

Marine Science Review - 262

Marine protected areas and reserves

In this review:

A. Recent articles with abstracts

O/A denotes an open access article or journal

A. Recent articles with abstracts

Schrope, M. **Providential outcome.** *Nature* 451(7175): 122-123, 2008.

Notes: A winning combination of isolation, local involvement and a broad ecological remit are making the management of the seas around Colombia's San Andrés islands a model for other conservationists.

Kaiser, M.J., Blyth-Skyrme, R.E., Hart, P.J.B., Edwards-Jones, G., and Palmer, D. **Evidence for greater reproductive output per unit area in areas protected from fishing.** *Canadian Journal of Fisheries and Aquatic Sciences* 64(9): 1284-1289, 2007.

Notes: Marine protected areas are advocated as an essential management tool to ensure the sustainable use of marine resources by providing insurance against over-exploitation and through the provision of refuge for a large biomass of sexually mature adults. Using a unique fishing gear-restriction, voluntary management system as a large-scale experiment, we found that adult scallops (*Pecten maximus*) within areas protected from towed bottom-fishing gear had heavier adductor muscle tissue and gonads that were 19%-24% heavier than those of scallops in fished areas, while other body and age characteristics were similar in both areas. The scallops within the protected area also occurred at a much higher abundance than adjacent, chronically fished (x 12.83) and wider commercially exploited (x 2.18) areas. These results provide evidence that the use of towed bottom-fishing gear can further exacerbate the effects of overfishing through the suppression of the reproductive potential of individuals of similar body size. These findings underline the utility of using closed areas as tools for fisheries conservation of sedentary species of commercial importance.

Bartholomew, A., Bohnsack, J.A., Smith, S.G., Ault, J.S., Harper, D.E., and McClellan, D.B. **Influence of marine reserve size and boundary length on the initial response of exploited reef fishes in the Florida Keys National Marine Sanctuary, USA.** *Landscape Ecology* 23: 55-65, 2008.

Notes: We examine the influence of reserve size and boundary length on the relative rate of fish density change in reserves versus fished reference reefs for three exploitable-sized reef fish categories: (1) combined fish (34 species of Haemulidae, Lutjanidae, Serranidae, and hogfish *Lachnolaimus maximus*); (2) Haemulidae (13 species); and (3) Lutjanidae (9 species). If reef habitat boundaries are highly permeable to fish movements then fish recovery within a reserve would be inversely proportional to: reserve perimeter (RP)/total reserve area (RA) (RP/RA). If, however, reef habitat boundaries are relatively impermeable barriers to fish movements, recovery within the reserve would be inversely proportional to: reserve boundary that intersects reef habitat (HI)/reef habitat area within the reserve (HA) (HI/HA). From 1994 to 2001 we monitored reef fishes within and outside of no-take marine reserves established in 1997 in the Florida Keys, USA. A significant majority of reserves had greater rates of density change than reference reefs for Lutjanidae and combined fish (22 of 24 reserves for both categories). Significantly higher rates of density change were found in ten reserves for Lutjanidae, two reserves for combined fish, and one

reserve for Haemulidae. Reserves appeared to promote an increased density of exploitable fishes. A significant, negative, but weakly correlated relationship was found between the relative rate of density change (RDC) for combined fish and the HI/HA ratio. Reserve size and placement appeared to have a minimal effect upon RDC.

Aswani, S. and Furusawa, T. **Do marine protected areas affect human nutrition and health? A comparison between villages in Roviana, Solomon Islands.** *Coastal Management* 35(5): 545-565, 2007.

Notes: The implementation of marine protected areas (MPAs) for fisheries management has increased recently due to the perceived role of MPAs in conserving biodiversity, increasing fish stocks, and enhancing the food security of coastal communities. However, it is unclear whether MPAs may restrict the availability of marine resources and decrease overall food security and the health of the people. In the Roviana Lagoon of the Solomon Islands, we conducted cross-comparisons of villages with MPAs and a village without an MPA to assess whether MPAs influenced local perceptions of governance, environmental change, livelihood strategies, and actual human nutrition and health. Results showed that residents of villages with effective MPAs had higher energy and protein intake than those who had no MPA or an ineffective MPA. We conclude that "no-take" marine reserves do not have adverse effects and that when MPAs are effectively sustained they may enhance local nutrition and health.

Rius, M. **The effect of protection on fish populations in the Ses Negres marine reserve (NW Mediterranean, Spain).** *Scientia Marina* 71(3): 499-504, 2007. **O/A**

Notes: This work is the result of a 3-year monitoring programme for assessing the effect that the Ses Negres marine reserve has had on fish populations. Species richness (based on fish species that are considered to be reserve effect indicators), and the size structure of 4 species vulnerable to angling and spear fishing were studied by visual censuses conducted both inside and outside the marine reserve. Analysis of fish populations inside the reserve showed a reserve effect (larger sizes, higher abundance and richer fish assemblages) when compared to the non-reserve sites, especially by the end of the study period. The results highlight the importance of marine reserves for the recovery of fish populations. Future management plans are discussed for this marine reserve.

