Marine Science Review – 165

Marine protected areas and reserves

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A. Recent articles – no abstract available

Sanchirico, J.N., Viatella, K.C., and Emerson, P.M. **Socioeconomic implications of siting marine protected areas in U.S. waters.** Ocean Yearbook 19, 2005.

Craig, R.K. **International marine biodiversity preservation: National systems of marine protected areas and international treaties.** *Journal of Land Use and Environmental Law* 20(2): 333-369, 2005.

Mangel, M. **Commentary: Accounting for uncertainty in marine reserve design.** *Ecology Letters* 9(1): 11-12, 2006.

Mora, C., Andrefouet, S., Costello, M.J., Kranenburg, C., Rollo, A., Veron, J., Gaston, K.J., and Myers, R.A. **Coral reefs and the global network of marine protected areas.** *Science* 312(5781): 1750-1751, 2006.

Dawson, M.N., Grosberg, R.K., and Botsford, L.W. **Connectivity in marine protected areas.** *Science* 313(5783): 43-44, 2006.

Steneck, R.S., Cowen, R.K., Paris, C.B., and Srinivasan, A. **Connectivity in marine protected areas - Response.** *Science* 313(5783): 44-45, 2006.

B. Recent publications available online

Kimball, L.A. 2005. **The International Legal Regime of the High Seas and the Seabed Beyond the Limits of National Jurisdiction and Options for Cooperation for the establishment of Marine Protected Areas (MPAs) in Marine Areas Beyond the Limits of National Jurisdiction.** Secretariat of the Convention on Biological Diversity, Montreal, Technical Series no. 19. 64pp.

Available at: http://www.iucn.org/themes/marine/pdf/cbd-ts-19.pdf

Notes: This study outlines the UNCLOS framework and its application to marine areas beyond national jurisdiction, together with specific provisions in UNCLOS and other global and regional agreements that offer options for establishing marine protected areas in these areas. It then reviews the adequacy of the existing legal regime for establishing marine protected areas beyond national jurisdiction and considers its adequacy with respect to the priority high seas areas identified in the scientific background paper, *Patterns of species richness in the high seas*. This study also suggests further options for cooperation in establishing marine protected areas beyond national jurisdiction.

PROTECT. 2006. **Review of Marine Protected Areas as a Tool for Ecosystem Conservation and Fisheries Management.** PROTECT, Danish Institute for Fisheries Research, Charlottenlund. 148pp.

Available at: http://www.mpa-eu.net/

Notes: This review concludes that a great deal is known regarding the use and development of MPAs. However, it also reveals substantial knowledge gaps and limitations in the current decision base and instruments to select, develop, implement and evaluate MPAs. This is apparent in the review of past and present MPAs, where none of the reviewed North Sea MPAs have had much success in fulfilling their management objectives. In some cases, effects of MPAs were not detectable due to limitations in available data, monitoring strategies and/or clear, pre-defined management objectives. In addition, there is a need to better integrate fisheries management and ecosystem conservation objectives in MPA development. Even when it comes to the the use of MPAs in relatively well-researched and well-defined geographic areas, much is still unknown regarding the interrelated processes controlling fisheries and the marine environment.

C. Recent articles with abstracts

Langlois, T.J., Anderson, M.J., Babcock, R.C., and Kato, S. **Marine reserves demonstrate trophic interactions across habitats.** *Oecologia* 147(1): 134-140, 2006.

Notes: Several infaunal bivalve taxa show patterns of decreased biomass in areas with higher densities of adjacent reef-associated predators (the snapper, *Pagrus auratus* and rock lobster, *Jasus edwardsii*). A caging experiment was used to test the hypothesis that patterns observed were caused by predation, using plots seeded with a known initial density of the bivalve *Dosinia subrosea* to estimate survivorship. The caging experiment was replicated at several sites inside and outside two highly protected marine reserves: predators are significantly more abundant inside these reserves. Survivorship in fully caged, partially caged and open plots were then compared at sites having either low (non reserve) or high (reserve) predator density. The highest rates of survivorship of the bivalve were found in caged plots inside reserves and in all treatments outside reserves. However, inside reserves, open and partially caged treatments exhibited low survivorship. It was possible to specifically attribute much of this mortality to predation by large rock lobsters, due to distinctive marks on the valves of dead *D. subrosea*. This suggests that predation by large rock lobster could indeed account for the distributional patterns previously documented for certain bivalve populations. Our results illustrate that protection afforded by marine reserves is necessary to investigate how depletion through fishing pressure can change the role of upper-level predators and trophic processes between habitats.

Halpern, B.S., Regan, H.M., Possingham, H.P., and McCarthy, M.A. **Accounting for uncertainty in marine reserve design.** *Ecology Letters* 9(1): 2-11, 2006.

Notes: Ecosystems and the species and communities within them are highly complex systems that defy predictions with any degree of certainty. Managing and conserving these systems in the face of uncertainty remains a daunting challenge, particularly with respect to developing networks of marine reserves. Here we review several modelling frameworks that explicitly acknowledge and incorporate uncertainty, and then use these methods to evaluate reserve spacing rules given increasing levels of uncertainty about larval dispersal distances. Our approach finds similar spacing rules as have been proposed elsewhere - roughly 20-200 km - but highlights several advantages provided by uncertainty modelling over more traditional approaches to developing these estimates. In particular, we argue that uncertainty modelling can allow for (1) an evaluation of the risk associated with any decision based on the assumed uncertainty; (2) a method for quantifying the costs and benefits of reducing uncertainty; and (3) a useful tool for communicating to stakeholders the challenges in managing highly uncertain systems. We also argue that incorporating rather than avoiding uncertainty will increase the chances of successfully achieving conservation and management goals.

