A Review of the Ecological Effectiveness of Subtidal Marine Reserves in Central California

Part II: Summary of Existing Marine Reserves in Central California and their Potential Benefits

Sebastes chrysomelas, black-and-yellow rockfish

A report to the Monterey Bay National Marine Sanctuary

by

Richard M. Starr[1], Mark H. Carr[2], Jennifer Caselle[3],
James A. Estes[4], Craig Syms[2], David A. VenTresca[5], Mary M. Yoklavich[6]

August 2002

[1] University of California Sea Grant Extension Program
[2] University of California Santa Cruz
[3] University of California Santa Barbara
[4] U.S. Geological Survey
[5] California Department of Fish and Game
[6] National Marine Fisheries Service

Acknowledgements

The Monterey Bay National Marine Sanctuary provided funds to produce this report. We thank Andrew DeVoegelaere and Erica Burton of the MBNMS research program for their guidance and support for producing this report. We also thank the home institutions of the authors for providing the support for the authors to be involved in this project. This work was supported in part by the University of California Sea Grant Extension Program, the University of California Santa Cruz, the University of California Santa Barbara, the U.S. Geological Survey, the California Department of Fish and Game, the National Marine Fisheries Service, and Moss Landing Marine Laboratories, and the Friends of Moss Landing Marine Labs. Support was also provided for M. Carr, C. Syms, and J. Caselle by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), funded by the David and Lucile Packard Foundation.

CONTENTS

Introduction…….…….. 1

1) How do marine reserves conserve biodiversity and habitat? …… 3

1a) Do the existing marine reserves in Central California protect depleted, threatened, rare, or endangered species? …….. 3
1b) Do the existing marine reserves in Central California protect representative habitats and species? …… 4
1c) What are the other potential ecological functions of reserves in Central California? …. 4
1d) What is the evidence that reserves in Central California actually conserve biodiversity? …….. 5
1e) How much area is needed to adequately protect Central California species and habitats? …….. 6

2) How can reserves improve fishery management? …….. 7
2a) Do the reserves in Central California control fishery exploitation rates?……..7
2b) Do the reserves in Central California protect critical stages in the life history of a species?……. 8
2c) Do the reserves in Central California reduce secondary fishing impacts?……..…….. 9
2d) Do the reserves in Central California ensure against possible failures of conventional regulatory systems?……. 9
2e) Do the reserves in Central California conserve life history traits and genetic diversity? 10

3) Do the reserves in Central California increase scientific knowledge?…….……..… 10

4) Do the reserves in Central California increase educational opportunities?…….…… 11

5) Do the reserves in Central California increase recreational opportunities and tourism?…… 11

6) Do the reserves in Central California provide sustainable environmental benefits?…..…… 11

7) Do the reserves in Central California provide protection of cultural heritage?……. 11

Summary……..…….. 12

Introduction

In Central California, and elsewhere around the world, a great deal of discussion is occurring about the use of marine protected areas (MPAs) as a tool to help manage marine resources. This discussion is taking place because there is growing evidence that humans have depleted marine resources in many parts of the world, often despite strong regulatory efforts. Moreover, there is also mounting evidence that the degradation of marine resources began long ago, and we do not fully realize how much humans have altered "natural" environments. This uncertainty has led people to discuss the use of MPAs as a precautionary tool to prevent depletion or extinction of marine resources, and as a means of redressing past damages.

The discussion about the use of marine reserves is increasing in intensity in California because several resource management agencies are considering reserves as they create or revise management plans. Often, the discussions surrounding this important public policy debate lead to questions about the biological or ecological value of existing marine protected areas. More than 100 MPAs exist along the coast of California. Many of these were established arbitrarily and lack specific purposes. Some California marine protected areas also have co-occurring or overlapping boundaries, have conflicting designations for use, and have conflicting rules and regulations. Because few of the existing marine protected areas have clearly articulated goals or objectives, however, it is difficult or impossible to evaluate their ecological effectiveness.

Marine reserves, often referred to as no-take MPAs, are defined as areas within which human activities that can result in the removal or alteration of biotic and abiotic components of an ecosystem are prohibited or greatly restricted. Usually, marine reserves are established to conserve biodiversity or enhance nearby fishery resources. Thus, goals and objectives of marine reserves can be inferred, even if they are not specifically articulated at the time of reserve formation. The National Research Council published a report in 2001 that identified seven potential goals for marine reserves. The report suggested that marine reserves could improve:

1) Conservation of biodiversity and habitat,
2) Fishery management,
3) Scientific knowledge,
4) Educational opportunities,
5) Enhancement of recreational activities and tourism,
6) Sustainable environmental benefits, and
7) Protection of cultural heritage.

