A report by the

Ocean Studies Board
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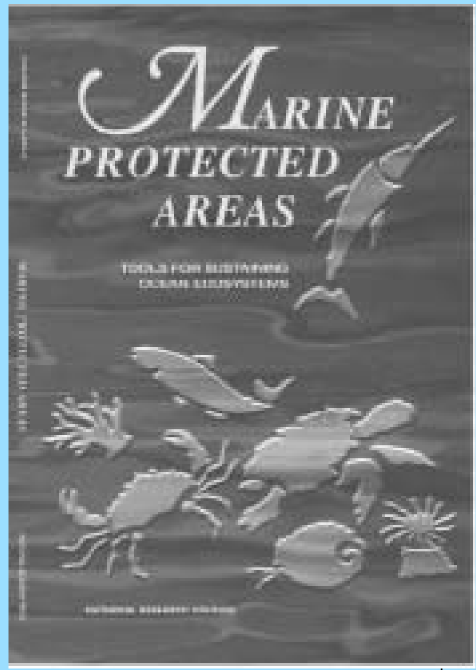
The National Academies
of the United States



The National Research Council , a division of the United States National Academies which includes the National Academy of Sciences, directed a study on Marine Protected Areas. It is my pleasure to have this opportunity to present a small subset of the results of this study, Marine Protected Areas: Tools for Sustaining Ocean Ecosystems published by the National Academy Press in 2001.

Committee Members

Dr. Edward Houde, Chair
University of Maryland

Dr. Felicia Coleman
Florida State University

Dr. Paul Dayton
Scripps Institution of Oceanography

Dr. David Fluharty
University of Washington

Dr. Graeme Kelleher
Consultant, Great Barrier Reef Marine Park

Dr. Steven Palumbi
Harvard University

Dr. Ana Maria Parma
International Pacific Halibut Commission

Dr. Stuart L. Pimm
Columbia University

Dr. Callum Roberts
University of York

Dr. Sharon Smith
University of Miami, RSMAS

Dr. George Somero
Hopkins Marine Station, Stanford University

Dr. Richard Stoffle
University of Arizona

Dr. James Wilen
University of California, Davis

OCEAN STUDIES BOARD STAFF:

Dr. Susan Roberts, Study Director
Ann Carlisle, Senior Project Assistant

This study was undertaken by a panel of distinguished international scientists in the fields of marine ecology, fisheries science, economics and anthropology, and marine policy. The committee was chaired by Dr. Edward Houde, a fish ecologist at the University of Maryland's Chesapeake Biological Laboratory.

Goals of Marine Reserves and Protected Areas

- Conservation of Biodiversity and Habitat
- Fishery Management
- Maintain other Ecosystem Services
- Protection of Cultural Heritage
- Increase Scientific Knowledge
- Provide Educational Opportunities
- Enhance Recreation and Tourism

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Why has there been such a surge of interest in the establishment of MPAs in coastal nations around the world? The appeal lies in the potential of MPAs for addressing the multiple goals of marine and coastal resource management. These goals include:

- Conserve Biodiversity and Habitat
- Augment Conventional Fishery Management
- Maintain Other Ecosystem Services
- Protect Cultural Heritage
- Increase Scientific Knowledge
- Provide Educational Opportunities
- Enhance Recreation and Tourism

The National Research Council report focuses on the goals for conserving biodiversity and habitat and managing fishery resources and hence forms the focus for the rest of my presentation.

MPA Terminology

- Marine Protected Area
- Marine Reserve
- Fishery Reserve
- Ecological Reserve

A confusing aspect of proposals to increase the use of MPAs in marine resource management has been the multiplicity of terms used to refer to MPAs and the lack of consistent usage of these terms. The committee supported the IUCN's protected area category system, but chose to use a simplified terminology for the purpose of the report as seen here: The terms used are Marine Protected Area, Marine Reserve, Fishery Reserve and Ecological Reserve.

