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Could European marine conservation policy benefit from systematic conservation planning?

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ABSTRACT

1. The Natura 2000 network of protected areas aims to assure the long-term survival of Europe's most valuable and threatened species and habitats. Yet, evidence shows that the present network fails to represent effectively the biodiversity of the region.
2. Priority areas for conservation of coastal and offshore biodiversity features in the Greek Ionian Sea were identified, based on the principles of systematic conservation planning (SCP). SCP is a transparent method for the design of MPA networks and is considered more efficient and successful in representing the biodiversity of a region.
3. The prioritization software Marxan was used and three scenarios with different sets of targets for 17 (high and low priority) conservation features were produced. These scenarios explicitly took into account socio-economic factors expressed as a single cost metric, weighting different economic sectors in proportion to their contribution to the GDP of the region. Then results were compared with the existing Natura 2000 sites in terms of goal achievement, area requirements, and cost.
4. The solutions produced by the systematic approach demanded less area and lower cost to achieve the goals set, when the selection of all Natura 2000 sites was not forced. Existing Natura 2000 sites alone failed to achieve conservation goals for some EU priority and other important coastal and offshore habitats and species of the Mediterranean Sea.
5. It is suggested that the use of systematic conservation planning and related computational tools could benefit the selection of European marine priority areas, especially in the context of ecosystem-based marine spatial management.

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KEY WORDS: biodiversity; birds; coastal; ecosystem approach; fishing; Habitats Directive; invertebrates; lagoon; mammals; recreation

INTRODUCTION

The Natura 2000 network of protected areas forms the cornerstone of European nature conservation policy. This European-wide conservation network is based on the Birds Directive (European Commission, 1979; 2009) and the Habitats Directive (European Commission, 1992), and aims at establishing a solid ecological foundation for sustainable development (European Commission, 2004). The initial list of

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sites to be included in the Natura 2000 network proposed by each EU Member State was basically expert-driven (Jongman, 1995; Maiorano *et al.*, 2007).

The marine component of the Natura 2000 network is an integral part of the overall Natura 2000 network. The marine network aims to protect sites of European conservation importance for marine habitats and species listed in the Habitats and Birds Directives, in order to ensure that these features can be maintained or, where appropriate, restored to a favourable conservation status in their natural range (European Commission, 2007). More than 160 000 km^2 have been designated as areas for conservation within the Natura 2000 network. However, even considering that the marine component of the network represents an important part of the overall Natura 2000, only 3% of the EU sea area is covered (European Environmental Agency (EEA), 2012).

Furthermore, there is evidence indicating that Natura 2000 sites are not effective at representing terrestrial and marine biodiversity. Dimitrakopoulos *et al.* (2004) identified priority areas for plants in Crete using hot spot and complementarity analysis and found little overlap with Natura 2000 sites, demonstrating their inefficiency in representing plant biodiversity. Maiorano *et al.* (2007) used habitat suitability models and distribution data for terrestrial vertebrates and freshwater fishes and concluded that Italian Natura 2000 sites were unable to provide adequate protection for biodiversity, in terms of preventing extinction of species. In order to identify priority areas for conservation in the Cyclades Archipelago (Greece), Giakoumi *et al.* (2011) used a systematic approach with a site-selection algorithm and found that Natura 2000 sites alone were not able to achieve conservation targets for EU priority habitats and that their effective protection would require larger areas to be included. Most of the marine Natura 2000 sites are near-shore areas and many of the European marine biotopes (especially offshore, pelagic and deep seabed biotopes) are under-represented or not represented at all in the Natura 2000 network. The effectiveness of Natura 2000 network in conserving biodiversity is even more questionable when climate change is taken into account. Araujo *et al.* (2011) found that Natura 2000 areas retain climate suitability for species no better and sometimes less effectively than unprotected areas. Besides the shortcomings in representing biodiversity, the Natura 2000 sites are also failing to explicitly consider human activities during the planning procedure, which is crucial to effective planning and implementation (Hiedanpaa, 2002; Apostolopoulou and Pantis, 2009; Opdam *et al.*, 2009).

Systematic conservation planning provides an efficient and transparent approach, guiding the location, configuration and management of conservation areas (Moilanen *et al.*, 2009). The involvement of stakeholders in the planning procedure from an early stage is required in order for these decision tools to be efficient and achieve acceptance of marine protected areas by the wider community (Stewart and Possingham, 2005). Moreover, stakeholders' involvement in the planning procedure helps to establish strong relationships between the protected areas' users and the decision makers (Dimitrakopoulos *et al.*, 2010; Rojas-Nazar *et al.*, 2012). One way to facilitate the involvement of stakeholders in the systematic conservation planning is through the integration of socio-economic data with bio-physical data in order to identify priority areas (Carwardine *et al.*, 2008; Ban *et al.*, 2009). Systematic conservation prioritization schemes should implicitly take into account the spatial variability of anthropogenic uses and the associated cost of excluding these for the sake of protection (Naidoo *et al.*, 2006). Ideally, the cost included should be monetary (Naidoo *et al.*, 2006). Yet, such data are rarely available, especially in marine conservation planning (Ban and Klein, 2009). When this is the case, spatially variable cost surrogates should be used rather than just assuming that area is a surrogate for cost (Ando *et al.*, 1998).