White, C. and Kendall, B.E. **A reassessment of equivalence in yield from marine reserves and traditional fisheries management.** *Oikos* 116(12): 2039-2043, 2007.

Notes: Lively debate continues over whether marine reserves can lead to increased fishery yields when compared to conventional, quota-based management, apparently driven by differences in the complexity and biological richness of the models being used. In an influential article, Hastings and Botsford used an analytically tractable, spatially implicit, non-age-structured model to assert that reserves are typically incapable of increasing yields relative to conventional management, regardless of the type (pre- or post-dispersal, involving adults and/or larvae) or functional form (Ricker or Beverton-Holt) of density dependence present. A recent numerical (simulation) model by Gaylord *et al.* concludes that reserves can enhance yield compared to conventional management, a result the authors attribute to their spatially-explicit evaluation of stage-structured adult growth, survivability and fecundity; and intercohort (adult-on-larvae) post-dispersal density dependent population dynamics. Here we demonstrate that the increased model complexity is not responsible for the different conclusions. We analyze a spatially-implicit model without stage structure that incorporates intercohort post-dispersal density dependence. In this simple model we still find annual extirpation of adult populations outside reserves due to fishing to enhance larval recruitment there, allowing for increased yields compared to those achieved when harvest is evenly spread across the entire domain under conventional management. Consideration of neither spatially-explicit dispersal dynamics nor stage-structure in adult demographics is required for reserves to substantially improve yield beyond that attainable under conventional management. In contrast, consideration of within cohort post-dispersal density dependence among larva during settlement in an otherwise identical model generates equivalence in yield between the two management strategies. These results recast a common message characterizing the relative benefit of reserve versus non-reserve management from "equivalence at best" to "potentially improved".

Kar, T.K. and Matsuda, H. **A bioeconomic model of a single-species fishery with a marine reserve.** *Journal of Environmental Management* 86(1): 171-180, 2008.

Notes: This study examines the impact of the creation of marine protected areas (MPAs), from both economic and biological perspectives. In particular, we examine the effects of protected patches and harvesting on resource populations. We conclude that protected patches are an effective means of conserving resource populations, even though extinction cannot be prevented in all cases. We discuss the dynamic optimization of a harvest policy by choosing $E(t)$, the harvesting effort, as the dynamic variable. We also discuss the optimal equilibrium harvest policy and explain the biological and bioeconomic interpretations of the results.

Unsworth, R.K.F., Powell, A., Hukom, F., and Smith, D.J. **The ecology of Indo-Pacific grouper (Serranidae) species and the effects of a small scale no take area on grouper assemblage, abundance and size frequency distribution.** *Marine Biology* 152(2): 243-254, 2007.

Notes: This paper used the case study of the Wakatobi Marine National Park, Indonesia to examine changes in the diversity, density and maturity of grouper species over a 5-year period following the establishment of a small-scale no-take area (NTA). This work was carried out to investigate whether "small" NTAs could be effective management strategies over a time scale that is relevant to local fishery communities and their perception of management success. Our research also documents the ecology of these species, information essential if we are to understand how management practises are to affect coral reef fish species. Designation of this "small NTA" increased the density of groupers by 30% over a 5-year period of protected status. After 5 years of protection, grouper populations within this NTA were more mature and double the density of those within the adjacent lightly fished sites and nearly five times those of a heavily fished site. During this time all other nearby fished sites underwent large declines in grouper density. The nearby lightly fished Kaledupa site decreased by up to 50% year⁻¹. Such drastic declines are considered the impact of the exponential development of ever efficient and unsustainable methods of fishing within the study region. This NTA was not of benefit to all grouper species, the reasons for which are not clear. Such questions require further detailed research about the life history, population and behavioural ecology of Indo-Pacific grouper species. Such information is critical for urgently needed fisheries management. The present study found that a small scale NTA of 500 m length was large enough to increase the population of top predatory fish. In conjunction with other socially acceptable small scale NTAs it could help maintain and increase important fish stocks over a larger area. The use of "small" NTAs within networks of reserves should become a useful tool in the management of the locally exploited coral reefs.

Tupper, M.H. **Spillover of commercially valuable reef fishes from marine protected areas in Guam, Micronesia.** *Fishery Bulletin* 105(4): 527-537, 2007. **O/A**

Notes: Does adult spillover (movement out of marine protected areas [MPAs]) of fish create a net export of fish biomass from MPAs to adjacent fished reefs? Biomass of five commercial reef fish species was estimated by visual census within and outside three MPAs in Guam, Micronesia. For most species and sites, biomass was significantly higher within the MPAs than in adjacent fished sites. Movement of fishes into and out of the MPAs was determined by mark-recapture experiments, in which fishes were tagged both inside and outside of MPAs. Four out of five species studied showed little or no net movement out of MPAs. However, the orangespine surgeonfish (*Naso lituratus*) showed a net spillover of biomass from all three MPAs; 21.5% of tagged individuals and 29% of the tagged biomass emigrated from MPAs. Patterns of spillover were strongly influenced by physical habitat barriers, such as channels, headlands, or other topographic features. MPAs that are physically connected by contiguous reef structures will likely provide more spillover to adjacent fished sites than those that are separated by habitat barriers. This study demonstrates that MPAs can enhance export of fish biomass to fished areas, but spillover is species-specific and depends on factors such as species size and mobility.

