Ecological effects of Marine Managed Areas

SCIENCETOACTION

A network of interdisciplinary studies was used to investigate the ecological effects of Marine Managed Areas (MMAs) dispersed widely across the tropics. The results indicate that rigorously enforced MMAs can be an effective management strategy to reduce natural resource overuse and allocation conflicts. In addition, MMAs create important data streams for an adaptive management approach to coastal marine resource sustainability.

Ecological monitoring studies supported by the Marine Management Area Science Program use a variety of metrics to characterize the health of coral reef habitats. Choices made today about reef management and protection will help to determine where on the poor (red)-to-excellent (green) trajectory local reefs will be found.

What are Marine Managed Areas (MMAs)?

MMAs are multiuse, ocean zoning schemes that typically encompass several types of subareas, such as no-take areas (e.g., no fishing, mining), buffer zones with particular restrictions (e.g., no oil drilling), or areas dedicated to specific uses (e.g., fishing, diving). MMAs can take many forms, addressing different issues and objectives. Some MMAs involve areas where multiple uses (e.g., fishing, tourism) are allowed under specific circumstances. Others involve areas where no extractive human uses (e.g., fishing, mining, drilling) at all are allowed. Still others restrict certain areas to one specific use (e.g., local fishing) that is judged to be the most beneficial use of that area to the exclusion of others.

MMAs **are critical** to healthy oceans

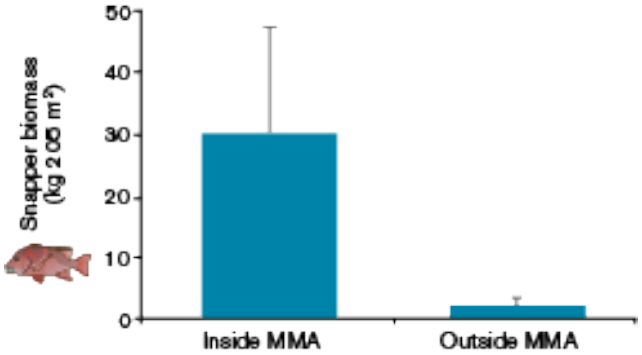
Major stressors on coral reefs can be grouped into three categories: pollution (e.g., nutrients, sediments, or toxicants derived from marine or terrestrial sources that negatively impact the reef), fishing (e.g., overfishing, destructive fishing, illegal fishing), and climate change (e.g., ocean acidification, sea surface temperature-induced coral bleaching, sea level rise). These stressors can lead to reductions in fish biomass, biodiversity, and hard coral cover, and increases in macroalgae. Healthy reefs are typified by high biodiversity, abundant hard corals, reduced macroalgae, and fish populations that include large predators.

Conceptual diagram illustrating the gradient of coral and fish from a degraded reef (left) to a healthy reef (right).

Increased **fish biomass** is an effect of MMAs

Marine Managed Areas result in more fish biomass (= abundance x size) because they are a controlling mechanism for which type of fish you take out of the system. The management regime selected for sustainability and ecological resilience can allow for extractive use of fish that are not too small, and not too big. This is the best management option as it allows the very big fish to live and function as broodstock, therefore producing many more offspring and at more frequent intervals. The smallest fish are left to grow and can be taken out of the system when they are medium size. MMAs also provide for spillover, as fish of all sizes move outside the MMA boundaries and augment the local fishery.

Comparison of fish biomass inside and outside Coiba National Park, Panama, in 2009

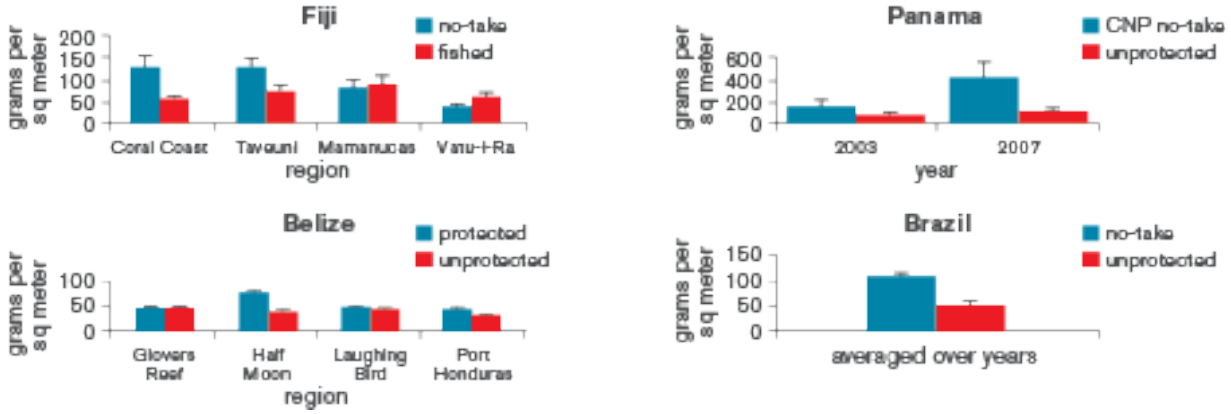


Fish biomass within Coiba National Park, Panama, is much higher than outside the reserve. Part of Coiba National Park was a penal colony until 2004, providing a perfect example of an enforced no-take zone.[1]

Type of **MMA** affects ecosystem structure and function

An MMA is a mosaic of management regimes, often including no-take zones, extractive reserves, and open access areas. No-take zones provide a baseline for adaptive management and harbor brood stock that help restore exploited areas. Extractive reserves facilitate livelihoods while protecting habitat and future yields. As illustrated in these graphs from comparative study sites around the world, the strongest effects of management are seen in no-take zones. Even there, results vary due to differing reserve histories and levels of enforcement. Any MMA can only be as good as peoples' compliance with its rules.

