

Marine Science Review - 243

Marine protected areas and reserves

In this review:

A. Recent articles with abstracts

O/A denotes an open access article or journal

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Jones, P.J.S. **Arguments for conventional fisheries management and against no-take marine protected areas: only half of the story?** *Reviews in Fish Biology and Fisheries* 17(1): 31-43, 2007. O/A

Notes: Recent arguments for conventional fisheries management approaches (CFMAs) and against no-take marine protected areas (NTMPAs) are reviewed, i.e. CFMAs are more effective, density-dependent factors will lead to reduced fish stock production in and around NTMPAs, rights-based approaches in combination with CFMAs will be more effective, and natural refuges from fishing already exist. It is concluded that these are largely valid but only from a fisheries management perspective. The arguments of proponents of NTMPAs and those of proponents of CFMAs are considered as contrasting storylines, the divergences between which are based on two key factors: different objectives and different science. In relation to different objectives, it is concluded that the arguments against NTMPAs based on their lack of fisheries management benefits must be considered as only applying to the secondary resource conservation objectives of such designations and not to the primary marine biodiversity conservation objectives. On this basis it is argued that it is counter-productive for NTMPAs to be 'sold' on a win-win basis, including their potential to deliver fisheries management benefits, as this detracts from their marine biodiversity conservation objectives and leaves such calls open to arguments that CFMAs are better able to deliver fisheries management objectives. In relation to different science, it is concluded that criticisms of NTMPAs and support for CFMAs implicitly resist the shift from Mode 1 (reductive, intradisciplinary) to Mode 2 (holistic, trans-disciplinary) science that is inherent in calls for NTMPAs as part of an ecosystem approach. Mode 2 science attempts to accommodate both uncertainty and wider societal values and preferences, and it is argued that arguments for NTMPAs should be more explicitly focussed on this potential. It is difficult, if not impossible and inappropriate, to extend the reductive approach inherent in CFMA analyses to encompass the broader ethical and scientific concerns for the health of marine ecosystems and their component populations and habitats that arguments for NTMPAs reflect. NTMPA proponents might focus on stressing that arguments against such designations and in favour of CFMAs do not encompass such valid concerns, therefore they tell only half of the story.

Mumby, P.J., Harborne, A.R., Williams, J., Kappel, C.V., Brumbaugh, D.R., Micheli, F., Holmes, K.E., Dahlgren, C.P., Paris, C.B., and Blackwell, P.G. **Trophic cascade facilitates coral recruitment in a marine reserve.** *Proceedings of the National Academy of Sciences [USA]* 104(20): 8362-8367, 2007. O/A

Notes: Reduced fishing pressure and weak predator-prey interactions within marine reserves can create trophic cascades that increase the number of grazing fishes and reduce the coverage of macroalgae on coral reefs. Here, we show that the impacts of reserves extend beyond trophic cascades and enhance the process of coral recruitment. Increased fish grazing, primarily driven by reduced fishing, was strongly negatively correlated with macroalgal cover and resulted in a 2-fold increase in the density of coral recruits within a Bahamian reef system. Our conclusions are robust because four alternative hypotheses that may generate a spurious correlation between grazing and coral recruitment were tested and rejected. Grazing appears to influence the density and community structure of coral recruits, but no detectable influence was found on the overall size-frequency distribution, community structure, or cover of corals. We interpret this absence of pattern in the adult coral community as

symptomatic of the impact of a recent disturbance event that masks the recovery trajectories of individual reefs. Marine reserves are not a panacea for conservation but can facilitate the recovery of corals from disturbance and may help sustain the biodiversity of organisms that depend on a complex three-dimensional coral habitat.

Armstrong, C.W. **A note on the ecological-economic modelling of marine reserves in fisheries.** *Ecological Economics* 62(2): 242-250, 2007.

Notes: This paper gives an overview of the bioeconomic modelling of marine reserves, and illustrates how economists have responded to the modelling results found in the ecological literature. The economic analysis is shown to be far more pessimistic with regards to the potential of marine reserves as a fisheries management tool, than what one finds in the purely ecological analysis, the reason being the latter's neglect of issues such as discounting and economic incentive behaviour. However, economic analysis, despite some of it being relatively advanced with regards to spatiality, is still simplistic with regards to for instance ecosystem and habitat content. A simple expansion of the existing bioeconomic models with regards to positive habitat effects of area closures is presented and analysed, showing room for improved results from marine reserve implementation as compared to the existing analysis.

Rockmann, C., St. John, M.A., Schneider, U.A., and Tol, R.S.J. **Testing the implications of a permanent or seasonal marine reserve on the population dynamics of Eastern Baltic cod under varying environmental conditions.** *Fisheries Research* 85(1-2): 1-13, 2007.