Coelho, V.R. and Manfrino, C. **Coral community decline at a remote Caribbean island: Marine no-take reserves are not enough.** *Aquatic Conservation: Marine and Freshwater Ecosystems* 17(7): 666-685, 2007.

Notes: 1. Coral reefs around the world have been deteriorating over decades owing to anthropogenic pressure. In the Caribbean recent rates of decline are alarming, particularly for coral reefs under high local human impact, many of which are severely degraded, although regions with lower direct anthropogenic influence seem less affected. 2. Little Cayman is a relatively undeveloped island, with less than 150 permanent residents. About 20% of its reefs have been protected by no-take marine reserves since the mid-1980s. We analysed the dynamics of coral communities around the island from 1999 to 2004 in order to test the hypothesis that a lack of major local anthropogenic disturbances is enough to prevent decline of coral populations. 3. Live hard coral coverage, coral diversity, abundance, mortality, size, and prevalence of disease and bleaching were measured using the Atlantic and Gulf Rapid Reef Assessment methodology (line transects) at nine sites. Despite the apparent undisturbed condition of the island, a 40% relative reduction of mean live coral coverage (from 26% to 16%, absolute change was 10%) was recorded in five years. Mean mortality varied from year to year from 23% to 27%. Overall mean diameter and height have decreased between 6% and 15% on average (from 47 to 40 cm for diameter, and from 31 to 29 cm for height). 4. The relative abundance of large reef builders of the genus *Montastraea* decreased, while that of smaller corals of the genera *Agaricia* and *Porites* increased. Disease prevalence has increased over time, and at least one relatively large bleaching event (affecting 10% of the corals) took place in 2003. 5. Mean live coral cover decline was similar inside (from 29% to 19%) and outside (from 24% to 14%) marine no-take reserves. No significant difference in disease prevalence or clear pattern in bleaching frequency was observed between protected and non-protected areas. It is concluded that more comprehensive management strategies are needed in order to effectively protect coral communities from degradation.

Smith, J.R., Fong, P., and Ambrose, R.F. **The impacts of human visitation on mussel bed communities along the California coast: Are regulatory marine reserves effective in protecting these communities?** *Environmental Management* 41(4): 599-612, 2008.

Notes: Rocky intertidal habitats frequently are used by humans for recreational, educational, and subsistence-harvesting purposes, with intertidal populations damaged by visitation activities such as extraction, trampling, and handling. California Marine Managed Areas, particularly regulatory marine reserves (MRs), were established to provide legal protection and enhancement of coastal resources and include prohibitions on harvesting intertidal populations. However, the effectiveness of MRs is unclear as enforcement of no-take laws is weak and no regulations protect intertidal species from other detrimental visitor impacts such as trampling. The goal of this study was two-fold: (1) to determine impacts from human visitation on California mussel populations (*Mytilus californianus*) and mussel bed community diversity; and (2) to investigate the effectiveness of regulatory MRs in reducing visitor impacts on these populations. Surveys of mussel populations and bed-associated diversity were compared: (1) at sites subjected to either high or low levels of human use, and (2) at sites either unprotected or with regulatory protection banning collecting. At sites subjected to higher levels of human visitation, mussel populations were significantly lower than low-use sites. Comparisons of mussel populations inside and outside of regulatory MRs revealed no consistent pattern suggesting that California no-take regulatory reserves may have limited effectiveness in protecting mussel communities. In areas where many people visit intertidal habitats for purposes other than collecting, many organisms will be affected by trampling, turning of rocks, and handling. In these cases, effective protection of rocky intertidal communities requires an approach that goes beyond the singular focus on collecting to reduce the full suite of impacts.

Jones, P.J.S. **Fishing industry and related perspectives on the issues raised by no-take marine protected area proposals.** *Marine Policy* 32(4): 749-758, 2008.

Notes: In the face of growing calls for no-take marine protected areas (NTMPAs), the views of fishing industry representatives in south-west (SW) England on related issues are analysed. Only 23% thought NTMPAs were the way forward and a range of concerns were expressed, e.g. that the 'terrestrial' protected areas approach and related biodiversity conservation objectives will be extended to the seas, and that fish yield reductions from the loss of access to NTMPAs are very unlikely to be compensated for through spillover/export. Some interesting approaches to ameliorating these concerns emerged, such as being open and honest that NTMPAs are primarily intended to achieve biodiversity conservation benefits, reducing uncertainty concerning the potential for any secondary fisheries spillover/export benefits, justifying NTMPAs on an objective, rational basis rather than on a subjective, precautionary basis, and the *quid pro quo* streamlining of wider fisheries management approaches. This research reveals a more diverse range of perspectives amongst fishing industry representatives on the issues raised by NTMPA proposals than is often assumed.

