Application of the MESMA Framework.
Case Study:
Inner Ionian Archipelago & adjacent gulfs

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STEP 7. Recommend adaptations to current management

In Step 7, during the first run of the MESMA framework, and since interaction with stakeholders is still in progress through the governance analysis, it was decided to investigate the possibility of identifying emerging priority areas, where conflicts with economic human activities are minimum. Then, in the frame of the second run and according to stakeholders’ feedback, areas where consensus is reached can be proposed as new sites for protection, constituting thus effective adaptations to the existing management system.

Through the analysis in Step 5 it became evident that specific operational objectives related to priority habitats and species are rarely met (e.g. the case of the Natura 2000 network). Hence, we proceeded in developing different scenarios/provisional targets for particular features of conservation interest, considering at the same time the main economic activities in the area (fisheries and tourism). The latter were fed into the Marxan software and the context of the application, as well as the results are presented below.

Systematic Conservation Planning

Systematic conservation planning provides an efficient and transparent approach, guiding the location, configuration and management of conservation areas (Moilanen et al. 2009). Core principles that a reserve system should satisfy, when systematic conservation planning is applied, are: comprehensiveness (the inclusion of many biodiversity features), representativeness (the samples used should be representative of biodiversity), adequacy (to ensure the persistence of the biodiversity features), efficiency (to achieve the conservation objectives with the least cost) and connectivity (ensuring ecological connections between sites via passive dispersal or active migration) (Wilson et al. 2009). Margules & Pressey (2000) identified the following stages in systematic planning process: 1) identification and involvement of stakeholders, 2) identification of conservation goals, 3) compilation of data (ecological and socio-economic), 4) formulation of conservation targets, 5) revision of existing target achievement, 6) selection of new conservation areas, 7) implementation of new conservation areas and 8) maintenance and monitoring.

Given the complexity of locating new areas for conservation management, spatial conservation prioritization decision support tools are often used to guide selection. Conservation goals are explicitly defined and can include a number of ecological, social and economic considerations (Sala et al. 2002, Airame et al. 2003, Leslie et al. 2003, Fernandes et al. 2005). Many decision support tools select areas based on complementarity, taking into account what is already protected and identifying new areas that complement this (Wilson et al. 2009). The involvement of stakeholders in the planning procedure from early stage is required in order these decision tools to be efficient and achieve acceptance of marine reserves by the community (Stewart & Possingham 2005). Top–down impose of regulations to local fishermen have been proved inefficient. Therefore bottom–up support by local fisheries and community should be sought before the imposition of any management measure (Hilborn et al. 2004). Additionally, their input is necessary as it can complement numerical optimization tools and
spatial modelling regarding tradeoffs and costs related to the creation of reserves (Grafton & Kompas 2005, Klein et al. 2008a).

One way to facilitate the involvement of stakeholders into systematic conservation planning is through the integration of socioeconomic data with biophysical data to identify priority areas (Ban et al. 2009, Carwardine et al. 2008, Naidoo et al. 2006). Although, it has been suggested that networks of marine reserves must first be biologically robust and then consider socioeconomic factors (Roberts et al. 2003), integrating such data into the prioritization minimises conflicts between stakeholders and conservation plans (Scholz et al. 2004, Klein et al. 2008b). Moreover, this facilitates the implementation of adaptive management procedures (Sale et al. 2005). In their review, Ban & Klein (2009) have identified several types of spatial socioeconomic data that have been used as cost in the design of Marine Protected Areas (MPAs), with most prominent, the opportunity cost to fishermen in terms of area. According to the same authors, other types of cost, taken into account in marine reserve planning, are management and transaction costs. However, detailed spatially explicit economic information is often not available (Naidoo et al. 2006) or its resolution is inadequate (Richardson et al. 2006). When this is the case spatially variable cost surrogates could be used rather than assuming just area is a surrogate for cost (Ando et al. 1998, Giakoumi et al. 2011).