Marine Protected Area

A geographic area designated to enhance conservation of marine and coastal resources, managed by an integrated plan that includes MPA-wide restrictions on some activities such as oil and gas extraction and higher levels of protection on delimited zones, designated as marine reserves.

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A Marine Protected Areas is defined as a geographic area designated to enhance conservation of marine and coastal resources, managed by an integrated plan that includes MPA-wide restrictions on some activities such as oil and gas extraction and higher levels of protection on delimited zones, designated as marine reserves. Reserves are defined in the next slide…

Marine Reserve

A zone where some or all of the biological resources are protected from removal or disturbance. This includes reserves established to protect threatened or endangered species, and fishery and ecological reserves.

A zone where some or all of the biological resources are protected from removal or disturbance. This includes reserves established to protect threatened or endangered species, and fishery and ecological reserves. A fishery reserve is designed specifically for addressing management of commercial and recreational fish stocks while ecological reserves are designed for conserving unique habitats and maintaining biological diversity within the MPA. An example of a marine protected area in the United States is the Florida Keys National Marine Sanctuary shown on the following map.

The shaded area surrounding the Florida Keys corresponds to the boundaries of the sanctuary, a marine protected area. Within this area a variety of reserves have been designated for many ecological goals, but mainly to protect coral reef communities. The new Tortugas Ecological Reserve, which is too new for this map, is designed to function both as an ecological and fishery reserve. The new reserve is comprised of two sections, Tortugas North which contains some of the most pristine coral reef habitat in North America and Tortugas South which includes critical spawning grounds supporting area fish populations.

Conserving Biodiversity

Values associated with marine biodiversity:

Market - biological products such as food, pharmaceuticals, biomaterials, biodegrading microbes

Ecosystem Services - water purification, bioremediation, nutrient recycling, carbon sequestration, and others.

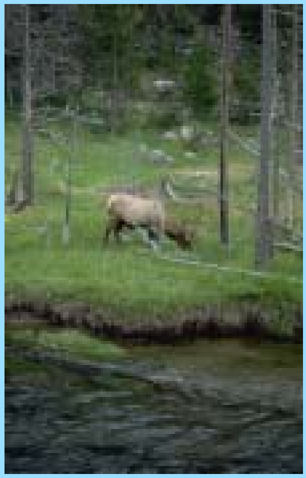
Esthetic - recreational activities, tourism

Existence/Heritage - desire to maintain the natural world for current and future generations

What is biodiversity and why do we care? Biodiversity refers to the community of organisms that live within a given area. The community includes the most minute bacteria and algae and the giant sharks and whales. Each member of the community contributes to the food web and the flow of energy from sunlight to corals to fish to scavengers. Values associated with marine biodiversity include:

- Market - biological products such as seafood, pharmaceuticals, biomaterials, biodegrading microbes
- Ecosystem Services - water purification, bioremediation, nutrient recycling, carbon sequestration, and others.
- Esthetic - recreational activities, tourism
- Existence/Heritage – reflect the desire to maintain the natural world for current and future generations

Parks on Land and in the Sea



The concept of protecting land to preserve a fragment of the natural world for current and future generations is rooted in many cultures. It includes the valuation of biodiversity although this is not always an explicit goal. But embedded in the idea of protecting the land is the belief that this will allow the indigenous plants and animals to persist in an ecosystem relatively untouched by human activities. The same concept has only infrequently been applied to the protection of marine biodiversity. In part this is due to doubt that the fluid, seemingly boundary-less marine ecosystems would benefit from the imposition of regulatory fences that have no physical correlate. However, a recent analysis of marine reserves, in many different types of habitats, of different sizes, and established in coastal waters in many parts of the globe, conclusively demonstrates that marine reserves perform much like their terrestrial counterparts.

