Project nº SSP8-006539
EMPAFISH
European Marine Protected Areas as tools for Fisheries management and conservation

Specific Programme "Integrating and strengthening the ERA" (6th Framework Programme), under the activity "Scientific Support to Policies" and the research priority for "Modernisation and sustainability of fisheries, including aquaculture-based production system".

# Developing a management tool for MPAs in southern Europe: the EMPAFISH project

Deliverable reference number: 28

***Due date of deliverable: September 2007***
***Actual submission date: April 2008, revised October 2008***
***Start date of project: 1st March 2005 Duration: 36 months***
***Organisation name of lead contractor for this deliverable: Plymouth Marine Laboratory (PML, UK)***

Revision: Final

| **Dissemination Level** | | |
|---|---|---|
| **PU** | Public | X |
| **PP** | Restricted to other programme participants (including the Commission Services) | |
| **RE** | Restricted to a group specified by the consortium (including the Commission Services) | |
| **CO** | Confidential, only for members of the consortium (including the Commission Services) | |

**EMPAFISH Deliverable No. 28**

# Developing a management tool for MPAs in southern Europe: the EMPAFISH project

**Stephen Mangi**
**Melanie Austen**

**Plymouth Marine Laboratory**
**Prospect Place, The Hoe**
**Plymouth PL1 3DH**
**United Kingdom**

**October 2008**

For further information contact Dr Stephen Mangi at stcma@pml.ac.uk

# 1. Introduction

Marine scientists are being challenged to identify appropriate management approaches for our seas that not only preserve biodiversity and prevent environmental degradation, but also recognise the existence of societal values held by stakeholders. In order to organise information and facilitate evaluation of management options and their impacts, scientists need to develop procedures to organize data and create information. This report demonstrates the use of multi-criteria analysis in the management of marine protected areas (MPAs) in southern Europe.

One of the aims of the European Marine Protected Areas as tools for Fisheries Management and Conservation (EMPAFISH) project is to provide the EU with a set of guidelines and tools to be integrated into the decision-making and management of MPAs. A framework consisting of a structure and procedures has been developed that is simple and flexible, but can also allow rigorous analysis where appropriate.

Many MPAs in southern Europe were created on an opportunistic basis or in response to public pressure rather than through an integrated and objective evaluation of the need for these MPAs. This situation is not unique to the Mediterranean: worldwide many MPAs need to be rationalized and defendable (Hockey and Branch 1997). This requires a rigorous and objective procedure that will allow an evaluation of the relative merits of different areas that have already been proclaimed or are being considered for MPA status. In particular there is a need to plan a system of MPAs that will protect the structural and functional components of biodiversity, contribute towards fisheries management, and promote human uses of the sea that are compatible with these objectives.

# 2. Approach used to assess MPAs

Marine protected areas are under consideration as a tool for improving fishery management and protecting biodiversity. When the use of MPAs is considered, the basic questions concern the size of MPAs, where MPAs should be sited, what level of protection (either fully or partial protection) should be implemented, and the length of time required for reserve effects to be achieved. These questions should be answered from empirical studies that compare results from MPAs of different sizes, spacing and were established at different times.

### 2.1. Time from protection

Time series studies are important to understand the scale of various recovery processes. Some studies have suggested that fishery recovery after protection could be rapid for target species (e.g. Halpern and Warner 2002) while others have shown that recovery takes a few years (e.g. Russ and Alcala 2004, McClanahan and Graham 2005). Because many ecological processes vary over considerable timescales and because human influences are widespread, there is a need for concerted efforts to collect data at multiple scales in areas with minimum human influences. Such information is useful to establish baselines for understanding human influences. This would enable us to establish baselines for understanding such influences. This was of particular concern for marine ecosystems, given that most MPAs are comparatively modern conservation phenomenon. In addition, most studies of MPAs, apart from meta-analyses, are based on only a few closed areas and often only at one point in time and measured effects are sensitive to the selection of control sites used for comparison of effectiveness.

### 2.2. Size of MPA

The size and configuration of marine protected areas best suited to reaching fisheries and conservation goals are poorly understood. There is a growing body of literature that addresses spatial aspects of MPA design (e.g. Botsford et al 2003, Kaplan and Botsford 2005). Some have focused on developing rules for choosing configurations that maximise biodiversity, habitat heterogeneity including vulnerable habitats, or life stages of species within no-take areas (e.g. Hockney and Branch 1997, Leslie et al. 2003, Roberts et al. 2003). While these MPA sitting schemes are needed to create reserves with the appropriate selection of desired habitats, species and ecosystems, they do not specify the combination of protected area locations, sizes and spacing necessary for species sustainability and high fisheries yields.

