



CEE review 09-018

EVALUATING THE COMPARATIVE BIOLOGICAL EFFECTIVENESS OF FULLY AND PARTIALLY PROTECTED MARINE AREAS

Systematic Review Protocol

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1. Background

Only in the last decade has there been recognition that marine ecosystems worldwide are suffering massive and acute declines in biodiversity and irreparable alterations to ecosystem functioning (Boersma and Parrish, 1999; Millennium Ecosystem Assessment, 2005). Marine protected areas (MPAs) and other forms of marine spatial closures are increasingly common components of management programmes for living marine resources (NRC, 2001). The use of MPAs has been primarily advocated for protection of sensitive marine habitats and associated species (Roberts *et al.*, 2001; Willis *et al.*, 2003). Increasingly, these management tools have been proposed and implemented for use in achieving traditional fishery management goals, for limiting by-catches, and for increasing biomass in adjacent fished areas (Horwood *et al.*, 1998; Piet and Rijnsdorp, 1998; Frank *et al.*, 2000; Gell and Roberts, 2003; Sissenwine and Murawski, 2004). By protecting defined areas, including both resident species and their biophysical environments, MPAs offer an ecosystem-based approach to conservation or fisheries management, which is distinct from the traditional focus on single species conservation or management (Browman and Stergiou, 2004; Sissenwine and Murawski, 2004).

Various types of MPAs exist, all of which can be defined based mainly upon the level of protection and their primary goals. Some MPAs such as no-take marine reserves, prohibit all extractive and damaging anthropogenic activities, with the aim of protecting individual features of the marine environment, as well as restoring or maintaining the natural ecological balance within the ecosystem. Alternatively, multiple-use marine areas seek a balance between biodiversity protection and continued human use. Despite the beneficial effects of marine reserves for enhancing biomass and density of exploited species within reserves (Garcia-Rubies and Zabala, 1990; Garcia-Charton *et al.*, 2004; Guidetti *et al.*, 2005), rehabilitating community structure (Castilla, 1999; Shears and Babcock, 2002), enhancing reproductive output (Planes *et al.*, 2000; Goni *et al.*, 2003) and biomass exportation through adult migration (Chapman and Kramer 1999; Gell and Roberts, 2003), prohibiting all extractive activities in certain areas can have socio-economic costs. Indeed, even if reserves benefit fisheries (e.g. higher revenue per unit effort in the vicinity of the MPA boundary for haddock fishery, (Murawski *et al.*, 2005)), local fishers may be negatively affected by the loss of fishing grounds, decreased catches and increased travelling time, at least in the short-term (Fiske, 1992). Consequently, marine reserves may face strong opposition by extractive users, making the process of reserve implementation and subsequent enforcement difficult. MPAs imparting partial protection from certain types of fishing are often advocated by groups with direct fishing interests and promoted as a 'compromise' solution allowing both protection and fishing (Denny and Babcock, 2004).

Ecological effects of MPAs are typically measured in terms of changes in biomass, abundance, species richness and body size (age) of species that occur within and outside the protected area (Pelletier *et al.*, 2005). There is some evidence that the response of a species to protection depends, in part, on its life-history parameters (Blyth-Skyrme *et al.*, 2006). For example, species that demonstrate a positive and rapid response to protection are often relatively sedentary and spend much of their life in the MPA (Boersma and Parrish, 1999; Murawski *et al.*, 2000; Tawake *et al.*, 2001). In contrast, for species of greater mobility or that utilize a variety of habitats, there is

some debate over whether MPAs would be an effective conservation measure (Murawski *et al.*, 2000; Kaiser, 2005), and what size MPA is required to achieve effective conservation of fish stocks (Mangel, 2000; Halpern, 2003; Claudet *et al.*, 2008). In addition, characteristics of MPAs such as age (years since establishment), location, enforcement, regulation, size, distance from other protected areas have often been invoked as potential sources of heterogeneity in the response of marine assemblages to protection (Cote *et al.*, 2001; Halpern, 2003; Halpern and Warner, 2002; Micheli *et al.*, 2004; Guidetti *et al.*, 2008).