Notes: A spatially disaggregated, discrete time, age-structured model for the Eastern Baltic cod (*Gadus morhua callarias* L.) stock was constructed, in order to test the implications of the establishment of a marine reserve in the Baltic Sea. Functional relationships for recruitment and predation mortality were developed by multiple regression analyses. The resultant model output compares well with observed data from the fishery. The model was then applied to simulate stock development over a 50 year time period using different management policies and a variety of environmental conditions. The investigated management policies reduce fishing mortality and range from a moratorium on the Eastern Baltic cod fishery via the establishment of a permanent or a seasonal marine reserve in ICES subdivision 25 to a fishing as usual scenario. The environmental conditions incorporated were based on the size of the reproductive volume (RV) and comprise a best case and a worst case of reproductive conditions, and two more realistic scenarios, where we assumed that a historic series of RV-sizes reoccurs over the simulation period. Our results show a strong dependence of stock dynamics on the environmental conditions. Under prevailing low RV, our model projects stock extinction by the year 2020, if fishing continues as usual. Under the restrictive scenarios, where fishing mortality is reduced either directly or by implementation of a marine reserve, the stock benefits from an increase in stock size and an improved age structure. A seasonal closure of subdivision (SD) 25 as opposed to a closure of the entire Baltic Sea appears to be sufficient to prevent the Eastern Baltic cod stock from failing below safe biological limits.

Barrett, N.S., Edgar, G.J., Buxton, C.D., and Haddon, M. **Changes in fish assemblages following 10 years of protection in Tasmanian marine protected areas.** *Journal of Experimental Marine Biology and Ecology* 345(2): 141-157, 2007.

Notes: Most studies examining effects of marine protected areas (MPAs) on fish assemblages are potentially confounded, either because they are once off comparisons between fished and unfished locations, or because they are snapshot studies over a fixed period. Here we compare long-term changes within fully protected Tasmanian marine reserves with changes at external reference sites on an annual basis over the first ten years of protection. The results highlight the importance of long-term datasets for differentiating changes occurring over differing time scales. Notable results include a statistically significant increase in abundance of *Latridopsis forsteri* and large fish (>300 mm) when examined across all reserves relative to controls, and a 10-fold increase in the abundance of large fish and a doubling of per site species richness of large fish within the Tinderbox Marine Reserve relative to controls. Short-term resident species that recruit sporadically show very different patterns in reserves compared to those that recruit regularly and have long-term age-class storage. While several recent reviews have suggested size of MPAs and duration of protection has little influence on the extent of recovery, our results suggest this is not the case and that responses can be slow, complex and species-specific. The extent of localised fishing pressure appeared to

have a substantial influence on the degree of change detected, potentially confounding meta-analyses of recovery rates in MPAs if overlooked as a relevant parameter.

Alpine, J.E. and Hobday, A.J. **Area requirements and pelagic protected areas: is size an impediment to implementation?** *Marine and Freshwater Research* 58(6): 558-569, 2007.

Notes: Global oceans are experiencing not only increased levels of human exploitation, but also major changes to their physics, chemistry and biology. These alarming changes have prompted calls for new and improved conservation and management tools if the future sustainability of oceanic ecosystems is to be assured. Spatial management, although widely used in coastal and nearshore environments, is one strategy yet to be adequately considered for open ocean systems. Resistance to both investigation and implementation of this management approach stems predominantly from the perception that given the highly dynamic nature of the ocean, adequate protection of both its biological and physical components would require regulation of vast regions. To examine this assertion, a series of reserve networks were modelled using the reserve design tool Marxan for an oceanic region off eastern Australia. Consideration was given to a set of biological, physical and social features. Three distinct management approaches were evaluated; fisheries priority, conservation priority, and equal fisheries-conservation priority. Reserve solution area requirements ranged from 7 to 26% of the focus area, falling within the lower end of the range of areas suggested in the published reports. This analysis suggests that percentage area requirements for oceanic protected areas should not be an impediment to further consideration.

Le Quesne, W.J.F., Hawkins, S.J., and Shepherd, J.G. **A comparison of no-take zones and traditional fishery management tools for managing site-attached species with a mixed larval pool.** *Fish and Fisheries* 8(3): 181-195, 2007.

Notes: No-take zones (NTZs) can generate higher larval production by sessile, sedentary and site-attached species per unit area than in exploited areas, and may increase recruitment and yield compared to status quo management. Whilst NTZs may be considered an essential part of optimal management, few studies have specifically compared the effects of NTZs with those of correctly applied gear and effort controls. A yield-per-recruit (YPR) population model, based on the sedentary abalone *Haliotis laevigata*, was used to compare the effects of management by minimum landing size (MLS), effort limitation and NTZs, either singularly or in combination. Initially, a minimum basic YPR model was used. Three additional assumptions were sequentially added to the model to see if they affected conclusions drawn from the model. The additional assumptions were the inclusion of: (i) a length-fecundity relationship; (ii) an age-dependent natural mortality function; and (iii) mortality of undersized individuals due to fishery operations. In the absence of undersized mortality caused by fishing, under virtually all conditions the population is best managed with a combination of MLS and effort control, without any NTZs. For simulations that included mortality of undersized individuals in the fished area, under nearly all circumstances NTZs were considered an essential part of optimal fishery management, and management incorporating NTZs greatly increased the sustainable yield that could be taken.

Walters, C.J., Hilborn, R., and Parrish, R. **An equilibrium model for predicting the efficacy of marine protected areas in coastal environments.** *Canadian Journal of Fisheries and Aquatic Sciences* 64(7): 1009-1018, 2007.