Gravestock, P., Roberts, C.M., and Bailey, A. **The income requirements of marine protected areas.** *Ocean and Coastal Management* 51(3): 272-283, 2008.

Notes: Given the growing impact of human activities on the sea, managers are increasingly turning to marine protected areas (MPAs) to protect marine habitats and species. Many MPAs have been unsuccessful, however, and lack of income has been identified as a primary reason for failure. In this study, data from a global survey of 79 MPAs in 36 countries were analysed and attempts made to construct predictive models to determine the income requirements of any given MPA. Statistical tests were used to uncover possible patterns and relationships in the data, with two basic approaches. In the first of these, an attempt was made to build an explanatory "bottom-up" model of the cost structures that might be required to pursue various management activities. This proved difficult in practice owing to the very broad range of applicable data, spanning many orders of magnitude. In the second approach, a "top-down" regression model was constructed using logarithms of the base data, in order to address the breadth of the data ranges. This approach suggested that MPA size and visitor numbers together explained 46% of the minimum income requirements ($p < 0.001$), with area being the slightly more influential factor. The significance of area to income requirements was of little surprise, given its profile in the literature. However, the relationship between visitors and income requirements might go some way to explaining why northern hemisphere MPAs with apparently high incomes still claim to be under-funded. The relationship between running costs and visitor numbers has important implications not only in determining a realistic level of funding for MPAs, but also in assessing from where funding might be obtained. Since a substantial proportion of the income of many MPAs appears to be utilized for amenity purposes, a case may be made for funds to be provided from the typically better resourced government social and educational budgets as well as environmental budgets. Similarly visitor fees, already an important source of funding for some MPAs, might have a broader role to play in how MPAs are financed in the future.

Kulbicki, M., Sarramegna, S., Letourneur, Y., Wantiez, L., Galzin, R., MouTham, G., Chauvet, C., and Thollot, P. **Opening of an MPA to fishing: Natural variations in the structure of a coral reef fish assemblage obscure changes due to fishing.** *Journal of Experimental Marine Biology and Ecology* 353(2): 145-163, 2007.

Notes: Marine Protected Areas (MPAs) are known to enhance diversity, density and biomass of coral reef fishes and to modify the size and trophic structures of these fish assemblages. Opening to fishing has the opposite effects, but on a much shorter time scale. The present study compares the evolution of the fish assemblages of two adjacent reef zones, both initially MPAs, one of them being afterwards opened to fishing. The study was conducted on Abore Reef, a New Caledonian barrier reef (SW Pacific) which constituted a 148 km² marine protected area, of which 69 km² are within the lagoon. Two surveys of a coral reef fish assemblage, using underwater visual censuses, were performed, the first one was conducted in July 1993 following 5 years of protection from fishing, the second one was conducted in July 1995; part of the reef having been opened to fishing activity in September 1993. This study examined the effects of two factors on these fish communities: time (1993 vs. 1995) and zone (reefs protected from fishing vs. unprotected reefs); the interaction of these two factors indicating an effect of either protection or opening to fishing. Diversity (species/ transect), density and biomass were tested for all species together (377 species), then according to diet, size and commercial use. There was a significant decrease over time of most values in both fished and unfished areas, the decrease being greater in the zone opened to fishing. The magnitude of decrease over time was within the range of known time variations from other studies in New Caledonia and other Pacific locations. However, this decrease was so large that it prevented the detection of effects linked to protection. Only some minor effects could be detected for 16 species with no specific pattern according to diet, size or use. The density and biomass of species of low commercial value were also affected by opening to fishing. Relative changes in diversity could be better detected than relative changes in density or biomass. This study demonstrates that on a short-term basis (2 years), natural variations can be of larger magnitude than changes that may be induced by management options, especially when fishing pressure is not very high.

Ewers, R.M. and Rodrigues, A.S.L. **Estimates of reserve effectiveness are confounded by leakage.** *Trends in Ecology and Evolution* 23(3): 113-116, 2008.

Notes: In situ conservation often requires the designation of sites where land-use is restricted, such as protected areas and no-fishing zones. Such areas are designed to reduce human impacts on the ecosystem, but the overall benefits of this approach might be compromised if 'leakage' takes place - that is, if impacts that would take place inside the restricted area are displaced to a nearby, unrestricted area. Recently, Oliveira and colleagues became the first group to measure leakage from newly created

forest concessions. They showed that restricting land-use reduced deforestation within the concession areas, but dramatically increased it in the surrounding areas. We discuss these findings in the wider context of growing global interest in quantifying the effectiveness of nature reserves.

