HOW LARGE SHOULD MARINE RESERVES BE?

Background

How Large Should Reserves Be?
(A summary of findings of the National Research Council s committee on the evaluation, design, and monitoring of marine reserves and protected areas in the United States

A summary of findings of the MRWG s science advisory panel for marine reserves at the Channel Islands

Key Points

MRWG Science Advisory Panel

National Research Council

National Research Council Ocean Studies Board

National Research Council Commission on Geoscience, Environment and Resources

References

How large should marine reserves be?

BACKGROUND

The California Channel Islands have the unique distinction of being both a National Marine Sanctuary and a National Park supporting a diverse array of marine life. Accordingly, one of the primary goals set forth by the Marine Reserves Working Group (MRWG) for establishing a network of no-take marine reserves in the Channel Islands was to ensure the conservation of ecosystem biodiversity. This goal was primarily intended to protect representative and unique marine habitats, ecological processes and populations of interest in the region.

The MRWG also established a goal of achieving sustainable fisheries by integrating marine reserves into fisheries management. Given the long history of fishing in the Channel Islands region, the MRWG prioritized a need to maintain long-term economic viability of fisheries while minimizing short-term economic cost of marine reserves.

The science advisory panel (see roster below) considered the goals for conservation of ecosystem biodiversity and sustainable fisheries as they developed a recommendation for reserve size. Given limited time (May-Sept 2000) and no funding for additional research, the science advisory panel did not attempt to develop new models of individual species of concern in the Channel Islands. Rather, the science advisory panel reviewed the existing literature and synthesized existing information on resources in the Channel Islands region to develop a recommendation on reserve size for the MRWG.

At the same time that the MRWG science advisory panel conducted its review, the National Research Council (NRC) commissioned a similar review of literature on marine reserves. The NRC panel included 48 marine scientists from a variety of academic institutions and resource management agencies (see roster below). Both the MRWG science panel and the NRC panel agreed that a network of no-take marine reserves would improve the conservation of ecological communities, provide insurance against uncertainty associated with fisheries management, and provide a means to evaluate the effects of natural versus human impacts through long-term monitoring. In their review the NRC panel found that most theoretical and empirical studies indicate that protecting between 20 to 50 % of fishing grounds will minimize the risk of fisheries collapse and maximize long term sustainable catches. Results from other studies, summarized by the NRC panel, suggest that a minimum of 10% to 40% of all marine habitats should be protected for effective conservation of ecosystem biodiversity. The MRWG science advisory panel s recommendations for establishing no-take reserves at the Channel Islands are consistent with these findings by the NRC panel. The science advisory panel to the MRWG recommended protecting at least 30%, and possibly as much as 50%, of each of the representative habitats in each bioregion of the CINMS to achieve the conservation and fisheries goals established by MRWG. Both science panels concluded that reserve networks must incorporate reserves of a variety of sizes to meet multiple goals for conservation and fisheries. Below we summarize the findings of the published (and peer-reviewed) NRC report (NRC 2001) to provide background for establishing reserve size at the Channel Islands.

HOW LARGE SHOULD RESERVES BE?

A summary of findings of the National Research Council s committee on the evaluation, design, and monitoring of marine reserves and protected areas in the United States

One of the most important questions in conservation and resource management is how large reserves must be to provide specific benefits and how we can predict this size given a lack of information. The question of reserve size is complicated by numerous factors, including the goals for marine reserves, the diversity of life history characteristics of marine species, and unpredictable environmental variation. The degree to which a reserve will provide certain benefits or achieve specific goals will vary depending on life-history characteristics of the species of concern and various aspects of reserve design.

For conservation, the benefit of a reserve increases with size. Larger reserves protect more habitats and populations, providing a buffer against losses from environmental fluctuations or other natural factors that may increase mortality or reduce population growth (Daan 1993, Clark 1996, Sumaila 1998, Roberts and Hawkins 2000, NRC 2001, Allison et al. in press).

For fisheries, the benefit of a reserve does not increase directly with size. The maximum benefit of no-take reserves for fisheries, in terms of sustainability and yield, occurs when the reserve is large enough to export sufficient larvae and adults, and small enough to minimize the initial economic impact to fisheries (see review in Guenette et al. 1998). Data from harvested populations indicate that species differ greatly in the degree to which they can be reduced below normal carrying capacity before they are not self-sustainable in the long term (e.g., Mace and Sissenwine 1993, Hilborn, personal communication). If reserves are designed for fisheries enhancement and sustainability, the vast majority of studies done to date indicate that protecting 20% to 50% of fishing grounds will minimize the risk of fisheries collapse and maximize long term sustainable catches (NRC 2001, Table 1).

