

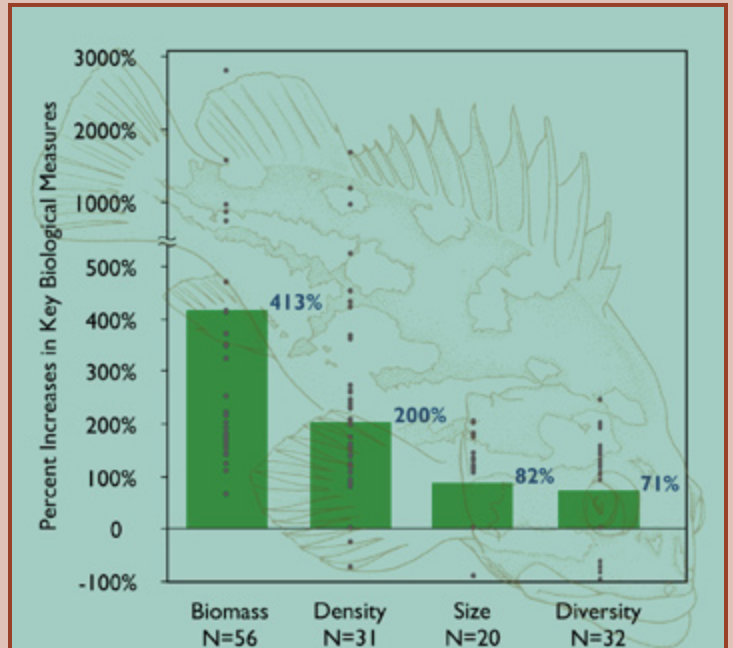
Can reserves produce benefits inside their boundaries?

a major purpose for establishing marine reserves is to protect the habitats and to restore animals and plants in particular sites.

Do marine reserves typically accomplish these goals? Scientists have studied the performance of more than 80 marine reserves of many different sizes in a variety of temperate and tropical habitats. A comprehensive review of these studies reveals that most well-enforced marine reserves result in relatively large, rapid, and long-lasting increases in the population sizes, numbers of species, and reproductive output of marine animals and plants. The review found that the average biomass, or weight of all animals and plants studied, is more than four times larger in reserves than in unprotected areas nearby. On average, the density, or number of animals in an area, triples, and the number of species is 1.7 times higher in marine reserves than in unprotected areas. In addition, the average body size of animals is 1.8 times larger in reserves than in fished areas. These findings include not just fished species but other plants, invertebrates, and fishes.

Why do these changes occur within reserves? First, protection from fishing allows animals in reserves to survive longer and grow larger. Second, habitats can recover inside reserves and better sustain the plants and animals that rely on them. Third, the plentiful prey in reserves can support more predators. Marine reserves are currently the only marine management tool that provides this unique combination of effects, promoting the recovery of entire ecosystems.

Why are large populations important? Small populations are more likely to be driven extinct by unpredictable catastrophes, such as oil spills. Large populations include more individuals, so they are more likely to contain individuals that are capable of surviving various stresses. In addition, population size can influence the reproductive success of animals that release their eggs and sperm into the water, such as abalone and sea cucumbers; when these animals are rare, their eggs and sperm can become so diluted that little or no fertilization occurs.