Notes: Quantitative models of marine protected area (MPA) proposals can be used to compare outcomes given current biological knowledge. We used a model of a linear coastline, with 200 discrete cells each spanning 1.6 km of coast. This model is used to evaluate alternative proposals for marine protected area networks, predicting equilibrium changes in abundances and harvests while accounting for dispersal of larvae and older fish, changes in fecundity with reduced mortality in reserves, impacts of displaced fishing effort on abundances outside reserves, and compensatory (stock-recruitment) changes in postsettlement juvenile survival. The model demonstrates that modest dispersal rates of older fish can substantially reduce abundance within protected areas compared with predictions from models that ignore such dispersal. The strength of compensatory improvements in postsettlement juvenile survival is the most critical factor in determining whether a reserve network can rescue populations from the impacts of severe overharvesting. We use the model to compare specific alternative proposals for protected area networks along the California coast, as mandated through California's Marine Life Protection Act, and show that achieving the goals of the Act depends primarily on the fisheries management regulations outside of protected areas and that the size and configuration of MPAs has little impact.

Watson, D.L., Harvey, E.S., Kendrick, G.A., Nardi, K., and Anderson, M.J. **Protection from fishing alters the species composition of fish assemblages in a temperate-tropical transition zone.** *Marine Biology* 152(5): 1197-1206, 2007.

Notes: Closure of areas to fishing is expected to result in an increase in the abundance of targeted species; however, changes to populations of species not targeted by fishermen will depend upon their role in the ecosystem and their relationship with targeted species. The effects of protection on targeted and non-targeted reef fish species at the Houtman Abrolhos Islands, Western Australia were studied using baited remote underwater stereo-video cameras. Video images were collected from shallow (8-12 m) and deep (22-26 m) reef sites inside a Marine Protected Area (MPA) at each of three island groups and from three replicate fished locations at each of these groups that span a temperate-tropical transition area. The MPAs were established in 1994 and vary in size from 13.72 km² at the Pelsaert group in the south to 22.29 km² at the Easter group to 27.44 km² at the Wallabi group in the north. The relative abundances of 137 fish species from 42 families were recorded. Large differences in fish assemblage structure existed between MPA and fished locations, and also between shallow and deep regions. Targeted fish species *Plectropomus leopardus*, *Lethrinus miniatus*, *Lethrinus nebulosus*, *Pagrus auratus* and *Glaucosoma hebraicum* were more abundant inside MPAs than in areas open to fishing. Their abundance inside MPAs was between 1.13 and 8 times greater than their abundance at fished locations. For non-targeted fish species many were more abundant in areas open to fishing, e.g. *Coris auricularis*, *Thalassoma lutescens*, *Thalassoma lunare*, *Dascyllus trimaculatus*, however others were conversely more abundant inside MPAs, e.g. *Gymnothorax* spp, *Kyphosus sydneyanus*, *Scarus microbinus*, *Chromis westaustralis*, *Chaetodon* spp. This study demonstrates that the removal of abundant targeted species from an ecosystem by fishing can indirectly impact non-fished species and alter the trophic structure of fish assemblages.

Lombard, A.T., Reyers, B., Schonegevel, L.Y., Coopers, J., Smith-Adao, L.B., Nel, D.C., Froneman, P.W., Ansorge, I.J., Bester, M.N., Tosh, C.A., Strauss, T., Akkers, T., Gon, O., Leslie, R.W., and Chown, S.L. **Conserving pattern and process in the Southern Ocean: Designing a marine protected area for the Prince Edward Islands.** *Antarctic Science* 19(1): 39-54, 2007.

Notes: South Africa is currently proclaiming a Marine Protected Area (MPA) in the Exclusive Economic Zone (EEZ) of its sub-Antarctic Prince Edward Islands. The objectives of the MPA are to: 1) contribute to a national and global representative system of MPAs, 2) serve as a scientific reference point to inform future management, 3) contribute to the recovery of the Patagonian toothfish (*Dissostichus eleginoides*), and 4) reduce the bird bycatch of the toothfish fishery, particularly of albatrosses and petrels. This study employs systematic conservation planning methods to delineate a MPA within the EEZ that will conserve biodiversity patterns and processes within sensible management boundaries, while minimizing conflict with the legal toothfish fishery. After collating all available distributional data on species, benthic habitats and ecosystem processes, we used C-Plan software to delineate a MPA with three management zones: four IUCN Category Ia reserves (13% of EEZ); two Conservation Zones (21% of EEZ); and three Category IV reserves (remainder of EEZ). Compromises between conservation target achievement and the area required by the MPA are apparent in the final reserve design. The proposed MPA boundaries are expected to change over time as new data become available and as impacts of climate change become more evident.

Harris, J., Haward, M., Jabour, J., and Woehler, E.J. **A new approach to selecting Marine Protected Areas (MPAs) in the Southern Ocean.** *Antarctic Science* 19(2): 189-194, 2007.