Gardmark, A., Jonzen, N., and Mangel, M. **Density-dependent body growth reduces the potential of marine reserves to enhance yields.** *Journal of Applied Ecology* 43(1): 61-69, 2006.

Notes: 1. Some models of marine no-take reserves predict that reserves can enhance fishery yield. However, empirical evidence of this remains inconclusive. One reason for this may be the disregard for density-dependent body growth in most models. Density-dependent body growth links the number and size of individuals, and thus could influence the biomass of fishery yield. 2. We developed an age- and size-structured model of an exploited population and analysed the effect of implementing a no-take reserve of varying size. 3. Protecting part of a population from exploitation in a no-take reserve results in a rapid build-up of biomass inside the reserve because of increased survival. However, when body growth is density-dependent it also results in reduced length at a given age within the no-take reserve because of crowding effects. This prediction is backed up by empirical observations. 4. If there is export of individuals (here larvae) from the no-take reserve, length at a given age will also decrease in the fished part of the population outside the reserve. An increase in the number of exploitable individuals thus results in decreased individual body mass. The positive effect of larval drift on fished population size and catch numbers will therefore rarely translate into an increase in equilibrium yield biomass. 5. Synthesis and applications. When body growth is density-dependent, implementation of no-take reserves affects the body size of both protected and exploitable individuals. Although reserves can have several benefits besides increasing yields, our study shows that, if density-dependent somatic effects are important, a general increase in yield biomass cannot be expected. In populations with density-dependent body growth, reserves are more likely to decrease yield biomass unless the population is severely overexploited. Analyses of the efficiency of marine reserves as a means of enhancing the yield of fisheries need to account for ecological processes, and density-dependent body growth is likely to be key.

Mumby, P.J., Dahlgren, C.P., Harborne, A.R., Kappel, C.V., Micheli, F., Brumbaugh, D.R., Holmes, K.E., Mendes, J.M., Broad, K., Sanchirico, J.N., Buch, K., Box, S., Stoffle, R.W., and Gill, A.B. **Fishing, trophic cascades, and the process of grazing on coral reefs.** *Science* 311(5757): 98-101, 2006.

Notes: Since the mass mortality of the urchin *Diadema antillarum* in 1983, parrotfishes have become the dominant grazer on Caribbean reefs. The grazing capacity of these fishes could be impaired if marine reserves achieve their long-term goal of restoring large consumers, several of which prey on parrotfishes. Here we compare the negative impacts of enhanced predation with the positive impacts of reduced fishing mortality on parrotfishes inside reserves. Because large-bodied parrotfishes escape the risk of predation from a large piscivore (the Nassau grouper), the predation effect reduced grazing by only 4 to 8%. This impact was overwhelmed by the increase in density of large parrotfishes, resulting in a net doubling of grazing. Increased grazing caused a fourfold reduction in the cover of macroalgae, which, because they are the principal competitors of corals, highlights the potential importance of reserves for coral reef resilience.

Moustakas, A., Silvert, W., and Dimitromanolakis, A. **A spatially explicit learning model of migratory fish and fishers for evaluating closed areas.** *Ecological Modelling* 192(1-2): 245-258, 2006.

Notes: Fisheries models usually characterise the concentrations of fish and the distribution of the fishing fleet by spatial averages over large areas assuming homogeneous spatial characteristics. Many important management questions, such as those related to the spatial effects of closed areas, cannot be addressed by such models. This paper presents a model which describes the spatial movement of individual fish schools and the spatial response of individual fishing boats, and which can be applied on a much finer scale and thus can be used to analyse the scale-dependent development of the fishery. The motion of the fish is based on assumptions about time-dependent gradients in the relative attractiveness of nearby grid cells which motivate migrations based on feeding and spawning factors. The motion of fishing boats is modelled in a similar fashion, with the attractiveness of neighbouring cells based on historical catch records as a function of position and time of year, as well as whether current catch rates are high enough to justify staying in the same cell. Our model showed that marine reserves increase fish biomass but decrease fish catches. It is also indicated that marine reserves are of limited use when not combined with quotas of catches. Our findings also point that transfer rates of fish increase the benefits of marine reserves in terms of fish biomass but decrease fish catches.

Hyrenbach, K.D., Keiper, C., Allen, S.G., Ainley, D.G., and Anderson, D.J. **Use of marine sanctuaries by far-ranging predators: commuting flights to the California Current System by breeding Hawaiian albatrosses.** *Fisheries Oceanography* 15(2): 95-103, 2006.