**Spatial prioritization software: Marxan**

Marxan is software that delivers decision support for protected areas system design (Ball et al. 2009). The basic idea behind a protected areas design problem is that a conservation planner has a large number of potential sites (or planning units) from which to select new conservation areas. They may wish to devise a protected areas system which is made up of a selection of these planning units which will solve a problem that includes several ecological, social and economic criteria and principles. Marxan is primarily intended to solve a particular class of protected areas design problem known as the ‘minimum set problem’, where the goal is to achieve some minimum representation of biodiversity features for the smallest possible cost. The rationale is that cheaper or less socially disruptive protected areas networks are more likely to be implemented. Furthermore, meeting a set of targets for all conservation features provides a solid platform for expanding a protected areas system in the future. Given reasonably comprehensive data on species, habitats and/or other relevant biodiversity features, Marxan aims to identify the protected areas system (a combination of planning units) that will meet user-defined biodiversity targets for the minimum cost. Marxan uses a simulated annealing algorithm to find systems of protected areas that meet conservation targets while attempting to minimize socio-economic costs. By repeatedly using simulated annealing, many different solutions are produced.

The mathematical problem to which Marxan finds good solutions is:

\[
\text{minimize} \quad \sum_{i}^{N_s} x_i c_i + b \sum_{i}^{N_s} \sum_{h}^{N_h} x_i (1 - x_h) c_{vh} \quad (1)
\]

subject to the constraint that all the representation targets are met.
\[ \sum_{i}^{N_{f}} x_{i} r_{ij} \geq T_{j} \quad \forall j \quad (2) \]

\[ x_{i} \in \{0, 1\} \quad \forall i \]

where \( r_{ij} \) is the occurrence level of feature \( j \) in site \( i \), \( c_{i} \) is the cost of site \( i \) and, \( N_{s} \) is the number of sites, \( N_{f} \) is the number of features, and \( T_{j} \) is the target level for feature \( j \). The control variable \( x_{i} \) has value 1 for sites selected for the protected areas network and value 0 for sites not selected.

The first term in the equation (1) is a penalty associated with the cost of all sites (planning units) that are in the system. The second term of the same equation is a penalty associated with configuration. A protected areas network with a smaller boundary length has a more compact configuration. The more fragmented the protected areas system, the greater its boundary length. The parameter \( b \) in equation (1) is the boundary multiplier which determines the cost of the system relative to the penalty for its spatial configuration. The matrix \( CV \) is the connectivity matrix with elements \( c_{v_{i}h} \) which reflects the cost of the connection shared by planning units \( i \) and \( h \). If one site is in a protected areas system, and the other is not, then the connection cost must be paid.

**Conservation objectives**

Our conservation objectives included the representation of species and habitats, including critical habitats for endangered and vulnerable species in a network of coastal and off-shore MPAs which would expand the already designated Natura 2000 network. At the same time, we aimed at selecting priority areas that minimize conflict with economic activities in the area, basically fishing and tourism. We also excluded from our analysis areas that were negatively affected by the major industry in the area, and deteriorated coastal areas due to human constructions and activities (ports, coastal cities, aquaculture farms).

**Marxan application**

In order to apply Marxan, for the selection of priority areas, we generated a grid of 15331 planning units, each 1 km², based on the European grid adopted for the implementation of the Habitats Directive\(^1\). Planning units are used as candidate areas to be either chosen or not by Marxan. The extent of each ecological feature and socio-economic cost was calculated for each planning unit. We forced the selection of all planning units for which at least 50% of their area corresponded to Natura 2000 sites. We also produced scenarios that forced only the

\(^1\) For the needs of the 2001-2006 progress report of the Habitats Directive a pan-european grid 10X10 Km was created. Every member state had to put into this standard grid all the habitats of the Annexe I of the Directive. Given the great diversity of the Greek coastal and marine environment and the adverse topography of the bottom the 10X10 km grid was deemed impractical in the case of Greek marine areas. In order to adapt the methodology to the Greek coastal environment, the 10x10 km grid was subdivided into 100 pixels of 1x1 km.
selection of planning units for which at least 50% of their area were National Parks, i.e. the National Marine Park of Zakynthos and the National Park of Messolonghi - Aitoliko.