Notes: Conservation of the high seas marine environment poses a significant challenge to policy-makers and managers. Marine conservation efforts are often hindered by the lack of data and the difficulties in addressing multiple, and typically conflicting uses. The majority of extant Marine Protected Areas (MPAs) are in coastal or tropical regions within national jurisdiction. Conservation of high seas MPAs has emerged on the international agenda as a critical issue requiring the application of novel approaches, international cooperation and political will. Knowledge and understanding of the marine environment and data on marine biodiversity are all typically limited for the high seas, and the use of surrogates to assist in the identification of areas of high conservation value is one possible mechanism to address and potentially overcome these limitations. Drawing upon a database spanning more than 20 years and containing approximately 140 000 records of seabird sightings at sea, this study assesses the potential use of seabirds as surrogates for marine biodiversity in the Indian sector of the Southern Ocean. At-sea ranges, species diversity and the distributions of endangered species may be appropriate selectors or filters to identify areas with high conservation values. Integrating policy with science provides an appropriate mechanism to identify and prioritise MPAs in the Southern Ocean.

Kellner, J.B., Tetreault, I., Gaines, S.D., and Nisbet, R.M. **Fishing the line near marine reserves in single and multispecies fisheries.** *Ecological Applications* 17(4): 1039-1054, 2007.

Notes: Throughout the world "fishing the line" is a frequent harvesting tactic in communities where no-take marine reserves are designated. This practice of concentrating fishing effort at the boundary of a marine reserve is predicated upon the principle of spillover, the net export of stock from the marine reserve to the surrounding unprotected waters. We explore the consequences and optimality of fishing the line using a spatially explicit theoretical model. We show that fishing the line: (1) is part of the optimal effort distribution near no-take marine reserves with mobile species regardless of the cooperation level among harvesters; (2) has a significant impact on the spatial patterns of catch per unit effort (CPUE) and fish density both within and outside of the reserve; and (3) can enhance total population size and catch simultaneously under a limited set of conditions for overexploited populations. Additionally, we explore the consequences of basing the spatial distribution of fishing effort for a multispecies fishery upon the optimality of the most mobile species that exhibits the greatest spillover. Our results show that the intensity of effort allocated to fishing the line should instead be based upon more intermediate rates of mobility within the targeted community. We conclude with a comparison between model predictions and empirical findings from a density gradient study of two important game fish in the vicinity of a no-take marine-life refuge on Santa Catalina Island, California (USA). These results reveal the need for empirical studies to account for harvester behavior and suggest that the implications of spatial discontinuities such as fishing the line should be incorporated into marine-reserve design.

McClanahan, T.R., Graham, N.A.J., Calnan, J.M., and MacNeil, M.A. **Toward pristine biomass: Reef fish recovery in coral reef marine protected areas in Kenya.** *Ecological Applications* 17(4): 1055-1067, 2007.

Notes: Identifying the rates of recovery of fish in no-take areas is fundamental to designing protected area networks, managing fisheries, estimating yields, identifying ecological interactions, and informing stakeholders about the outcomes of this management. Here we study the recovery of coral reef fishes through 37 years of protection using a space-for-time chronosequence of four marine national parks in Kenya. Using AIC model selection techniques, we assessed recovery trends using five ecologically meaningful production models: asymptotic, Ricker, logistic, linear, and exponential. There were clear recovery trends with time for species richness, total and size class density, and wet masses at the level of the taxonomic family. Species richness recovered rapidly to an asymptote at 10 years. The two main herbivorous families displayed differing responses to protection, scarids recovering rapidly, but then exhibiting some decline while acanthurids recovered more slowly and steadily throughout the study. Recovery of the two invertebrate-eating groups suggested competitive interactions over resources, with the labrids recovering more rapidly before a decline and the balistids demonstrating a slower logistic recovery. Remaining families displayed differing trends with time, with a general pattern of decline in smaller size classes or small-bodied species after an initial recovery, which suggests that some species- and size-related competitive and predatory control occurs in older closures. There appears to be an ecological succession of dominance with an initial rapid rise in labrids and scarids, followed by a slower rise in balistids and acanthurids, an associated decline in sea urchins, and an ultimate dominance in calcifying algae. Our results indicate that the unfished "equilibrium" biomass of the fish assemblage > 10 cm is 1100-1200 kg/ha, but these small parks (< 10 km²) are likely to underestimate prehuman influence values due to edge effects and the rarity of taxa with large area requirement, such as apex predators, including sharks.

Castilla, J.C., Campo, M.A., and Bustamante, R.H. **Recovery of *Durvillaea antarctica* (Durvilleales) inside and outside Las Cruces marine reserve, Chile.** *Ecological Applications* 17(5): 1511-1522, 2007.

Notes: We present the results for over two decades of monitoring on intertidal food-gatherers and the population of the low rocky shore dweller kelp *Durvillaea antarctica*, a short-distance disperser, inside and outside the no-take marine reserve, Estacion Costera de Investigaciones Marinas (ECIM), at Las Cruces, central Chile. It was hypothesized that protection of an initially extremely depleted population would recover by recolonizing first the no-take area and then adjacent non-protected (exploited) areas. We found that recovery of *D. antarctica* occurred slowly inside ECIM, with increase in density and biomass, of up to three orders of magnitude as compared to an adjacent non-protected area, which showed ~ 2-yr delay. These results suggest that the kelp population inside ECIM was likely regulated via intraspecific competition, which did not occur outside. Results showed no evidence for juvenile vs. adult density dependence other than a weak relationship for the central area of ECIM. These findings also suggest that the population recovery and cross-boundary seeding subsidies affected the population dynamics. Understanding these dynamics may enhance management and conservation policies. Our work highlights the critical

value of baseline and long-term comparative studies in marine no-take protected and non-protected areas for understanding how population processes respond to human and conservation practices.