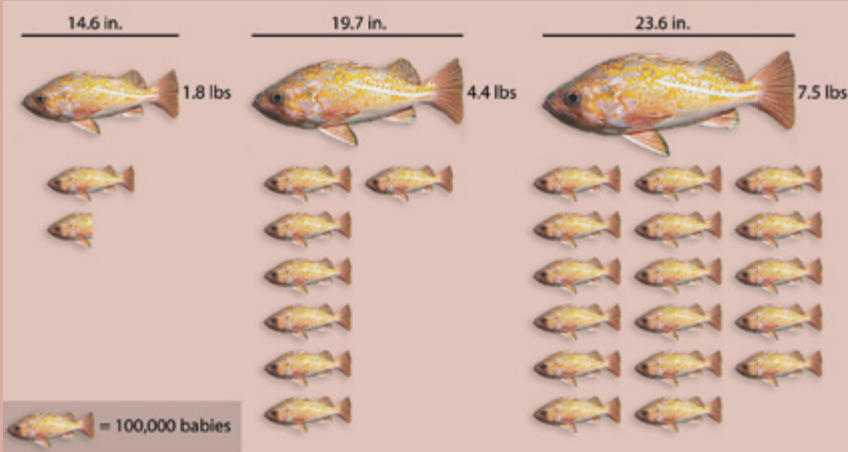


N = the number of reserves in which a particular characteristic was measured

Marine reserves usually increase the biomass, density, size, and diversity of species living within their boundaries. The bar graph (modified from Halpern, in press, and Palumbi, in press) indicates the percent change in key biological measures inside marine reserves. The average increases (green bars) are based on data from marine reserves around the world. The actual changes at particular reserves varied (gray dots), but the vast majority of all reserves showed positive responses in all biological variables.

Key Findings

- In marine reserves, animals and plants usually increase in their biomass, abundance, numbers of species, and body size — factors that can increase ecosystem resilience and productivity.
- Biological changes in marine reserves occur because individuals are not killed by fishing, and because their habitat is protected.
- Larger fishes and invertebrates typically produce substantially more young.
- Many species, not just those that are fished, respond positively to the protection of entire ecosystems in marine reserves.



Average numbers of babies produced by three different sizes of vermilion rockfish.

Bigger body size is one of the most important biological changes in marine reserves, because large fishes and invertebrates can produce enormous numbers of young. The relationship between body size and the number of young is well known. For many marine fishes and invertebrates, small increases in body size can lead to large increases in the number of eggs produced. For example, a 23-inch vermilion rockfish can produce 17 times more young than a 14-inch fish. The bigger and more abundant animals living in a marine reserve can produce far more young than their smaller neighbors in unprotected waters. As a result, marine reserves can support higher growth rates.

The Importance of Healthy Ecosystems

Healthy ecosystems are the building blocks of productive and resilient oceans. People depend on productive oceans for “goods,” such as food and medicines, and essential “services,” such as the detoxification of pollutants, recycling of nutrients, control of pest outbreaks and diseases, and regulation of climate, atmospheric gases, and the water cycle. These essentials are called “ecosystem goods and services.” Healthy ocean ecosystems provide these goods and services for free. If the ecosystem is damaged, for example by habitat destruction, pollution, or overfishing, the delivery of goods and services is impaired. As a result there may be a loss of productivity, increases in outbreaks of undesirable species, and less resilience to disasters.

Essential goods and services are provided by many types of ocean ecosystems: coral reefs, kelp forests, mangroves, salt marshes, mud flats, estuaries, rocky shores, sandy beaches, sea mounts, continental shelves, abyssal plains, and open oceans. Each ecosystem contains many types of species that interact with each other and influence the physical and chemical environment. Goods and services are simply byproducts of the functioning of intact ecosystems.

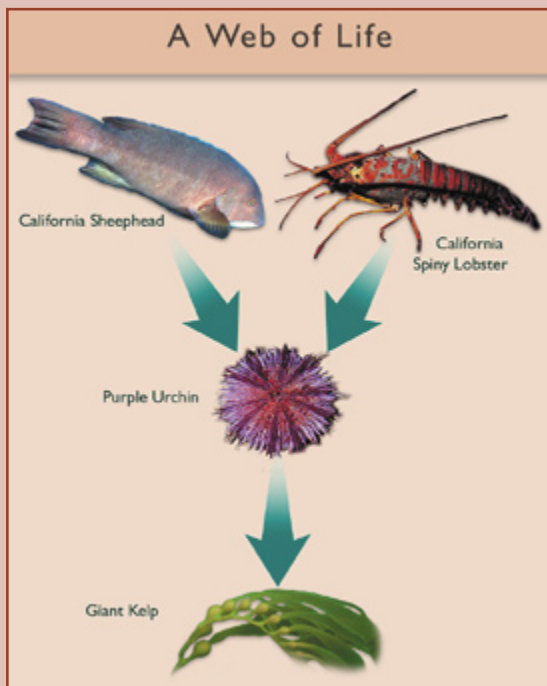
Unlike other management tools, marine reserves protect major portions of an ecosystem, including all the habitats, plants, and animals. This protection allows the environment, the species, and their interactions to function in a manner that provides the ecosystem goods and services that humanity wants and needs.