We evaluated the ecological effectiveness of subtidal marine reserves in Central California by comparing existing information with the predicted benefits of the goals listed by the National Research Council. We reviewed information from the three marine reserves in the Monterey Bay National Marine Sanctuary (Fig. 1: Hopkins Marine Life Refuge with about 32 ha of protected area established in 1984; Point Lobos Ecological Reserve with about 280 ha of protected area established in 1973; Big Creek Ecological Reserve with about 378 of protected area established in 1994), and the one marine reserve in the Channel Islands National Marine Sanctuary (about 12 ha of Natural Area protected in 1978 on the north side of East Anacapa Island) in Southern California.

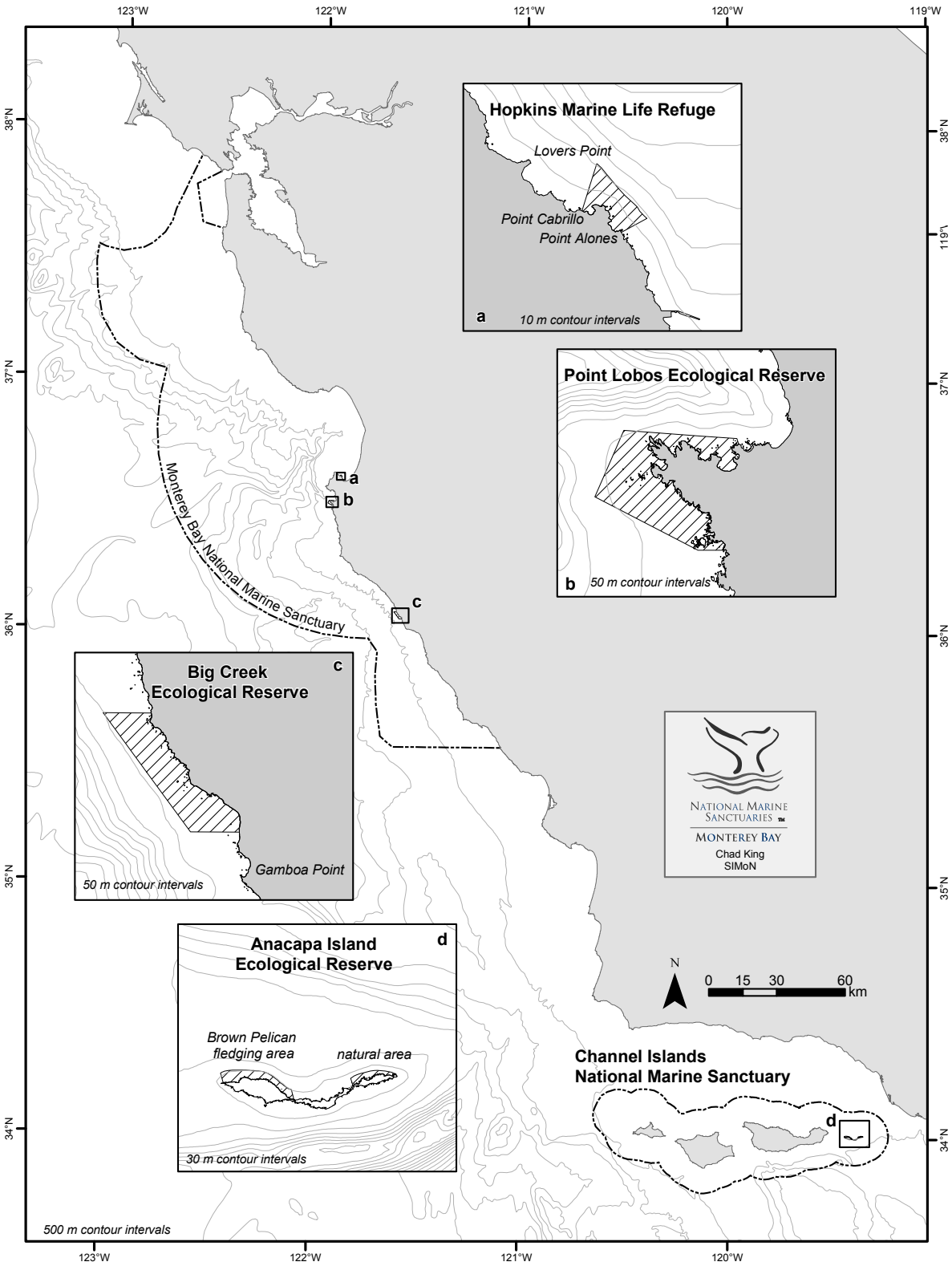

Figure 1. Four subtidal marine reserves, located in the Monterey Bay and Channel Islands National Marine Sanctuaries, reviewed for their ecological effectiveness: Hopkins Marine Life Refuge, Point Lobos Ecological Reserve, Big Creek Ecological Reserve, and the natural area on the north side of East Anacapa Island.

We also reviewed studies of marine reserves in other temperate and tropical ecosystems to determine if there are lessons to be learned about the effectiveness of marine reserves from other parts of the world. After reviewing the available literature, we provided our best estimates of what conservation or fishery benefits could be expected from existing reserves in Central California. A more detailed discussion of the scientific studies that have been conducted on marine reserves in Central California can be found in the companion document to this summary (see: A Review of the Ecological Effectiveness of Subtidal Marine Reserves in Central California. Part I: Synopsis of Scientific Investigations).

The purpose of this review is to provide information for the public policy debate, not to advocate or oppose the formation of marine reserves. As a way of reporting the results of our review, we present answers to frequently asked questions about the potential benefits of marine reserves in Central California. It is very important to note that we were asked to focus on biological parameters. Although we included a summary overview of socioeconomic concerns, relatively little research has been done on this topic in Central California reserves. Any public policy decision about the use of marine reserves also must include an analysis of how people interact with, and are affected by, marine reserves.

1) How do marine reserves conserve biodiversity and habitat?

Marine reserves set up to conserve biodiversity and habitat are established either to 1) protect depleted, threatened, rare, or endangered species or habitats, or 2) conserve representative habitats and species. In the first case, the primary purpose of the reserve (or reserve system) may be to provide extra protection for a species or habitat whose abundance is well below normal levels or is declining at rates higher than that expected of natural variations. In the second case, the primary purpose of a system of reserves is to conserve all species or biological processes in representative habitats or portions of ecosystems.