Notes: Quantifying the dispersion and habitats of far-ranging seabirds, turtles, and cetaceans is essential to assess whether zoning strategies can help protect upper-trophic marine predators. In this paper, we focus on Black-footed Albatross (*Phoebastria nigripes*) use of three US national marine sanctuaries off central California: Cordell Bank, Gulf of the Farallones, and Monterey Bay. We assessed the significance of these protected areas to albatrosses by: (i) documenting commuting flights between Hawaiian breeding sites and the California Current System (CCS); (ii) quantifying albatross dispersion patterns on the central California continental shelf and slope, and (iii) characterizing albatross habitats within sanctuary waters using concurrent satellite-tracking data and vessel-based sightings. Chick-rearing albatrosses commuted from their colony on Tern Island, Hawaii (23.878ºN, 166.288ºW), to the CCS (34-48 ºN) and two of the eight satellite-tracked birds entered the marine sanctuaries. Among the telemetry locations within sanctuary waters, two-thirds (24 of 36) straddled the shelf break and slope (201-2000-m depth), a pattern underscored by a concurrent vessel-based survey in which 144 Black-footed Albatrosses were sighted. This study illustrates the value of coordinated satellite telemetry and vessel-based surveys to assess the distributions of protected species within existing marine protected areas. More specifically, our results underscore the importance of three central California marine sanctuaries to Hawaiian albatrosses breeding in subtropical waters, approximately 4500 km away.

Armstrong, C.W. and Skonhoft, A. **Marine reserves: A bio-economic model with asymmetric density dependent migration.** *Ecological Economics* 57(3): 466-476, 2006.

Notes: A static bioeconomic model of a marine reserve allowing asymmetric density dependent migration between the reserve and the fishable area is introduced. This opens for habitat or ecosystem differences allowing different fish densities within and outside a reserve, not described in earlier studies. Four management scenarios are studied; (a) maximum harvest, (b) maximum current profit, (c) open access and (d) maximum sustainable yield (MSY) in the reserve. These are all analysed within the Induced Sustainable Yield Function (ISYF), giving the relationship between the fish abundance inside the reserve and the harvesting taking place outside. A numerical analysis shows that management focused on ensuring MSY within the reserve under the assumption of symmetric migration may be negative from an economic point of view, when the area outside the reserve is detrimental compared to the reserve. Furthermore, choice of management option may also have negative consequences for long run resource use if it is incorrectly assumed that density dependent migration is symmetric. The analysis also shows that the optimal area to close, either a more or a less attractive ecosystem for the resource in question, may differ depending on the management goal.

Gleason, M.G., Merrifield, M.S., Cook, C., Davenport, A.L., and Shaw, R. **Assessing gaps in marine conservation in California.** *Frontiers in Ecology and Environment* 5(4): 249-258, 2006.

Notes: Implementation of marine conservation strategies lags far behind terrestrial conservation efforts. Quantifying what is protected and what is not, or "gap analysis", helps to show just how much work there is to do; systematic conservation planning provides guidance on how to best fill those gaps. We conducted the first marine gap analysis for California by comparing distributions of major ecosystems and habitats with existing marine protected areas. Less than 0.3% of state and federal waters (to the bottom of the continental slope) are within no-take or limited-take marine protected areas (MPAs). With few exceptions, less than 5% of marine habitats are within no-take or limited-take MPAs that afford a high level of ecosystem protection. Efforts to create new MPAs to include representative habitats will help to fill some gaps, but additional conservation strategies, such as ocean zoning and ecosystem-based management of fisheries, are needed to balance protection and sustainable use of marine biodiversity.

Bevilacqua, S., Terlizzi, A., Fraschetti, S., Russo, G.F., and Boero, F. **Mitigating human disturbance: can protection influence trajectories of recovery in benthic assemblages?** *Journal of Animal Ecology* 75(4): 908-920, 2006.

Notes: 1. Understanding whether Marine Protected Areas (MPAs) can be considered as a suitable tool for restoring the structure and function of populations and assemblages is urgently needed to achieve an effective policy of mitigation of human impact in coastal management. However, to date, the role played by MPAs in enhancing ecosystems resilience has been more advocated than unambiguously documented. 2. This study was designed to test whether full protection in marine reserves facilitates recovery of benthos impacted by the date mussel *Lithophaga lithophaga* fishery, one of the most harmful human activities affecting subtidal rocky habitats in the Mediterranean Sea. 3. The effects of this destructive fishery were reproduced

at one fully protected location (P) and at two unprotected control locations (Cs) in the SW Mediterranean Sea. At each location, three plots (4 m(2)) of rocky surface at 4-6 m depth were disturbed experimentally, while another three plots served as reference. In each plot, the species composition and relative cover of the sessile benthic assemblages were sampled photographically on each of five occasions during a period of 20 months. 4. Over and above variation in habitat features among locations, multivariate and univariate analyses revealed significant differences between P-vs.-Cs in patterns of assemblage recovery and showed that, at the fully protected location, recovery was faster than at the unprotected control locations. 5. Our results suggest that MPAs have the potential to change the trajectories of recovery of disturbed assemblages by accelerating the processes of recolonization and call for further investigation to identify the specific mechanisms underlying increased resilience.

Jaworski, A., Solmundsson, J., and Ragnarsson, S.A. **The effect of area closures on the demersal fish community off the east coast of Iceland.** *ICES Journal of Marine Science* 63(5): 897-911, 2006.