Changes within Reserves
(Halpern, 2002)

	Overall	Carnivore	Herbivore
Density	1.91 +/- .28	2.21 +/- 5.63	2.39 +/- 2.67
Biomass	2.92 +/- .92	3.12 +/- 1.23	3.33 +/- 4.82
Size	1.31 +/- .07	1.31 +/- .10	1.52 +/- .36
Diversity	1.23 +/- .07	2.40 +/- .43	1.39 +/- .27

Ben Halpern, a doctoral candidate at the University of California, aggregated the results of 76 studies of marine reserves from around the world. Briefly, he found that areas designated as reserves consistently showed higher densities of organisms, an increase in the overall biomass, an increase in the number of species, and an increase in the size of individuals. To determine if the cessation of fishing caused major shifts in the food web, Ben broke these results down into herbivores and carnivores and found that there were no significant differences in the responses of these two trophic groups to the establishment of the reserves. Also, but not shown on this slide, he found that the response to establishment of the reserve was directly proportional to the size, hence small reserves performed comparably to large reserves. This work shows that marine reserves serve a similar function to the wildlife preserves on land. However, marine reserves have been proposed not only as saltwater parks, but also as a tool for managing use of living marine resources, in particular fisheries management.

Fishery Reserves

Potential roles for marine reserves to augment conventional fishery management:

- Allow recovery of depleted fish stocks
- Prevent the depletion or collapse of fish stocks
- Provide insurance against uncertainty
- Enhance overall recruitment
- Prevent damage to fish habitat

Fishery reserves have been proposed to address many goals of fishery management. These include the recovery of depleted fish stocks, prevention of the inadvertent depletion or collapse of fish stocks, insurance against uncertainty both in environmental conditions, and uncertainty in our ability to assess the condition of fish stocks. Reserves have also been proposed to enhance the survival of juvenile fish improving recruitment in the adult population, and finally as a means to prevent damage to fish habitat. But these goals are shared by conventional management. Why are reserves different?

Single Species Management

COMMON ASSUMPTIONS

•Productivity depends on the size of the adult stock
Problem: Reproductive success and recruitment are variable and depend on environmental conditions.

•Fish stocks are temporally or spatially segregated
Problem: Many species co-occur and cannot be fished without the unintended catch of other species (bycatch).

•Individual fish are evenly distributed through space such that fishing induced mortality is spread throughout the stock
Problem: Sedentary or territorial species concentrate in specific locations that are subject to serial depletion.

Conventional management has been based primarily on the single species approach. This approach involves a suite of assumptions that sometimes limit the effectiveness of this approach. For example,

Productivity depends on the size of the adult stock (Models used in stock assessments predict future productivity based on estimates of the size of adult or spawning populations)

•The problem with this assumption is that reproductive success and recruitment are variable and depend on environmental conditions.

Another assumption is that fish stocks are temporally or spatially segregated and therefore can be fished without affecting the abundance of other species of fish.

•In this case, the problem is that many species co-occur and cannot be fished without the unintended catch of other species (bycatch). A notable example of this problem occurs in the shrimp fishery in the Gulf of Mexico. In their trawls, the fishermen catch ten times more by weight of various species of finfish than shrimp, including red snapper, a favorite target species for recreational fishermen.

•**A third assumption used in fish stock assessment models is that individual fish are evenly distributed through space such that fishing induced mortality is spread throughout the stock.**

The problem with this assumption is that sedentary or territorial species concentrate in specific locations that are subject to serial depletion. There are some species with lifestyles that are particularly unsuited for these common assumptions used in conventional management. These species may be relatively sedentary, patchy in their distribution, and/or have young whose survival to adulthood is especially sensitive to natural environmental fluctuations.

Single Species Management

LIMITATIONS

• Habitat protection - habitat quality affects productivity and esthetic value.

• Species interactions - interdependence of species affects the food web, nutrient cycling, biogenic structures, and other ecological processes.

• Conservation of biodiversity - disturbance may shift the species assemblage of marine communities.

In addition to the fish stocks that don't match the models used in stock assessment, there are a few other limitations of the single species approach. These include the need for:

•Habitat protection - habitat quality affects productivity and esthetic value.

• Accounting for species interactions – interactions and interdependencies among species affect the food web, nutrient cycling, biogenic structure formation, and other ecological processes.