Klein, C.J., Steinback, C., Scholz, A.J., and Possingham, H.P. **Effectiveness of marine reserve networks in representing biodiversity and minimizing impact to fishermen: a comparison of two approaches used in California.** *Conservation Letters* 1(1): 44-51, 2008. **O/A**

Notes: We compared the effectiveness of marine reserve networks designed using a numerical optimization tool with networks designed by stakeholders during the course of California's Marine Life Protection Act Initiative at representing biodiversity and minimizing estimated negative impacts to fishermen. We used the same spatial data representing biodiversity and recreational fishing effort that were used by the stakeholders to design marine reserves. In addition, we used commercial fishing data not explicitly available to the stakeholders. Networks of marine reserves designed with numerical optimization tools represented the same amount of each habitat, or more, and had less of an estimated impact on commercial and recreational fisheries than networks designed by the stakeholders. The networks designed by the stakeholders could have represented 2.0-9.5% more of each habitat with no additional impact on the fisheries. Of four different marine reserve proposals considered in the initiative, the proposal designed by fishermen was more efficient than the proposals designed by other stakeholder groups at representing biodiversity and minimizing impact to the fishing industry. These results highlight the necessity of using comprehensive information on fishing effort to design a reserve network that efficiently minimizes negative socioeconomic impacts. We recommend that numerical optimization tools support, not replace, the stakeholder-driven reserve design process along California's northern and southern coasts to help accomplish two of the initiative's core objectives: (1) Protect representative and unique marine habitats, and (2) Minimize negative socioeconomic impacts. The involvement of stakeholders is necessary as additional factors important to reserve design can not be considered using a numerical optimization tool.

Leathwick, J., Moilanen, A., Francis, M., Elith, J., Taylor, P., Julian, K., Hastie, T., and Duffy, C. **Novel methods for the design and evaluation of marine protected areas in offshore waters.** *Conservation Letters* 1(2): 91-102, 2008. **O/A**

Notes: There is strong international agreement on the need for marine protected areas to reverse pervasive human impacts on the oceans' biodiversity. However, their implementation is often hampered both by legal difficulties in defining reserves in international waters and the patchy nature of data in many offshore waters. We demonstrate the use of recent advances in statistical learning and conservation prioritization to produce MPA scenarios with varying costs and benefits for New Zealand's Exclusive Economic Zone, based on the analyses of distributions of 96 demersal fish species. MPAs based on our most cost-effective scenario would deliver conservation benefits nearly 2.5 times greater than those from equivalent-sized areas recently implemented at the request of fishers, and at lower cost to them. Such results demonstrate the power of quantitative, knowledge-based prioritization approaches, which can be applied at high resolution and at oceanic scales.

Christie, P. and White, A.T. **Best practices for improved governance of coral reef marine protected areas.** *Coral Reefs* 26(4): 1047-1056, 2007.

Notes: Coral reef marine protected areas (MPA) are widely distributed around the globe for social and ecological reasons. Relatively few of these MPAs are well managed. This review examines the governance of coral reef MPAs and the means to improve coral reef MPA management. It highlights common governance challenges, such as confused goals, conflict, and unrealistic attempts to scale up beyond institutional capacity. Recommendations, based on field experience and empirical evidence from around the world, are made for best practices at various stages of MPA implementation.

Evans, R.D., Russ, G.R., and Kritzer, J.P. **Batch fecundity of *Lutjanus carponotatus* (Lutjanidae) and implications of no-take marine reserves on the Great Barrier Reef, Australia.** *Coral Reefs* 27(1): 179-189, 2008.

Notes: This study investigated body size to fecundity relationships of a reef fish species targeted by line fishing, and examines the potential benefits of increased batch fecundity in no-take reserves compared to fished areas around the Palm, Whitsunday and Keppel Island Groups, Great Barrier Reef, Australia. *Lutjanus carponotatus* batch fecundity increased with fork length in a non-linear relationship that was best described by a power function. Batch fecundity differed by more than 100-fold among individuals, with a range from 7,074 to 748,957 eggs in fish ranging from 184 to 305 mm fork length. Furthermore, egg diameter increased with fish size. Based on underwater visual census, the potential batch fecundity per unit area in all three island groups ranged from 1.0 to 4.2 times greater in the no-take reserves than in the fished areas between 2001 and 2004. In 2002, a mean 2.3-fold difference in biomass between no-take reserves and fished areas converted to a mean 2.5-fold difference in batch fecundity per unit area. Greater batch fecundity, longer spawning seasons and potentially greater larval survival due to larger egg size from bigger individuals might significantly enhance the potential benefits of no-take marine reserves on the Great Barrier Reef.

Byers, J.E. and Noonburg, E.G. **Poaching, enforcement, and the efficacy of marine reserves.** *Ecological Applications* 17(7): 1851-1856, 2007.