While there have been numerous reviews of the effects of marine reserves on target and non-target species (Roberts and Polunin, 1991; Cote *et al.*, 2001; Fraschetti *et al.*, 2002; Halpern, 2003; Ojeda-Martinez *et al.*, 2007; Claudet *et al.*, 2008; Garcia-Charton *et al.*, 2008; Lester *et al.*, 2009), only one review examined the efficacy of partially protected MPAs to date (Lester and Halpern, 2008) and none of these reviews were done systematically (but see Stewart *et al.*, 2008). Whereas the systematic review by Stewart *et al.* (2008) examined the impacts of temperate zone no-take areas on biological measures of marine biota, the systematic review to be undertaken will encompass a global synthesis of studies that have examined the efficacy of MPAs that confer varying levels of protection from extractive activities. Data on the life-history traits and ecological parameters of the reported species will be extracted and if correlations between effects on the response variable (e.g. fish biomass or abundance) and species characteristics (e.g. maximum body size, mobility) can be determined this may enable us to generate predictions about the response of particular species to spatial management measures.

2. Objective of the Review

To investigate the effectiveness of MPAs that confer varying levels of protection, from full to partial to no protection, to conserve biodiversity and to analyze when possible the effects of life history and ecological parameters of individual species and MPA parameters on the results.

2.1 Primary question

Is there a relationship between the level of protection from anthropogenic extractive activities and the magnitude of the effect of the MPA intervention on biological measures?

To address the primary question, studies that investigate the biotic influences of marine areas that have been closed to all or some anthropogenic extractive activities on a temporary or permanent basis will be considered. Studies that investigate the effectiveness of management options including total allowable catches (TACs), fish size limits and bag/mesh size limits will not be considered. Extractive activities considered in this review refer to fishing activities that include both recreational and commercial practice.

Table 1: Definition of components of the primary systematic review question

Subject	Intervention	Biological measures	Comparators	Designs
Marine invertebrates; fish; algae	*Establishing an MPA involving implementation of a no-take zone and/or **extraction restrictions within MPA	Change in Species richness; diversity indices; density (abundance); biomass (area of organisms); body size (length); reproductive output; growth rate	Full access areas, with no restriction on fishing activity and anthropogenic use	Any primary studies providing measures that are quantified inside the full and/or partial protected MPA and in adjacent full access areas (control) after protection was implemented; or comparing MPAs before and after protection was implemented ; or both

* See list of definitions of different types of MPA interventions (Appendix I)

** The range of extractive activities permitted within the MPA will play a major role in defining different levels of partially protected MPAs (see Table 2)

2.2 Secondary questions

- a) Is there a relationship between species' life-history parameters, including growth, morphological and maturation factors (see Table 3) and response to protection?
- b) Which ecological parameters (see Table 3) influence the species' response to protection?
- c) Does response to protection vary among taxonomic groups (e.g. family, genus, species)?
- d) Does MPA effect on biodiversity and species vary in relation to size, age and habitat characteristics of the MPA (see Table 3)?

3. Methods

3.1 Search strategy

3.1.1 Search terms

Search terms used will be based on the following phrases (where * denotes a wild card to search for alternative word endings), and modified according to the search functionality of the resources:

“marine reserve*”
 marine sanctuary
 marine AND “no take zone”
 marine AND harvest refug*
 marine AND “buffer zone”
 marine AND partial* AND protect*
 marine AND closed area
 marine And area closure
 fisher* AND (reserve OR closure)

fishing gear restriction*
recreational fishing AND protection
marine protected area*

In addition, combinations of the following search terms will be used to target specific literature relevant to the review questions:

Subject terms: fish, fishes, invertebrate*, algae

Outcome terms: abundance, density, size, length, biomass, richness, diversity, growth

Searching will be carried out across a range of resources in order to access both grey literature and the more readily available published literature to minimise the possibility of publication and related biases.

3.1.2 Databases

The following databases will be searched:

General sources

- 1) ISI Web of Knowledge (Web of Science and Proceedings)
- 2) Science Direct
- 3) Directory of Open Access Journals
- 4) Copac
- 5) Index to Theses Online
- 6) CAB Abstracts

Specialist sources

- 1) ASFA

Searches for data published by statutory and non-statutory organizations will be included: Natural England (English Nature), Scottish Natural Heritage, Countryside Council for Wales, Environment and Heritage Service Northern Ireland, JNCC, CEH, CEFAS, FRS, CSIRO (Australian national science agency) and the US Nature Conservancy.