• Conservation of biodiversity - disturbance from fishing and other human activities may shift the species assemblage of marine communities.

Spatial Management

• Conserve communities of organisms, not just the target species

• Requires knowledge of life history of species targeted for conservation - dispersal, food, and habitat requirements (major limitation for designing fishery reserves)

• Facilitates adaptive management by providing reference sites to assess human-induced versus environmental changes

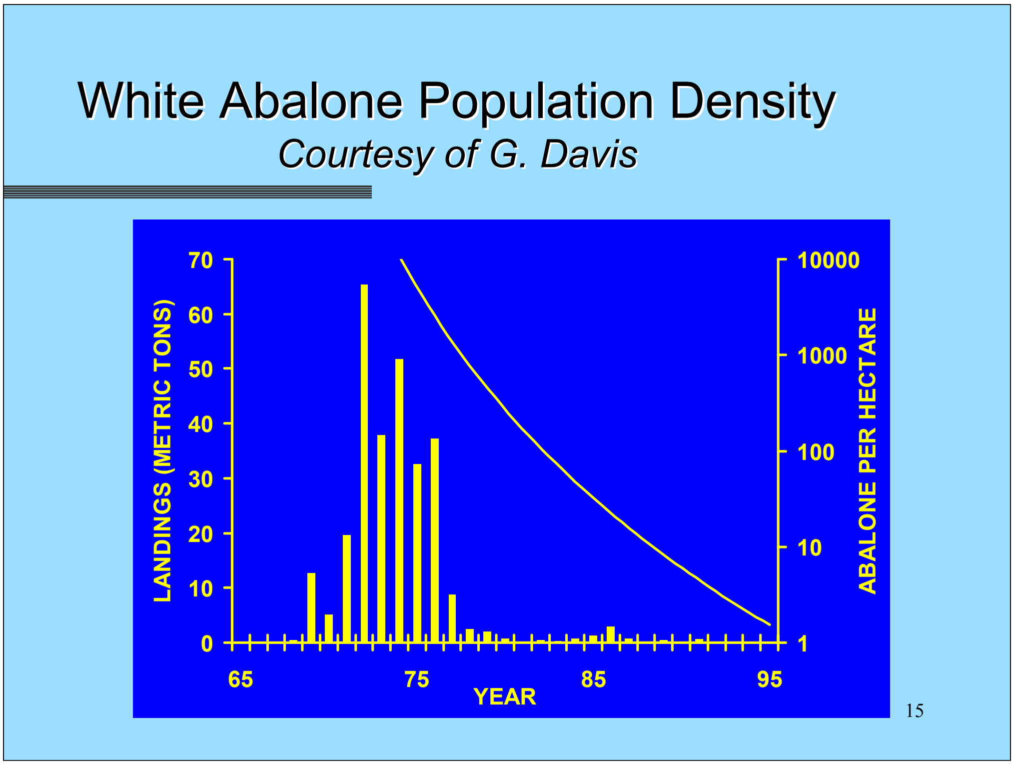
The alternative approach of marine protected areas emphasizes the spatial dimension of marine resource conservation rather than the abundance of any individual species. This allows

•Conservation of communities of organisms, not just the target species.

• However, it requires knowledge of life history of species targeted for conservation - dispersal, food, and habitat requirements to design the most effective reserve.

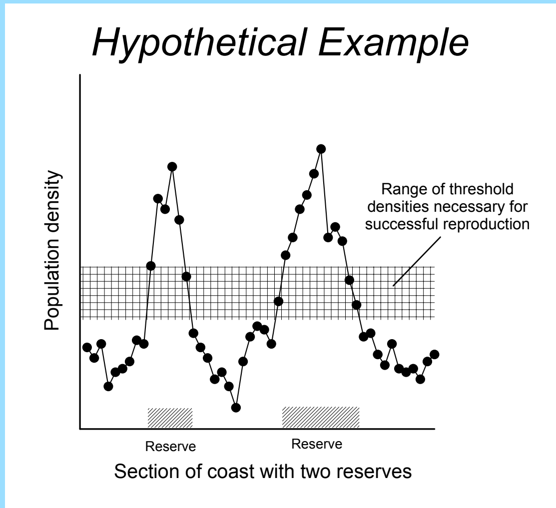
• In addition to the conservation benefits, spatial management facilitates adaptive management by providing reference sites that are needed to assess human-induced changes relative to the natural, environmental changes.