Reserves for fisheries

In 1990, the Reef Fishery Plan Development Team (RFPDT 1990) recommended protection of 20% of the continental shelf off the southeastern United States. In 2000, the U.S. Coral Reef Task Force (USCRTF 2000) recommended that 20% of coral reefs and associated habitats receive protection in reserves. Although the 20% figure is widely quoted, it is often criticized as being arbitrary and unscientific (NRC 2001). Justification for the recommendation of 20% set-aside requires the assumption that 20% of the target habitat is equivalent to 20% of the unfished stock, and that the stock will persist at 20% of its natural carrying capacity.

The rationale for protecting 20% comes from a fishery model indicating that recruitment overfishing could be avoided by maintaining stocks at or above 20% of their unfished biomass (Goodyear et al 1993). However, the accuracy of this target is limited by several sources of uncertainty. First, it is difficult to determine the true size of an unexploited stock. Second, the estimates of fishing mortality may be inaccurate, especially if target species are caught as bycatch in other fisheries (Guenette et al. 1998). Third, not all species will persist when populations are reduced to 20% of their natural carrying capacity. For some species (e.g., lobster), the proportion required to sustain the population may be lower (Hilborn, pers. comm.). For other species (e.g., rockfish), the proportion required to sustain the population may be substantially higher. Recent analyses suggest that stocks should be kept above 15-40% of their unfished population size (Hilborn, pers. comm.). Because of the uncertainty associated with these fisheries statistics, protecting 20% of a stock or habitat may not be sufficient to sustain exploited or bycatch species. Several studies suggest that stocks should be maintained at 60-75% of their natural population size if reserves are to be used as the primary management approach (Hannesson 1998, Lauck et al. 1998). Without other management measures, highly mobile and migratory species will require very large closures (70-80%) (NRC 2001).

Reserves may be used to provide insurance against the uncertainty associated with conventional management, environmental stochasticity, and other unforeseeable events (Ballantine 1991, Guenette et al. 1998, NRC 2001). Several studies (e.g., Roughgarden and Smith 1996, Roughgarden 1998, Lauck et al. 1998) showed that irreducible uncertainties in estimates of population size and fishing mortality make it difficult for managers to maintain stocks above critical target levels. Large closures provide a risk-averse strategy for meeting management objectives (NRC 2001, Allison et al. in press). Models developed by Mangel (2000) indicate that for stocks that are initially heavily fished (i.e. at 35% of their carrying capacity) reserves of 20 to 30% guarantee a high level of persistence for time horizons of 20 or 100 years and provide higher levels of cumulative catch than management with no reserves. Dahlgren and Sobel (2000) modeled the percent of biomass in fished and unfished areas in the Dry Tortugas to estimate the size of the reserve needed to meet specific management objectives. Results from their model indicate that a no-take reserve protecting 30-40% of the region of influence is needed to elevate overexploited stocks to sustainable target levels. Models developed by Lauck et al. (1998) incorporate uncertainties in controlling targeted quotas that lead to variable harvests, which are inherent in most traditional fisheries management schemes. Results from their modeling show that when harvests are moderately variable (±20% to 50% of the targeted quota), the chances that an initially unfished population will remain in the region of optimal sustainability (defined as > 60 % of carrying capacity by the Marine Mammal Protection Act and the Magnuson Fishery Management and Conservation Act) for a 20 year time horizon rapidly drops from 1 once the fraction of the total area available for fishing becomes greater than 30% to 40%. When variability in harvests exceed 60% of the targeted quota the chances that the stock will remain in the region of optimum sustainability are less than 1 even when only 5% of the area is available for harvest.

How large should marine reserves be?

Reserves are likely to support increased yields for overexploited fisheries, but large areas must be protected to achieve fisheries benefits (NRC 2001). As fishing pressure increases outside reserves, the size of the area in reserves must also increase to sustain the population. A marine reserve constituting 40% or more of a fisheries management area, according to Nowlis and Roberts (1999), would enhance catches and reduce annual catch variability in surrounding fishing grounds for species whose young (i.e., larvae) freely cross reserve boundaries, but whose adults do not. Guenette and Pitcher (1999) recommend setting aside at least 30% to provide a larger spawning biomass for cod and Foran and Fujita (1999) recommend protecting 25% in reserves to rebuild reproductive output of an overfished species (Pacific Ocean Perch). In general, most models suggest that reserves covering between 20 and 50% of management areas would support increased yields for overexploited fisheries (NRC 2001, Table 1).