The spatial distribution of human activities in the marine environment is a major concern also when considering the broader concept of Ecosystem-Based Marine Spatial Management (EB-MSM). EB-MSM is a management approach that recognizes the full array of interactions among ecosystem components and human users at different spatial scales, rather than considering in isolation single sectors, species or ecosystem services (Leslie and McLeod, 2007; Halpern *et al.*, 2008). EB-MSM is being promoted by various organizations worldwide, including EU institutions, as the best way to deal with inter-sectoral and cross-border conflicts over marine space, and to ensure the sustainability of marine ecosystems and their services to humans (Crowder and Norse, 2008; Katsanevakis *et al.*, 2011). MPA networks are an area-based management tool within EB-MSM providing a means for focused protection of features and processes in a given ecosystem that merit site specific management measures (Katsanevakis *et al*., 2011). In this context, systematic conservation planning can be a useful tool facilitating the effective implementation of EB-MSM.

Within the framework of the EU project 'Monitoring and Evaluation of Spatially Managed Areas (MESMA; www.mesma.org)', which focuses on EB-MSM and aims to produce integrated management tools (concepts, models, and guidelines) for monitoring, evaluation, and implementation of spatially managed marine areas, the principles of systematic conservation planning were implemented in the study area. Using a systematic approach, priority areas for conservation in the Greek Ionian Sea and the adjacent gulfs (Korinthiakos and Patraikos Gulfs) were identified. In the analysis, targets were set for EU priority conservation features (marine habitats listed in Annex I of the Habitats Directive, species listed in Annexes II and IV of the Habitats Directive and in Annex I of the Birds Directive) for endangered or threatened species in the Mediterranean listed in Annex II of the Protocol concerning Specially Protected Areas and Biological Diversity (UNEP MAP, 1996). The results of the analysis were then compared with the existing Natura 2000 sites in terms of goal achievement, area requirements, and cost.

METHODS

Study area

The coastline was defined as the eastern boundary of the study area. In the region, sperm whales (*Physeter macrocephalus)* are abundant in offshore waters at depths up to 2000 m; Cuvier's beaked whales (*Ziphius cavirostris)* are also found in the same depth range (Frantzis *et al*., 2003). Conservation of these cetacean populations is considered important at a Mediterranean scale (Anonymous, 2007). Therefore, we decided to include the entire core habitat of these species in the study area by defining the 2000 m depth contour as its western and southern boundary. The limits of the study region were extended southwards in order to include Strofades Islands, since they constitute a significant area for the conservation of seabirds. The northern border of the study area was defined by 38° 53' latitude, and the south-eastern borders by a strait line joining Cape Katakolon with the 2000 m contour south of Strofades Islands (straight lines were used for these borders as there was no ecological reasoning for a different boundary selection; the northern border was such that the entire Lefkada Island and its coastal zone was included in the study area). Extensive human activities occur both along the coasts of the study area and in offshore waters. Growing conflicts exist among human uses and between uses and nature conservation. In the study area there are ten entirely or partially marine Natura 2000 sites, including two established MPAs: the National Marine Park of Zakynthos, which also embraces the Strofades Islands, and the National Park of Messolonghi – Etoliko (Figure 1). These ten Natura 2000 sites cover altogether an area of 1834 km^2.

Spatial prioritization methods

Our conservation objective was the effective representation of species and habitats, with emphasis to critical habitats for endangered and vulnerable species, in a network of coastal and pelagic MPAs. At the same time, attempts were made to avoid the inclusion of priority areas of great conflict with human activities. To select priority areas the conservation planning software Marxan (Ball *et al*., 2009) was used. Marxan uses a simulated annealing algorithm to find a range of good near-optimal systems of protected areas that meet conservation targets while attempting to minimize socio-economic costs. Trial solutions are generated iteratively by randomly changing the status of a single planning unit and assessing the new configuration in terms of achieving Marxan's goal, i.e. minimize cost of the reserve network and the boundary length of the system while meeting a set of biodiversity targets.

In order to apply Marxan, a grid of 15331 1 km² planning units was generated, based on the European grid adopted for the implementation of the Habitats Directive.[†] 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.

Using Marxan, solutions were produced that were spatially compact, as this is an important consideration for marine reserve design (Roberts *et al*., 2003). In order for the network to have the desired level of spatial compactness a solution was

[†]For the needs of the 2001–2006 progress report of the Habitats Directive a pan-European grid 10 × 10 km was created. Every member state had to put into this standard grid all the habitats of the Annex I of the Directive. Given the great diversity of the Greek coastal and marine environment and the adverse topography of the bottom the 10 × 10 km grid was deemed impractical in the case of Greek marine areas. In order to adapt the methodology to the Greek coastal environment, the 10 × 10 km grid was subdivided into 100 cells of 1 × 1 km.