Notes: Marine reserves are promoted as an effective supplement to traditional fishery management techniques of harvest quotas and effort limitation. However, quantitative fishery models have ignored the impact of noncompliance (poaching). Here we link a model of a harvested fish population to a game-theoretic representation of fisherman behavior to quantify the effect of poaching on fishery yield and the enforcement effort required to maintain any desired level of reserve effectiveness. Although higher fish densities inside reserves will typically entice fishermen to poach, we show that the initial investment in enforcement efforts provides the greatest return on maintaining the benefits of the reserve to the fishery. Furthermore, we find that poaching eliminates the positive effect of fish dispersal on yield that is predicted by traditional models that ignore fisherman behavior. Our results broaden a fundamental insight from previous models of marine reserves, the effective equivalence of the harvest quota and reserve fraction, to the more realistic scenario in which fishermen attempt to maximize their economic payoffs.

Tetreault, I. and Ambrose, R.F. **Temperate marine reserves enhance targeted but not untargeted fishes in multiple no-take MPAs.** *Ecological Applications* 17(8): 2251-2267, 2007.

Notes: Although many papers report the effects of no-take marine protected areas (MPAs or reserves), scientifically rigorous empirical studies are rare, particularly for temperate reef fishes. We evaluated the responses of fish populations to protection from fishing in reserves by comparing densities and sizes inside and outside of five no-take reserves in southern California, USA. Our results are robust because we compared responses across multiple rocky-reef reserves in two different years and controlled for possible site differences by (a) ensuring that habitat characteristics were the same inside and outside reserves, and (b) sampling species that are not targeted, which would not be expected to have a direct response to fishing. We compared fish density and size and calculated biomass and egg production across all five sites. Fishes targeted by recreational and/or commercial fisheries consistently exhibited increases in mean density (150%), size (30%), biomass (440%), and egg production (730%) inside reserves. Reserve effects were greatest for legal-sized targeted fishes: significantly greater densities were found exclusively inside reserves for targeted species (580%), the largest size classes existed only inside reserves, and mean biomass was 1000% higher. These responses were unlikely to have been caused by habitat differences because there were no significant differences in habitat characteristics between reserve and control locations. Densities of non-targeted species did not differ between reserve and non-reserve locations, further supporting the conclusions that differences in targeted species between reserve and control locations were due to harvesting rather than site-specific effects. Although MPAs cannot replace traditional fisheries management, the concentration of increased biomass and egg production is a unique MPA benefit that serves both reserves and fisheries. Scientifically rigorous studies that include multiple reserves, such as this study, are needed to inform management and policy decisions.

White, C., Kendall, B.E., Gaines, S., Siegel, D.A., and Costello, C. **Marine reserve effects on fishery profit.** *Ecology Letters* 11(4): 370-379, 2008.

Notes: Some studies suggest that fishery yields can be higher with reserves than under conventional management. However, the economic performance of fisheries depends on economic profit, not fish yield. The predictions of higher yields with reserves rely on intensive fishing pressures between reserves; the exorbitant costs of harvesting low-density populations erode profits. We incorporated this effect into a bioeconomic model to evaluate the economic performance of reserve-based management. Our results indicate that reserves can still benefit fisheries, even those targeting species that are expensive to harvest. However, in contrast to studies focused on yield, only a moderate proportion of the coast in reserves (with moderate harvest pressures outside reserves) is required to maximize profit. Furthermore, reserve area and harvest intensity can be traded off with little impact on profits, allowing for management flexibility while still providing higher profit than attainable under conventional management.

Claudet, J., Osenberg, C.W., Benedetti-Cecchi, L., Domenici, P., Garcia-Charton, J.A., Perez-Ruzafa, A., Badalamenti, F., Bayle-Sempere, J., Brito, A., Bulleri, F., Culioli, J.M., Dimech, M., Falcon, J.M., Guala, I., Milazzo, M., Sanchez-Meca, J., Somerfield, P.J., Stobart, B., Vandeperre, F., Valle, C., and Planes, S. **Marine reserves: size and age do matter.** *Ecology Letters* 11(5): 481-489, 2008.

Notes: Marine reserves are widely used throughout the world to prevent overfishing and conserve biodiversity, but uncertainties remain about their optimal design. The effects of marine reserves are heterogeneous. Despite theoretical findings, empirical studies have previously found no effect of size on the effectiveness of marine reserves in protecting commercial fish stocks. Using 58 datasets from 19 European marine reserves, we show that reserve size and age do matter: Increasing the size of the no-take zone increases the density of commercial fishes within the reserve compared with outside; whereas the size of the buffer zone has the opposite effect. Moreover, positive effects of marine reserve on commercial fish species and species richness are linked to the time elapsed since the establishment of the protection scheme. The reserve size-dependency of the response to protection has strong implications for the spatial management of coastal areas because marine reserves are used for spatial zoning.

Pitchford, J.W., Codling, E.A., and Psarra, D. **Uncertainty and sustainability in fisheries and the benefit of marine protected areas.** *Ecological Modelling* 207(2-4): 286-292, 2007.