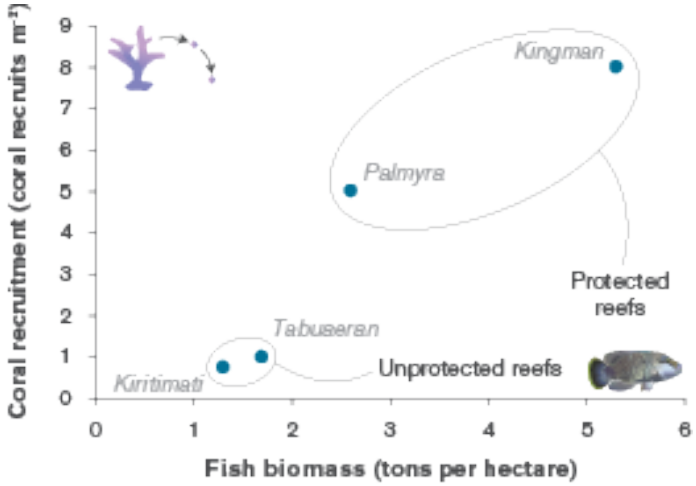
Comparisons between marine reserve (no-take) and open-access: total fish biomass



Estimated total fish biomass (from visual censuses) inside and outside of no-take zones in four parallel studies of MMA effects.[2]

MMAs **increase adaptive capacity** to climate change

A population is resilient when it can rebuild itself after a very high mortality event. Causes of degradation include climate change, storms, and pollution. Die-off of mature corals from this degradation leads to open space on the reef where fleshy algal can grow, which in turn, leads to the microbial community favoring pathogens.



However, recent studies in tropical coral reef systems have shown that this process does not occur in Marine Managed Areas. The coral reefs in MMAs are more resilient to high mortality events by fostering large populations of herbivores, such as parrot fish, that in turn, graze fleshy algae and therefore, favor the growth of crustose crystalline algae. Coralline algae is a suitable settlement substratum for baby corals. Furthermore, these herbivores tend to be very large in size because predators are eating smaller herbivores (see figure). Large herbivores escape the predators and graze a significant amount of fleshy algae. If anything were to suddenly remove a lot of coral cover, the system is set to recover very quickly.

Coral recruitment and fish biomass on four reefs in the Line Islands, showing reefs with better protection recovered better after an El Niño-related bleaching event in 1997-98.[3]

Conclusions and recommendations

MMAs result in more fish biomass, providing potential enhanced food resources

The effectiveness of MMAs varies depending upon location, duration, size, and, most importantly, level of governance. A wide variety of results were obtained across the network nodes due to different variables, but increases in fish biomass did occur in select MMAs in Belize, Brazil, Fiji, and Panama. The spillover of fish that are produced in MMAs can provide a potential food resource, enhancing the food security of coastal communities relying on this protein source.

MMAs need to be located within a zoning network, maintained for extended time periods (decades), and be of sufficient size to avoid significant edge effects (>km^2 scale). Since MMAs are only as effective as enforcement and/or compliance, they need to be effectively staffed and accompanied by a dialogue with stakeholders.

The type of management regime affects ecosystem structure and function

MMAs in which no-take zones are effectively maintained result in diverse, productive reefs with large predators, extensive coral cover, and reduced macroalgae. Data from reference sites indicate that even modest human development pressures can have significant impacts on coral reefs, including subtle impacts on microbial communities. The highest level of biodiversity and ecosystem services are maintained in MMAs with the most protection.

Networks of MMAs need to be created in which biodiversity and ecosystem services are maintained. Ecological monitoring programs are important for tracking MMA effectiveness. In addition to monitoring fishes, corals, macroalgae, and benthic communities, microbial communities can provide diagnostic indicators of trajectories.

MMAs can make coral reefs more resilient, within limits

MMAs can reduce fishery declines by providing sanctuaries and/or by reducing harvest, but are not sufficient to reverse degradation due to pollution or climate change. They cannot compensate for human population increases and associated pressures, but MMAs can provide resilience to various stressors, increasingly important in the face of global change.

MMAs need to be viewed as an important marine conservation tool, but not the only tool. In regions with fishery declines, MMAs become quite important, but in regions suffering from pollution, habitat degradation or climate change impacts, other approaches like watershed management need to be prioritized.

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