Scientists and resource managers can use marine reserves to compare habitats and biological communities in relatively undisturbed areas with those that are affected by human activities. Protecting representative habitats from direct human alteration provides a good benchmark with which to determine if observed changes are caused by human activity or environmental change. Marine reserves established to conserve biodiversity also serve to protect a wide variety of species, some of which may have been affected by human activities without our knowing it. An additional benefit of a system of marine reserves designed to protect representative habitats and species is that it can facilitate ecosystem recovery after either natural catastrophes (e.g., severe El Niño events), or human-induced catastrophes, such as oil spills.

1a) Do the existing marine reserves in Central California protect depleted, threatened, rare, or endangered species?

Some of the researchers studying the three marine reserves in the Monterey Bay National Marine Sanctuary identified modestly increased size and abundance of various species exploited in commercial and recreational fisheries. These studies also noted the presence of lingcod and several rockfish species (e.g., bocaccio, yelloweye, canary, darkblotched) that have officially been declared as overfished by the Pacific Fishery Management Council or are species of

concern identified by the California Department of Fish and Game. Because the area of protection inside existing reserves is very small, however, the number of fish inhabiting existing reserves is small compared to the total population size of the species of concern. Thus, existing reserves protect a small number of individuals of overfished species, but are not large enough to provide protection for a significant portion of the entire population of these species.

Red abalone, an overharvested species, have been observed in several of the reserves in Central California. A few officially protected bird and mammal species occur in Central California, but existing reserves are far too small to provide these species with meaningful benefits. Although not officially part of the Anacapa Island Ecological Reserve in the Channel Islands in Southern California, a small area on the north side of West Anacapa Island protects a fledgling area for the endangered brown pelican.

No rare habitats have been identified in the existing marine reserves. Although some overfished or endangered species have been observed, the existing studies were not designed to locate rare species temporarily residing in marine reserves, thus more may use Central California reserves. Additionally, existing reserves may harbor species whose populations are low, but have not received protected status because so little is known about them; this includes most of the nearshore species that are harvested without any assessment of population size and structure.