Notes: Over-exploitation of fisheries is a serious and immediate global problem that current management policies struggle to solve. Scientists and managers accept that new strategies based on a long-term approach are required for future fisheries management policies. But to succeed, such strategies are likely to require more than just attempts by management to control annual levels of exploitation. Recent studies show that using MPAs (marine protected areas, marine reserves) can improve yield as well as protect stocks and sustain fishery viability. In this paper, we use a deliberately simple model, which describes an exploited fishery as a nonlinear dynamical system close to a point of bifurcation; small stochastic perturbations can therefore build up to cause fishery collapse. Extending the model shows that a MPA can buffer this stochasticity and alleviate the propensity to collapse. The model illustrates two main points: (i) evaluating fisheries management strategies such as MPAs in a deterministic framework is inherently misleading; at worst it leads to fishery extinction, at best it fails to maximise yield; (ii) management strategies that are designed explicitly to buffer uncertainty in the system can provide a sustainable and productive fishery. Compared with harvest control rules based on uncertain estimates of stock size, our simulations indicate that MPAs can substantially reduce the risk of fisheries collapse for only a very small cost to total yield.

Doyen, L., DeLara, M., Ferraris, J., and Pelletier, D. **Sustainability of exploited marine ecosystems through protected areas: A viability model and a coral reef case study.** *Ecological Modelling* 208(2-4): 353-366, 2007.

Notes: Overexploitation of marine resources remains a problem worldwide. Many works advocate for the use of marine reserves as a central element of future stock management in a sustainable perspective. In the present paper, we address the influence of protected areas upon fisheries sustainability within an eco-systemic framework through a dynamic bio-economic model integrating a trophic web, catches and environmental uncertainties. The model is spatially implicit. The evaluation of the ecosystem is designed through the respect along time of constraints of both conservation and guaranteed captures. Using the mathematical concept of invariance kernel in a stochastic context, we define different MPA effects according to biodiversity catches or mixed points of view. Numerical simulations inspired from data of Abore coral reef reserve in New

Caledonia illustrate the main concepts. In this case, it is pointed out how MPA conservation effect is not necessarily conflicting with MPA catches effect. It is shown that such a co-viability requires medium exploitation rate. Moreover, the climatic changes represented by rise in cyclonic events seem to reinforce these assertions.

Sumaila, U.R., Zeller, D., Watson, R., Alder, J., and Pauly, D. **Potential costs and benefits of marine reserves in the high seas.** *Marine Ecology Progress Series* 345: 305-310, 2007.

Notes: The issue of conservation and sustainable use of high seas resources is increasingly becoming significant, as is reflected in the number of planned international activities in ocean science and management, e.g. the United Nations General Assembly Working Group on marine bio-diversity beyond national jurisdiction. Essentially, the increasing exploitation pressure on high and deep sea resources makes discussion of viable policy options for international waters an important topic. To our knowledge, this paper provides the first global, economically supported assessment of the impact on fisheries of potentially protecting a portion of the high seas in no-take marine protected areas. Such closures are likely to result in relatively little global annual profit loss. For example, closure of 20% of the high seas may lead to the loss of only 1.8% of the current global reported marine fisheries catch, and a decrease in profits to the high seas fleet of about US\$270 million per year. Thus, at globally minimal costs, the international community could benefit substantially by securing insurance against extinctions and the loss of the spectacular marine diversity in the high and deep seas, while protecting many market and non-market values for the benefit of both current and future generations.

Kramer, K.L. and Heck, K.L. **Top-down trophic shifts in Florida Keys patch reef marine protected areas.** *Marine Ecology Progress Series* 349: 111-123, 2007.

Notes: Special Protected Areas (SPAS) were established within the Florida Keys National Marine Sanctuary in 1997 to address a variety of management goals including coral reef resource protection and recovery. Within these areas all consumptive activities are prohibited. To evaluate whether SPA establishment has resulted in reef assemblage differences on inshore patch reefs, we quantified reef fish abundance and biomass, grazing intensity and benthic cover on abiotically similar protected and reference reefs. Transect surveys indicated that biomass and mean body lengths for several common predatory fish species were significantly greater within SPAS. Size classes of herbivorous fish also varied with protection; adult herbivorous fish were significantly more abundant, while juveniles were significantly less abundant within SPAS. Grazing intensity and benthic cover were site-specific and did not vary consistently with protection, suggesting that SPA establishment has not immediately (within 10 yr) driven observable indirect effects on the benthos.

Stokesbury, K.D.E., Harris, B.P., Marino, M.C., and Nogueira, J.I. **Sea scallop mass mortality in a Marine Protected Area.** *Marine Ecology Progress Series* 349: 151-158, 2007.

Notes: A mass mortality of the sea scallop *Placopecten magellanicus* occurred between 2004 and 2005 in the Nantucket Lightship Closed Area (NLCA), a Marine Protected Area (MPA) in the Great South Channel, USA. On a broad scale (3951 km²), scallop density (ind. m⁻²) in the MPA declined by 35%. On a fine scale (504 km²), in the northeast corner of the MPA where most scallops occur, density declined by 50%. The scallops that perished were large and probably old; 80% had shell heights > 130 mm (H_∞ = 155 mm). Only 6% of the decline in the northeast corner was explained by fishing mortality. The mass mortality equaled approximately 6484 metric tons of harvestable scallop meat (equivalent to US \$100 million ex-vessel). Closing the NLCA to fishing in 1994 removed fishing mortality, increasing scallop survival rates. Scallops that recruited in 1994 reached 10 yr of age in 2004. Individuals of this age may suffer the effects of senescence, including parasitism by shell borers and prokaryotic infection, which likely caused the mass mortality. If MPAs are used to manage fisheries, surveys with the accuracy and precision to resolve population dynamics on the spatial scale of the MPA are required or the benefits may be offset by increases in natural mortality.