### 2.3. Distance from nearest MPA

To ensure that young fish are available to replenish and sustain populations within MPAs, the area protected must be large relative to the movement of adults. Single large MPAs, however, are often not an economically viable way to protect marine ecosystems. Establishing networks of several smaller MPAs can reduce economic impacts without compromising the conservation of biodiversity and fisheries benefits. Because different species can have different patterns of movement, whether as random dispersal or directed migration, MPAs can affect species differently. Managers need to know how MPAs will affect species with different movement characteristics so that they can anticipate how protection will affect target species, and predict differences in effects between species. Mathematical models of MPA networks advocate for different optimal distances between MPAs based on management goals and data input (Hastings and Botsford 2003). Using twenty case study MPAs in the Mediterranean region, EMPAFISH project partners used a meta-analytical approach to compare fully protected with unprotected locations against sources of variation including distance to nearest MPA. Results showed no evidence of an optimal distance between MPAs.

### 2.4. Level of protection and zonation

There are inconsistencies in the terminology used to describe MPAs, which vary in their designated function from the equivalent of nature reserves, where no exploitation is allowed, to areas where limited exploitation is allowed. Further, some MPAs are made up of only one zone, mainly a no-take zone where all extractive exploitation is prohibited. Others have two zones i.e. the no-take zone plus a buffer zone where fishing techniques are regulated, yet others have three zones comprising of the no-take zone, buffer zone and a transitional zone where further regulations on fishing gear types are imposed.

## 3. Multi-criteria analysis

Multi-criteria analysis (MCA) is a general approach dealing with problems that involve multiple dimensions or criteria. MCA usually proceeds by generating information on the decision problem from available data and ideas, effectively generating solutions (options) to a problem. Such an analysis is appropriate and useful for assessing MPAs since it allows the ranking of management options based on a range of criteria: ecological, fisheries and socio-economic (Table 1). The most preferred management option is the one that provides the optimum combination of the set desirable criteria.

Table 1: Criteria used in assessing MPAs as tools for fisheries management and conservation.

| Criteria | Sub-criteria | Measure | Units | Source of data |
|---|---|---|---|---|
| Ecological | Fish density | Commercial species | Ratio | Underwater visual census, Fishing experiments |
| Fisheries | Catch per unit effort | Target species | Ratio | Fishing landing |
| | | Target and by-catch species | Ratio | Fishing landing |
| Socio-economic | Commercial fishing | Value of landings | € | Survey |
| | Recreational fishing | Expenditure | € | Survey |
| | Diving | Income | € | Survey |
| | Divers | Budget | € | Survey |

There are two advantages of using multi-criteria analysis to assess management options for MPAs in southern Europe. First, MCA is capable of working with mixed data (in different measurements units) and allows the incorporation of both qualitative and quantitative information. This is particularly important in the present application where the ecological and fisheries data were in ratios while the socio-economic data were in monetary terms (Table 1). The second advantage of MCA is that it permits direct involvement of stakeholder weighting of the set criteria. This facilitates collaborative decision making for public goods by allowing stakeholders to compare management options based on their preferences for criteria.