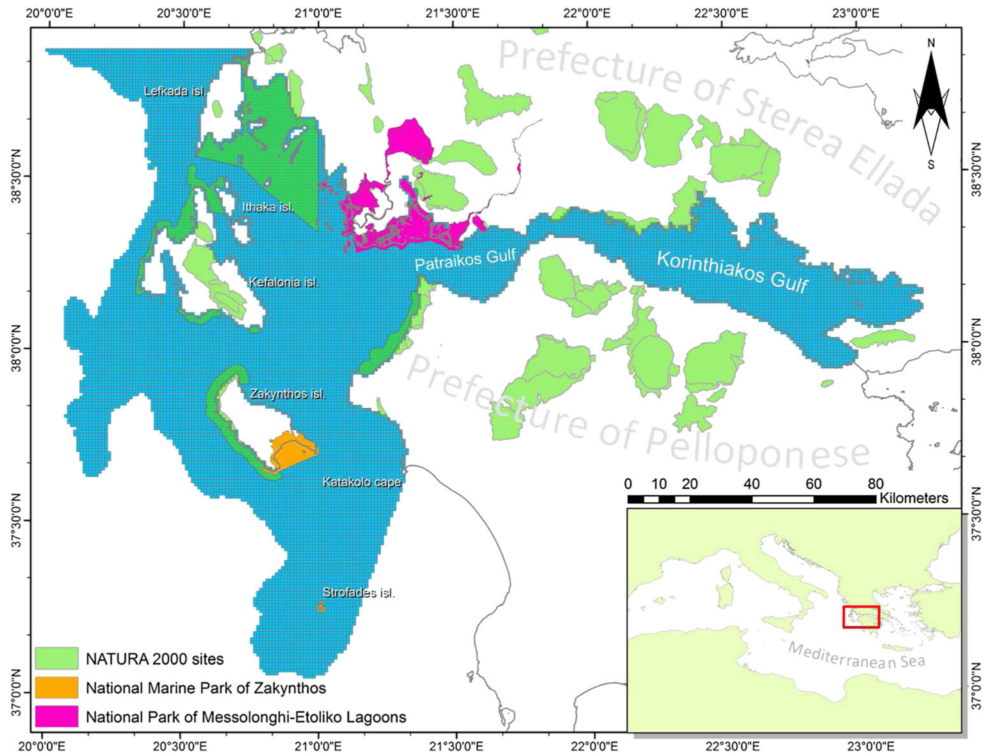

Figure 1. Study area in the Greek Ionian Sea and the adjacent gulfs (Korinthiakos and Patraikos Gulfs). Natura 2000 sites are represented in light green, the National Marine Park of Zakynthos in orange and the National Park of Messolonghi-Etoliko Lagoons in bright pink.

chosen for each scenario by calibrating the boundary length modifier (BLM) to generate a reasonable trade-off between boundary length and cost (Stewart and Possingham, 2005). For calibration of the BLM value the appropriate application in software Zonae Cogito (Segan *et al*., 2011) was used, which is a decision support and database management system to supplement Marxan software. Based on the range of cost values (0–1), BLM values between 0 and 1 were tested. After several trials and calibration of the model, it was found that using a BLM value of 0.04 produced solutions with a good level of compactness, i.e. selected planning units were not scattered all over the study area but were sufficiently clustered with a reasonable trade-off with cost (Hermoso *et al*., 2011). Marxan was run 300 times, from which a best solution, which met all targets with the lowest cost and boundary penalties, was produced for each scenario. The selection frequency, which was the proportion of runs in which a site was selected among the 300 runs, was used to define the areas of greater irreplaceability and hence higher priority for protection.

Conservation features

In Marxan the user sets a target for the features of conservation interest, which in this case was expressed as the percentage of its extent. In order to determine the targets for the conservation features, the features were classified into two categories. The first category, 'high priority', included priority features according to the EU Habitats Directive (92/43/EEC): coastal lagoons, meadows of the seagrass *Posidonia oceanica*, habitat of the Mediterranean monk seal (*Monachus monachus*), and nesting beaches of the loggerhead turtle (*Caretta caretta*). The second category, 'low priority', included other important features of the case study area: coralligenous communities and deep-sea corals, cold seeps, the bottlenose dolphin (*Tursiops truncatus*), the short-beaked common dolphin (*Delphinus delphis*), the striped dolphin (*Stenella coeruleoalba*), Cuvier's beaked whale, the sperm whale, seahorses (*Hippocampus* spp.), the fan mussel (*Pinna nobilis*), the coral *Savalia savaglia*, nursery areas for the European hake (*Merluccius merluccius*), and two seabirds: the shag (*Phalacrocorax aristotelis*) and Cory's shearwater (*Calonectris diomedea*). For all species and habitats areas of conservation importance were defined based on presence–absence data, previous dedicated habitat mapping surveys, and expert judgment (Issaris *et al*., 2012).

Three scenarios were produced with the following targets for high and low priority features respectively: (1) 60% and 20%; (2) 70% and 40%; (3) 80% and 60%. These sets of targets were based on the EU additional guidelines for assessing sufficiency of Natura 2000 proposals (SCIs) for marine habitats and species (European Topic Centre on Biological Diversity (ETC./BD), 2010). In the ETC./BD document it is stated: 'Where quantitative data on habitat areas are available, it would be possible to apply the arbitrary sufficiency levels 20–60% for non-priority habitats and >60% for priority habitats (e.g. *Posidonia* beds)'. Moreover, the targets were based on trends in current literature (e.g. Maiorano *et al.*, 2009).