Using Marxan, we produced solutions that were spatially compact because this is an important consideration for marine reserve design (Roberts et al. 2003). In order for our network to have the desired level of spatial compactness we chose a solution for each scenario by calibrating the Boundary Length Modifier (BLM) to generate a reasonable trade-off between boundary length and cost (Stewart & Possingham 2005). We used a BLM value of 0.04. We ran Marxan 300 times. From these runs a best solution, which meets all targets with the lowest cost and boundary penalties, was produced for each scenario. We also used the selection frequency, which was the proportion of runs in which a site was selected amongst the 300 runs.

Conservation features

In Marxan the user sets a target for the features of conservation interest, which in our case was expressed as the percentage of its extent. For determining the targets for the conservation features we divided the features into two categories. The first category, “high priority” includes priority features according to the EU Habitats Directive (92/43/EEC): coastal lagoons, the seagrass *Posidonia oceanica*, the Mediterranean monk seal (*Monachus monachus*) and the loggerhead turtle (*Caretta caretta*). The second category, “low priority”, includes other important features of the case study area: gorgonians and corals, cold seeps, the bottlenose dolphin (*Tursiops truncatus*), the short-beaked common dolphin (*Delphinus delphis*), the stripped dolphin (*Stenella coeruleoalba*), Cuvier’s beaked whale (*Ziphius cavirostris*), the sperm whale (*Physeter macrocephalus*), seahorses (*Hippocampus spp.*), the fan mussel (*Pinnna nobilis*), the coral *Savalia savaglia*, nursery areas for the European hake (*Merluccius merluccius*), and the seabirds: shag (*Phalacrocorax aristotelis*) and Cory’s shearwater (*Calonectris diomedea*). For all species and habitats we used presence-absence data, apart from *Posidonia oceanica*, for which percentage coverage values were available.

We produced three scenarios with the following targets for high and low priority features, respectively: a) 60% and 20%, b) 70% and 40%, c) 80% and 60%. These sets of targets were based on EU directions and experts’ opinion (Marine Biogeographic Seminar, Brindisi, June 2010) and trends in current literature (e.g. Maiorano et al. 2009).

Socio-economic factors

The economic activities incorporated in our cost metric are: fishing and tourism. We also took into account the major industry of the area (Aluminium of Greece S.A.) by excluding the planning units that were affected by the red mud, a by-product of the industry that has been disposed in the sea. Furthermore, we excluded the planning units containing coastal zones that: 1) were severely impacted/modified by urbanization (coastal front of cities with more than 5 000 inhabitants), 2) included major ports and 3) aquaculture activity was present.
Fishing activity was divided in three sectors: trawlers, purse seiners and small-scale coastal fisheries with nets or longlines. The spatial distribution of the trawler and purse seiner fleets was analysed using data from a GPS vessel monitoring system (VMS) operating on board of fishing vessels. Planning units with more records were considered more important for these fisheries and therefore more costly to be included in a network of MPAs. Accurate data on the spatial distribution of the fishing effort of the small-scale coastal fisheries is lacking. As most coastal vessels largely operate at areas close to their home port, the distance of each planning unit to the nearest port was used as a surrogate for the estimation of the relevant cost: the larger the distance from the nearest port the less the cost. The contribution of each fishing sector to the cost was weighted in respect to their relative contribution in the GDP of the study area.

Tourism was also a factor in our cost metric. The planning units were attributed a cost value of:

- 1, in areas where massive tourism is developed or under development
- 0, in non-touristic areas
- -1, in areas where alternative tourism is developed or under development (a negative cost is actually a bonus for the selection of the corresponding planning unit)

We considered that the creation or expansion of MPAs will benefit alternative tourism and consequently local communities by increasing commercial activities. Moreover, impacts of such type of tourism, with proper restrictions, e.g. regulation on the number of divers in sites, are not expected to deteriorate the marine environment. On the other hand massive tourism is known to have negative impacts on marine ecosystems through: habitat clearing for infrastructure development, the increased pressure on marine resources for food provision or souvenir collection (e.g. shells), inappropriate sewage disposal, heavy vessel traffic and their discharges and unregulated sporting activities (Stewart 1993).

The values regarding tourism in each planning units were attributed based on the General Framework Plan for Sustainable Tourism Spatial Planning in Greece (YPEKA, 2009).