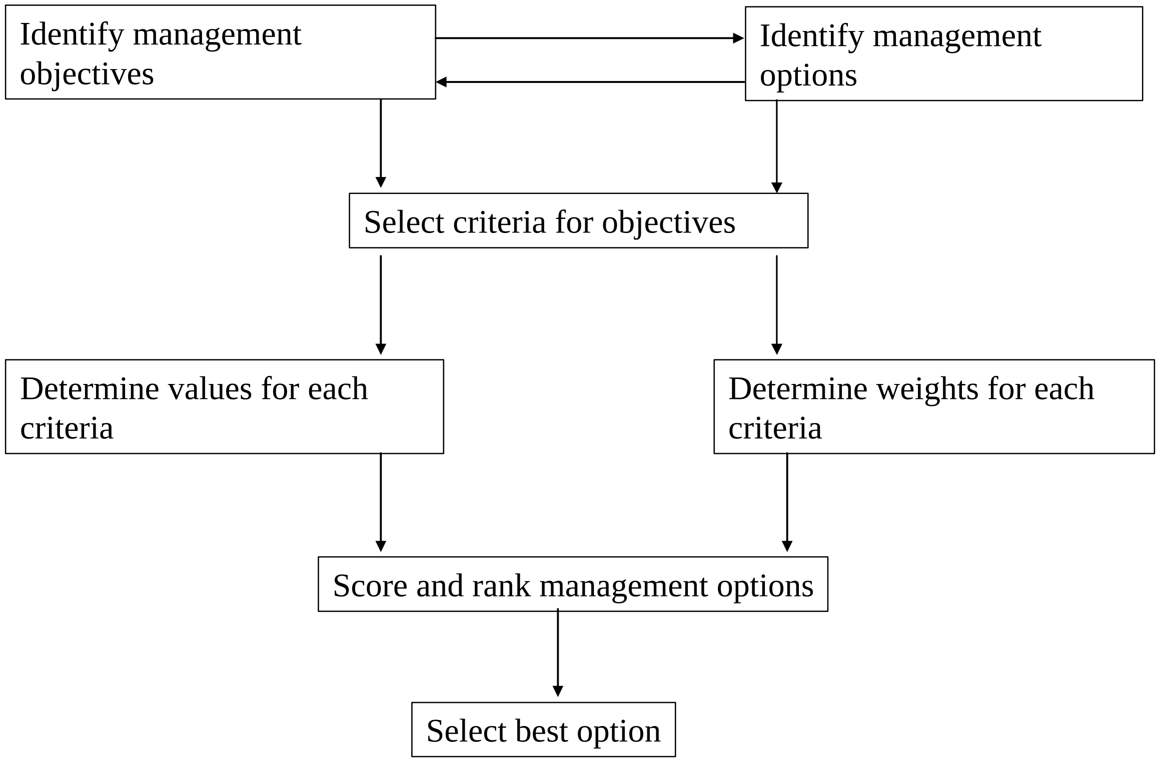


Figure 1: A general framework for multi-criteria analysis.

A general framework for MCA is illustrated in Figure 1. The framework requires:

1. Establishing the decision context where the aims of the MCA are clearly established and key decision makers and stakeholders affected by possible decisions are identified and involved in the process.
2. Identifying the options to be appraised: In the context of this project, this involves establishing the relevant management options relating to MPAs as tools for fisheries management and conservation.
3. Identifying criteria that will enable ranking of the management options. In this project these criteria corresponded to the main functions of MPAs: ecological, fisheries and socio-economic.
4. Scoring: This involves an evaluation of the effects of each management option upon the criteria identified. The effects used in our assessment (Table 1) were quantified from twenty European MPAs. The effects are expressed in different units of measurement (monetary units, ratios). To enable comparison of management options and to rank them in order of preference the effects were converted to scores and the overall mean score was calculated for each management option.
5. Weighting: This involves the incorporation of stakeholder preferences into the analysis through a process of assigning weights to each of the criterion to reflect its relative importance to each stakeholder. The process of eliciting stakeholder preferences

is central to the analysis and careful planning regarding the most appropriate and effective ways of doing this is essential. In this project weights from various stakeholder groups were provided through a questionnaire during stakeholder consultations. The total weighting for each criteria are shown in Figure 2.

6. Calculating weighted scores: Scores and weights were combined to produce an overall score for each management option. The result is usually a value between zero and one. The highest ranked management option is the optimum one.