In some circumstances, reserves may be the best approach for improving the sustainability and persistence of a highly valued species. An example of a species that is unsuited for conventional approaches to management is described next.



The white abalone is a marine gastropod highly prized for the quality of the meat in its large foot muscle. Unfortunately, the patchy distribution of this gastropod and its sedentary lifestyle has made it particular susceptible to overharvest and the stocks throughout its range in California have declined precipitously. One particular consequence of this sedentary lifestyle for the abalone is that reductions in the density of the population has a disproportionate effect on its reproductive success. The adults of this species must be close enough to each other, in other words at high enough density, to come find each other for mating. This, and the role of reserves in addressing this problem is illustrated by the next graph.

Allee Effect



Abalone are subject to what is known as the Allee effect. This refers to the density dependence of reproduction. In this graph, the x axis represents relative population density, while the y axis represents a transect through a region with two reserves. At the reserve sites, the population is maintained at a level that exceeds the threshold required for successful reproduction. The range of this threshold is represented by the hatched area. In the open, fished areas, the population has been reduced to a level that is too low to reproduce. Hence only areas in reserves will contribute to future populations of abalone. This raises the issue of whether or not reserves can support fisheries in open fishing grounds.

Spillover and Sources and Sinks

How might a marine reserve support fisheries in the open fishing grounds?

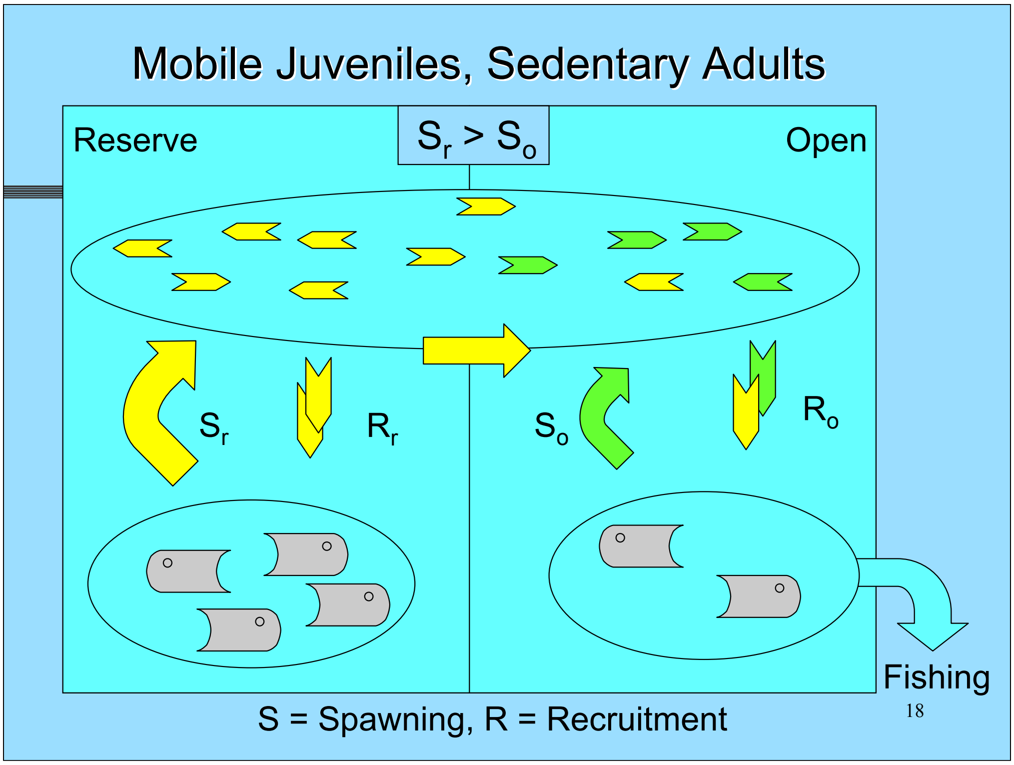
• Reserve supplies either juveniles or adults to the open areas, depending on dispersal characteristics