1b) Do the existing marine reserves in Central California protect representative habitats and species?

The existing reserves in Central California all contain a variety of habitats and species that are typical of temperate nearshore sand, rocky reef, and kelp forest habitats. Bottom types observed in the existing reserves include sediment and shell substrates and a variety of rock substrates, ranging from low relief rock shelves to high relief boulders and pinnacles. Small algae and a variety of kelp species commonly cover the rocky habitats. Habitats and species within the reserves closely match those found in adjacent areas. Thus, the existing reserves contain habitats that are representative of shallow-water habitats in Central California. The fish species inhabiting Central California reserves have been well documented; they are primarily rockfishes, flatfishes, perches, gobies, and cottids. Invertebrate and algal species are not as well documented, but appear to be similar to areas outside the reserves. Although existing reserves contain representative habitats and species, they are too small to provide protection for a significant proportion of these habitats and species occurring in Central California.

1c) What are other potential ecological functions of reserves in Central California?

Field studies of ecological roles played by marine reserves in other parts of the world have focused primarily on changes in species protected from fishing. Surprisingly few studies or mathematical models have been developed to understand how the structures of entire biological communities, and species interactions, change with reserve protection. The ecological process that involves species interactions and community change is termed trophic cascades. The few field and modeling studies that have attempted to evaluate trophic cascades involved the role of predators on major grazers such as sea urchins and the resulting influence on the cover and density of macroalgae. Based on these studies, and other scientific literature, there is sufficient

evidence to expect that marine reserves will experience different trophic cascades in different regions within California. For example, in kelp forests in Southern California, protection of lobsters and sheephead (that limit sea urchin populations) is predicted to increase kelp density within reserves and thus species associated with kelp forests. In Central California, where sea otters limit sea urchin populations, reserves will probably have little effect on urchin populations, and thus no cascading effect on kelp forests is anticipated. Instead, any change in community structure would likely result from changes in fish assemblages and in the invertebrates fed upon by different species of fishes. In Northern California, where commercial fishing is the primary control of sea urchin populations, species composition in kelp forest reserves may exhibit fluctuations that are caused by natural variations in sea urchin abundance.

The literature describing trophic cascades, however, indicates that when ecosystems are heavily degraded, the interactions between predators and prey may limit recovery of depleted species. This implies that there is no guarantee that an area that was once rich in marine life, but is now barren, will recover to its original state if protected inside a marine reserve. Simply stated, we know that abundance and size of fished species will increase in marine reserves, but we cannot fully predict what the trophic structure of the community will look like in the reserve. Moreover, changes in community structure will occur over an unknown period of time. This makes it difficult to use a fixed date in the future to determine if a marine reserve has successfully recovered to a pre-harvest condition.

1d) What is the evidence that reserves in Central California actually conserve biodiversity?

Research that has been conducted in other parts of the world has shown that well designed reserves contain higher species diversity, more abundant species, larger fish, and better habitat than similar areas outside the reserve. These characteristics, termed reserve effects, have been shown to accrue rapidly in tropical areas, but more slowly in temperate environments.

Reserve effects are apparent in Central California marine reserves. In two of the three marine reserves in Central California (Pt. Lobos and Hopkins), fish abundance and size are greater inside the reserves relative to adjacent areas with similar habitat, although differences are modest. At the Anacapa Island Ecological Reserve in Southern California, the density of harvested species is much greater than densities measured outside the reserve. The densities of species that are not commonly harvested, however, are similar or greater outside the reserve. Species composition, size composition, and abundances of fishes are similar inside and outside the Big Creek Ecological Reserve. Given that this reserve has been in place less than a decade, the fact that most fish species there are rockfishes, and that most rockfishes grow slowly and experience only episodic successful recruitment, it is not surprising that marked differences have not been observed inside versus outside the reserve. The lack of differences may also be due to lower fishing pressure on that part of the coast, or movements of fishes using the reserve. More years will need to pass before we would expect to see differences in fish abundance inside and outside Big Creek Ecological Reserve.