Notes: The effect of reduced fishing effort on the demersal fish community, following area closures in 1993, was analysed for two protected areas off the east coast of Iceland. Digranesflak and Breiddaisgrunn. The data were collected using a standardized bottom trawl during ground-fish surveys in the period 1985-2004. The aspects of the fish community that were analysed included abundance by size class, mean size, species richness, diversity, and composition. The analysis was conducted for closed areas and adjacent reference (fished) areas, as well as for periods before and after the closure (and also after the re-opening in Breiddalsgrunn), using an ANOVA model and planned comparisons. The closure had a favourable impact on abundance of haddock (*Melanogrammus aeglefinus*) and small long rough dab (*Hippoglossoides platessoides*) in Digranesflak, and on exploitable sizes of haddock and cod (*Gadus morhuo*) in Breiddalsgrunn. The mean size of haddock increased considerably within the protected areas relative to the reference areas: by 16 cm in Digranesflak and by 10 cm in Breiddalsgrunn. Species richness, diversity, and composition varied over the study period and between areas, but no effect of area closure was found. The observed changes in the fish community in Breiddalsgrunn were reversed within 7 years of the reopening of the area to fishing. The possible causes for the observed patterns of response to area closures are discussed.

Blyth-Skyrme, R.E., Kaiser, M.J., Hiddink, J.G., Edwards-Jones, G., and Hart, P.J.B. **Conservation benefits of temperate marine protected areas: Variation among fish species.** *Conservation Biology* 20(3): 811-820, 2006.

Notes: Marine protected areas, and other fishery management systems that impart partial or total protection from fishing, are increasingly advocated as an essential management tool to ensure the sustainable use of marine resources. Beneficial effects for fish species are well documented for tropical and reef systems, but the effects of marine protected areas remain largely untested in temperate waters. We compared trends in sport-fishing catches of nine fish species in an area influenced by a large (500-km(2)) towed fishing-gear restriction zone and in adjacent areas under conventional fishery management controls. Over the period 1973-2002 the mean reported weight of above-average-sized (trophy) fish of species with early age at maturity and limited home range was greatest within the area influenced by the fishing-gear restriction zone. The reported weight of trophy fish of species that mature early also declined less and more slowly over time within the area influenced by the fishing-gear restriction zone. Importantly, the mean reported weight of trophy fish of species that mature late and those that undertake extensive spatial movements declined at the same rate in all areas, hence these species are likely to require protected areas > 500 km(2) for effective protection. Our results also indicated that fish species with a localized distribution or high site fidelity may require additional protection from sport fishing to prevent declines in the number or size of fish within the local population.

Narvarte, M., Gonzalez, R., and Fernandez, M. **Comparison of Tehuelche octopus (*Octopus tehuelchus*) abundance between an open-access fishing ground and a marine protected area: Evidence from a direct development species.** *Fisheries Research* 79(1-2): 112-119, 2006.

Notes: Marine protected areas (MPAs) have been established during the last few decades for conservation and management purposes. Most studies showing a positive effect of MPAs on abundance or size have focused on species exhibiting a planktonic larval stage. In this study, the impact of an MPA on the local abundance of a direct development species, the Tehuelche octopus *Octopus tehuelchus*, is evaluated. Octopus abundance (catch per unit of effort) was compared between a

traditional fishing ground (El Fuerte) and an MPA in northern Patagonia (Argentina), during one spawning/recruitment period (August-October; pre-fishing) and during the following fishing season (January-April). Abundance in the MPA was twice as high as in El Fuerte during the fishing season, but not during the pre-fishing season. Females were more abundant than males at both sites. Contrary to expectations, mean octopus weight was lower in the MPA than in El Fuerte, which can be explained by higher abundance of recruits. In fact, the ratio recruit/spawner was three times higher in the MPA than in El Fuerte. Removal of brooding females during the brooding season in El Fuerte may affect the survival of the embryos, since females provide parental care. More information on the wide diversity of life history of marine species is needed since the current literature on MPAs is strongly biased towards species exhibiting planktonic stages.

Abesamis, R.A., Alcala, A.C., and Russ, G.R. **How much does the fishery at Apo Island benefit from spillover of adult fish from the adjacent marine reserve?** *Fishery Bulletin* 104(3): 360-375, 2006.

Notes: The contribution of the no-take marine reserve at Apo Island, Philippines, to local fishery yield through "spillover" (net export of adult fish) was estimated. Spatial patterns of fishing effort, yield, and catch rates around Apo Island were documented daily in 2003-2004. Catch rates were higher near the reserve (by a factor of 1.1 to 2.0), but fishing effort was often lowest there. Higher catch rates near the reserve were more likely due to spillover than to low fishing intensity. Lower fishing effort near the reserve may have been due to 1) weather patterns, 2) traditional importance of other fishing grounds, 3) high variability in catch rates, 4) lower market value of target species, and 5) social pressures. The yield taken near the reserve was only 10% of the total yield, but the actual spillover contribution was probably much less than this. This study is one of the few to estimate the spillover contribution to overall yield and to document the responses of fishermen to spillover.

Mumby, P.J. **Connectivity of reef fish between mangroves and coral reefs: Algorithms for the design of marine reserves at seascape scales.** *Biological Conservation* 128(2): 215-222, 2006.