Socio-economic factors

The economic activities incorporated in the cost metric were fishing and tourism. Also taken into account was the major industry of the area (Aluminium of Greece S.A. based on the mainland in the innermost region of Korinthiakos Gulf) by excluding the planning units that were affected by the red mud, a by-product of the industry that has been disposed of in the sea. Furthermore, the planning units along coastal zones that (1) were severely impacted/modified by urbanization (coastal front of cities with more than 5000 inhabitants), (2) included major ports, and (3) included aquaculture farms, were excluded.

Fishing activity was divided into three sectors: trawlers, purse seines, and small-scale coastal fisheries with nets or bottom 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 these fishing vessels. For trawlers, it was assumed that records with speeds between 0 and 4 knots correspond to fishing, while speeds >4 knots correspond to cruising and were excluded. For purse seiners, offshore signals with nil recorded speed were selected as corresponding to fishing. Planning units with more records were considered more important for these fisheries and therefore more costly to be included in a network of MPAs. Coastal fishers do not operate with VMS. To estimate the fishing pressure from coastal fisheries a multi-criteria decision analysis was applied, mainly based on expert opinion. The criteria used included depth (based on the assumption that the fishing pressure is greater in shallower waters); banning period of trawlers (it varies in the study area, and affects the activity of the coastal fleet; when trawlers are banned, coastal fisheries are generally more active); fishing effort of trawlers (it is negatively correlated with fishing effort of the coastal fleet); distance from coast (the fishing effort of coastal fisheries is reduced with distance from the coast); fleet distribution (based mainly on the distribution and capacity of fishing ports; the larger the fleet in a locality, the larger the fishing effort). The methodology is thoroughly described in Issaris *et al.* (2012). The contribution of each fishing sector to cost was weighted with respect to its relative contribution to the GDP of the study area.

Tourism was also a factor in the cost metric, affecting only coastal planning units. Coastal planning units were attributed a cost value of 1 in areas where mass tourism is developed or under development, 0 in non-touristic areas, –1 in areas where ecotourism is developed or under development (thus, a negative cost is a bonus for the selection of the corresponding planning unit). It was considered that tourism would not affect significantly off-shore features and therefore in off-shore planning units cost from tourism was given a value of 0. The values regarding tourism in each planning unit were attributed based on the General Framework Plan for Sustainable Tourism Spatial Planning in Greece (Ministry of the Environment, Energy, and Climate Change, 2011).

To calculate the total cost of each planning unit i, the cost metrics from fishing and tourism were combined into a single cost C:

$$C_i = \mathrm{Max}\big[\,0.0062Tr_i + 0.0194Ps_i + 0.0662Cf_i + 0.9082T_i,\ 0\big]$$

where Tr_i is the fishing pressure on planning unit i from trawlers, Ps_i the fishing pressure from purse seiners, Cf_i is the fishing pressure from coastal fishing boats and T_i is the cost or benefit associated with tourism according to its type. The overall cost of each planning unit (C_i) did not take negative values, as Marxan does not accept negative cost values, i.e. benefits; negative values were replaced by 0. The values of all variables were normalized (using max value) to a 0 to 1 scale. 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, coefficients were estimated as:

$$A_T = \frac{\sum_j GDP_{Tj}}{\sum_j GDP_{Tj} + \sum_j GDP_{Fj}} \text{ and}$$

$$A_F = \frac{\sum_j GDP_{Fj}}{\sum_j GDP_{Tj} + \sum_j GDP_{Fj}}$$

where A_T and A_F are the coefficients for tourism and fishing respectively; $A_T + A_F = 1$; GDP = Gross Domestic Product. The index j corresponds to the prefectures of the study area. 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 estimation of coefficients was based on GDP data (prices at year 2008) from the Hellenic Statistical Service (EL.STAT, 2012).

Comparison with Natura 2000 sites

Scenarios (one for each set of goals) were produced that forced the selection of all planning units for which at least 50% of their area corresponded to Natura 2000 sites (scenarios a). This means that if >50% of a planning unit is included within a Natura 2000 site, the entire planning unit is considered protected and its selection is forced into the model, while if <50% of the planning unit falls within a Natura 2000 site, the selection of the unit is not forced a priori. The threshold value (50%) is arbitrary but necessary to be defined in the prioritization exercise as not all planning units will be entirely in or entirely out of Natura sites. Then the solution that included all those sites was compared with the solution without considering all Natura 2000 sites but only National Parks, i.e. the National Marine Park of Zakynthos and the marine part of the National Park of Messolonghi - Etoliko (scenarios b). Although the two National Parks are part of the Natura 2000 network, the level of protection and enforcement is higher there. The solutions from scenarios a and b were compared in terms of area requirements, goal achievement, and cost.

RESULTS

Area requirements

When targets of 60% were set for high priority conservation features and 20% for low priority features and included all existing Natura 2000 sites (scenario 1a), the best solution (in terms of conservation goals achievement at lower cost) accounted for 32% (4879 km^2) of the study region (Figures 2 and 3(a)). Whereas, when the selection of all existing Natura sites, except for the two National Parks (scenario 1b) was not forced, the best solution accounted for a substantially smaller proportion of the total area (23.5%; 3614 km^2) (Figures 2 and 3(b)). In the best solution for scenario 1b, 53% of the designated Natura 2000 network was not selected. In scenario 1a (all Natura 2000 sites locked in) 16% of the planning units had very high selection frequency (80–100%), while in scenario 1b (only National Parks locked in) this percentage decreased to 6% (Figure 4(a) and 4(b)).