Research conducted in Central California reserves has shown that fish abundance, size, and species composition in reserves are directly related to type, size, and extent of habitats located in

the reserve. This indicates that the number and variety of habitat types and depth ranges encompassed by reserves in Central California directly influences the effectiveness of existing reserves for conserving biodiversity. The existing marine reserves are all located in shallow water (less than 50–120 m deep). In that respect, it is clear that existing reserves in Central California protect only those animals inhabiting shallow water habitats. If the goal of a marine reserve system in Central California is to protect a large number of species (protect biodiversity) at various life stages, then it is important to establish marine reserves that extend into deeper water than those currently in existence. Similarly, if a goal is to increase the number of species protected, then it is important to establish marine reserves that contain a mixture of habitats, but especially high relief rocky habitats. High relief rocky habitats in Central California contain a larger number of species than other habitats. From a practical standpoint, rocky habitats probably require more protection, because many species inhabiting shallow soft bottom habitats are already somewhat protected by limitations on the use of trawl and gillnet fishing gear in State waters.

1e) How much area is needed to adequately protect Central California species and habitats?

The size of a reserve needed to successfully protect populations and ecosystem processes is currently unknown, but likely dependent upon a variety of factors such as the density, amount of movement, reproductive capability, and larval dispersal distances of protected species. Other factors, such as the location and shape of a reserve, the amount of pollution entering a reserve, or the rate of poaching in a reserve, also influence the amount of area needed for a reserve to be effective. Based on what we know about fish movements and larval dispersal of most species in Central California, it is probable that existing marine reserves are too small to protect all but the most sedentary species. Abalones, and other sedentary species with short larval dispersal distances, are the most likely species to benefit from the existing reserves. Highly mobile species, such as migratory fishes, birds, and mammals are less likely to benefit from reserves.

The specific amount of area recommended for inclusion in a reserve is usually dependent upon the exact goals delineated; recommended sizes are usually smaller for conservation reserves than those designed to enhance fisheries. For the sake of this review, assume that a public policy goal is to help conserve or protect at least some amount of all the representative species and habitats in Central California. In terms of the international discussions about the amount of area needed to conserve biodiversity, scientists have recommended protecting a minimum of 5% of a habitat area or species population size. The existing reserves in Central California cover an area that is less than 0.3**%** of state waters in this region, and less than 0.1% of the area in California's national marine sanctuaries, although these numbers may be slightly higher if you just measure shallow rocky habitats. This means that existing reserve area is 17–50 times smaller than the minimum amount of area suggested by international scientists for areas comparable to California coastal waters and national marine sanctuaries, respectively. Thus, existing marine reserves in Central California protect an area that is too small to achieve a goal of conserving biodiversity or habitats in this region. The actual size needed to protect biodiversity would depend upon specific conservation goals, other management actions outside reserves, and the level of risk the public is willing to take.

2) How can reserves improve fishery management?

Reserves may be designed to meet a variety of fishery-related goals and objectives. For example, marine reserves can help control fishery exploitation rates by directly protecting a portion of the population from overfishing. Marine reserves may serve as controls for fishery scientists to study biological processes in unfished populations, and this information is useful to develop more accurate stock assessment models. Also, marine reserves may be used as a precautionary tool to ameliorate the effects of recruitment overfishing. Recruitment overfishing occurs when fishing pressure causes a fish stock to become too small to sustain its population size through reproduction. Reserves reduce the impacts of recruitment overfishing by providing a haven for larger fish (that carry more eggs than smaller fish) than would occur in fished areas. This could be especially relevant to rockfish populations that have dramatically variable recruitment success. Similarly, reserves may minimize the effects of growth overfishing. Growth overfishing occurs when high fishing pressure greatly reduces the mean size of fish caught. Reserves can minimize the effects of growth overfishing if some of the larger fish leave the reserve and are caught in nearby fisheries. The export of fish from a reserve to adjacent fisheries may thus increase fishery yield, as long as effort shifts and reduced fishable areas are accounted for in fishery management. An important socioeconomic point to consider is that reserves have the potential to redistribute fishing effort, and thus yield, a factor that must be evaluated when reserves are established. Thus, the extent to which reserves affect yield is dependent upon the design of the reserve network, how much fishing occurs outside the protected area, and the extent to which the closed areas are matched with more conventional approaches to controlling fishing effort. In this respect, it is important that a new marine reserve be designed in conjunction with other fishery management actions outside the reserve.

2a) Do the reserves in Central California control fishery exploitation rates?