Notes: Many species of coral reef fish undertake ontogenetic migrations between seagrass beds, mangroves, and coral reefs. A recent study from the Caribbean found that the availability of mangrove nursery habitat had a striking impact on the community structure and bio-mass of reef fish in their adult, coral reef habitat. The biomass of several species more than doubled when the reefs were connected to rich mangrove resources (defined as having at least 70 km of fringing *Rhizophora* mangle within a region of 200 km^2). Here, the results of this large-scale empirical study are translated into a series of algorithms for use in natural resource management planning. Four algorithms are described that identify (i) the relative importance of mangrove nursery sites, (ii) the connectivity of individual reefs to mangrove nurseries, (iii) areas of nursery habitat that have an unusually large importance to specific reefs, and (iv) priority sites for mangrove reforestation projects. The algorithms generate a connectivity matrix among mangroves and coral reefs that facilitates the identification of connected corridors of habitats within a dynamic planning environment (e.g., reserve selection algorithms).

Claudet, J., Pelletier, D., Jouvenel, J.Y., Bachet, F., and Galzin, R. **Assessing the effects of marine protected area (MPA) on a reef fish assemblage in a northwestern Mediterranean marine reserve: Identifying community-based indicators.** *Biological Conservation* 130(3): 349-369, 2006.

Notes: Marine protected areas (MPAs) are increasingly envisaged as a tool to manage coastal ecosystems and fisheries. Assessment of their performance with respect to management objectives is therefore important. A number of WAS provided conservation benefits for fished species. Observed benefits do not apply to all species at all times, and responses to protection are also highly variable among fish taxa. Among the many empirical studies on marine reserves, only a few designs considered 'before and after data' and spatial variation. In this paper, we are interested in assessing the effect of a no-take reserve on the reef fish assemblage in a northwestern Mediterranean example. Data were obtained from a three-year survey using underwater visual censuses (UVC), before and after MPA establishment. Permutational multivariate analysis of variance (PERMANOVA) and multivariate regression trees (MRT) were used to evaluate the effects of reserve protection on the reef fish assemblage, while accounting for habitat. Modelled biological responses were abundances and diversity indices calculated at different levels of the assemblage. Significant effects were found for many of these metrics. In addition to PERMANOVA, univariate models provided more insight into the magnitude and direction of effects. The most sensitive metrics were related to large species and

species targeted by fishing. These results may be used to choose the metrics that are more suitable as community-based indicators of MPA impact in the perspective of monitoring programs.

Goni, R., Quetglas, A., and Renones, O. **Spillover of spiny lobsters *Palinurus elephas* from a marine reserve to an adjoining fishery.** *Marine Ecology Progress Series* 308: 207-219, 2006.

Notes: We investigate the effects of the Columbretes Islands Marine Reserve (CIMR, Western Mediterranean) on the adjacent *Palinurus elephas* (Fabricius, 1787) fishery. After 9 to 12 yr of no-take protection there was a gradient of lobster density from the interior of the reserve up to a distance of about 4 km from its boundary. Catch and effort data were collected onboard commercial fishing boats in the fishery adjacent to the CIMR, and combined with catch per unit effort (CPUE) data from monitoring surveys conducted annually inside the reserve. Generalized additive (GAM) and linear (GLM) models were employed to examine the relationships of CPUE and catch per unit area (CPUA) as a function of distance to the reserve boundary. CPUE showed a significant non-linear decline with distance from the centre of the reserve, with a depression at the boundary followed by a plateau. This depression was caused by local depletion associated with concentration of fishing effort at the reserve boundary, while the plateau suggests that lobster export from the reserve is sufficient to maintain stable catch rates up to 1500 m from the boundary. Commercial catch and effort data were combined to estimate CPUA, which declined linearly with distance from the reserve. Analysis of recaptures of lobsters tagged and released inside the reserve indicates that the density gradient is caused by lobsters emigrating from the reserve.

Kaplan, D.M. **Alongshore advection and marine reserves: consequences for modeling and management.** *Marine Ecology Progress Series* 309: 11-24, 2006.

Notes: The appropriate configuration of marine reserves for maximizing harvests or ensuring species persistence when there is uncertainty or variability in larval dispersal patterns is not completely understood. This is particularly true in environments with large alongshore advection rates, as the success of a system of marine reserves depends on connectivity through larval and/or adult dispersal between adjacent marine reserves. In this paper, the consequences of alongshore advection in the presence of marine reserves for a fish species with sedentary adults and widely dispersing larvae are examined. First, a uniform configuration of reserves with constant alongshore advection rate is considered. The highest overall catch and recruitment rates occur when the spacing between reserves is precisely tuned to the advection distance. When the alongshore advection distance is allowed to vary in time, catch and recruitment are considerably less sensitive to alongshore advection. At small diffusion distances, catch values differ from what would be predicted from the time-averaged larval dispersal pattern due to density-dependent post-settlement effects. It is important to include short time scale settlement variability in marine reserve models under these conditions. When the spacing between reserves is allowed to vary, the tuning of the system to particular advection distances is less precise. Configurations of marine reserves with a variety of spacings between reserves exhibited more uniform catch levels as a function of advection distance. This suggests that variability in the spacing between reserves is desirable for protecting a diverse group of species with different dispersal patterns.

Cicin-Sain, B. and Belfiore, S. **Linking marine protected areas to integrated coastal and ocean management: A review of theory and practice.** *Ocean and Coastal Management* 48(11-12): 847-868, 2005.