To calculate the total cost of each planning unit we combined the cost metrics from fishing and tourism into a single cost, $C_i$, for each planning unit, $i$:

$$C_i = \text{Max}[0.0062T_{ri} + 0.0194P_{si} + 0.0662C_{fi} + 0.9082T_i, 0]$$

where, $T_{ri}$ is the fishing pressure on planning unit $i$ from trawlers, $P_{si}$ the fishing pressure from purse seiners, $C_{fi}$ is the fishing pressure from coastal fishing boats and $T_i$ is the cost or benefit associated with tourism regarding its type, as mentioned in the previous paragraph. The coefficients of the variables were calculated based on the relative contribution of each sector to the Gross Domestic Product (GDP) of the study area. In particular, the estimation of coefficients was estimated as:
\[ \begin{align*}
A_T &= \frac{\sum_j GDP_{Tj}}{\sum_j GDP_{Tj} + \sum_j GDP_{Fj}} \\
A_F &= \frac{\sum_j GDP_{Fj}}{\sum_j GDP_{Tj} + \sum_j GDP_{Fj}}
\end{align*} \]

Where:

\(A_T\) and \(A_F\) are the coefficients for tourism and fishing respectively.

\(A_T + A_F = 1\). The coefficient for fishing was further broken down to the coefficients for trawlers, purse seines and small-scale coastal fisheries in proportion to the relative contribution of each fishing sector to the total landings in the case study area.

The index \(j\) corresponds to the prefectures of the study area.

GDP = Gross Domestic Product per sector

The estimation of coefficients was based on data from the Hellenic Statistical Service (prices at year 2008).

Identification of priority areas

Biodiversity hotspots

In order to identify biodiversity hotspots for our study area, we compiled the available data on the spatial distribution of the conservation features we used in the analysis and produced the following map (Fig. 1). The highest biodiversity values were found in Laganas Gulf, Zakynthos. Intense surveying of Zakynthos National Marine Park site, in contrast to poor investigation in other parts of the study area, could justify the higher recorded biodiversity values.

Scenario 1 (low conservation targets)

When we set targets of 60% for high priority conservation features and 20% for lower priority features and forced the selection of all Natura 2000 sites (scenario 1a), the best solution accounted for 24% (3646 km\(^2\)) of the study region (Fig.3). Whereas, when we forced the selection of National Parks only (scenario 1b), the best solution accounted for 18% (2720 km\(^2\)) of the total area (Fig.4).
Moreover, in scenario 1a (all Natura 2000 sites locked in) 14.5% of the planning units had very high selection frequency (80-100%), while in scenario 1b (only National Parks locked in) this percentage decreased to 5% (figs. 5 & 6).

**Scenario 2 (medium conservation targets)**

When we set goals of 70% for high priority conservation features and 40% for lower priority features and forced the selection of all Natura 2000 network sites (scenario 2a), the best solution accounted for 34% ($5198 \text{ km}^2$) of the study region (fig. 7). Whereas, in the case we forced the selection of National Parks only (scenario 2b), the best solution accounted for 30% ($4621 \text{ km}^2$) of the total area (fig. 8).

Furthermore, in scenario 2a, 17% of the planning units had very high selection frequency while in scenario 2b this percentage was reduced to 9% (figs. 9 & 10).

**Scenario 3 (high conservation targets)**

In contrast with the other scenarios, for the highest set of goals: 80% for high priority conservation features and 60% for lower priority features, the best solution in both cases, i.e. forcing the selection of all Natura 2000 sites (scenario 3a) and forcing the selection of National Parks
only (scenario 3b), accounted for 45% (6929 km$^2$ and 6230 km$^2$ respectively) of the study region (figs. 11, 12).

However, the planning units which presented very high selection frequency were 32% in scenario 3a (fig. 13) and 26% in scenario 3b (fig. 14).

Figure 6. Priority areas for Scenario 1a. The priority areas are illustrated in orange.
Figure 7. Priority areas for Scenario 1b. Priority areas are illustrated in orange.