Stewart, R.R., Ball, I.R., and Possingham, H.P. **The effect of incremental reserve design and changing reservation goals on the long-term efficiency of reserve systems.** *Conservation Biology* 21(2): 346-354, 2007.

Notes: Selecting reserve areas based on percentages, such as 10% or 12% of a bioregion, is common in conservation planning despite widespread admission that such percentages are arbitrary and likely to be inadequate for the conservation of all biodiversity. Reserve systems based on these relatively low percentage targets are likely to require expansion in the future, resulting in the assembly of reserve systems over many years (incremental reserve design). How then will incremental reserve design, such as increasing percentage targets over time, affect the long-term efficiency of marine reserve systems? We used South Australia as a case study to investigate how changing percentage targets affects the contribution of individual planning units to efficient reserve design. Selection frequency counts provided a measure of a planning unit's conservation value. For the majority of planning units, changing targets led to a change in their conservation value indicating, for example, that planning units identified as high-value sites at a low-percentage conservation target may be of lesser importance when targets are increased. Despite the variability in the value of individual planning units at different targets, there was no loss in efficiency from incremental design of reserve systems based on systematic methods compared with purpose-built reserve systems (i.e., the system is assembled in a single iteration). The exception was when incrementally designed systems were based on South Australia's existing marine reserve system - a system developed in an *ad hoc* method. The result was reserve systems that were less efficient, less compact, and larger in size. This suggests that systematic approaches have an important role for efficient reserve design when there is uncertainty about the target level of reservation.

Guidetti, P. **Potential of marine reserves to cause community-wide changes beyond their boundaries.** *Conservation Biology* 21(2): 540-545, 2007.

Notes: Fishing and other human activities can alter the abundances, size structure, and behavior of species playing key roles in shaping marine communities (e.g., keystone predators), which may in turn cause ecosystem shifts. Despite extensive evidence that cascading trophic interactions can underlie community-wide recovery inside no-take marine reserves by protecting high-level predators, the spatial extent of these effects into adjacent fished areas is unknown. I examined the potential for community-wide changes (i.e., the transition from overgrazed coralline barrens to macroalgal beds) in temperate rocky reefs within and around a no-take marine reserve. For this purpose I assessed distribution patterns of predatory fishes, sea urchins, and barrens across the reserve boundaries. Predatory fishes were significantly more abundant within the reserve than in adjacent locations, with moderate spillover across the reserve edges. In contrast, community-wide changes of benthic assemblages were apparent well beyond the reserve boundaries, which is consistent with temporary movements of predatory fishes (e.g., foraging migration) from the reserve to surrounding areas. My results suggest that no-take marine reserves can promote community-wide changes beyond their boundaries.

Beger, M., McKenna, S.A., and Possingham, H.P. **Effectiveness of surrogate taxa in the design of coral reef reserve systems in the Indo-Pacific.** *Conservation Biology* 21(6): 1584-1593, 2007.

Notes: Implementing systematically designed reserve systems is crucial to slowing the global decline of coral reef health and diversity. Yet, the paucity of spatial data for most coral reef taxa often requires conservation planners to design reserve systems based only on a subset of taxonomic groups as surrogates for all other taxa. In terrestrial systems the validity of surrogates for reserve design is established by testing for cross-taxon congruence (similarities in spatial patterns of species richness), but this concept has rarely been examined in the marine environment. We tested the suitability of taxa as conservation representation surrogates of coral reef species richness across the Indo-Pacific, based on species lists of fishes, corals, and mollusks from 167 sites. First, we tested the relevance of cross-taxon congruence patterns to predict these surrogacy patterns. We determined congruence between taxonomic groups by conducting a correlation analysis of dissimilarity values between pairs of sites. We then evaluated how well each taxonomic group represented the other groups in a marine reserve system selected by a greedy reserve-selection algorithm relative to reserve systems selected by chance. No taxonomic group we examined was a reliable surrogate for the other groups such that site selection based on that group always represented other taxa significantly better

than random selection of sites. Sites selected based on hard corals represented the other taxonomic groups in a reserve system worse than randomly selected sites. Although we found high cross-taxon congruence between fishes and corals and between corals and mollusks, for some regions cross-taxon congruence was not always a reliable indicator of the ability of one taxonomic group to efficiently represent another in a reserve system. We concluded that in Indo-Pacific coral reef ecosystems one can only be sure that a target taxon is efficiently represented in a reserve system when data on that taxon are used to select a reserve system.

Gerber, L.R., Wielgus, J., and Sala, E. **A decision framework for the adaptive management of an exploited species with implications for marine reserves.** *Conservation Biology* 21(6): 1594-1602, 2007.