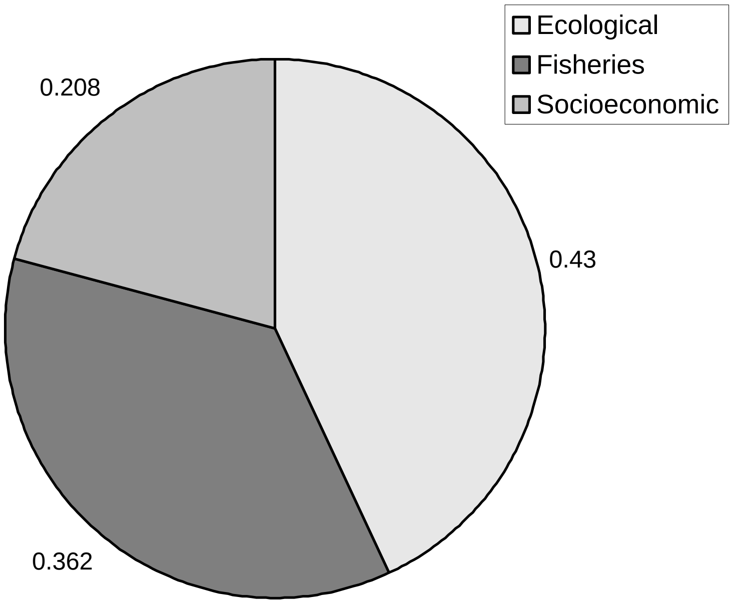


Figure 2: Relative importance of ecological, fisheries and socio-economic criteria in evaluating MPAs as ranked by stakeholders.

### 3.1 Defining management options and criteria

A set of management options and criteria are required to frame the multi-criteria analysis within this framework. We selected our management options based on the results of our analyses of the available ecological, fisheries and socio-economic data. By employing meta-analyses, we compared data collected from no-take zones and those from partially protected areas with data from unprotected areas. Findings showed that fish density and catch per unit effort were influenced by a combination of the size of no-take and partially protected zone interacting with time since the MPA was established. Therefore the management options ideal for assessing MPAs as tools for fisheries management and conservation would include a full set of combinations of all the following variables:

1. Length of time of protected area management: The longest time series data we used in this analysis was 34 years.

2. Size of core zone (i.e. no-take zone also referred to as an integral reserve). The MPAs we used in the analysis had core areas ranging from 65 to 1883 hectares (Table 2).
3. Size of partially protected zone (buffer area). The MPAs we used had partially protected zones ranging from zero to 78 800 hectares.

Table 2: The size of no-take zone and partial (buffer) protected zone for each MPA used in the analysis of ecological data.

| MPA | No-take zone | Buffer zone |
|---|---|---|
| Banyuls - Cerbère | 65 | 585 |
| Carry-le-Rouet | 85 | 0 |
| Medes Island | 93 | 418 |
| San Antonio | 110 | 390 |
| Tarbaca | 120 | 1280 |
| La Restinga | 180 | 813 |
| Cap couronne | 210 | 0 |
| Cabo de Palos | 270 | 1628 |
| Sinis - Mal di Ventre | 529 | 25144 |
| Bouches de Bonifacio | 1200 | 78800 |
| La Graciosa | 1225 | 68775 |
| Columbretes Island | 1883 | 2517 |

An important aspect in selecting management options to investigate under MCA is that they should represent feasible and believable futures for local stakeholders. Since it takes time after cessation of fishing for populations to build up in MPAs and reach abundances where they can disperse and support adjacent fisheries, temporal patterns were used to investigate all the effects. In order to simplify the wide range of sizes of no-take and partial protected zones, MPAs were termed small if they were less than 150 ha, medium if they were between 151 to 600 ha, and large when they were over 601 ha. The resulting set of management options includes having a:

1. Small MPA comprising a no-take zone of 50 hectares and a partial protected zone of 25 ha (partial protected zone is half the size of no-take zone)
2. Small MPA comprising a no-take zone of 50 hectares with a similar sized (50 ha) partially protected area (partial protection zone same size as no-take zone)
3. Small MPA comprising a no-take zone of 50 ha with a partially protected area twice its size (100 ha) (partial protection zone twice the size of no-take zone)
4. Medium-sized MPA comprising a no-take zone of 300 hectares and a partially protected zone of 150 ha (partial protected zone is half the size of no-take zone)

5. Medium-sized MPA comprising a no-take zone of 300 hectares with a similar sized (300 ha) partially protected area (partial protection zone same size as no-take zone)
6. Medium-sized MPA comprising a no-take zone of 300 ha with a partially protected area twice its size (600 ha) (partial protection zone twice the size no-take zone)
7. Large MPA comprising a no-take zone of 900 hectares and a partially protected zone of 450 ha (partial protected zone is half the size of no-take zone)
8. Large MPA comprising a no-take zone of 900 hectares with a similar sized (900 ha) partially protected area (partial protection zone same size as no-take zone)
9. Large MPA comprising a no-take zone of 900 ha with a partially protected area twice its size (1800 ha) (partial protection zone twice the size no-take zone)

### 3.2. Measurement of criteria

Twenty existing MPAs in Europe were used as case studies. These case studies represented management regimes ranging from areas where fishing is completely prohibited through the implementation of no-take zones to protected areas where different levels of fishing are accepted either on a seasonal or activity basis. A broad geographic area is represented from the Mediterranean to the Canary Islands and the Azores.