• Reserve must be located in a site that supports the productivity of the stock

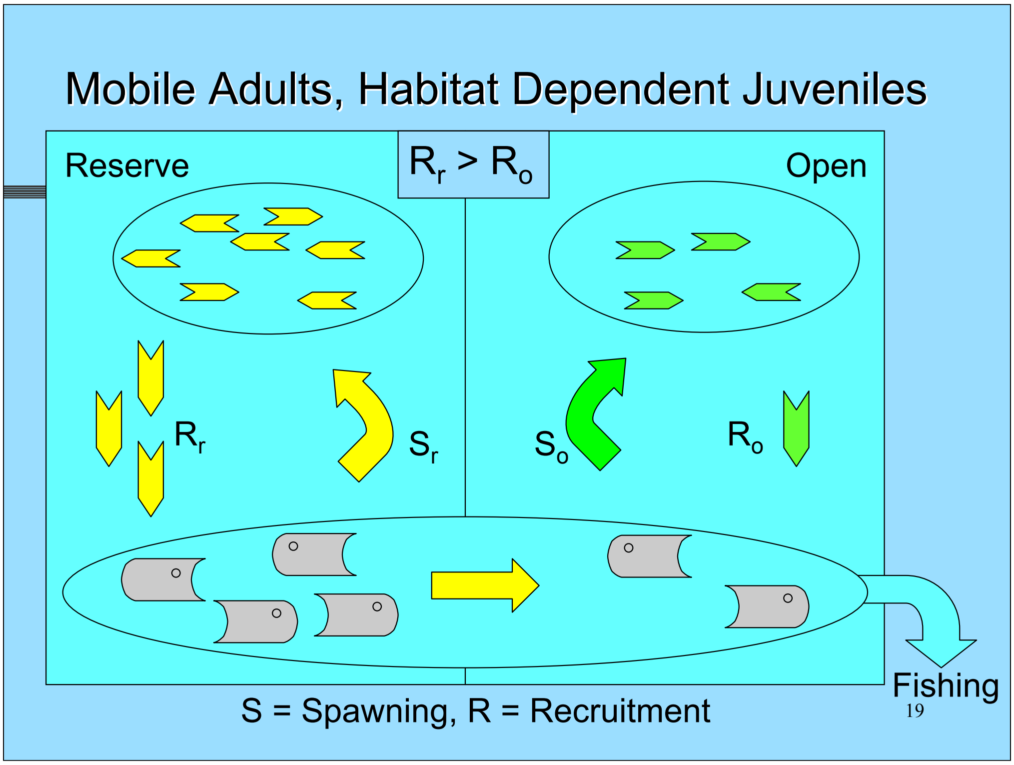
The concepts underlying the success of reserves in supplementing fished populations are commonly referred to as spillover and sources and sinks. They address the question of how a marine reserve might support fisheries in the open fishing grounds?

•For spillover, the idea is that the reserve supplies either juveniles or adults to the open areas, depending on dispersal characteristics

•Sources and sinks are direct corollary to the spillover concept. For a reserve to supply another area with juveniles or adults it must be located in a source – a productive area where emigration exceeds immigration – not a sink where most individuals originate in another area. Spillover effects may be simply modeled as follows.



In this figure, adult fish do not migrate, but are associated with particular habitats or sites. Reserves that are located in these sites or habitats protect a fraction of this adult population, which is then predicted to produce more offspring per unit area than the fished areas. This is represented by the larger arrow for Sreserve than for Sopen. The offspring, juveniles are mobile and freely mix throughout the region. Hence the recruitment of juveniles into the adult population will be equivalent in the open fished area as the reserve and will be higher than recruitment in the absence of the reserve. Loss of adults to fishing is represented in the open area as a large arrow exiting the bounded area which represents the ecosystem.