Notes: Marine reserves have both conservation and fishery benefits. Nevertheless, there are no general criteria about when and where to establish new reserves, how to evaluate their efficacy, and how to conduct adaptive management to achieve conservation goals. We applied a decision-theory framework to optimally allocate conservation resources between improving data on population status and establishing a reserve for species conservation. Our goal was to maximize reserve benefits given the constraints of a population growth rate that would permit sustainability of resources. We illustrate our decision framework with a retrospective analysis of a 7-year time series on abundance of the leopard grouper (*Mycteroperca rosacea*) in the Sea of Cortés, Mexico. We used the lower bound of the distribution of the population growth rate (λ) as a decision rule for determining how many years of monitoring are needed to detect reserve effects. We determined the minimum time frame needed to estimate λ based on a stated level of risk tolerance for four sites. As expected, the coefficient of variation for the λ declined with the number of years of data. This increased precision with additional years of data resulted from the high degree of annual variability in the system. Where populations were slow to respond to reserves, more data were needed to detect a positive λ value. For the leopard grouper case study, confidence in the estimate of λ increased with the number of years of data. Our decision framework may be used to identify the minimum number of years of data needed before a management decision about reserve establishment could be made that is reasonably likely to meet its management objectives.

Baskett, M.L. **Prey size refugia and trophic cascades in marine reserves.** *Marine Ecology Progress Series* 328: 285-293, 2006.

Notes: After the establishment of marine reserves, trophic cascades, with an increase in top predators, decrease in herbivores and increase in producers, are often expected but not consistently observed. Recent empirical results suggest that the lack of cascades in a Caribbean coral reef reserve may be due to larger herbivores escaping predation. To explore the potential for such prey size refugia to prevent trophic cascades after reserve establishment, I construct a simple trophic model with and without herbivore size refugia and determine the conditions necessary for herbivorous fish to decrease after the elimination of harvest mortality. Generally, cascades do not occur and herbivores increase if the effect of harvest on herbivores before reserve establishment is greater than the effect of predation after reserve establishment. The parameter space where herbivores increase is much greater when accounting for size refugia. The potential for prey size refugia to prevent cascades makes it an important dynamic to consider in community-level approaches to reserve design and monitoring.

Meyer, C.G., Holland, K.N., and Papastamatiou, Y.P. **Seasonal and diel movements of giant trevally *Caranx ignobilis* at remote Hawaiian atolls: implications for the design of Marine Protected Areas.** *Marine Ecology Progress Series* 333: 13-25, 2007.

Notes: We need to understand the long-term movement patterns of coral reef top predators in order to design marine protected areas that will provide these animals with effective, long-term protection. We used acoustic telemetry to quantify the movements of giant trevally, a large coral reef top predator, at 5 atolls in the Northwestern Hawaiian Islands Marine National Monument. We did not observe any inter-atoll movements but found that giant trevally were attached to core activity areas from which they made periodic atoll-wide excursions of up to 29 km. Within the core areas, the tagged fish exhibited diel habitat shifts. We identified Rapture Reef at French Frigate Shoals (FFS) atoll as a spawning site, where giant trevally form seasonal mating aggregations. Giant trevally that use Rapture Reef as their core daytime area live there year-round, whereas those that occupy other areas of FFS migrate to Rapture Reef in the summertime during specific phases of the moon. Although giant trevally were wide-ranging and would require large marine protected areas (e.g. entire atolls or islands) to protect their entire range, core activity areas and spawning sites for giant trevally could be contained within relatively small

marine protected areas. Identification of spawning sites could assist in the establishment of focused marine protected areas that, while quite small in size, could have significant impact in preserving the spawning biomass of this species. Very large marine protected areas are not feasible in most heavily populated areas, hence effective alternative management strategies must be found for this fishery-targeted, wide-ranging top predator. We suggest using a combination of relatively small marine protected areas, to protect core activity areas and spawning sites for giant trevally, and conventional measures such as minimum size or 'slot' limits to further safeguard spawning stocks.

Jessopp, M.J. and McAllen, R.J. **Water retention and limited larval dispersal: implications for short and long distance dispersers in marine reserves.** *Marine Ecology Progress Series* 333: 27-36, 2007.

Notes: Although the establishment of reserves is central to marine conservation, previous criteria for the selection of appropriate areas has often been based on historical, aesthetic or logistic factors, resulting in a network of marine reserves that may not effectively meet conservation objectives. Since the dispersal of larvae plays an integral role in determining whether reserves can sustain themselves, whether they can exchange larvae with other protected sites, or whether they can supplement surrounding exploited areas, effective reserve design requires consideration of the processes that may affect larval dispersal. Plankton tows were conducted monthly for 12 mo in a semi-enclosed marine reserve with long water retention time, in bays with low water retention, and along open coastline, to establish whether larval retention plays an important role in limiting dispersal and creating discrete communities. Significant spatial and temporal differences in larval assemblages were found, with the semi-enclosed reserve, bay, and coast areas showing consistent differences throughout the year. An ANOVA carried out on 11 species identified as differentiating between these areas supported the hypothesis that limited larval exchange was occurring between reserve and non-reserve areas, despite potentially large dispersal distances. Designating bays as reserve areas may provide a means of protecting various species with both long and short dispersal distances, but this must be balanced against the reduced likelihood of closed populations to recover from local catastrophes and the possibility of limited genetic differentiation and inbreeding.