Figure 8. Percentage of the runs a planning unit is selected (selection frequency) in Scenario 1a. Yellow: 0-20%, light orange: 21-40%, dark orange: 41-60%, light brown: 61-80% and dark brown: 81-100%.
Figure 9. Percentage of the runs a planning unit is selected (selection frequency) in Scenario 1b. Yellow: 0-20%, light orange: 21-40%, dark orange: 41-60%, light brown: 61-80% and dark brown: 81-100%.

Figure 10. Priority areas for Scenario 2a. Priority areas are illustrated in orange.
Figure 11. Priority areas for Scenario 2b. Priority areas are illustrated in orange.

Figure 12. Percentage of the runs a planning unit is selected (selection frequency) in Scenario 2a. Yellow: 0-20%, light orange: 21-40%, dark orange: 41-60%, light brown: 61-80% and dark brown: 81-100%.
Figure 13. Percentage of the runs a planning unit is selected (selection frequency) in Scenario 2b. Yellow: 0-20%, light orange: 21-40%, dark orange: 41-60%, light brown: 61-80% and dark brown: 81-100%.

Figure 14. Priority areas for Scenario 3a. Priority areas are illustrated in orange.
Figure 15. Priority areas for Scenario 3b. Priority areas are illustrated in orange.

Figure 16. Percentage of the runs a planning unit is selected (selection frequency) in Scenario 3a. Yellow: 0-20%, light orange: 21-40%, dark orange: 41-60%, light brown: 61-80% and dark brown: 81-100%.
Figure 17. Percentage of the runs a planning unit is selected (selection frequency) in Scenario 3b. Yellow: 0-20%, light orange: 21-40%, dark orange: 41-60%, light brown: 61-80% and dark brown: 81-100%.

Conclusions

Different targets produced sensitivity in the selection frequency of planning units. Higher targets resulted in more planning units in the solutions. Scenario 1, based on low targets (i.e. 60% and 20%), had 10% less planning units than scenario 2 based on medium level targets (70% and 40%), based on the best solution. Similarly, changing targets from medium (scenario 2) to high (scenario 3: 80% and 60%) resulted in 11% increase in planning units. Higher targets were also more costly, measuring socio-economic cost as defined earlier.

In the scenarios with low and medium targets, forcing the inclusion of all Natura 2000 sites resulted in best solutions that required more area to be included in a network of MPAs, than the respective scenarios that forced the selection of National Parks uniquely. In the high target scenarios (3a and 3b) there was no difference amongst the best solutions. Nevertheless, in all scenarios (for all pairs of targets), forcing the inclusion of all Natura 2000 sites resulted in more costly MPA networks.

In all scenarios, we achieved at least the target we had defined for each feature. The features’ proportion included in the MPA network in each scenario is presented in the following table (Table 1).

We found 1164 higher priority planning units (selection frequency> 80%) across all scenarios (fig. 15). These were located in: both national parks (South Zakynthos Island and Messo-longhi Lagoon), the north and south of Cephalonia Island, the south and south eastern of
Lefkada Island, the coastal areas of the north-western Peloponnese, a pelagic area west and north-west of Zakynthos, a pelagic area in the south and south-east of Zakynthos and west of the Peloponnese, and a pelagic area in the Korinthiakos Gulf (near Loutraki).

The proposed MPAs should be subjected to zoning. Each zone should specify which activities can take place within its limits and with what restrictions. For instance in deep pelagic areas, the only measure that should be adopted is the regulation of the shipping traffic, in order to avoid conflicts with cetaceans. In shallower pelagic areas restrictions could also be imposed on trawlers.

### Table 1. Targets accomplished in each scenario.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Scenario 1</th>
<th>Scenario 1a</th>
<th>Scenario 1b</th>
<th>Scenario 2</th>
<th>Scenario 2a</th>
<th>Scenario 2b</th>
<th>Scenario 3</th>
<th>Scenario 3a</th>
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<tbody>
<tr>
<td>Posidonia oceanica</td>
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<td>60%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
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<td>100%</td>
<td>70%</td>
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<td>100%</td>
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<td>81%</td>
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Figure 18. Priority areas across all scenarios. Percentage of the runs a planning unit is selected (selection frequency). Yellow: 0-20%, light orange: 21-40%, dark orange: 41-60%, light brown: 61-80% and dark brown: 81-100%.
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