When goals of 70% were set for high priority conservation features and 40% for lower priority features and the selection of all Natura 2000 network sites (scenario 2a) was forced, the best solution accounted for 44.5% (6835 km^2) of the study region (Figures 2 and 3(c)). When the selection of all existing Natura sites, except for the two National Parks (scenario 2b) was not forced, the best solution accounted for 34.5% (5281 km^2) of the total area (Figures 2 and 3(d)). In the best solution for scenario 2b, 38% of the designated Natura 2000 network was not selected. In scenario 2a, 20% of the planning units had very high selection frequency while in scenario 2b this percentage was reduced to 9% (Figure 4(c) and 4(d)).

For the highest set of goals (80% and 60% for high and low priority conservation features, respectively), 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 almost the same percentage of the total area (52.5% and 52%; 8043 km^2 and 7983 km^2 respectively) of the study region (Figures 2, 3(e) and 3(f)). In the best solution for scenario 3b, 25% of the designated

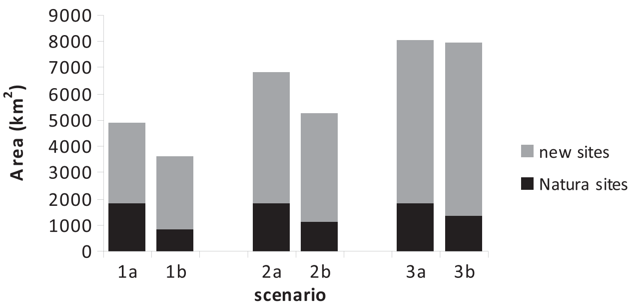

Figure 2. Total area required for protection by each scenario and the proportion of Natura 2000 sites included. The black part of the column corresponds to Natura 2000 sites and the grey to new non-Natura sites selected by the analysis in order to achieve the targets set by each scenario.

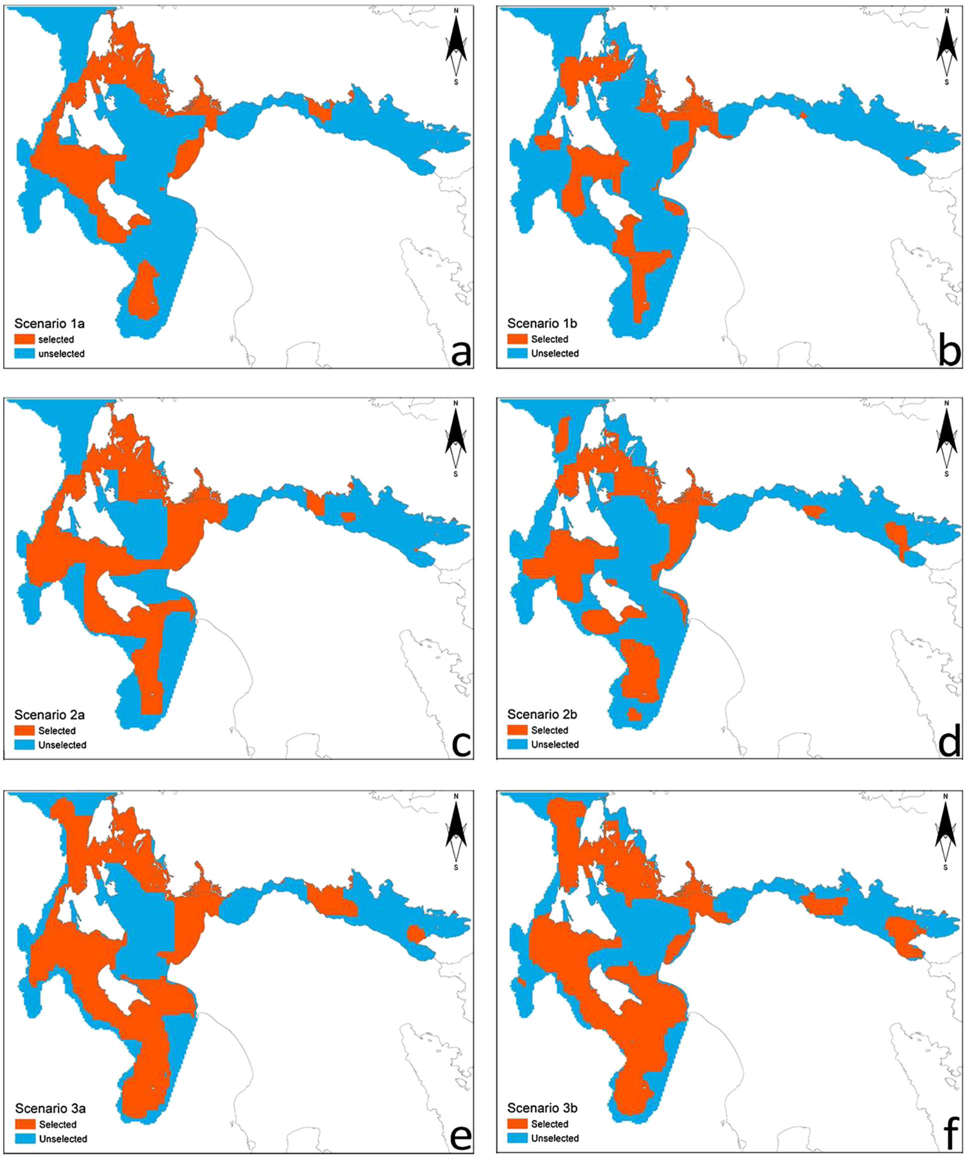

Figure 3. Best solutions for low target scenarios (a: all Natura sites locked in, b: only National Parks locked in), medium target scenarios (c: all Natura sites locked in, d: only National Parks locked in) and high target scenarios (e: all Natura sites locked in, f: only National Parks locked in). Selected areas are illustrated in orange while unselected areas in blue.

