07	1 species	×		×		+2.44		+2.0		Rice et al. (1989)

APPENDIX. Continued.

Reserve	Size (km^2)	No. taxa	Functional group: C	H	P/I	I	Biological measure: D	B	S	Div	Reference
Hopkins, CA	2.75	10 species	×				ND (1.56)		+1.21	ND	Paddock and Estes (*unpublished data*)
Point Lobos, CA	3.14	10 species	×				ND (1.13)		+1.26	ND	Paddock and Estes (*unpublished data*)
Big Creek, CA	6.78	10 species	×				ND (1.23)		ND	ND	Paddock and Estes (*unpublished data*)
Edmonds Underwater Park, WA	0.002	3 species	×				+		+		Palsson and Pacunski (1995)
Shady Cove, WA	1.71	3 species	×				+1.76		+		Palsson and Pacunski (1995)
Two reserves, WA	1.712	3 species	×						+1.28		Palsson and Pacunski (1995)
Manele, HI	1.25						+1.06	+1.24		−0.96	Grigg (1994)
Kealakakua, HI	1.28						+1.57	+4.13		+1.02	Grigg (1994)
Huanama, Honolua, Manale, Molokini, and Kealakakua, HI							+1.35	+1.61	+	+1.07	Grigg (1994)
Kennedy Space Center, FL	39.6	50 species	×	×	×		+1.51			ND	Johnson et al. (1999)
Molasses Reef, FL	0.9	132 species	×				+6.1		+	−0.93	Bohnsack (1981)
French Reef, FL	0.37	132 species	×				+1.65			−0.93	Bohnsack (1981)
Looe Key Reef, FL	15.54	3 families	×		×		−0.67			+	Clark et al. (1989)
Looe Key Reef, FL	15.54	1 species				×	ND				Hunt et al. (1991) (in Childress 1997)
Dry Tortugas, FL	190	1 species				×	+4.5				Hunt et al. (1991) (in Childress 1997)
Fort Jefferson, FL	19	1 species				×	+1.55				Davis (1997)
"Prison Reserve," B.C.		1 species				×	+1.22		+1.15		Wallace (1999)
"Ecological Reserve," B.C		1 species				×	+1.11		ND (0.99)		Wallace (1999)
Chile											
Las Cruces	0.044	2 species				×	+10.63		+		Castilla and Duran (1985)
Las Cruces	0.044	1 species				×	+1.96	+7.26	+1.72		Castilla and Bustamante (1989)
Las Cruces	0.044	6 species				×	+			+	Duran and Castilla (1989)
Las Cruces	0.044	1 species					ND	+	+		Bustamante and Castilla (1990)
Las Cruces	0.044	2 species				×	ND (0.8)		+		Oliva and Castilla (1986)
Las Cruces	0.044	3 species				×		+4.67			Duran et al. (1987)
Mehuin	0.006	6 species				×	+9.56		+		Moreno et al. (1986)

APPENDIX. Continued.

Reserve	Size (km^2)	No. taxa	Functional group C	H	P/I	I	Biological measure D	B	S	Div	Reference
Mehuin	0.006	4 species				×	+		+		Moreno et al. (1984)
Montemar	0.025	1 species				×	ND	+	+		Bustamante and Castilla (1990)
New Zealand											
Leigh (Goat Island)	5.18	12 species	×			×	−0.73			+1.41	Cole et al. (1990)
Leigh (Goat Island)	5.18	1 species					+2.3		+1.17		McCormick and Choat (1987)
Leigh (Goat Island)	0.55					×	+11.25				Davis (1989)
Leigh (Goat Island)	0.55	1 species				×	+4.5	+13.05	+		MacDiarmid and Breen (1993)
Tasmania											
Maria Island	7	117 species				×	ND		+	+1.29	Edgar and Barrett (1999)
Tinderbox	0.53	117 species				×			+	ND	Edgar and Barret (1999)
Governor Island	0.6	117 species				×				ND	Edgar and Barrett (1999)
Ninepin	0.59	117 species				×				ND	Edgar and Barrett (1999)
Spain											
Isles Medes	4.18	51 species	×	×	×		−0.55		+	+	Garcia-Rubies and Zabala (1990)
Isles Medes	4.18	1 species				×	−0.26		−0.89		Sala and Zabala (1996)
Isles Medes	4.18	2 species				×	ND		ND		Sala et al. (1998*b*)
France											
Banyuls-sur-Mer	1.5	35 species	×	×	×		+2.06		+1.19	+1.17	Bell (1983)
Banyuls-sur-Mer	1.5	41 species					ND		+		Dufour et al. (1995)
Cerbere-Banyuls	6	1 species			×				+		Sasal et al. (1996)
Carry-le-Rouet	0.85	54 species		×	×		+1.78		+	+1.16	Harmelin et al. (1995)
Carry-le-Rouet	0.85	47 species	×		×		ND			+	Harmelin (1992)
Scandola	0.72	26 species		×	×		+1.6	+2.14	+1.8	+	Francour (1994)
Scandola	0.72	18 species	×		×		+1.37	+2.51		+1.24	Francour (1996)
Scandola	0.72	25 species	×		×		ND	+1.71			Francour (1991)
Unnamed in Brittany		1 species				×		ND	+		Conan (1986)

Notes: The summarized information is organized by general region of the globe in which each reserve occurs. The "outside" reserve at Sumilon in the Phillipines refers to the area outside the reserve that received protection at various times (it is distinct from, but adjacent to, the Sumilon reserve). Data were occasionally reported for groups of reserves; in these cases the names of all the reserves measured are listed as one entry. The number of taxa studied in each reference gives a general idea of the breadth of each study. Although the number of species was reported in many of the reviewed studies (and therefore reported here), changes in biological measures were usually only reported at the taxonomic level of family. Functional group information describes how I was able to categorize the taxa studied and includes carnivorous fishes (C), herbivorous fishes (H), planktivorous fishes/invertebrate eaters (P/I), and invertebrates (I). An "×" indicates that data for the functional group were available from the reference. Overall values were recorded for all cases, when available, and are listed under the appropriate biological measure column. Trends are reported as +, ND, and −, corresponding to higher values, no difference in values, or lower values of a measure inside the reserve compared to outside (or after compared to before the creation of a reserve). In cases where trends were not significantly different from each other (ND) but ratio values could be calculated, biological measures are reported as ND with the ratio value in parentheses. The biological measures are density (D), biomass (B), size of the organism (S), and diversity (Div). Blank species indicate that the information was not reported in the reference and was therefore not available for analyses in this review.