Notes: If managed in isolation, coastal and marine protected areas (MPAs) are vulnerable to natural resource development and exploitation occurring outside these areas-in particular, overfishing, alteration and destruction of habitats, and water pollution. Thus, protection of coastal and marine areas-of species, habitats, landscapes, and seascapes-should be integrated into spatial development strategies for larger areas, under the umbrella of integrated coastal and ocean management (ICM). This is typically easier said than done, since the actors involved in MPA networks and in ICM programs are often different, reflecting different cultures, networks of relationships, ministries, and goals and motivations. This article reviews the ecological, social and economic linkages between MPAs and the governance of broader ocean and coastal areas; sets forth nine guiding principles for managing MPAs within an ICM context; reviews work conducted under the Convention on Biological Diversity to operationalize the linkages between ICM and MPAs; and develops strategic guidance for addressing these linkages. The article ends with a call to bring together the diverse communities involved in marine protected areas, coastal and

ocean management, and watershed management to collaborate in national-level ocean and coastal planning, including in the designation of networks of marine protected areas.

Cooke, S.J., Danylchuk, A.J., Danylchuk, S.E., Suski, C.D., and Goldberg, T.L. **Is catch-and-release recreational angling compatible with no-take marine protected areas?** *Ocean and Coastal Management* 49(5-6): 342-354, 2006.

Notes: Marine protected areas (MPAs) have become a common conservation and management tool for reducing exploitation from the commercial and recreational fisheries sectors. However, the recreational fisheries sector has the potential to be compatible with no-take MPAs when catch-and-release angling is practiced because, in theory, no fish are actually harvested. This presumes that the effects of catch-and-release angling and related activities do not cause appreciable declines in fish populations as a result of direct mortality, sub-lethal effects, or indirect effects on fish habitats, or other problems contrary to the goal of a given MPA. Here, we explore the idea that recreational catch-and-release angling may be compatible with some no-take MPAs provided there are no substantive negative ecological consequences. We argue that it is not currently possible to answer definitively the question of whether recreational catch-and-release fisheries can be compatible with no-take MPAs. Mortality rates of released fish vary extensively (between zero and near 100%) and are influenced by a number of factors including environmental conditions, fishing gear, angler behavior, and species-specific characteristics. Nevertheless, research in the field of catch-and-release is beginning to show that certain handling techniques can significantly reduce post-release mortality in fish. With appropriate regulation and angler education, catch-and-release could help enhance conservation and management goals associated with MPAs while maintaining public support and providing alternative tourism-based revenues for displaced fishers. Until sufficient data are available, research should focus on contrasting the fish community characteristics in regions with no fishing and those that permit catch-and-release fishing (i.e., opportunistic observations and controlled manipulations) as well as population-level mathematical modeling to assess the effects of angling on long-term population viability and ecosystem dynamics. Additional efforts should focus on education and outreach that provide anglers and fishing guides with the best available information to reduce catch-and-release mortality, sublethal angling-induced impairments, and broader effects on aquatic environments.

Smith, M.D., Zhang, J.J., and Coleman, F.C. **Effectiveness of marine reserves for large-scale fisheries management.** *Canadian Journal of Fisheries and Aquatic Sciences* 63(1): 153-164, 2006.

Notes: As more no-take marine reserves are established, the importance of evaluating effectiveness retrospectively is growing. This paper adapts methods from program evaluation to quantify the effects of establishing a marine reserve on fisheries using fishery-dependent data. The approach analyzes the effects of a policy at the individual vessel level and accommodates the coarse spatial resolution of fishing logbooks. It illuminates implicit assumptions in previous retrospective analyses of marine reserves that are unlikely to hold for large-scale fisheries. We illustrate the empirical model with an application to the Gulf of Mexico reef-fish fishery. Isolating the effects of reserves requires a full accounting of multiple gear production technologies, heterogeneity in vessel captain skill, spatial heterogeneity of fish stocks, seasonal patterns in abundance, the effects of coexisting management policies, and the possibility that the harvest sector anticipates reserve establishment. We find that the effect of two recently established marine reserves on catch is negative and trending downward, though the reserves have only been in place for 4.5 years.

Hilborn, R., Micheli, F., and De Leo, G.A. **Integrating marine protected areas with catch regulation.** *Canadian Journal of Fisheries and Aquatic Sciences* 63(3): 642-649, 2006.

Notes: Previous models of marine protected areas (MPAs) have generally assumed that there were no existing regulations on catch and have frequently shown that MPAs, by themselves, can be used to maintain both sustainable fish stocks and sustainable harvests. We explore the impact of implementing an MPA in a spatially structured model of a single-species fish stock that is regulated by total allowable catch (TAC). We find that when a stock is managed at maximum sustainable yield, or is overfished, implementation of an MPA will require a reduction in TAC to avoid increased fishing pressure on the stock outside the MPA. In both cases, catches will be lower as a result of overlaying an MPA on existing fisheries management. Only when the stock is so overfished that it is headed towards extinction does an MPA not lead to lower catches. In a TAC-regulated fishery, even if the stock is overfished, MPA implementation may not improve overall stock abundance or increase

harvest unless catch is simultaneously reduced in the areas outside the MPA. Models that consider differential adult and larval dispersal need to be explored to see if these results are found with the more complex biology of a two-stage model.

