Adaptive Management based on Monitoring of Marine Protected Areas in California

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Summary
Adaptive management of marine protected areas (MPAs) requires an approach for comparing expected responses to results from in situ monitoring. We describe this approach for recently implemented MPAs in central California. Because the spatial planning process for these MPAs was based on long-term projections, we developed new models describing the short-term, transient response of populations to the removal of fishing mortality. These models showed how the initial response, a 'filling in' of the age structure as fish grow older and larger, depends on the prior fishing mortality rate and the natural mortality rate. Spatio-temporal modeling showed how monitoring results depend on simple rules involving MPA size and both larval and adult movement rates. Simulations of expected responses for California rockfish species showed that natural variability in recruitment substantially lengthens the time required to detect positive changes from MPAs. These indications underscore the importance of accounting for uncertainty in the analysis and presentation of monitoring results. These findings indicate that the observed patterns of no increases in the size or abundance for three rockfish species (genus *Sebastes*) at three different locations over the first seven years of MPA existence is not an unexpected result, given the levels of variability in larval recruitment in those populations.

Adaptive Management of MPAs
With the increasing implementation of MPAs worldwide, adaptive management will be increasingly important to assure that we can learn from existing MPAs in order to inform the designs and management of future MPAs (Walters 1986). The science of MPAs (i.e., our understanding of how marine populations with a dispersing larval stage and mobile adults will respond to a seascape with varying mortality rates) is in a nascent state. There is a need to improve our ability to project the short-term effects of MPAs and how MPAs will interact with fished areas managed by more conventional means.

California's MPAs
California's recently implemented MPAs are the result of a decision-making process pursuant to a law passed in 1999 mandating a network of MPAs along the California coast (Botsford, et al. 2014). Stakeholder groups designed competing proposals for MPAs networks, and the favored designs were chosen based on adherence to scientific guidelines. Foremost among those guidelines were recommendations for size and spacing, which led implicitly to a specific fraction of the coast in MPAs. California now has 132 MPAs covering more than 15 percent of the coastline. Population models for a number of species were developed and used to project long-term effects of proposed networks on population sustainability and fishery yields, assuming various levels of fishing. However, these model outputs did not supplant the size and spacing guidelines as the primary scientific consideration. Size and spacing guidelines do not provide the population projections of expected results, on which to base the adaptive management.

Near-term, Transient Responses to MPAs
Many of the California MPAs have been monitored by empirical field surveys following their implementation. However, to evaluate these monitoring results one must know the expected immediate response of populations to the cessation of fishing. To develop this theory, we first described how population abundance would change as the age structure filled back in after being truncated by fishing (White, et al. 2013). Following implementation of an MPA, a population will increase by a factor of (M+F)/M, where M and F are natural mortality and fishing mortality rates respectively. The time scale of increase is set by the value of M, such that the increase is almost

complete after ~2/M years. When we additionally accounted for the post-MPA increase in reproduction, we showed that for high ages of maturity and high F, the response can be cyclic, initially declining before increasing.

The response of population abundance to MPA implementation will also depend on where the samples are taken, and how they are compared (i.e., before/after vs. inside/outside). Our analysis showed that the largest effects of MPAs should be expected with 'outside' samples located at least 2 times the mean larval dispersal distance from the edge of the MPA, and after 2 generations have passed since establishment (Moffitt, et al. 2013).

Developing Adaptive Management

We formulated an adaptive management approach for three species of rockfish (*Sebastes* spp), each at 3 locations. These fishes are some of the most abundant fished species in the region, have had recent fishery assessments, and are of great interest to management agencies. We had annual observations of size distributions and abundance. We were also able to estimate the variability in annual recruitment from these data. The stock assessments for these species provided valuable life history information, and an estimate of F, but over a vastly larger scale than would be relevant to transient local responses to MPAs. We therefore developed a method for estimating F from size data from the fished populations. Through simulations using the observed variability in recruitment we showed that it would be at least a decade after implementation before we could detect an increase due to the implementation of an MPA.

Advantages of this Approach

Our model-based adaptive management approach allowed us to go beyond the typical practice for assessing MPA success, which is to merely examine ratios of fish abundance or biomass (inside/outside or after/before) to assess MPA performance. By having a clear, specific statement of expected results for each species we reduced the likelihood of finding a positive outcome by chance alone, and we were able to draw firmer conclusions regarding the effects of fishing and life histories on MPA function.

References

Botsford, L.W., White, J.W., Carr, M.E., and Casselle, J.E. 2014. Marine protected area networks in California, USA. In Marine Managed Areas, Vol. 69 of Advances in Marine Biology, Ed. By M.L. Johnson and J. Sandell, Elsevier, Oxford, UK

Moffitt, E.A., White, J.W., and L.W. Botsford. 2013. Accurate assessment of marine protected area success depends on metric and spatiotemporal scale of monitoring. Marine Ecology Progress Series 489: 17-28.

Walters, C.J. 1986. *Adaptive management of renewable resources*. MacMillan, New York, NY.

White, J. W., Botsford, L.W., Hastings, A. Baskett, M.L., and Kaplan, D.M. 2013. Transient responses of fished populations to marine reserve establishment. Conservation Letters 6:180-191.