can reserves produce benefits outside their boundaries?

Marine reserves not only affect populations living within their borders but may also influence populations in adjacent waters. Adults and juveniles from a reserve may swim or crawl into neighboring areas. This process is known as "spillover." In addition, tiny newly born animals, called "larvae," and plant "propagules" may drift out of a reserve and "seed" the surrounding waters. This process is called "export." Spillover and export may enable marine reserves to replenish nearby populations. Although not widely documented, spillover and export from reserves are believed to occur commonly.

Key Findings

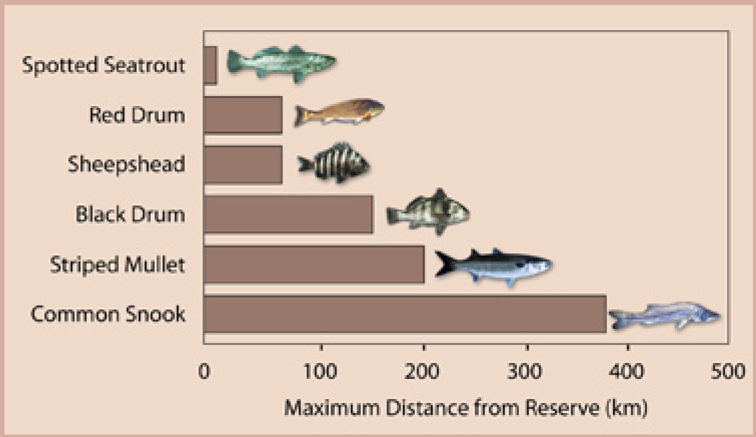
- Animals from marine reserves may swim or crawl outside to supplement surrounding populations.
- Larvae and plant propagules that disperse out of reserves may seed and boost populations in surrounding waters.

Spillover: Movement of Adult & Juvenile Animals

Because marine reserves tend to harbor larger populations than surrounding waters, some animals may move into less-crowded areas nearby to avoid competition for resources such as food and living space. The rate of spillover of adults and juveniles increases with time after reserve establishment as populations become increasingly dense in the protected area. In addition, some fishes, such as rockfishes and lingcod, move from one habitat to another as they grow, regardless of population size, and may leave a reserve for this reason.

Whether or not spillover happens for a given species depends in part on its mobility. Species that are attached to the seafloor as adults, such as mussels and clams, cannot migrate outside reserve boundaries, but swimming and crawling species like fish and crabs can. Transient animals, such as migratory fish, may merely pass through reserves. Thus, their populations are unlikely to build up in reserves and contribute to increased population sizes in adjacent waters.

Studies of animal movement from reserves provide direct evidence that fish and invertebrates spill over. For example, many species of fish tagged in the marine reserve at Florida's Merritt Island National Wildlife Refuge were later caught outside by recreational anglers. Some species, such as the spotted seatrout, moved only short distances from the reserve. However, most species, including two popular sport fish, black drum and red drum, moved between 50 and 200 km from the reserve. A few species, such as common snook, exhibited even longer distance dispersal.