Will reserves increase the abundance of all species?

Although many fished and nonfished animals and plants become more plentiful within newly established marine reserves, some decline. For example, a fished animal, such as lobster, may increase in number and size in marine reserves and consequently reduce the number of its prey, such as sea urchins (see illustration). In addition, some species that were absent may not become reestablished in a reserve if no viable populations remain nearby.

Although it is difficult to predict the exact changes for any particular species or location, the data from existing reserves show that, on average, increases in abundance, body size, biomass, and the number of species are common outcomes after marine reserves are established.



A food web shows the feeding (or trophic) relationships among species. In southern California, sheephead and lobster eat purple urchins, which consume giant kelp.

Case Study: Anacapa Island, California, USA



Anacapa Island Natural Area



Lessons Learned

- Some important species, such as lobster and California sheephead, are larger and more abundant in the Anacapa Island marine reserve than in surrounding fished waters.
- Inside the reserve, kelp forests flourish because lobsters and sheephead, which are predators, reduce populations of kelp-eating purple urchins.
- As a result, the kelp forest ecosystem in the reserve is more productive and stable over time than kelp forests outside. Outside the Anacapa Island reserve, purple sea urchins have periodically destroyed kelp forests.
- Similar effects through the food web are likely to occur in other reserves because marine animals and plants often strongly affect one another.

Ecosystem Responses in a Marine Reserve

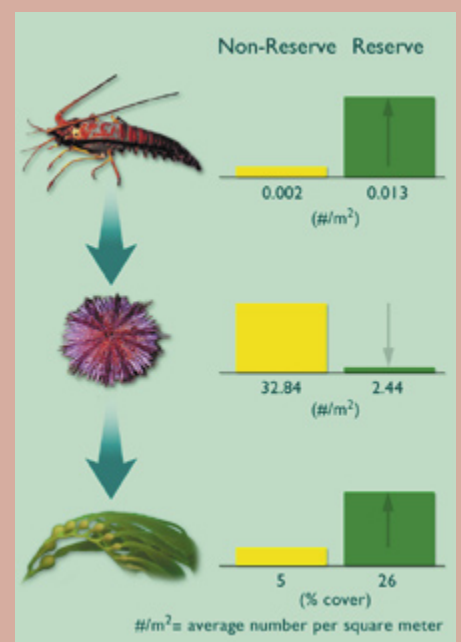
In 1978, the National Park Service established a closed area in the Anacapa Island Ecological Reserve in southern California. The ban on all fishing in the reserve protects lobsters, fish, sea urchins, and many other species living in the rocky reefs and kelp forest habitats of the reserve.

Since 1980, the National Park Service and partner agencies have collected biological data from the Anacapa Island reserve and unprotected areas nearby. The data show that the marine reserve supports some of the richest kelp forests in California's Channel Islands. Lobsters are six times more numerous, red urchins grow 1.7 times larger, and sheephead fish are three times more plentiful in the reserve than in nearby fished waters. Kelp plants, which form crucial habitats for other species, grow five times more densely and persist longer in the reserve than in waters nearby.



The ecosystem protected in the Anacapa Island reserve now contains most of its animals and plants in a relatively natural state. The populations in the reserve remain more stable over time than those outside the reserve, because interactions among species are not affected by fishing. Lobster and California sheephead protected inside this reserve feed on sea urchins, thereby keeping urchin numbers in check. Reduced numbers of urchins allow stands of kelp to flourish, which in turn support many other species inside the reserve. In contrast, outside reserves where lobster and sheephead are fished, large numbers of urchins periodically overgraze kelp forests, turning reefs into rocky "barrens."

