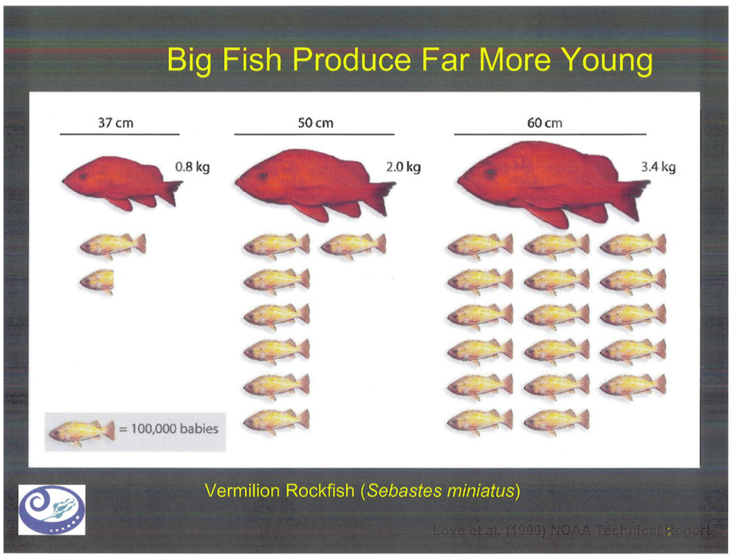
MPA Science Brief: What Does the Science Say?

DO “NO-TAKE” MARINE RESERVES BENEFIT ADJACENT FISHERIES?

Despite using conventional fishery management tools such as changes in gear used, use of short-term closures, and the reduction in fishing effort and catch of non-targeted species, the abundance of fish has continued to decline globally. One approach to building sustainable fisheries is the creation of “no-take” marine reserves which removes fishing pressure completely from key areas, such as spawning, nursery, feeding, or sheltering habitats. Under these management conditions, targeted fish stocks and the larger communities of which they are a part of are given the opportunity to rebound. Some marine reserves have existed for decades and contribute to a range of ecosystem and community goals, including preserving biodiversity, protecting habitat, helping reduce user conflicts and enhancing fisheries in adjacent areas (Gaines et al. 2010). Still, uncertainties remain about how effective marine reserves can be in meeting fisheries conservation and enhancement goals (Hart 2006). Establishing networks of reserves to enhance regional fisheries is a balancing act as to the best size and placement of such an area. Can marine reserves provide fishery benefits to adjacent fished areas? If so, then how?

What happens to fish stocks inside marine reserves?



Studies have consistently shown that organisms within marine reserves tend to grow larger and live longer than individuals in adjacent unprotected areas. Monitoring results from 89 no-take marine reserves around the world have shown that, on average, fish density, biomass, size, and diversity all increased within marine reserves (Halpern 2003, Lester et al. 2009). This is very important because fish that are larger and older tend to produce significantly more eggs and larvae than smaller fish. Also, larvae produced from older fish tend to have a higher survival rate (Francis et al. 2007).

How can marine reserves provide fishery benefits outside these areas?

Fisheries can be enhanced in areas surrounding marine reserves through two processes: spillover (active movement of juveniles and adults into fished areas) and larval seeding (new fish being born and added to the fishery through the export of eggs and larvae). Adult spillover from marine reserves into adjacent fished areas has been clearly documented through tagging studies (McClanahan and Kaunda-Arara 1996) and has shown that some fish species swim from inside marine reserves to adjacent fished areas (Lowe et al. 2003). As larger and older fish in the closed area produce more eggs and more larvae, adjacent fished areas can benefit from larval seeding due to the increase in eggs and larvae being supplied from marine reserves, with some drifting out to the open fished areas (Hilborn et al. 2004). In addition, marine protected areas (MPAs) that protect spawning aggregations will allow for more individuals to spawn, increasing the output of offspring (Murawski et al. 2000, Hilborn et al. 2004).

To maximize fishery benefits to the surrounding areas, several conditions need to be favorable. If species are more sessile, or sedentary (i.e. some invertebrates), they may not move into the fished open area. This means there will be little spillover of juvenile or adult individuals and potentially little benefit (although their eggs and larvae could still seed distant areas). Conversely, if individuals move long distances, virtually all will move into the fished open area. This will mean that the marine reserve offers little protection and there will not be the buildup of bigger and older spawning fish inside the reserve. Thus, the anticipated benefit of exporting eggs and larvae to seed the adjacent fished areas will be lost. It is important to understand the “home range” (the distance a species routinely travels from a particular area) of a species when setting up an MPA designed to protect it (Lowe 2003, Grüss 2011). Ocean conditions must also be such that enough eggs and larvae are transported from the reserve to the open fished areas via ocean currents to benefit these areas.