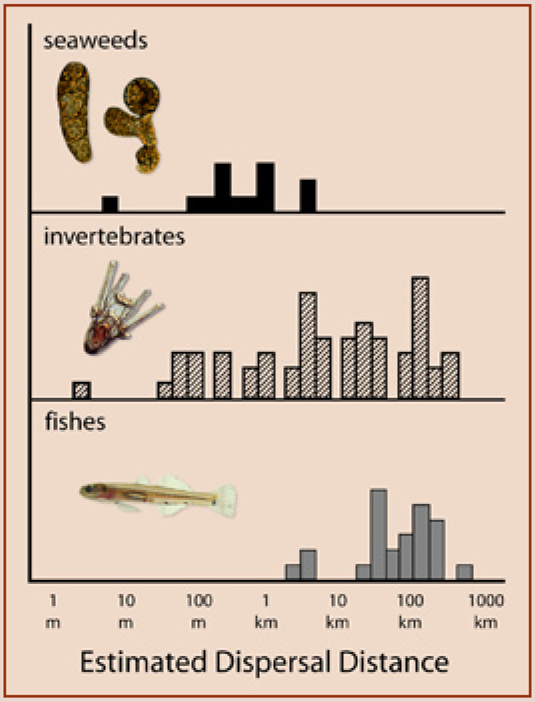


The graph shows the maximum distance traveled (km) by over 125 sport fish tagged in the Merritt Island National Wildlife Refuge. Some species (e.g., spotted seatrout) move only short distances, while others (e.g., common snook) travel much farther. Many tagged fish moved out of the Merritt Island reserve into nearby fishing grounds.

Does spillover actually augment populations outside reserves?

If so, animals should be most abundant inside reserves and just across their boundaries. Indeed, this pattern has been found for fishes and invertebrates at several marine reserves in the United States, Kenya, Barbados, Philippines, Japan, and elsewhere. Moreover, fishing boats often congregate along the borders of marine reserves, because that is where catches are highest. This practice of "fishing the line" has been observed at marine reserves in California, Florida, New England, Spain, Belize, New Zealand, and other places.

References: 10, 11, 12, 13.



This graph shows the average dispersal distance for young marine plants, invertebrates, and fish, estimated from genetic data. In general, plants do not disperse as widely as animals. Young invertebrates exhibit a wide range of dispersal distances. Some young invertebrates do not disperse more than a few hundred feet from their parents. In contrast, sea urchin larvae can move distances over 100 kilometers. Young fish tend to have higher dispersal; some kinds move more than 100 kilometers, on average. Data: B. Kinlan & S. Gaines (UCSB)

Export: Dispersal of Young from Reserves

Fishes and invertebrates typically produce hundreds of thousands of microscopic young that drift on ocean currents for weeks or months, potentially traveling hundreds of miles. Most fishes, mussels, clams, sea urchins, and numerous other animals pass through this early life stage of dispersal. Eventually, some of the larvae settle onto a reef, or other appropriate habitat, where they can grow into juveniles and adults. Most marine plants also produce microscopic young that can be dispersed by currents.

Species vary in how far their larvae travel (see graph). Distances that larvae go depend on their behavior, how long they drift, and the prevailing currents. Depending on the species and the local conditions, larvae may stay close to their parents or they may disperse far away. Because of larval and propagule dispersal, marine reserves can seed populations in surrounding regions.

For example, reserves in the coastal waters of Nova Scotia and the Bay of Fundy protect just 10 percent of the lobster population, but these protected animals are estimated to account for over 50 percent of the larvae produced in the entire region. Currents distribute the larvae across the region, and many of the young lobsters settle in places outside the reserve.

Can Reserves Benefit Migratory Fish?

Some fish are homebodies. But others swim dozens, hundreds, or even thousands of miles each year depending on their breeding and feeding habits. How can marine reserves, which are fixed in certain locations, play a role in aiding animals that may routinely enter and leave the protected areas?

Although migratory fish move great distances and can be distributed across expanses of ocean, entire populations become extremely vulnerable to fishing when they aggregate in spawning grounds, migratory pathways, nursery areas, or other sites. Because the animals come together in large numbers in such places, often returning to the same locations year after year, fishermen can catch them more readily, and a large fraction of a population can be killed in a short period of time.

If reserves are established at key locations, they can protect migratory fish during these vulnerable stages. Wildlife refuges on land protect migratory birds at breeding and feeding sites in a similar manner. Marine reserves have the potential to enhance catches of migratory fish in unprotected areas. For example, the nursery grounds of the migratory, flat-bodied fish called plaice were protected in the North Sea for over ten years and catches in the large region outside these protected zones increased an estimated eight percent. Similar measures to protect spawning grounds of Nassau groupers in the Caribbean are currently underway in the Bahamas. Tuna are another migratory fish that could benefit greatly from protection of their breeding grounds.