#### 3.2.1 Ecological criteria

Fish density is used in this study as one of the major ecological indicators of ecosystem health. Fish density was collected from locations that were fully protected and compared with that from unprotected areas. The data set had all fish species that could be identified and counted in the marine reserves and the unprotected locations from underwater visual census and fishing experiments. The final database consisted of data from 12 MPAs distributed over 2500 km from north-western Mediterranean to central-eastern Atlantic, and ranging from three years before establishment of marine reserves to 34 years after (You can read more on our data collection in the WP1 report - www.um.es/empafish). The main goal of the MPAs, stated by managers of the marine reserves that were studied, was the restoration of size and assemblage structure of fish species that have been over-harvested by commercial fisheries. Thus, the analyses focused on the size of fishes and on the commercial value of each fish species. Findings showed that increasing the size of the no-take zone relative to the size of partially protected zone increases the density of commercial fishes within the reserve compared to outside; whereas increasing the size of the partially protected zone relative to no-take zone reduces fish density

#### 3.2.2. Fisheries criteria

Commercial fisheries data were collected from 16 established MPAs representing a broad spectrum of habitats, fisheries and fishery management regimes. Diverse fishery regimes were characterised and classified according to fishing and management attributes (Read more in the WP2 report – www.um.es/empafish). For each location, an appraisal of the trend in catch per unit effort (CPUE) of aggregated catch was undertaken for fishers operating in restricted areas of MPAs and in their vicinity. Project partners indicated the top three most important fish species from their MPA region, and also the most important fishing gear. Meta-analysis was used to determine the patterns in CPUE across study sites. The trends were investigated in terms of the size of the respective MPA and the length of time elapsed since protection was established. Patterns in yields between zones of the MPAs, representing levels of enforcement, were also investigated. Our fisheries criteria include the catch per unit effort for targeted species only and for all species together (target species plus by-catch). The species were further separated based on whether they were caught using the single most important gear used at the landing site or by a mixture of gears.

### 3.2.3. Socio-economic criteria

The socio-economic criteria include value of landings by professional fishers, expenditure of recreational fishers, income from diving operators and budget for divers. Comparative analyses were performed on 14 coordinated socioeconomic field surveys of extractive and non-extractive uses of MPAs in southern Europe. These surveys were conducted in 2005 and 2006 and covered commercial and sport fishing, diving and snorkelling. A total of 4 083 questionnaires were completed, providing information on the behaviour and attitudes of users as well as the economic impact of their activity (Read more in the WP3 report – www.um.es/empafish).

### 3.2.4. Stakeholder consultations

Perceptions of stakeholders on the importance of MPAs as areas for conservation, fisheries management, or recreational uses were sought through a questionnaire. The questionnaire was translated into local languages and each respondent questioned using a face-to-face interview. Questions concerning objectives of marine protection provided the respondent with a list of nine specific objectives including whether MPAs are sites to protect representative sections of marine environment, protect marine biodiversity from damaging activities, prevent overexploitation of species, improve or sustain yields in adjacent areas, provide undisturbed localities for research or promote the development of tourism. Each respondent was asked to rank the objectives in order of importance using 1 for the most important objective, 2 for second most important …and 9 for least important (read more in the Stakeholder report Deliverable 29).

In order to compute the objective considered highly by stakeholders, ranks provided by respondents were reversed such that what the stakeholders ranked 1 was scored 9, 2 was scored 8…while 9 was scored 1. The mean score for each major stakeholder category for each objective was calculated.

### 3.3. Selection of favoured management option

Primary data for each sub-criteria were used to undertake multi-criteria analysis using the software DEFINITE (decisions on a finite set of alternatives). This Windows-based software systematically leads an expert through a number of interactive assessment sessions and uses an optimization approach to integrate the information provided to a full set of value functions. It contains related procedures such as weight assessment, standardization and discounting for sensitivity analysis.

In order to select the favoured management option, the data from the various effects had to be standardized to make the measured units comparable across the options. Maximum standardization procedure was used where each of the effects scores were divided by the maximum value of the effect thereby creating a linear function between zero and the highest absolute score. The use of multi-criteria methods requires information on the relative importance of each effect. For this, quantitative weights for each of the effects and criteria were assigned directly based on ranks from the stakeholder consultations. The results were displayed using bar plots with the management options on the x-axis and the value of the ranking on the y-axis.