Reserves for conservation

Even small reserves are effective for rebuilding and enhancing populations of fished species within the reserve (Halpern in press). However, human threats and environmental catastrophes might wipe out entire populations within small reserves (Allison et al. in press).

Larger reserves will contain more species and larger populations are more likely to survive periodic disturbances (Roberts and Hawkins 2000). Ward et al. (1999) suggest that habitats and species assemblages can be used as surrogates for biological diversity when designing marine reserves. Simulations showed that the number of species protected in a reserve design increased with the levels of representation within the surrogates (e.g habitats or species assemblages). When habitat was used as a surrogate, approximately 40% protection of all habitats included more than 93% of the species of concern. Bustamante et al. (1999 in Roberts and Hawkins 2000) developed a reserve design for protecting coastal habitats in the Galapagos archipelago whose objective was to protect sites for tourism and sites of high biological importance. Their design included representing all coastal habitat types in each of five biogeographic zones encompassed by the archipelago in the reserve. They estimated that it was necessary to protect 36% of the region from fishing to achieve the conservation objective. Using data from Turpie et al. (2000), Roberts and Hawkins (2000) estimated that setting-aside 10-36% of the coast of South Africa would maximize long-term persistence of coastal fish species. A system covering 10% of the South African coast could be designed to represent over 95% of the species. However, this system would not represent a number of narrowly distributed, endemic species. A reserve system covering 29% of the coast would represent all species and a reserve system of at least 36% would protect all species at the core regions of their ranges (a common goal for conservation).

Most scientists agree that preserving the same species and habitats through replication in several different sites (e.g., in a network of reserves) increases the benefits of marine reserves for conservation (RFPDT 1990, Dye et al. 1994, Schackell and Lien 1995, Bohnsack 1996, NRC 2001). Conservation of migratory species, or conservation of interacting assemblages of species may require interconnected reserve networks (e.g., in adjacent biogeographic regions). Species that depend on other populations for recruitment will require networks of reserves that have high connectivity (NRC 2001). If management outside reserves is not effective, larger reserves will be needed to sustain species of concern (NRC 2001). In general, data and models suggest that a network of interacting reserves covering between a minimum of 10% and 40% of all marine habitats is needed to contribute to conservation of ecosystem biodiversity (NRC 2001, Table 1).

Even with excellent management of non-reserve areas, a reserve system would improve the conservation of ecological communities, provide insurance against uncertainty, and allow monitoring of natural versus human impacts (NRC 2001). With less effective management outside reserves, large reserves may be needed to achieve conservation goals.

A summary of findings of the MRWG s science advisory panel for marine reserves at the Channel Islands

Reserves for fisheries and conservation

In the Channel Islands, marine reserves could be used as an effective tool to supplement traditional fisheries management. Although the top commercial fishery in the Channel Islands (squid) appears relatively stable (Leeworthy, unpublished data), other resources exhibit high variability in landings from year to year (e.g. urchin) or have declined. Marine resources have declined under pressure from a variety of factors, including commercial and recreational fishing, changes in oceanographic conditions associated with El Ni o cycles, disease, and increased levels of pollutants (e.g. Dugan and Davis 1993, CalCOFI 1995, PFMC 2000).

As an example, many rockfishes (*Sebastes* spp.) have declined throughout their ranges and five species [Pacific Ocean perch (*Sebastes alutus*), cowcod (*S. levis*), bocaccio (*S. paucispinis*), canary rockfish (*S. pinniger*), and lingcod (*Ophiodon elongatus*)] are considered overfished (Love et al. 1998, Yoklavich 1998, Moser et al. 2000). Rockfishes are particularly vulnerable to commercial and recreational fishing because they are long-lived (approximately 13-100 years) and have relatively slow growth, late maturity (4-12 years), and unpredictable recruitment from year to year (Horn and Allen 1978, Cross and Allen 1993, Love 1996, personal communication). Although efforts are underway to specifically address rockfish declines (e.g., California Code of Regulations, Title 14, Section 150.06), additional protection for rockfishes and other vulnerable species is necessary to help depleted populations recover from the cumulative impacts of commercial and recreational fishing.

There have been major changes in abundance and size distribution of California sheephead (*Semicossyphus pulcher*) in southern California. Recreational landings of California sheephead reached a peak at 230 metric tons in 1980, and subsequently decreased to 50-100 metric tons per year since 1994. Commercial landings of California sheephead exhibited two peaks in 1987 (100 metric tons) and 1992 (150 metric tons), with a subsequent decline to ~60 metric tons in 2000.