Marine reserves provide outcomes that supplement those of traditional fisheries measures. In some cases, marine reserves might be unable to protect fish that swim frequently out of the reserves. However, if reserves are large enough, or interconnected in a network of reserves that protects critical habitats, mobile species may benefit by spending a substantial portion of time in reserves.

Case Study: Merritt Island, Florida, USA

Merritt Island
National Wildlife Refuge

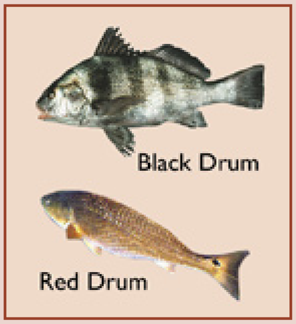
Lessons Learned

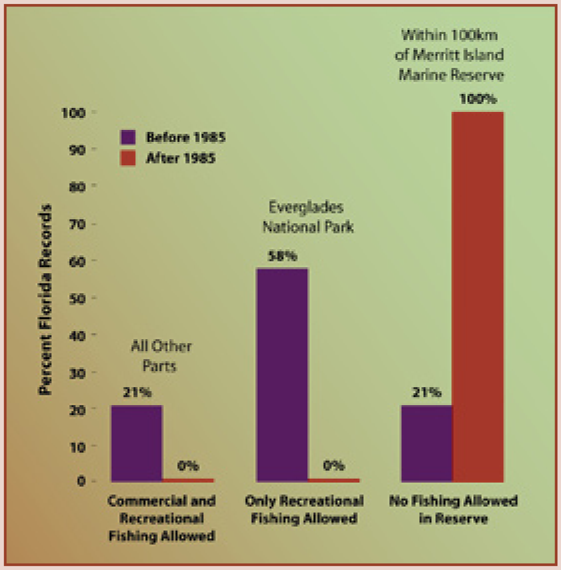
- The Merritt Island marine reserve has older, bigger, and more abundant game fish than fished waters outside the reserve.
- Several decades after the reserve was established, recreational fishermen are catching more world-record game fish near the reserve.
- Today, the majority of Florida's record-breaking fish are caught near the reserve.

Spillover: Reserve Supplies Trophy Fishes

Historically, the estuaries at Merritt Island were popular places for recreational fishing. In 1962, the U.S. government banned all access to portions of the Merritt Island National Wildlife Refuge to create a security zone at Cape Canaveral. Today the site on the Atlantic Coast of Florida is one of the oldest fully protected marine reserves in the United States. Studies show the protected zone now produces enormous game fish that live in and move outside the reserve into nearby fishing grounds.

The changes at Merritt Island developed over a period of decades after protection, because the game fish are slow growing and long lived. In the late 1980s, biologists compared the marine reserve to nearby fished waters and found that fish in the reserve were older, bigger, and 2 to 13 times more abundant. Fish tagged inside the reserve were recaptured outside, demonstrating spillover of adults and juveniles. More world records of some popular sport fish are caught near marine reserves than in all other areas of Florida combined. The rest of the state has yielded no new world records for black drum since 1985, despite a variety of statewide management measures, while areas near the reserve continue to produce bigger and bigger fish. Red drum and spotted seatrout show similar results; a disproportionate number of Florida's recent record-breaking fish come from waters near the reserve.



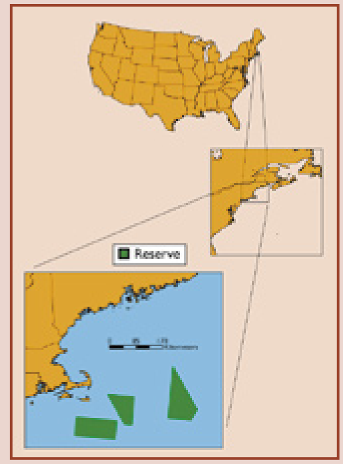


In recent years, far more world-record fish have been caught near the Merritt Island marine reserve than in the Everglades National Park, where only recreational fishing is allowed. Similar habitats in other places in Florida, where both commercial and recreational fishing are allowed, have produced even fewer world records.