Guidetti, P. and Sala, E. **Community-wide effects of marine reserves in the Mediterranean Sea.** *Marine Ecology Progress Series* 335: 43-56, 2007.

Notes: We investigated the community-wide effects of no-take marine reserves at the regional scale in the Mediterranean Sea. Reserves had general positive effects of protection on fish targeted by fishing, and variable effects on non-target species. Differences in the structure of fish assemblages (in terms of abundance of species and trophic groups) were greater between geographic locations than when compared among all protected and adjacent fished areas at the regional scale. These results suggest that the assemblage-wide response to protection at the species level may be spatially idiosyncratic, as a function of local factors. However, the functional (trophic group) response of the fish assemblages to protection appears to be more general. Response of fish assemblages to protection was significantly related to reserve age (i.e. duration of protection) only when evaluated at functional level, whereas reserve size did not appear to influence fish assemblages at either species or functional level. Reserves can enhance trophic cascades and ecological shifts once the density of fish predators of sea urchins reaches a density threshold of about 15 adult sea breams (*Diplodus sargus* and *D. vulgaris*, the most important sea urchin predators) per 100 m². These non-linearities in the community-wide effect of reserves suggest that caution is needed in simplistically treating reserves and unprotected areas as 2 experimental treatments in ecological studies.

Winberg, P.C., Lynch, T.P., Murray, A., Jones, A.R., and Davis, A.R. **The importance of spatial scale for the conservation of tidal flat macrobenthos: An example from New South Wales, Australia.** *Biological Conservation* 134(3): 310-320, 2007.

Notes: Planners of Marine Protected Areas (MPAs) commonly use maps of habitat types when choosing areas to conserve. This assumes that habitats are homogeneous, and therefore, that any area of habitat will represent the full spectrum of ecological diversity within that habitat. Here, we report that macrobenthic assemblages in tidal flat habitats were spatially heterogeneous in terms of beta diversity (taxonomic turnover), abundance, taxonomic richness and Shannon-Wiener H' Diversity. Importantly, the patterns of heterogeneity were scale dependent for the three spatial scales we examined; plots (20 m), sites (100s of m) and estuaries (< 30 km). The three estuaries in the study were compositionally similar as they shared the same dominant taxa, although one estuary had significantly more taxa and a higher abundance of macrobenthos. Assemblages

within tidal flats differed at scales of 100s of m for all ecological measures. Most notably, beta diversity was highest at this scale. Assemblages were relatively more homogeneous at the 20-m scale. These findings highlight the value of examining more than one ecological measure and estimating magnitude of effects across a variety of scales. This work presents two important considerations for MPAs. First, although tidal flats in different estuaries are compositionally similar for dominant taxa, rarer taxa and high heterogeneity in abundance should influence the choice and number of tidal flats in MPAs. Second, strong compositional heterogeneity within individual tidal flats implies that conservation of whole habitat, rather than sections of a tidal flat, is essential if this habitat type is to be used to represent taxonomic diversity.

Pillans, S., Ortiz, J.C., Pillans, R.D., and Possingham, H.P. **The impact of marine reserves on nekton diversity and community composition in subtropical eastern Australia.** *Biological Conservation* 136(3): 455-469, 2007.

Notes: The effectiveness of marine reserve protection on the biodiversity of aquatic assemblages (i.e. nekton) in subtropical eastern Australia was examined within two small (<6 km²) marine reserves and four non-reserve areas. The two marine reserves, and their corresponding non-reserves, were located in different geographical locations within Moreton Bay (north and south) and sites were surveyed with multiple hauls of a seine net. Species richness, evenness, density and mean size of the inshore communities were compared between the reserves and non-reserves. No statistical significant difference was detected in species richness between the areas however species evenness was significantly lower in the only non-reserve site impacted by commercial net fishing. Mean size of nekton was found to be significantly greater in the marine reserves compared to non-reserves but no statistical significant difference was found in the density of nekton between the study sites. Multivariate analysis revealed differences in community composition, particularly between the geographical locations where areas were impacted by different types of fishing pressure (recreational v commercial). These results highlight the impact commercial fishing can have on entire nekton assemblages, not just on targeted species. Our study demonstrates that the small marine reserves in Moreton Bay are protecting marine biodiversity and are thus at least partially achieving their management objective (to enhance the zone's marine biodiversity).

Stelzenmuller, V., Maynou, F., and Martin, P. **Spatial assessment of benefits of a coastal Mediterranean Marine Protected Area.** *Biological Conservation* 136(4): 571-583, 2007.