When one species in the food web is fished, other species are affected. For example, when lobsters are fished, sea urchins become abundant and kelp declines. In a reserve, lobsters grow larger and more abundant, keeping the urchin population down and allowing the kelp to grow. K. Lafferty/M. Behrens (USGS/UCSB) analysis of NPS data.



Case Study: San Juan Islands, Washington, USA



San Juan Islands Marine Preserves

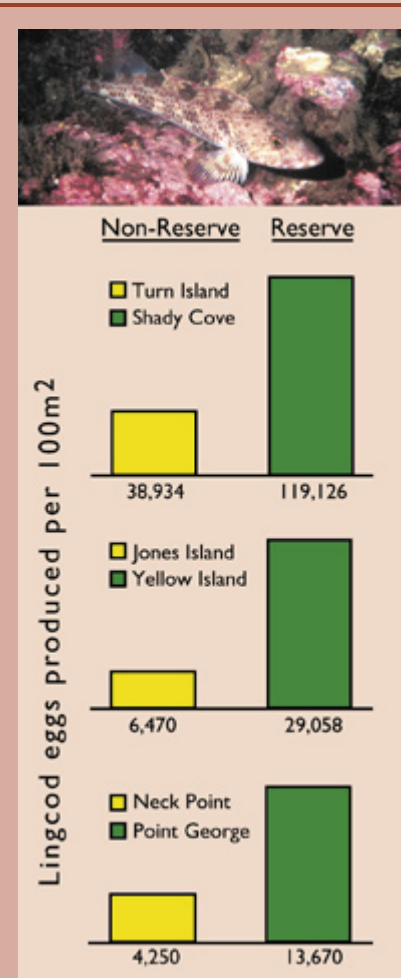
Reserves Boost Abundance, Size & Reproduction

In 1990, the Washington Department of Fish and Wildlife and the University of Washington established five small marine reserves in the San Juan Islands of Puget Sound. They took this action to protect marine biodiversity and to provide undisturbed habitats for scientific research in a region heavily affected by fishing. A decade later, studies show that the San Juan Islands Marine Preserves contain larger and more plentiful fish than unprotected areas. Production of young fish is much greater in the reserves, because both the number and size of fish are larger.

Since establishment of the reserves, lingcod, which had dropped to low levels by the early 1990s because of intensive recreational fishing, increased tremendously. Their biomass is two to four times greater inside the protected areas than outside. Lingcod that are old enough to reproduce are ten times more abundant in reserves. In recent surveys, the biggest lingcod found in a reserve was 110 cm, compared to only 70 cm outside. Each lingcod in the reserves produces an estimated three times as many eggs as those outside.

Quillback and black rockfish have not yet recovered in the reserves. Because of intense fishing, these species are extremely rare in the region. Without breeding stock to provide young to settle in reserves, reserves can offer little immediate aid. However, small numbers of young rockfish have begun to appear in the past few years, offering the potential for future recovery.

Striped surfperch, which are not fished, show no difference in size or abundance inside and outside the reserves. Three times more Puget Sound rockfish, which also are not fished, live outside the reserves than inside. However, lingcod and other large fish eat these small fish. Therefore, rising numbers of lingcod may account for the observed declines of Puget Sound rockfish in the reserves.



The estimated number of lingcod eggs produced per 100 square meters was much larger in marine reserves than in unprotected areas around the San Juan Islands. The total numbers of eggs varied with habitat quality, but habitats in reserves and paired unprotected areas were similar.

Data: E. Eisenhardt (U. Washington)

Lessons Learned

- Lingcod are much bigger and more abundant inside the San Juan Islands Marine Preserves than outside.
- Because of their size and abundance, lingcod in the reserves produce large quantities of young, many more than the number produced in fished areas.
- Quillback and black rockfish are extremely rare in the region. These species have not yet recovered in reserves, probably because they lack breeding stock in the region.