Black sea bass (*Stereolepis gigas*) were once plentiful in local kelp forests in southern California (Dayton et al. 1998). There is no quantitative information on the density of black sea bass, but historically divers reported seeing several of these fish on a single dive. Because of their size (hundreds of kilograms) and their tendency to remain in a specific home range (possibly 2-3 ha), black sea bass are particularly vulnerable to spearfishers, net fishers and other anglers. Since the ban on nearshore gill net fishing in 1994, fishers and divers report a few more observations of black sea bass (De Wet Oleson, pers. communication, Dayton et al. 1998).

Invertebrate fisheries in the Channel Islands traditionally targeted abalone (*Haliotis* spp.) (no longer taken), spiny lobster (*Panulirus interruptus*), rock crab (*Cancer* spp.), and ridgeback prawns (*Sicyonia ingentis*). In the 1950s and 1960s, abalone (*Haliotis* spp.) supported thriving commercial and recreational fisheries in the Channel Islands. Commercial fisheries for pink and green abalone (*H. corrugata* and *H. cracherodii*) peaked between 1950-1960, and 1971, respectively. The commercial fishery for black abalone (*H. cracherodii*) peaked in the 1970s, reached a second, lower peak in the mid 1980s, and subsequently declined, coincident with the spread of withering disease and continued fishing. The commercial fishery for white abalone (*H. sorenseni*) collapsed by 1980, after heavy fishing (Tegner et al. 1996). There is no association of white abalone declines with withering syndrome (Haaker, personal communication). The commercial and recreational fisheries for abalone were closed in 1996. Recently white abalone was designated for protection under the federal Endangered Species Act and a similar designation is being considered for black abalone. Red abalone (*H. rufescens*) is the only abalone species that remains locally common in some areas on San Miguel Island.

Today, squid (*Loligo opalescens*) and red sea urchins (*Strongylocentrotus franciscanus*) dominate the commercial fisheries in the Channel Islands, far exceeding the market value of all other species (Leeworthy, unpub. data). Stocks of both species appear to be negatively affected by El Nino events. The fishery for squid targets spawning aggregations on the nearshore shelves of the Channel Islands (Vojkovich 1998). After a peak in 1981, the squid fishery collapsed during the 1983-1984 El Nino, and eventually rebounded to record levels in 1995-1997. The fishery declined slightly during another El Nino in 1998. The squid management plan (DFG 2001) requires reductions in the capacity of the squid fleet to limit the potential for future overfishing. The commercial fishery for red sea urchins (for roe) targets large (> 3 _ test diameter) individuals. Red sea urchin landings steadily increased from the beginning of the fishery in 1971 through 1981. A substantial drop in catch occurred during the 1982-84 El Nino. Landings gradually increased to levels exceeding the 1981 peak and subsequently decline during the 1992-93 and 1997-98 El Ninos. This latest decline was about twice the size of that seen in 1982-84 and to date the subsequent recovery in landings (and CPUE) has been far less dramatic (P. Kalvass, unpublished CDFG data). Data on red sea urchin abundance collected by the National Park Service suggest that fishing has contributed to a general decline in the abundance of large individuals. Since 1985 abundances of harvestable size red urchins of have declined by 1% per year at fished sites on Santa Rosa and San Miguel Islands (the sites contributing most to the catch) relative to non-fished reserve sites on

Anacapa Island (S. Schroeter & D. Reed, unpublished analysis of NPS kelp forest monitoring data). Similar declines were not observed in the abundance of young-of-year recruits (urchins < 1 or 2.5 cm).

The lobster fishery in southern California has persisted, in part due to persistence of source populations in Mexico, but abundance and size distributions are clearly different from historical patterns (Dayton et al. 1998). The commercial fishery began in 1872 and in 1887 the average lobster taken was approximately 150 mm in carapace length (CL). By 1955, the average lobster from the commercial fishery was ~119 mm CL. Average harvest in San Diego from 1976-1980 varied from 86-90 mm CL. In 1888, 260 traps yielded ~231,060 lbs. By 1975, 19,000 traps were required to harvest almost the same mass (~233,179 lbs) (references in Tegner and Levin 1983). Lobster landings, although well below the peaks of the 1950s have continued through the mid 1990s at relatively high levels.