Natura 2000 network was not selected. In scenarios 3a and 3b, 38% and 34%, respectively, exhibited very high selection frequencies (Figure 4(e) and 4(f)).

Goal achievement

When only Natura 2000 sites were considered, most of the conservation features, among which priority conservation features such as the Mediterranean monk seal and the sea grass *Posidonia oceanica*, did not even achieve the goals of the low target scenario 1 (Table 1). Moreover, some of the conservation features, such as the sperm whale, were not represented at all in the present Natura 2000 network as they are not included in the Annex II of the Habitats Directive (Table 1). Comparing the best solutions generated by the scenarios including the Natura 2000 sites (scenarios a) and those including only the National Parks (scenarios b), it can be seen that generally scenarios a achieved higher targets than scenarios b, which is reasonable as scenarios b cover less area. However, higher achieved goals were observed in scenarios b for: *P. nobilis* in the low target scenario 1; *P. macrocephalus* and *Z. cavirostris* in the medium target scenario 2; and *P. aristotelis*, *S. savalia*, *S. coeruleoabla*, nursery areas of *M. merluccius*, and coralligenous communities-deep corals in the high target scenarios.

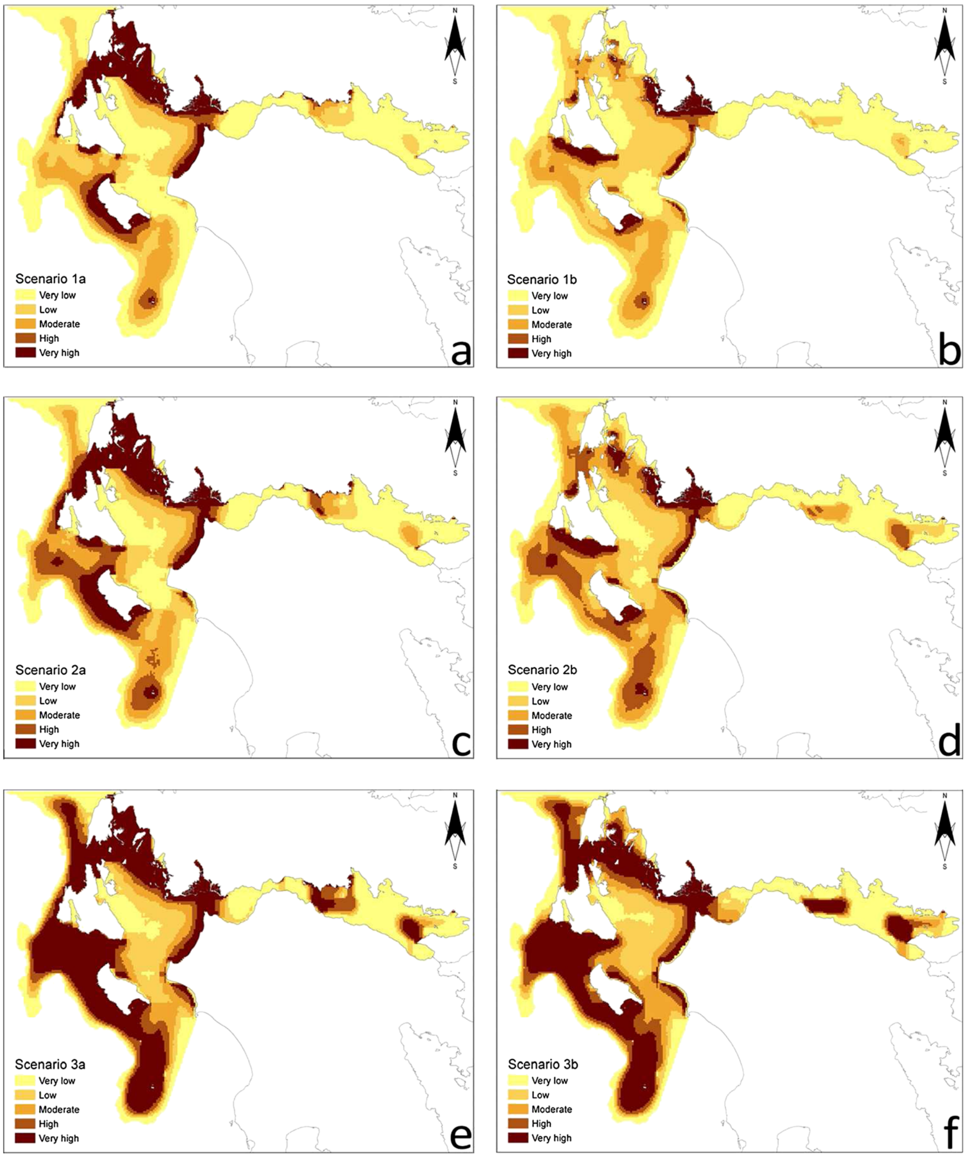

Figure 4. Areas of higher irreplaceability, and hence priority for low target scenarios (a: all Natura sites locked in, b: only National Parks locked in), medium target scenarios (c: all Natura sites locked in, d: only National Parks locked in) and high target scenarios (e: all Natura sites locked in, f: only National Parks locked in). Planning units depicted in lighter shades have lower selection frequency, while planning units in darker shades present higher selection frequency and therefore are of higher priority.

Cost

When comparing the best solutions of the scenarios in terms of cost, all scenarios including Natura 2000 sites (scenarios a) were more expensive. Scenario 1a was higher in cost than scenario 1b by 28.5%. Scenario 2a was more costly than 2b by 22%. Even high target scenario 3b which covered almost the same area as scenario 3a, was less costly by 4.5%. The inclusion of cost data in the prioritization scheme displaced priority areas from regions important for fishers and massive tourism to areas of lower human activity (Figure 5).

DISCUSSION

The mapping of ecosystem components is often a bottleneck for conservation planning. A common excuse to justify the lack of conservation actions is that there is insufficient information on the distribution, state, functioning, and interactions of ecological components. However, the rapid degradation of the marine ecosystems, specifically in the Mediterranean Sea (Coll *et al*., 2010; Salomidi *et al*., 2012), dictates the urgent need for management measures that could be modified later through adaptive management with the acquisition of new data. Adaptive management

Table 1. Goal achievement by Natura 2000 sites and all scenarios. The percentage of the extent of each conservation feature included in all Natura 2000 sites and each scenario is presented