Existing reserves in Central California were not established with the goal of controlling fishing effort, and are probably too small to be used effectively as controls to differentiate natural changes in a population from changes caused by fishing. For species that are targets of commercial or recreational fisheries, reserves in Central California do protect a portion of the population from overfishing. As stated earlier, however, the size of the existing reserves is so small that this benefit is probably negligible. Similarly, the abundance of fishes in existing marine reserves is too small to effectively rebuild populations that have been overfished, because current fishery models indicate that even if fishing were closed along the entire coast, it would take 100 to 150 years to rebuild bocaccio and yelloweye rockfish populations, respectively, to 40% of their original population size.

Field studies of fishery benefits associated with reserves in other parts of the world have primarily focused on the abundance and size of harvested species that are protected in a reserve. There is a large body of evidence to show that numbers and sizes of heavily fished species increase within marine reserves. A small number of studies in tropical ecosystems have demonstrated transport from a reserve to fisheries immediately adjacent to the reserve, a process termed “spillover”. Few studies have demonstrated spillover in temperate systems.

To date, no studies have directly examined spillover or increased yield from a reserve in Central California, nor is much information available to evaluate fishing patterns near reserves. Information on short-term movements of targeted species and how that relates to the size of existing reserves is also lacking. Without such information it is very difficult to estimate rates of spillover and contributions of existing reserves to yield of nearby fisheries. Improved knowledge of fish distribution and movements, fish habitat use, and fishery responses to marine reserves (e.g., effort shifts and catch rates) will be critical to predict or interpret spillover from a reserve.

A few models have been developed that describe the potential role of reserves in contributing to fishery yields through their contribution to larval production, emigration, and recruitment to fished populations outside reserves. Models developed to evaluate potential benefits of spillover to a fishery indicate that emigration of adults out of reserves into fished areas can lead to increases in yield per recruit, primarily when emigration rates are moderately high and fishing mortality outside the reserve is high, but regulated. These models also indicate that the contribution to increased yield is constrained to areas close to the reserve. Predictions of how much reserves can increase yield vary widely. Some models suggest that a system of reserves can provide comparable yields as those obtained through traditional effort control. In these models, the effect of adding reserves on total yield is essentially the same as decreasing fishing mortality.

Several models suggest that to enhance yields, the proportion of a stock necessary to be set aside within reserves ranges from 20 to 70%, depending on stock size and distribution of fishing effort. Many of these models indicate that reserve benefits are greater when stocks have been overfished. Thus, any study measuring the relative effectiveness of a reserve will benefit greatly from good estimates of fishing mortality. Because recent stock assessments indicate that several California groundfish species are overfished (e.g., several rockfishes, lingcod), the existing models suggest there is potential for marine reserves to help some fisheries in Central California. There is general consensus, however, that marine reserves should not be established for fisheries conservation purposes without careful consideration of corresponding fishery management actions outside the reserve. One very important conclusion and implication from all of the above models is that for reserves to effectively increase yield in fisheries, they would need to cover far more area than the existing reserves, but not so much as to preclude fishing. Thus, before marine reserves could serve to augment fisheries management, a public policy debate would need to take place that discussed marine reserves in the context of all other fisheries management tools.

2b) Do the reserves in Central California protect critical stages in the life history of a species?

Many marine reserves around the world have been established to protect spawning or juvenile rearing grounds. Closing areas that are critical habitats for species is a very effective way to improve conservation of a species. Conservation benefits accrue for four reasons. First, fish on spawning grounds are often easier to catch, so protection of spawning areas reduces fishing mortality. Second, because more adults are able to spawn, more offspring are produced. Third, adults in reserves produce more offspring because larger adults often produce many more eggs and larvae than smaller adults. Also, there is some evidence to suggest that offspring of

larger fish are more likely to survive than offspring of smaller fish. Fourth, if fishing practices disturb habitat where adults aggregate to spawn, reserves protect the quality of these habitats.

There is no information to suggest that any of the reserves in Central California are important spawning or rearing grounds for any species, except that market squid migrate to spawn in parts of Hopkins Marine Reserve. Many of the species protected by marine reserves in Central California do not migrate to spawn. Thus, existing reserves protect a small part of the spawning population of many species. Existing reserves do protect important habitat, however, for many rockfishes that settle in shallow water as juveniles, and migrate to deeper habitats as they grow.