Notes: Marine reserves are increasingly advocated not only as conservation but also as fisheries management tools to safeguard the decline of coastal fishing resources. Still, conclusive evidence of their functioning is lacking, amongst others due to the influence of spatio-temporal variations in fish populations and habitat heterogeneity which could hamper a sound data interpretation. We conducted a spatial analysis of the benefits of the Medes Island Marine Reserve by combining geostatistical and Geographic Information System (GIS) tools. Concurrently, we analysed effects of trends reflecting habitat heterogeneity and spatial structuring of data on spatial predictions of fish catch per unit effort (CPUE) and length. Predicted spatial patterns showed the complexity and simultaneous action of trend factors leading to mostly non-linear gradients in CPUE and length data. CPUE of total fish and CPUE and length of common pandora (*Pagellus erythrinus*) increased close to the Integral Reserve due to direct and indirect reserve effects. CPUE and length of striped red mullet (*Mullus surmuletus*) slightly increased also near the Integral Reserve, but distinct reserve effects could not be identified due to the strong influence of artificial reefs. We conclude that the spatial dimension of the Buffer Zone, where artisanal fisheries are allowed, permits in general protection only for target species, favouring a habitat with no discontinuities from the reserve outwards. Our spatial approach to assess reserve benefits provides major insights into complex systems like coastal marine reserves in the northwestern Mediterranean. In addition, it contributes to a crucial aspect of marine conservation, viz. the decision on the spatial dimension of protected areas.

Samoilys, M.A., Martin-Smith, K.M., Giles, B.G., Cabrera, B., Anticamara, J.A., Brunio, E.O., and Vincent, A.C.J. **Effectiveness of five small Philippines' coral reef reserves for fish populations depends on site-specific factors, particularly enforcement history.** *Biological Conservation* 136(4): 584-601, 2007.

Notes: Community-managed, no-take marine reserves are increasingly promoted as a simple, precautionary measure to conserve biodiversity and sustain coral reef fisheries. However, we need to demonstrate the effects of such reserves to those affected by the loss of potential fishing grounds and the wider scientific community. We surveyed changes in fish communities

in five small marine reserves in the central Philippines and three distant Control sites over seven years. We conducted underwater visual censuses of 53 fish families within the reserve (inside), with a kilometre of the boundary (outside) and at Control sites. We found significant differences between fish communities inside and outside the reserve only at the two sites with strictest compliance with fishing prohibition, while there were significant differences to distant Control sites in all cases. The strongest responses to reserve protection were found in predatory fishes (groupers and breams) and in butterflyfish. Other abundant fish families showed weak effects of protection. For all taxa analysed, we found significant effects of reserve Site and Site x Treatment interactions. The detection of fish responses to reserves is complicated by potential spillover effects, site-specific factors, particularly compliance, and the difficulty of identifying appropriate control areas.

Banks, S.A. and Skilleter, G.A. **The importance of incorporating fine-scale habitat data into the design of an intertidal marine reserve system.** *Biological Conservation* 138(1-2): 13-29, 2007.

Notes: There is concern about the reliability of surrogate measures to represent biodiversity and the use of such measures in the design of marine reserve systems. Currently, surrogate measures are most often based on broad-scale (100-1000s of km) bioregional frameworks that define general categories (sandy beach, rocky shore) for intertidal systems. These broad-scale categories are inadequate when making decisions about conservation priorities at the local level (10-100s of m). In this study, 'shoreline types', derived using physical properties of the shoreline, were used as a surrogate for intertidal biodiversity to assist with the identification of sites to be included in a representative system of marine reserves. The use of local-scale shoreline types increased the likelihood that sites identified for conservation achieved representation goals for the mosaic of habitats and microhabitats, and therefore the associated biodiversity present on rocky shores, than that provided by the existing marine reserve protection. These results indicate that using broad-scale surrogate measures (rocky shore, sandy beach) for biodiversity (habitats, microhabitats and species) are likely to result in poor representation of fine-scale habitats and microhabitats, and therefore intertidal assemblages in marine reserves. When additional fine-scale data were added to reserve selection the summed irreplaceability of 24% (for spatial extent of habitats), and 29% (for presence/absence of microhabitats) of rocky shore sites increased above 0, where a value close to 1 means a site is necessary, for inclusion in a reserve system, to meet conservation targets. The use of finer-scale physical data to support marine reserve design is more likely to result in the selection of reserves that achieve representation at habitat and microhabitat levels, increasing the likelihood that conservation goals will be achieved.

Baskett, M.L., Micheli, F., and Levin, S.A. **Designing marine reserves for interacting species: Insights from theory.** *Biological Conservation* 137(2): 163-179, 2007.

Notes: The primary goals of marine reserves include protecting biodiversity and ecosystem structure. Therefore, a multispecies approach to designing and monitoring reserve networks is necessary. To gain insight into how the interactions between species in marine communities may affect reserve design, we synthesize marine reserve community models and community models with habitat destruction and fragmentation, and we develop new extensions of existing models. This synthesis highlights the potential for species interactions to alter reserve design criteria; in particular, accounting for species interactions often leads to an increase in reserve size necessary to protect populations. Accounting for species interactions also indicates the need to base reserve design and monitoring on a variety of species, especially long-distance dispersers, inferior colonizers, and specialists. Finally, the new model extensions highlight how, given dispersal, source populations outside reserves as well as increases in fished populations after reserve establishment may negatively affect reserve populations of competitors or prey. Therefore, multispecies harvest dynamics outside reserves and before reserve establishment are critical to determining the appropriate reserve size, spacing, and expectations after establishment. These models highlight the importance of species interactions to reserve design and provide guidelines for how this complexity can begin to be incorporated into conservation planning.