Baskett, M.L., Yoklavich, M., and Love, M.S. **Predation, competition, and the recovery of overexploited fish stocks in marine reserves.** *Canadian Journal of Fisheries and Aquatic Sciences* 63(6): 1214-1229, 2006.

Notes: Community interactions alter the management actions necessary to recover overfished species using marine reserves. For example, in communities where a larger species preys on their juveniles' competitors, overfishing of the larger species may cause prey population expansion; subsequent increased competition for the juveniles of the overfished species may impede its recovery within reserves. We explore the implications of such community interactions for reserve design with a model of a subtidal rockfish (genus *Sebastes*) system from the Northeast Pacific Ocean within a no-take reserve. Ignoring community interactions, the model predicts that a reserve large enough for internal recruitment to counterbalance mortality will allow recovery of the overfished species. However, after incorporating community interactions, the model predicts that two alternative stable states exist: one where the overfished species dominates and one where the prey dominates. In the community model, the ability of an overfished system to recover to the equilibrium where the overfished species dominates after reserve establishment depends on the initial densities of both species, and a larger reserve is required for recovery to be possible.

McClanahan, T.R., Verheij, E., and Maina, J. **Comparing the management effectiveness of a marine park and a multiple-use collaborative fisheries management area in East Africa.** *Aquatic Conservation: Marine and Freshwater Ecosystems* 16(2): 147-165, 2006.

Notes: 1. The coral reefs across the international border between Kenya and Tanzania, where historical differences in government policy and socio-economic conditions created two different management systems, were examined: a large permanent closed area and a collaborative fisheries management project that used gear management and small voluntarily and temporary closed areas, respectively. The diversity and ecology of the reefs in these two management systems were compared spanning a seven-year period to evaluate the effectiveness of the management and to assess the ecological response to a large-scale water-temperature anomaly in 1998. 2. Comparisons of rates of predation on sea urchins and of herbivory, using a seagrass assay, were made along with measures of benthic cover and fish abundance and diversity. 3. The collaborative fisheries management system was successful in increasing fish stocks, reducing erect algae, and maintaining ecological diversity and stability across the thermal anomaly. This management system, however, was not successful in protecting the expected full biodiversity of fish, predation rates on sea urchins, or the sensitive, branching coral species. Management of the fishery also increased fish stocks in the adjacent, large, permanently closed area, compared to Kenyan parks without this management. 4. The large, permanently closed area in the other system maintained high diversity, high predation rates on sea urchins and high herbivory rates, which maintained erect algae abundance and diversity at low levels. The temperature anomaly was destructive to a number of the dominant delicate branching coral species, but overall coral cover and diversity were maintained, although dominance switched from branching *Porites* spp. to *Seriatopora* spp. Over this period the large closed area system protected the undisturbed ecology of these reefs and associated ecological processes, and the full diversity of fish and coral, including sensitive species such as branching corals and slow-growing fish. 5. Collaborative fisheries and large permanent closed area management have different attributes that, when combined, should achieve the multiple purposes of sustainable fisheries, ecosystem functions and protection of fishing-sensitive species.

Klinger, T., Padilla, D.K., and Britton-Simmons, K.H. **Two invaders achieve higher densities in reserves.** *Aquatic Conservation: Marine and Freshwater Ecosystems* 16(3): 301-311, 2006.

Notes: 1. Invasive species threaten marine biodiversity on a global scale. 2. To test whether marine reserves provide resistance to invading species, the abundance of two conspicuous invaders, a seaweed and an oyster, were measured inside marine reserves and in comparable areas outside reserves in north-western Washington State. 3. Densities of both invaders were significantly higher in marine reserves than in comparable unprotected areas outside reserves. Although the causal mechanisms have not yet been identified, differential rates of human harvest do not appear to be responsible for the patterns observed. 4.

It is provisionally suggested that physical or biological aspects of the reserves themselves may directly or indirectly facilitate biological invasion.

Abesamis, R.A., Russ, G.R., and Alcala, A.C. **Gradients of abundance of fish across no-take marine reserve boundaries: evidence from Philippine coral reefs.** *Aquatic Conservation: Marine and Freshwater Ecosystems* 16(4): 349-371, 2006.

Notes: 1. An abundance gradient from high inside to low outside a no-take marine reserve may indicate net emigration of adult fish from the reserve ('spillover'). 2. We examined spatial patterns of abundance of fish across two ~900 m long sections of coral reef slope at each of two small Philippine islands (Apo and Balicasag). One section sampled the entire length of a no-take reserve and extended 200-400 m outside the two lateral reserve boundaries. The other section, without a reserve, was a control. The reserves had had 20 (Apo) and 15 (Balicasag) years of protection when sampled in 2002. 3. Significant spatial gradients of decreasing abundance of target fish occurred across only one (Apo Reserve northern boundary = ARNB) of four real reserve boundaries, and across none of the control 'boundaries'. Abundance of non-target fish did not decline significantly across reserve boundaries. 4. Abundance of target fish declined sharply 50 m outside the ARNB, but enhanced abundance extended 100-350 m beyond this boundary, depending on fish mobility. 5. Density of sedentary target fish declined 2-6 times faster than density of highly vagile and vagile target fish across the ARNB. 6. Habitat factors could not account for these ARNB results for target fish, but did influence abundance patterns of non-target fish. 7. The lack of abundance gradients of target fish at Balicasag may reflect reduced fishing outside the reserve since it was established. 8. Apo Reserve had a gradient of abundance of target fish across at least one boundary, a result consistent with spillover.