3.1.3 Web sources

An internet search will also be performed using meta-search engines and recommended sites:

General sources

- 1) <http://www.alltheweb.com>
- 2) <http://scholar.google.com>
- 3) <http://www.scirus.com> (all journal sources)
- 4) <http://data.esa.org/>
- 5) <http://scientific.thomsonwebplus.com/>

Specialist sources

- 1) <http://mpa.gov/>
- 2) <http://www.calcofi.org>
- 3) www.ukmpas.org

- 4) <http://depts.washington.edu/mpanews>
- 5) <http://www.um.es/empafish/>
- 6) <http://biomex.univ-perp.fr/>
- 7) <http://www.mpa-eu.net/>
- 8) <http://conserveonline.org>
- 9) <http://www.reefbase.org/pacific/database.aspx>
- 10) http://www.unep-wcmc.org/protected_areas/pubs.htm
- 11) <http://floridakeys.noaa.gov/>
- 12) www.gbrmpa.gov.au

The first fifty hits (Word and/or PDF documents) from each search will be checked for relevant pages or documents containing data. All references retrieved from the computerised databases will be exported into a bibliographic software package prior to assessment of relevance using inclusion criteria.

3.1.4 Bibliographies

Bibliographies of all articles accepted for viewing at full text will be hand searched to identify any additional evidence. Web based bibliographies identified during the web searching phase will also be checked for additional references.

Subject experts and practitioners will be contacted for additional references, and, for included studies authors may be requested to provide any unpublished material or missing data that may be relevant to the review.

3.2 Study inclusion criteria

All studies retrieved through the searching will be assessed for relevance at title and abstract level. Any articles not relevant to the search will be rejected. The following criteria will be used to accept articles for viewing at full text. In cases where it is not clear whether an article meets these criteria, for example when no abstract is available or it is not apparent whether data is presented, then the article will be automatically accepted for viewing at full text.

- **Relevant subject(s):** Marine invertebrates, algae and fish
- **Types of intervention:** Fully protected MPAs, that is no-take marine reserves and MPAs conferring partial protection (including closed areas, harvest refugia, fishery closure, seasonal closure)
- **Types of outcome:** change in species richness, biodiversity indices, density (or other abundance measure), biomass, body size, reproductive output, growth rate.

Types of study: Any primary studies providing biological measures that are quantified inside the full and/or partial protected MPA and in adjacent full access areas after protection was implemented; or comparing MPAs before and after protection was implemented; or both (i.e. BACI designs). Additionally studies comparing biological measures among areas with partial restrictions on different fishing activities (e.g. static gear vs. towed gear use only area) will be included.

- **Geographical scope:** studies from all geographical locations will be accepted initially, but may be narrowed down to particular geographical range during further stages of the review depending on the number of studies that meet the other inclusion criteria.

To check for consistency of application of inclusion criteria, two reviewers will independently apply the inclusion criteria to a subset of the articles, consisting either of 10% of the studies or 250 studies (whichever is greater), at the start of the abstract filter. Agreement between the two reviewers must be substantial (kappa statistic = 0.6) before the assessment proceeds. If kappa is less than 0.6, the reviewers will discuss the discrepancies and clarify the interpretation of the inclusion criteria. This may entail a modification in the criteria specification.

3.3 Potential effect modifiers and reasons for heterogeneity

Considerable heterogeneity may exist due to differences in characteristics of protected area that include;

- depth and habitat type
- size and shape
- the proportion of the protected area in relation to the size of the species range
- type of protected area and permitted uses within the latter
- area use history (i.e. degree of exploitation before protection)
- degree of enforcement and compliance to regulations inside the protected area

Additional potential sources of heterogeneity include:

- the level of habitat destruction within the species distribution range,
- the species' life history stages and differences in biological traits among species (e.g. juvenile migratory species may be attracted into reserve)
- the degree and type of use in the adjacent area, and its proximity to the MPA in question
- the degree of adjacent MPA designations – what is the effect of nearby reserves / MPAs on the species and community inside the MPAs investigated in the review?

3.4 Study quality assessment

Study quality assessment is required to add quality co-variables to the analyses, since well-conducted studies have less potential for bias than their poorer counterparts. Study quality will be scored according to a hierarchy of evidence adapted from systematic review guidelines used in medicine and public health (Stevens and Milne, 1997) and conservation (Pullin and Knight, 2003); e.g. a randomized control trial would be weighed higher than a site comparison study. Studies that employ linear rather than point sampling techniques have fewer replicates and therefore lower weight when combined. Studies will therefore be weighted by area surveyed to generate estimates of abundance

(Mosquera *et al.*, 2000). Studies reporting on fishing effort baselines, the frequency of permitted extractive activities, and the nature of habitat inside and outside the MPA will be given more weight. The impact of other data quality elements, associated with bias (Pullin and Stewart, 2006) will be explored where they confound results or are associated with significant heterogeneity between studies. Two reviewers will examine a random subset of at least 25% of the selected studies for assessment at full-text to assess repeatability of study quality assessment. The study quality assessment methodology will be further developed once the articles included in the review have been identified.