Conservation feature	Natura 2000 sites	Scenario 1 goals	Scenario 1a	Scenario 1b	Scenario 2 goals	Scenario 2a	Scenario 2b	Scenario 3 goals	Scenario 3a	Scenario 3b
Posidonia oceanica	36%	60%	60%	60%	70%	70%	70%	80%	80%	80%
Calonectris diomedea	4%	20%	78%	66%	40%	100%	94%	60%	100%	76%
Caretta caretta	100%	60%	100%	100%	70%	100%	100%	80%	100%	100%
Phalacrocorax aristotelis	39%	20%	73%	53%	40%	78%	78%	60%	82%	87%
Delphinus delphis	37%	20%	47%	24%	40%	50%	40%	60%	60%	60%
Corals & Gorgonians	0%	20%	79%	20%	40%	82%	43%	60%	83%	86%
Hippocampus spp.	0%	20%	33%	33%	40%	50%	50%	60%	67%	67%
Monachus monachus	50%	60%	74%	60%	70%	78%	70%	80%	82%	80%
Physeter macrocephalus	0%	20%	33%	20%	40%	45%	46%	60%	60%	60%
Ziphius cavirostris	0%	20%	33%	20%	40%	45%	46%	60%	60%	60%
Pinna nobilis	29%	20%	56%	61%	40%	75%	68%	60%	74%	67%
Savaglia savalia	0%	20%	24%	24%	40%	41%	41%	60%	65%	71%
Cold seeps	0%	20%	20%	20%	40%	40%	40%	60%	60%	60%
Stenella coeruleoabla	1%	20%	30%	20%	40%	40%	40%	60%	61%	62%
Tursiops truncatus	32%	20%	54%	38%	40%	62%	45%	60%	62%	60%
Merluccius merluccius	62%	20%	77%	34%	40%	90%	67%	60%	73%	86%
Lagoons	100%	60%	100%	100%	40%	100%	100%	100%	100%	100%

is critical to the success of ecosystem-based marine spatial management (Arkema *et al*., 2006; Katsanevakis *et al*., 2011), especially in data-poor regions, as it enables managers to improve management in the long term by learning in the short term. This is possible by gathering more information and reducing uncertainty. In the study area, all available information on 17 coastal and offshore conservation features (habitats and species) was used. For some ecological components there was high uncertainty in the available spatial information (Issaris *et al*., 2012), as the sampling effort to map ecological features was not evenly spread throughout the study area. Within an adaptive management scheme, these results provide substantial improvements to the prioritization of marine sites in the study area. However, further species monitoring and habitat mapping efforts should be made in the region, to further improve the conservation planning outcomes.

Owing to the absence of spatially distributed economic data, surrogates were used that reflected the distribution of the socio-economic activity in the region. Fishing and tourism are human uses for which opportunity cost has been considered in previous prioritization schemes (Klein *et al*., 2008; Weeks *et al*., 2010; Giakoumi *et al*., 2011). The novel element in this analysis was the way weights were attributed to the socio-economic factors to give the cost indices a monetary aspect. On many occasions, weights have been selected in an arbitrary manner resulting in poor representation of cost (Naidoo *et al*., 2006). Among prioritization software users there is concern regarding how to combine costs from different sectors into a single cost metric. Here, it is proposed that the weights of the variables (economic sectors) should be based on the contribution of each sector to the GDP of the study area. Breaking down the GDP into different economic sectors has been used extensively for examining the implications of environmental policies in economic processes (Rosenblum *et al*., 2000; Burger *et al*., 2001; Wielgus *et al*., 2010).