In the three older marine reserves (Pt. Lobos, Hopkins, and Anacapa Island in Southern California), fish abundance, size, and species composition are greater inside the reserves relative to adjacent areas. As a consequence, these older reserves in Central California have greater potential larval production than nearby populations outside of reserves. Studies conducted a few years after the Big Creek Ecological Reserve was established, however, showed little evidence of enhanced fish production potential. Given the slow growth of most rockfishes, and the relatively low fishing pressure in that area it is not surprising that marked differences were not observed inside versus outside the Big Creek Ecological Reserve. The magnitude of the reserve effect on increased potential of larval production appears to be directly related to the age of the reserve. More years will need to pass before we would expect to see differences in larval potential inside and outside Big Creek Ecological Reserve.

2c) Do the reserves in Central California reduce secondary fishing impacts?

Another potential role of marine reserves is to protect species and habitats from secondary impacts of fishing such as habitat destruction and incidental catch of unwanted species (bycatch). The protection of benthic habitats helps maintain biodiversity and may increase the production of a species by increasing the carrying capacity of a critical habitat. The placement of reserves in areas with historically high bycatch can reduce undesirable mortality of a species, providing fishing effort is not simply increased and displaced to another area with high bycatch.

The existing reserves in Central California were not designed to reduce secondary impacts of fishing. Many of the species harvested in Central California are rockfishes that have high mortality rates when brought to the surface, however, so existing reserves have the potential to reduce overall bycatch rates. The small area of existing marine reserves, however, indicates that total benefits accruing from reduced discard rates are likely small.

2d) Do the reserves in Central California ensure against possible failures of conventional regulatory systems?

Fishery managers often rely upon stock assessments to estimate allowable catch of a species. Once the allowable catch is estimated, managers regulate catch with input (e.g., fishing effort) or output controls (e.g., quotas). Often, stock assessments are inexact, quotas are difficult to monitor before they are exceeded, fishing efficiency is greater than anticipated for a given level of effort, and estimates of bycatch for use in fishery models are unreliable. The combined

uncertainty in fishing mortality and allowable catches can result in unexpected overfishing of a species. This has occurred for several groundfish species on the U.S. West Coast. By removing a portion of a fished population from exploitation, reserves can serve as a buffer or insurance against unexpected overfishing, as long as fishing effort outside is controlled and reserves are designed correctly. The small number of individuals protected by existing marine reserves, however, combined with potential movements of fish out of marine reserves, indicates that current reserves probably have little opportunity to ensure against possible failures of conventional regulatory systems.

2e) Do the reserves in Central California conserve life-history traits and genetic diversity?

Many fishing methods lead to a reduction in mean sizes and ages of fish in a population. This may in turn lead to a selection for slower growing fish and result in smaller size at maturity, or changes in the sex ratio of a population. By protecting a portion of a population from fishing pressure, reserves may help maintain or conserve the genetic diversity and a natural size and age distribution on a population. The existing reserves in Central California protect a small number of individuals of many heavily fished species. The small number of individuals protected, combined with potential movement of fish out of marine reserves, indicates that existing marine reserves probably have little opportunity to conserve life-history traits and genetic diversity in populations of harvested species.

3) Do the reserves in Central California increase scientific knowledge?

Marine environments are very dynamic. Often, it is difficult to attribute observed changes in an ecosystem to environmental change or to human alteration. Baseline studies that provide a benchmark for evaluating future change are needed to differentiate natural variation from anthropogenic change. A system of marine reserves may provide an opportunity to develop the baseline information needed to differentiate between natural and human-induced change.

The few studies of existing marine reserves will serve as a baseline for evaluating future changes. To date, however, little information exists on community-wide responses to protection by reserves in Central California, and only one study has examined the status of fish populations for more than two years. Moreover, the lack of sampling over the multiple years necessary to test for trends in populations inside and outside reserves makes it difficult to determine causes for observed differences. Thus, it is clear that ecosystem-wide responses have not been examined and remain unknown, the temporal persistence of differences between reserve and non-reserve populations is unknown, and it is currently not possible to determine causes for the differences between reserve and non-reserve populations in Central California. A more definitive understanding of the consequences of reserve establishment would require creation of larger reserves in concert with well-designed and funded monitoring studies over many years.

4) Do the reserves in Central California increase educational opportunities?