3.5 Data extraction strategy

Studies accepted at full text will be classified according to the protection regime reported within the MPA. Table 2 defines categories based on the extractive activities prohibited within the MPA that will be potentially used for study classification.

Table 2: Description of each of the potential categories used to classify studies based on the perceived extractive activities within the protected area.

Protection level	Activities allowed	Description of prohibited activities
0	All - Full access for recreational and extractive activities	None
1	All extractive activities, except for recreational fishing	Recreational fishing differs from commercial fishing in that the primary reason for participation is leisure, and does not include sale, barter or trade of all or part of the catch. Activities include angling, spearfishing, trolling, catch-and-release fishing and hand collection (Jennings <i>et al.</i> , 2001).
2	All extractive activities, except for those in protection level 1 and/or fishing with mid-water towed and/or static gear	Commercial fishing activities with mid-water towed fishing gear that include otter trawl, encircling nets (e.g. Danish seine, beach seine, purse seine) and activities with mid-water static fishing gear that include drift gill nets, subsurface longlines (Jennings <i>et al.</i> , 2001).
3	All extractive activities, except for those in protection level 2 and/or fishing using bottom static gear	Commercial fishing with bottom static fishing gear include the use of pots, traps, set gill nets, trammel nets, tangle nets, bottom-set long lines (Jennings <i>et al.</i> , 2001).

4	All extractive activities, except for those in protection level 3 and/or fishing with bottom towed gear	Commercial activities with bottom towed fishing gear include trawling (e.g. beam trawl, otter trawl) and dredging (e.g. scallop dredge) (Jennings <i>et al.</i> , 2001).
5	None	All, except research for monitoring purposes

Explanatory notes on Table2

1. *Protection level 0* refers to fully access areas where all types of extractive and other anthropogenic activities can take place
2. Categories 1 to 4 describe different types of partially protected areas, and were grouped according to the perceived impact that different fishing activities and fishing gears have on the biota and surrounding environment
 - Protection level 1* – Recreational fishing - Although recreational fishing practices may have significant demographic and ecological effects on fished populations (Coleman *et al.*, 2004; Cooke and Cowx, 2004), fishing pressure and efficiency are lower than for commercial fishing practices
 - Protection level 2* – Mid-water gear - Fishing using mid-water towed and static gear generate problems associated with by-catches in ‘ghost fishing nets’, however they have relatively little effect on benthic biotic and abiotic environment
 - Protection level 3 and 4* – Static and towed bottom gear - Fishing using bottom static gear (e.g. pots) was separated from bottom towed gear (e.g. trawls, dredges) since the associated by-catches of non-target species are significantly higher with towed than static gear. In addition towed bottom-fishing gears cause varying levels of disturbance to the seabed that alters seabed complexity, removes, damages or kills biota, and reduces benthic production and thereby can lead to substantial changes in benthic community structure and habitat (Dayton *et al.*, 1995; Collie *et al.*, 2000; Jennings *et al.*, 2001; Kaiser *et al.*, 2006)
3. *Protection level 5* refers to fully protected areas, and essentially include no-take marine reserves/areas
4. The number and type of categories will ultimately depend on the studies obtained from the searches. For example ‘*Protection level 1* and 2’ may be merged, whereas ‘*Protection level 4*’ may be split to create two other categories, for example those which ban bottom trawling and those which ban dredging.

To address the secondary review questions, response to protection will be examined for a number of quantitative and qualitative variables for life history, ecological and MPA parameters described in Table 3.

Table 3: Description of life history, ecological and MPA parameters

Life History parameter	Description
L_{max}	Maximum reported size
L_{inf}	Length the organism would reach if it was to grow indefinitely
L_{mat}	Average length at which the organism of a given population reaches sexual maturity
K	Growth coefficient – a parameter of the von Bertalanffy growth function that expresses the rate at which the asymptotic length is approached
t_{max}	Life span – approximate maximum age that an organism would reach
t_{mat}	Average age at which the organism of a given population reaches sexual maturity
Resilience	The ability of a species to recover from a disturbance. The American Fisheries Society (AFS) has suggested values for several biological parameters that allow classification of a fish population or species into categories of high, medium, low and very low resilience
Ecological parameter	
Habitat preference	The preferential habitat of the adult; benthopelagic, demersal, pelagic, benthic species
Mobility	Sedentary, mobile
Larval dispersal	None (as in the case of species with direct development which lack a larval stage), low (1 day), medium (<14 days) and high (>14 days) for species with planktonic larvae
Trophic category	Based on the species feeding method; predator, deposit feeder, suspension feeder, herbivore, omnivore
Fishing value	Target vs. non-target species or unfished species vs. low vs. medium vs. high fishing value
MPA parameter	
Size	Area of MPA
Age	Time since establishment of MPA
Duration of closure	Permanent or seasonal closure
Distance to the nearest MPA	Distance between adjacent MPAs in an MPA network