References: 15, 19, 20.

Case Study: Georges Bank, New England, USA

Middle photograph, above left: Scallops caught inside and outside closed areas on Georges Bank.

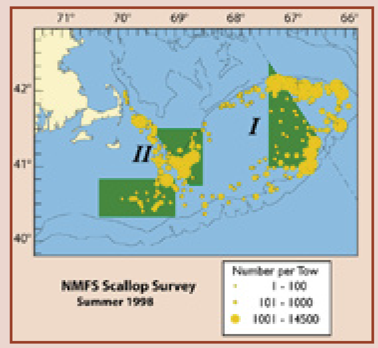


Georges Bank Closed Areas

Export: Closed Areas Boost Scallop Fishery

Georges Bank rises from the continental shelf to form the southeastern boundary of the Gulf of Maine. For centuries the area has ranked among the world's premier fishing grounds for cod, haddock, scallops, and numerous other species. However, by the early 1990s catches of cod and other groundfish in the region had decreased considerably. Resource managers and fishermen suspected that fishing gear used to catch groundfish and scallops contributed to this decline by damaging habitats of the seafloor. These places supported many different animals, including sponges, clams, worms, crustaceans, sea stars, anemones, and young fish, but trawling and dredging degraded these habitats. In addition, gear intended to catch scallops often took fish incidentally, and vice versa. To address these issues, the U.S. government banned all fishing gear except lobster traps from three large areas, totaling 6,500 square miles, in 1994. While these closed areas are not fully protected marine reserves, scientists have been able to use the closed areas to study the process of larval export at Georges Bank.

Although intended to restore cod and other groundfish, the closures dramatically affected other species as well. For example, within four years, there were 14 times more scallops in the closed areas than in surrounding waters. The scallops in closed areas grew far larger than people had thought possible. Scallops also became five times more numerous in neighboring waters.



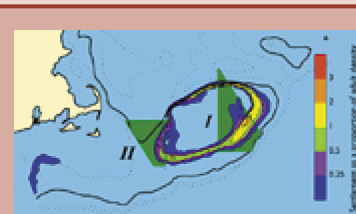
Adult scallop abundance inside and near closed areas on Georges Bank.

Lessons Learned

- Within five years, the abundance and body size of some species, including scallops, dramatically increased in the closed areas on Georges Bank.
- Large and abundant scallops in the closed areas can produce more young than smaller scallops outside the closed areas.
- These young boost populations of scallops in the closed areas and some drift into surrounding waters.
- After the closures were established, scallop abundance rose in unprotected waters nearby.
- Using known habitats and current patterns, scientists predicted the places that young scallops, produced in the closed areas, can settle and grow inside the closed areas and in adjacent waters.
- The actual distribution of scallops in waters around the closed areas matches the scientist's predictions.

What do these changes tell us?

The scallops provide some insight into how reserves can supply young to surrounding areas. Because the scallops in the closed areas are larger and more abundant, they can produce many more young than small scallops in surrounding waters. A portion of young scallops may stay and grow up near their parents, while others are carried outside the closed areas by ocean currents. Scientists use known current patterns and locations of suitable habitat to predict where scallops will make their homes and have the most successful growth (see maps). The distribution of adult scallops matches these predictions, demonstrating the potential impact of closed areas on surrounding waters.



Potential scallop settlement on Georges Bank from larvae originating in Closed Area I.

Potential scallop settlement on Georges Bank from larvae originating in Closed Area II.
Data: C.V. Lewis (UC Berkeley)

Reference: 17.