## 4. Results

Relative scores and ranks for each management option are presented in Figure 3. Scores generated by combinations of all effects for each criteria indicate that having a large MPA in which the size of the partially protected zone is half that of the no-take zone is the most preferred scenario (Fig 3a). This management option scored highly in all the criteria investigated: Ecological (Fig 3b), Fisheries (Fig 3c) and Socio-economic (Fig 3d). The least preferred management option is having a large MPA in which the size of the partially protected area is twice that of the fully protected area. Scores on the ranking of management options based on socio-economic criteria show that having a large MPA in which the size of partially protected zone is same as size of fully protected zone is preferred to having a medium-sized MPA where the size of partially protected zone is half that of the fully protected zone. These analyses indicate that the main functions of MPAs are maximised by having a fully protected area that is larger than the buffer zone.

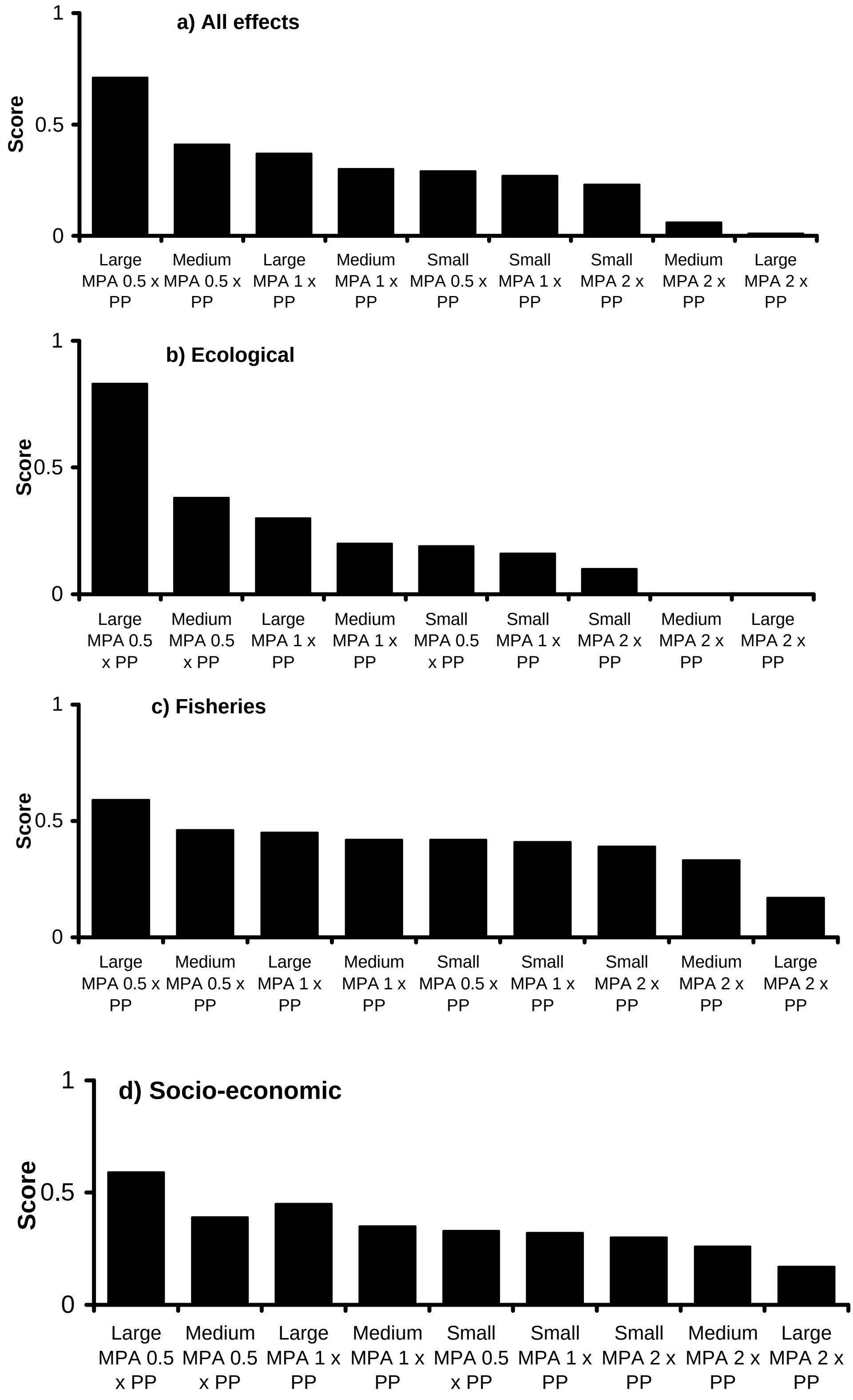


Figure 3: Results of the multi-criteria analysis showing scores of all the effects combined and for each effect separately for each management option. 0.5 x PP = partial protected zone is half the size of no-take zone; 1 x PP = partial protection zone same size as no-take zone; and 2 x PP = partial protection zone twice the size of no-take zone.

## 5. Conclusions

Increasing policy, legislation and public demand for the proclamation of marine protected areas necessitates the development of assessment procedures and evaluation of management options. This study has used a multi-criteria analysis to rank MPA management options on the basis of ecological, fisheries, socio-economic and stakeholder values. The analysis shows that fisheries benefits from MPAs are maximised by having fully protected zones that are larger than the surrounding buffer zones.

The system developed above should help users to make decisions on the management of marine protected areas and lead to improvements in the design and selection of such areas. The interactive web based tool (Deliverable 30) makes the results from the EMPAFISH project readily available and should aid the transfer of our techniques to other areas and assist the formulation of future fisheries regulation. The framework is sufficiently flexible to deal with MPAs in other regions and should provoke stimulating discussions among stakeholders.

The data used to build the decision support system are real, but the analysis is based on our models that compared fully and partially protected areas to areas that were not protected. As such management decisions should not be based solely on such a partial analysis but should include other important issues such as the cost of enforcement. There is a need to apply the framework to MPAs in other parts of the world to test its utility as a routine evaluation tool.