Habitat	Habitat will be subdivided into; hard bottom which include rocky reefs, gravel soft bottom which include sand, muddy sand, mud biogenic habitat
Enforcement	Degree of regulation enforcement within MPA; good or poor

Whenever given, the following data will be extracted from the selected studies; location of study, degree of protection/protection regime of MPA, size of MPA, year of establishment of MPA, degree of enforcement, experimental design, time of data collection/sampling, methods of data collection, environmental data sampled, biotic measures sampled (e.g. density, weight, biomass, size, species richness), species/taxa sampled. Electronic databases available at www.fishbase.org and www.marlin.ac.uk/biotic/, additional literature and experts will be consulted to obtain data on life history and ecological parameters included in Table 3. Additionally MPA databases including MPA Global (www.mpaglobal.org/home.html) and World Database on Marine Protected Areas (<http://www.wdpa-marine.org>) will be used to retrieve data on MPA parameters if these are not given in the study.

Estimates of the effect of protection on biotic measures will be extracted at the genus/species level where available and at higher taxonomic levels. Sample sizes, means, variance and standard deviations of variables (e.g. density, biomass) reported in studies will be either extracted as presented or calculated from raw data or the statistics presented in the study. Kappa analysis will be conducted on 10% of the studies accepted at full text for data extraction, with each reviewer recording exactly how and from where (e.g. figure x, etc) they extracted the relevant data and contextual information.

3.6 Data synthesis and presentation

Data synthesis will consist of meta-analyses to address the primary question with meta-regression and subgroup analyses used to investigate reasons for heterogeneity between studies. Any species that is present inside or outside the MPA but not both, will not be included in subgroup analysis, in order to eliminate bias that may be created by habitat preference rather than reserve effect. Graphical methods and statistical testing will be employed to investigate differences in results across studies.

4. Potential Conflicts of Interest and Sources of Support

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APPENDIX I – DEFINITIONS

Many different names have been given to marine areas that are, to some degree, protected by spatially explicit restrictions. While different designations undoubtedly have many important distinguishing characteristics, for the purposes of evaluating their biological effectiveness, three principal considerations are critical:

1) What are the biological goals of protection? Examples of goals include: to provide undisturbed critical habitat, to provide local release from fishing for some species, to act as centres of dispersion of propagules into surrounding areas, and to maintain high biomass or high diversity.

2) What types of human activities are restricted? Restrictions can be placed on: commercial and/or sport fishing (few or all species restricted), personal or subsistence collection, construction, tourism, education, and/or research.

3) To what degree are these restrictions followed or enforced? This can range from very strong compliance to no protection at all. Although protection on paper may be strict, compliance may be weak.

For the purposes of this review terms related to MPAs are defined as follows:

Marine Protected Areas (MPAs) as defined by IUCN (1998) are “any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment”.

Marine reserves are defined as areas of the ocean completely protected from all extractive and destructive activities, have explicit prohibitions against fishing and the removal or disturbance of any living or nonliving marine resource, except as necessary for monitoring or research to evaluate reserve effectiveness (Lubchenco *et al.*, 2003).

Synonyms: ecological reserves, no-take areas, no-take zones, marine sanctuary, integral zones

Area closure, “in a fishery management system, the closure to fishing by particular gear(s) of an entire fishing ground, or a part of it, for the protection of a section of the population (e.g. spawners, juveniles), the whole population or several populations” (FAO, 2009).

Synonym: closed area

Closure to fishing activities may be on a seasonal basis (**temporal/seasonal area closure**) but it could be permanent, or on a spatial basis (**rotational/rolling area closure**).

Fisheries reserves are spatially bounded areas where the harvesting of marine resources is restricted, according to gear types (restricted fishing areas) or forbidden (no-take zones). *Synonyms:* Gear-restriction systems (Blyth-Skyrme *et al.*, 2006)

Multiple-use area refers to an area within which extractive and non-extractive uses are regulated.

Synonyms: buffer zone, partially protected areas

Harvest refugium is used in the context of fisheries management to refer to protected areas that serve as a source of replenishment to surrounding harvest zones (Dugan and Davis, 1993). One way is through larval recruitment (Carr and Reed, 1993).
Synonyms: marine fishery refugium, harvest refuge