Small, but growing, markets for turban snails, whelks, and sea cucumbers have developed in the last decade (Dayton et al. 1998, Leeworthy, unpub. data). At present there are no regulations on the catch of these new emerging fisheries. Some of these species, such as the turban snail (*Kellettia kellettia*), reproduce in large aggregations (Rosenthal 1971) and are particularly vulnerable to unregulated take (Dayton et al. 1998). In the one fishery that has been examined (i.e. the dive fishery for warty sea cucumbers) there have been large significant declines (i.e. 33% -83%) in population size of fished areas at the Channel Islands relative to unfished reserves (Schroeter et al. in review). Given the historical expansion of invertebrate fisheries in the region, it is likely that fisheries will target additional species in the future. Given the uncertainty associated with existing and emerging fisheries, the MRWG established a goal of achieving sustainable fisheries by integrating marine reserves into fisheries management. Given the long history of fishing in the Channel Islands region, the MRWG prioritized a need to maintain long-term economic viability of fisheries while minimizing short-term economic cost of marine reserves.

Justification for a moderate set aside (i.e. 30% to 60%) often assumes that there is little or no protection from other more traditional forms of fishery management. In the Channel Islands, existing fishing regulations on bag limits, size, and season provide some protection for many species. Nonetheless populations of many exploited and bycatch species continue to experience declines in abundance and downward shifts in size structure (e.g., Dugan and Davis 1993, Dayton et al. 1998). For some species, particularly those species with low reproduction and delayed maturity, the assumption that there is little or no effective protection from traditional management strategies may be reasonable. In addition to the assumption that there is little protection from existing fisheries management, many theoretical studies on marine reserves evaluate persistence of an entire stock, rather than one or several populations within a management region (e.g. CINMS). Application of the recommendations from these studies involves assuming that single populations and stocks comprised of numerous populations will be similarly affected by no-take reserves. Empirical data (reviewed in Halpern in press) suggest that marine reserves, if properly enforced, contribute to increased biomass, increased size, and increased reproductive potential of exploited and bycatch species, regardless of overall reserve size.

With assistance from the science advisory panel, the MRWG identified 119 species of concern in the Channel Islands, including plants, invertebrates, fish, seabirds, and marine mammals. Given the incredible range of life-history characteristics of species of concern, it is nearly impossible to identify an optimal reserve size for all species. Additionally, fisheries models do not provide an appropriate framework for evaluation of persistence of unexploited species or multi-species complexes. The science advisory panel recommended a strategy of protecting representative marine habitats instead of attempting to design reserves for protecting individual species (Agardy 1997, Dayton et al. 2000). Numerous theoretical studies and limited empirical data indicate that protecting a minimum of 10-40% of all marine habitats will contribute to conservation of ecosystem biodiversity (NRC 2001) although most scientists agree that the benefit of a reserve for conservation increases with reserve size.

The science advisory panel recommended protecting between 30% to 50% of each of the representative marine habitats in each of the three biogeographic zones of CINMS to achieve the conservation and fisheries goals established by MRWG. Given the size of the CINMS (1252 nmi^2), the total area recommended for inclusion in marine reserves varies from approximately 375 to 625 nmi^2 (or approximately 0.4% to 0.7% of the Southern California Bight). To maximize conservation and fisheries benefits, the science advisory panel recommended maintaining the current fishing effort (or enforcing sustainable levels of fishing) outside marine reserves. This recommendation will require reduction in regional fishing effort in proportion to the area set-aside in reserves. Some fisheries (e.g. squid and sea urchin) are already in the process of reducing regional effort by reducing fleet size and capacity. Because of the complexity and uncertainty upon which this recommendation is based, continued evaluation of the effectiveness of marine reserves is necessary to determine whether subsequent alteration of reserve design (reduction or increase) is appropriate.

Individual reserve size

Ideally, the size of a single reserve should depend on the potential dispersal distance, population growth rate, and fishing pressure on species of concern.

Movement of organisms between reserves and fished areas will decrease as the size of the reserve increases (Kramer and Chapman 1999), and for this reason, conservation goals will be better served by large reserves (NRC 2001). However, net emigration out of reserves is required if fisheries are to benefit from spillover of adults and juveniles. Therefore, fisheries for species with low to moderate dispersal potential will be better served by smaller reserves spaced out across a management area. To meet multiple goals, networks must incorporate reserves of a variety of sizes (NRC 2001).