Molloy, P.P., Reynolds, J.D., Gage, M.J.G., Mosqueirac, L., and Cote, I.M. **Links between sex change and fish densities in marine protected areas.** *Biological Conservation* 141(1): 187-197, 2008.

Notes: Sex change is widespread among marine fishes, including many species that are fished heavily, and is thought to be of conservation concern under some circumstances. As such, an important question in conservation is whether the implementation of marine protected areas (MPAs), which is a commonly used marine conservation tool, works as effectively for sex-changers as for non-sex-changers. To address this issue, we used meta-analyses of the ratio of fish abundances inside vs. outside MPAs to determine whether sex change affects the extent to which fish densities respond to protection. When all data were considered, there were similar responses to protection irrespective of reproductive mode. However, when analyses were restricted to older reserves (at least 10 years' protection), female-first sex-changers consistently benefited from protection, Non-sex-changers and male-first sex-changers showed more variable responses to protection and, as a result, there were no significant differences between fish with different reproductive modes in their overall response to protection. The same results were observed when the effects of fisheries status (targeted vs. not targeted) were controlled. Our results support the use of MPAs as important components of conservation and demonstrate that old reserves are most consistently beneficial to female-first sex-changing species. Finally, our results highlight the fact that some effects of protection are only detectable after several generations.

Sethi, S.A. and Hilborn, R. **Interactions between poaching and management policy affect marine reserves as conservation tools.** *Biological Conservation* 141(2): 506-516, 2008.

Notes: To explore the effects of poaching within marine reserve boundaries under three different management policies this analysis uses a simple age-structured reserve model based on yield maximization or reproductive thresholds of Black rockfish (*Sebastes melanops*). Departures from the traditional assumptions of full compliance to reserve boundaries alter the conclusions of prior modeling work that demonstrate yield equivalence to no-reserve effort control management and augmented reproductive benefits when small reserves are implemented. By degrading the recruitment subsidization effect to nonreserve areas from protected reserve populations, poaching resulted in negative externalities for compliant fishermen in open areas in terms of yield and degraded the reproductive output and age-structure of the system. All three policies required effort reduction in open areas as a response to poaching in reserves. The strength of the impacts from poaching varied with policy choice and harvest intensity in the reserve, where at the highest level of poaching modeled here (15% annual exploitation rate of the vulnerable reserve population) biological and fishery benefits of implementing reserves were totally negated. Under the assumptions of this model, a policy managing for a reproductive threshold that excludes the reserve population is the precautionary choice if poaching is likely. The results of this exercise emphasize the importance of garnering compliance to reserve boundaries from resource-users for spatial closures to be successful ocean management tools.

Guidetti, P., Milazzo, M., Bussotti, S., Molinari, A., Murenu, M., Pais, A., Spano, N., Balzano, R., Agardy, T., Boero, F., Carrada, G., Cattaneovietti, R., Cau, A., Chemello, R., Greco, S., Manganaro, A., Notarbartolo di Sciarra, G., Russo, G.F., and Tunesi, L. **Italian marine reserve effectiveness: Does enforcement matter?** *Biological Conservation* 141(3): 699-709, 2008.

Notes: Marine protected areas (MPAs) have become popular tools worldwide for ecosystem conservation and fishery management. Fish assemblages can benefit from protection provided by MPAs, especially those that include fully no-take reserves. Fish response to protection can thus be used to evaluate the effectiveness of marine reserves. Most target fish are high-level predators and their overfishing may affect entire communities through trophic cascades. In the Mediterranean rocky sublittoral, marine reserves may allow fish predators of sea urchins to recover and thus whole communities to be restored from coralline barrens to macroalgae. Such direct and indirect reserve effects, however, are likely to be related to the enforcement implemented. In Italy, many MPAs that include no-take reserves have been declared, but little effort has been spent to enforce them. This is a worldwide phenomenon (although more common in some regions than others) that may cause MPAs and reserves to fail to meet their targets. We found that 3 of 15 Italian marine reserves investigated had adequate enforcement, and that patterns of recovery of target fish were related to enforcement. No responses were detected when all reserves were analyzed as a whole, suggesting enforcement as an important factor to be considered in future studies particularly to avoid that positive ecological responses in properly managed reserves can be masked by neutral/negative results in paper parks. Positive responses were observed for large piscivores (e.g. dusky groupers) and sea urchin predators at reserves where enforcement was effective. Those reserves with low or null enforcement did not differ from fished areas.