Marine reserves provide an opportunity to teach people about undisturbed marine ecosystems. High school and university educators and researchers frequently use the existing reserves in Central California. In that respect, existing marine reserves contribute to educational opportunities. Only the Point Lobos Marine Reserve typically provides educational activities for the general public, however.

5) Do the reserves in Central California increase recreational opportunities and tourism?

Marine reserves provide an opportunity for people to see undisturbed marine ecosystems. Recreational activities that do not damage or alter habitats or species in a reserve can provide social and economic benefits to local communities, subject to social and ecological carrying capacities. Recreational use of marine reserves can lead to resource damage if the number of people using the reserve is too high or the type of activities allowed are not compatible with local resources. Only the Point Lobos Marine Reserve provides recreational activities for the general public, however, and recreational use there is highly regulated.

6) Do the reserves in Central California provide sustainable environmental benefits?

Marine reserves can provide benefits that go beyond the protection of harvested species. These benefits can include protection of shoreline habitats, improvement of water quality, bioremediation of chemical and oil spills, and facilitation of a variety of ocean-atmospheric or nutrient cycling processes. Benefits accrued are dependent upon reserve location and the regulatory actions near the reserve. Benefits may also accrue from enhanced biological processes in the reserve, or because of increased regulatory measures that often co-occur with reserve formation. There is no evidence that water quality inside existing marine reserves is any better than the water quality in adjacent areas. The limited area encompassed by existing marine reserves in Central California indicates any reserve benefits are at best provided only to a small degree. The increased awareness of water quality issues, and increased attention to marine water quality by California regulatory agencies, that has occurred since the establishment of California's National Marine Sanctuaries, is helping to maintain or improve the relatively high level of water quality that occurs in Central California.

7) Do the reserves in Central California provide protection of cultural heritage?

Marine reserves can be used to protect specific areas such as archaeological sites, shipwrecks, sacred locations, or other culturally important features. The California coast contains many of these types of cultural attributes. Thus, existing marine reserves in Central California may contain unique or special cultural features which are not currently identified.

Summary

The exceedingly small size of existing marine reserves in Central California prevents them from achieving many of the goals and benefits attributed to marine reserves in the scientific literature. The number of fish and invertebrates inhabiting existing reserves is small, compared to the total population sizes of species in Central California. Existing reserves in Central California protect a variety of shallow water habitats and species, but do not provide reserve benefits for animals living in deeper water, unless they reside in existing reserves during a portion of their life. The older marine reserves in Central California show some of the primary benefits associated with protection from exploitation, including modest increases in size and abundance of fishes, but it is difficult to assess the degree to which these benefits represent pristine conditions. This is to be expected, as the primary fish species inhabiting these reserves (rockfishes) are slow growing and exhibit sporadic recruitment. Also, new scientific theories suggest that substantially altered habitats may or may not return to pre-existing states after the disturbance has been removed.

Marine reserves in other temperate and tropical oceans, and theoretical models of marine reserves, show substantial conservation and some potential fishery benefits. For these reasons, we expect marine reserves created in Central California for conservation purposes would accrue many of the benefits predicted by reserve theory. The extent to which reserves in Central California would successfully benefit fisheries, however, would depend on a large number of social and biological factors, such as social acceptance of reserves, fishery effort shifts, catch regulations, enforcement levels, the proportion of a stock protected in a reserve, rates of movement and larval production of protected species, and reserve size and location. Currently, only a small proportion of fished species are protected in reserves. To be an effective fishery management tool, more area would need to be placed in reserve status, but not so much as to preclude viable fisheries. If marine reserves are to be developed and successfully used in Central California as a tool for fisheries management, however, they will need to be integrated into existing fishery management processes. A structured and well-supported monitoring program, which clearly identifies a set of effectiveness parameters, will also need to be established to measure how well reserves achieve stated objectives.

Effective natural resource management requires public participation and buy-in to management goals, objectives, and regulations. Thus, just as it is vital to evaluate marine reserves for their ecological effectiveness, it is also critical that they be evaluated for their socio-economic values. In this respect, the use of marine reserves is a public policy decision that must be made with consideration of human activities. For marine reserves to be an effective public policy tool in Central California, human use patterns, perceptions, attitudes, and beliefs will need to be incorporated into the design process. Information about social and economic costs and benefits should also be incorporated to maximize the effectiveness of a reserve system. Ultimately, an understanding of how people interact with the biophysical environment is integral to the design and development of marine reserve goals and objectives.