To be successful, reserves should be large enough to support the persistence of species within the reserves. Hastings and Botsford (1999) modeled the impacts of marine reserves of different sizes on species with different dispersal characteristics. They found that persistence occurs if the width of the reserve exceeds the dispersal distance of resident species by 1.5 times (Hastings and Botsford 1999). The 119 species of interest in the Channel Islands include annual to long-lived species that vary immensely in their dispersal potential. For example, boccacio rockfish juveniles marked at an oil platform near Santa Barbara were recovered at Santa Cruz Island (12 miles), Santa Monica Bay (60 miles), and off the Santa Maria River (80 miles) (Love 1996). Following the guidelines established by Hastings and Botsford (1999), an effective reserve for bocaccio may extend between 18 and 120 miles. Other species such as blue rockfish, copper rockfish, greenspotted rockfish, and starry rockfish tend to be resident on a reef for extended periods (Love 1996). Small reserves, comprising a single reef system, may provide sufficient protection for these species.

In general, larger reserves are more likely to support the persistence of a greater number of species (Roberts and Hawkins 2000, NRC 2001). The most effective reserve design for achieving some level of protection for populations of concern is to distribute reserves of different sizes throughout the CINMS.

Other considerations for reserve design

Some fisheries models suggest that, as management outside reserves improves, less area would have to be protected in reserves (NRC 2001). Lowering regional fishing effort would provide some conservation benefit to exploited populations. Although the science advisory panel recognizes the benefits of managing catch outside reserves, there are several limitations to the effectiveness of this approach for conservation. Most fishing efforts result in bycatch of non-target species. Some fishing gear, such as trawl gear, impacts habitat structure and integrity. In spite of reduced fishing effort, bycatch and habitat modification will continue to affect fished areas. Consequently, reduction in fishing effort is not equivalent to setting aside no-take reserve areas. Additionally, regional reduction in fishing effort does not provide control sites for monitoring the impacts of fishing on marine populations and communities.

The science advisory panel also considered the constraints of risk management, experimental design, monitoring, and enforcement on individual reserve size and the total number of reserves in a network. As mentioned earlier, the precautionary approach to fisheries management and conservation requires protection of multiple areas so that not all protected areas are likely to be affected simultaneously by human threats or natural catastrophes. In addition, the statistical power of monitoring data will increase with the number of reserves in the network. The science advisory panel recognized that, although several state and federal agencies have agreed to enforce reserve regulations at any potential reserve site in the planning region, it would be difficult to enforce regulations in many small reserves. Consequently, the science advisory panel recommended establishing at least one, but not more than four, marine reserves in each biogeographical region. Given the size of the CINMS (1252 nmi^2), potential reserves may vary from approximately 25 to 225 nmi^2 (or approximately 0.03% to 0.2% of the Southern California Bight).

DRAFT
How large should marine reserves be?

KEY POINTS

- Even with excellent management of non-reserve areas, a reserve system would improve the conservation of ecological communities, provide insurance against uncertainty, and provide a means to evaluate the effects of natural versus human impacts through long-term monitoring.

- If reserves are designed for fisheries enhancement and sustainability, most theoretical studies and limited empirical data indicate that protecting 20 to 50% of fishing grounds will minimize the risk of fisheries collapse and optimize long term sustainable catches.

- If reserves are designed for conservation, most theoretical studies and limited empirical data indicate that protecting a minimum of 10 to 40% of all marine habitats is needed to help conserve ecosystem biodiversity.

- In general, larger reserves are more likely to support the persistence of a greater number of species.

- Interconnected networks, that protect the same species and habitats through replication in several different sites, increase the benefits of marine reserves for conservation.

- The size of an individual reserve within a network depends on the potential dispersal distance, population growth rate, and fishing pressure on species of concern.

- To meet fisheries and conservation goals, networks must incorporate reserves of a variety of sizes.

- If management outside reserves is not effective, then the level of human impact on exploited populations will be greater, and larger reserves will be needed to sustain species of concern.

- The science advisory panel recommended protecting at least 30%, and possibly 50%, of each of the representative habitats in each of the three biogeographic zones of CINMS to achieve the conservation and fisheries goals established by the MRWG.

- To maximize conservation and fisheries benefits, the science advisory panel recommended limiting catch outside marine reserves to current levels or reducing it if current levels are insufficient to achieve sustainability. This recommendation will require a reduction in the regional fishing effort that at a minimum is proportion to the area set-aside in reserves.

- Because of the complexity and uncertainty upon which this recommendation is based, continued evaluation of the effectiveness of marine reserves is necessary to determine whether subsequent alteration of reserve design (reduction or increase) is appropriate.

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