In the circumstance where the adults are migratory, it is possible that a reserve may still augment the fished population if juveniles congregate in habitats that contribute to survival but are susceptible to fishing impacts such as bycatch or habitat modification. In the figure, the distribution of juveniles is patchy and well defined. The adult population mixes throughout the region. A reserve sited in juvenile habitat will increase the survival of the juveniles within. When these juveniles mature, they will recruit into the mixed adult population and hence contribute to the open fished areas. In the figure this is represented by the higher level of recruitment in the reserve, Rreserve compared to the open area, Ropen.

Dispersal and Networking

- Local retention *versus* long distance dispersal
- Natal homing
- Connectivity

In addition to recognizing the whether a species has a sedentary adult or juvenile phase, there are additional considerations for evaluating how a reserve might contribute to the sustainability of marine species. First, is consideration of the dispersal properties of the species. In some cases, species that at first appear to have a broadly distributed larval or juvenile phase, may actually have high levels of local retention, where the young stay close to the site of the adults. In other cases, the young may disperse over long distances, dependent on currents such that renewal of the parent population depends on upstream locations populations. Another strategy is called natal homing. In this case the young adults return to their site of birth after spending time at sea. All of these various life history strategies have implications for the design of reserves and the concept of connectivity among reserve sites that would allow establishment of a self-sustaining network.

Tasks for Designing MPAs

Including Stakeholders in Decisionmaking

(1) Evaluate conservation needs at local and regional levels

(2) Define objectives and goals for establishing MPAs

(3) Describe key biological and oceanic features of the region

(4) Identify potential sites considering location, size, networking, and feasibility

In the next slides, I will discuss some of the considerations for designing marine protected areas. This long-term success of this process depends on participation of stakeholders in each of the following steps.

- Evaluate conservation needs at local and regional levels
- Define objectives and goals for establishing MPAs
- Describe key biological and oceanic features of the region
- Identify potential sites considering location, size, networking, and feasibility

Location and size of MPAs and reserves has often been a particularly contentious issue in the decision to set up an MPA.

Location

MPAs should be integrated into an overall plan for marine area management

- MPA success depends on the quality of management in the surrounding waters and coastal areas.

- Inclusion of MPAs in coastal zone management plans will help optimize the level of protection afforded to the marine ecosystem as a whole.

Once sites have been identified based on ecological criteria, the list may be narrowed by considering the how the MPA will affect and be affected by the surrounding areas. The success of MPAs depends on the quality of management in the adjacent waters and coastal areas. Therefore, choice of sites for MPAs should be integrated into an overall plan for marine area management that optimizes the level of protection afforded to the marine ecosystem as a whole.

Size

The optimal size of marine reserves and protected areas should be determined for each location by evaluating:

- Conservation needs and goals
- Quality and amount of critical habitat
- Levels of resource use
- Efficacy of other management tools
- Characteristics of the species or biological communities requiring protection.

The optimal size of marine reserves and protected areas should be determined for each location by evaluating the conservation needs and goals, quality and amount of critical habitat, levels of resource use, efficacy of other management tools, and characteristics of the species or biological communities requiring protection. There are no universal rules for determining how large an MPA or reserve should be. Each region has a different suite of species and resource uses that must be evaluated to decide how large an area needs to be. An adaptive approach that first protects the most vulnerable and valuable areas can be used to determine the optimal amount of reserve area, but this requires a commitment to monitoring and research.

Conclusion

MPAs will shift the focus from single species management to ecosystem-based policies that recognize the spatial heterogeneity of marine habitats and the need to preserve the structure of marine ecosystems.

In conclusion, the NRC committee supported the use of MPAs as part of a spatial management approach that shifts the focus from single species management to ecosystem-based policies that recognize the spatial heterogeneity of marine habitats and the need to preserve the structure of marine ecosystems.