The approach described above can also be used in a variety of assessments including integrated coastal zone management and coastal defence strategies. The main advantages of using frameworks like the one developed here are to ensure ‘best science’ is used to support decisions, to encourage acceptance of management strategies and to ensure equity through stakeholder involvement.

Multi-criteria analysis is a tool to provide assistance in working through a complex set of scenarios. It provides an insight into trade-offs, and takes stakeholder’s views into account. This involvement of stakeholders improves the likelihood of any selected management regime being followed. The weights provide a clear insight into who thinks what, and can be very useful in enabling discussions, as people’s priorities are very transparent.

**Acknowledgements**

We are grateful to all partners in EMPAFISH as they provided the data and analytical results to support development of the decision support tool for MPAs.

**References**

Botsford L.W., Micheli F. and Hastings A. (2003) Principles for the design of marine reserves. *Ecological Applications* 13, 25-31.

Halpern B.S. and Warner R.R. (2002) Marine reserves have rapid and lasting effects. *Ecology Letters* 5, 361-366.

Hastings A. and Botsford L.W. (2003) Comparing designs of marine reserves for fisheries and for biodiversity. *Ecological Applications* 13, S65-S70.

Hockney P.A.R. and Branch G.M. (1997) Criteria, objectives and methodology for evaluating marine protected areas in South Africa. *South African Journal of Marine Science* 18, 369-383.

Kaplan D.M. and Botsford L.W. (2005) Effects of variability in spacing of coastal marine reserves on fisheries yield and sustainability. *Canadian Journal of Fisheries and Aquatic Science* 62, 905-912.

Leslie H., Ruckelshaus M., Ball I.R., Andelman S. and Possingham H.P. (2003) Using siting algorithms in the design of marine reserve networks. *Ecological Applications* 13, S185-S198.

McClanahan T.R. and Graham N.A.J. (2005) Recovery trajectories of coral reef fish assemblages within Kenyan marine protected areas. *Marine Ecology Progress Series* 294, 241-248.

Roberts C.M., Branch G., Bustamente R., Castilla J.C., Dugan J., Halpern B., Lafferty K., Leslie H., Lubchenco J., McArdle D., Ruckleshaus M. and Warner R. (2003) Application of ecological criteria in selecting marine reserves and developing reserve networks. *Ecological Applications* 13, S215-S228.

Russ G.R. and Alcala A.C. (2004) Marine reserves: long term protection is required for full recovery of predatory fish populations. *Oecologia* 138, 622-627.