Abesamis, R.A. and Russ, G.R. **Density-dependent spillover from a marine reserve: Long-term evidence.** *Ecological Applications* 15(5): 1798-1812, 2005.

Notes: Spillover, the net export of adult fish, is one mechanism by which no-take marine reserves may eventually have a positive influence on adjacent fisheries. Although evidence for spillover has increased recently, mechanisms inducing movement of adult fish from reserve to fished areas are poorly understood. While density-dependent export is a reasonable expectation, given that density of fish targeted by fisheries should increase over time inside well-protected no-take reserves, no study to date has demonstrated development of the process. This study provides evidence consistent with density-dependent export of a planktivorous reef fish, *Naso vlamingii*, from a small no-take reserve (protected for 20 years) at Apo Island, Philippines. Mean density of *N. vlamingii* increased threefold inside the reserve between 1983 and 2003. Density approached an asymptote inside the reserve after 15-20 years of protection. Modal size in the reserve increased from 35 to 45 cm total length (TL) over 20 years of protection. In addition, both density and modal size increased outside the reserve close to (200-300 m), but not farther from (300-500 m), the reserve boundary over the 20 years of reserve protection. Movement of adult *N. vlamingii* across the boundaries of the reserve was rare. Aggressive interactions among adult *N. vlamingii* were significantly higher (by 3.7 times) inside than outside the reserve. This suggests that density-dependent interactions were more intense inside the reserve. When interacting adults differed in size, the larger individual usually chased away the smaller one. Furthermore, the mean size of adult fish captured by experimental fishing decreased from 35-cm TL 50-100 m outside the boundary, to 32-cm TL 250-300 m outside the boundary. This represents some of the best evidence available for density-dependent home-range relocation of fish from a no-take reserve.

Parnell, P.E., Dayton, P.K., Lennert-Cody, C.E., Rasmussen, L.L., and Leichter, J.J. **Marine reserve design: optimal size, habitats, species affinities, diversity, and ocean microclimate.** *Ecological Applications* 16(3): 945-962, 2006.

Notes: The design of marine reserves is complex and fraught with uncertainty. However, protection of critical habitat is of paramount importance for reserve design. We present a case study as an example of a reserve design based on fine-scale habitats, the affinities of exploited species to these habitats, adult mobility, and the physical forcing affecting the dynamics of the habitats. These factors and their interaction are integrated in an algorithm that determines the optimal size and location of a marine reserve for a set of 20 exploited species within five different habitats inside a large kelp forest in southern California. The result is a reserve that encompasses ~ 42% of the kelp forest. Our approach differs fundamentally from many other marine reserve siting methods in which goals of area, diversity, or biomass are targeted *a priori*. Rather, our method was developed to determine how large a reserve must be within a specific area to protect a self-sustaining assemblage of exploited

species. The algorithm is applicable across different ecosystems, spatial scales, and for any number of species. The result is a reserve in which habitat value is optimized for a predetermined set of exploited species against the area left open to exploitation. The importance of fine-scale habitat definitions for the exploited species off La Jolla is exemplified by the spatial pattern of habitats and the stability of these habitats within the kelp forest, both of which appear to be determined by ocean microclimate.

Guidetti, P. **Marine reserves reestablish lost predatory interactions and cause community changes in rocky reefs.** *Ecological Applications* 16(3): 963-976, 2006.

Notes: In the last decades, marine reserves have dramatically increased in number worldwide. Here I examined the potential of no-take marine reserves to reestablish lost predatory interactions and, in turn, cause community-wide changes in Mediterranean rocky reefs. Protected locations supported higher density and size of the most effective fish preying on sea urchins (the sea breams *Diplodus sargus* and *D. vulgaris*) than unprotected locations. Density of sea urchins (*Paracentrotus lividus* and *Arbacia lixula*) was lower at protected than at unprotected locations. Size structure of *P. lividus* was bimodal (a symptom of predation on medium-sized urchins) only at the protected locations. Coralline barrens were less extended at protected than at unprotected locations, whereas turf-forming and erect-branched algae showed an opposite pattern. Erect-unbranched and erect-calcified algae and conspicuous zoobenthic organisms did not show any pattern related to protection. Tethering experiments showed that predation impact on urchins was (1) higher at protected than at unprotected locations, (2) higher on *P. lividus* than on *A. lixula*, and (3) higher on medium-sized (2-3.5 cm test diameter) than large- sized (> 3.5 cm) urchins. Sea urchins preyed on by fish in natural conditions were smaller at unprotected than at protected locations. The analysis of sea urchin remains found in *Diplodus* fish stomachs revealed that medium-sized *P. lividus* were the most frequently preyed upon urchins and that size range of consumed sea urchins expanded with increasing size of *Diplodus* fish. These results suggest that (1) depletion and size reduction of predatory fish caused by fishing alter patterns of predation on sea urchins, and that (2) fishing bans (e.g., within no-take marine reserves) may reestablish lost interactions among strongly interactive species in temperate rocky reefs with potential community-wide effects.