How can we track the movement of eggs and larvae?

Acceptance of MPAs (both multiple-use and no-take areas) as a fishery enhancement tool has been hampered by lack of direct evidence that MPAs successfully "seed" adjacent areas with eggs and larvae of targeted species (Christie et al. 2010). Determining patterns of larval dispersal is difficult as larvae are extremely small and the ocean environment through which they travel is extremely big. This is confounded by the fact that favorable oceanographic factors (e.g. currents, temperature) are required to successfully transport larvae to appropriate habitats necessary for settlement and recruitment into the fishery. Recent advancements in the use of genetic analyses have shown promise for successfully identifying spawning adults and resulting larvae. This genetic approach allows scientists to accurately document dispersal of larvae from spawning sites to where larvae ultimately settle. Using this approach, scientists recently identified four parent-offspring pairs of yellow tang (*Zebrasoma flavescens*) from spawning areas along the island of Hawaii and where the larvae successfully settled, up to 184km away from where they were spawned (Christie et al. 2010). These observations provide the first direct evidence of marine reserves successfully seeding unprotected areas with larval fish.

Chemical tags have shown that species like young vagabond butterflyfish (*Chaetodon vagabundus*) return to the MPA where they were spawned. (Photo credit: EPA)

Chemical tags may also be used to track the dispersal of larvae and eggs (Hofmann and Gaines 2008). In an MPA in Papua New Guinea, Almany et al. (2007) injected females of vagabond butterflyfish (*Chaetodon vagabundus*) and orange clownfish (*Amphiprion percula*) with a Barium enriched solution that was transmitted by females to their young during development. Recently settled individuals were sampled to determine whether they contained this unique chemical and results demonstrate that ~ 60% of young individuals had returned to the MPA where they were spawned.

Assessing Fishery Costs vs. Benefits

Costs: Eliminating fishing from an area often causes fishermen to move to different areas, thus potentially concentrating fishing in smaller areas and adding to the stressors at those sites. Could this lead to unintended ecological consequences such as overfishing and habitat destruction in the adjacent fished area? The displacement of fishermen may also produce social anxiety, such as removing people from their "favorite fishing holes." Having to go to another area to fish may come with considerable economic costs as well, such as having to travel to fishing grounds that are further away (e.g., cost of fuel and time) and perhaps having to fish in areas that are less productive (Rijnsdorp et al. 2001). Coastal communities located next to the no fishing area may be negatively impacted, socially and economically, as well (Sanchirico et al. 2006).

Benefits: The establishment of a marine reserve creates a source of larvae as well as juvenile and adult organisms that not only populate the area inside the reserve, but also migrate (e.g., spillover) outside the reserve to live, feed, breed, and eventually be harvested elsewhere (Hofmann and Gaines 2008, Gaines et al. 2010). Eliminating bottom fishing tends to protect habitat from damage caused by trawling, pots, and other bottom tending fishing gear (Auster et al. 1996). Improved habitat is likely to contribute to improved fishery spawning, feeding, and refuge opportunities as well. Marine reserves also create an "insurance policy" against natural and anthropogenic disturbances that impact fisheries as well as inaccuracies in fish stock assessments and data poor situations. The National Research Council (2001) concluded that "marine reserves may provide the only effective means to ensure against overfishing of some species if exploitation is high and there is substantial uncertainty in the stock assessments."

Conclusion

Marine reserves can supplement adjacent areas with adult spillover and export of eggs and larvae. To be a useful management tool and aid in ensuring sustainable fisheries, the reserve must export enough larvae and adult organisms to at least make up for the increased impacts of the displaced fishing in areas remaining open (Hilborn et al. 2004). Benefits will accrue only if numbers of fish transported to the fished area from spillover and export of eggs and larvae are greater than before its closure (Hart 2006). In addition, there must be sufficient self-recruitment (within a single reserve or a network of reserves) to ensure sustainability when surrounding unprotected populations are fished down. The National Research Council (2001) concluded that "a growing body of literature documents the effectiveness of marine reserves for conserving habitats, fostering the recovery of exploited species, and maintaining marine communities." Thus, marine reserves can, increase yields in fisheries in which heavy fishing mortality has substantially reduced new fish being born (larvae).

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