The comparison among scenarios that forced the selection of all Natura 2000 sites (scenarios a) and scenarios that forced the inclusion of National Parks only (scenarios b), for three different sets of goals (low, medium, high), demonstrated that the latter were less demanding in terms of area and cost. The differences between the two groups of scenarios (a and b) decreased as the conservation goals increased and hence, the area set for conservation. The present Natura 2000 sites failed

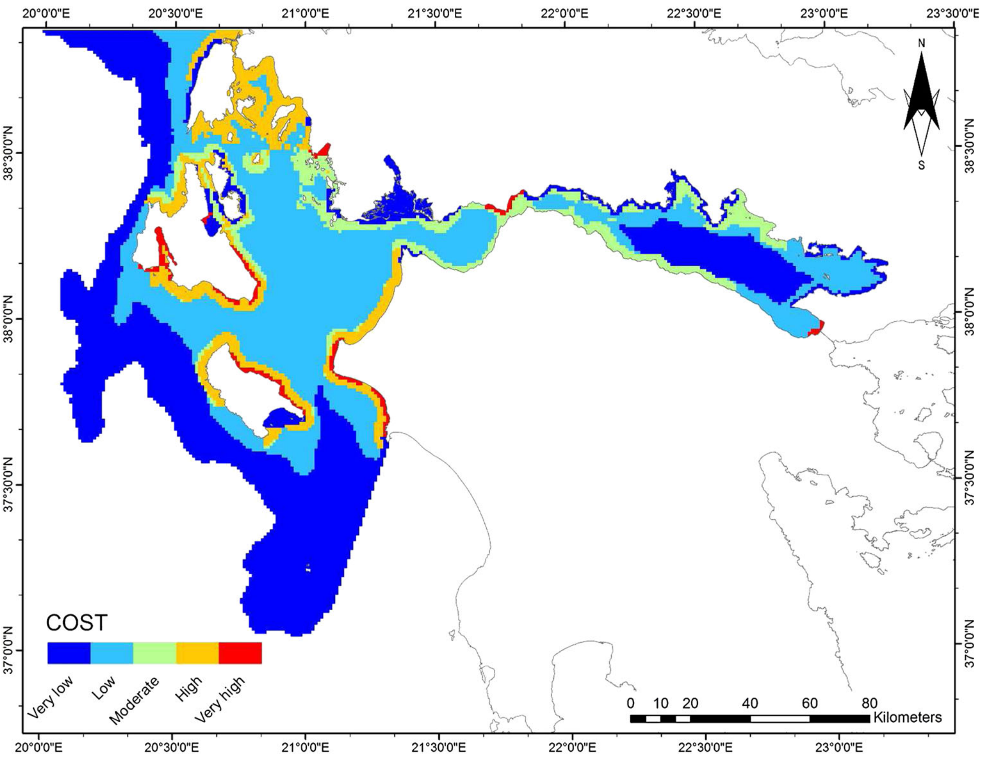

Figure 5. Combined cost of planning units. Planning units of lower cost (defined by the function: $C_i = \text{Max}[0.0062Tr_i + 0.0194Ps_i + 0.0662Cf_i + 0.9082T_i, 0]$) are illustrated in cold colours (dark and light blue) while those of higher cost appear in warm colours (orange and red).

to achieve the goals set for the conservation features included in the analysis. Some features remained unrepresented, as they were totally absent from Natura 2000 sites. The way Natura 2000 sites were designated gives a possible explanation for this shortcoming. The majority of the marine Natura 2000 sites in the study area were designated as extensions of terrestrial sites. The selection of marine sites was based on (a) the presence of a limited number and inadequately defined habitat types in the relevant Annex I of the Habitats Directive: sandbanks which are slightly covered by sea water all the time (1110), *Posidonia* beds (1120), estuaries (1130), mudflats and sandflats not covered by seawater at low tide (1140), coastal lagoons (1150), large shallow inlets and bays (1160), reefs (1170), submarine structures made by leaking gases (1180), submerged or partially submerged sea caves (8330) and (b) the presence of a limited number of species (18 in total; 10 relevant for the Mediterranean Sea) among which are the bottlenose dolphin (*T. truncatus*), the Mediterranean monk seal (*M. monachus*) and the loggerhead turtle (*C. caretta*) (European Commission, 2007). In Greece, the main criteria upon which the extension of a terrestrial site to the marine environment depended, were the presence of the endemic seagrass *Posidonia oceanica* and coastal lagoons (habitat types 1120 and 1150). Experts, considering often outdated and inadequate data, indicated which areas should be incorporated into the Natura 2000 network. In the present study area, only two sites, the 'Inner Ionian Archipelago' (between the islands of Lefkada and Ithaca, and mainland Greece) and the 'Western Coasts of Kefallinia', were selected for the conservation of marine mammals as well (more specifically *M. monachus* and *T. truncatus*), and only one site on the island of Zakynthos for the conservation of the loggerhead turtle.

The poor representation of offshore habitats and species in the study area is due to the very broad marine habitat categories of the Habitats Directive and to the consideration of only coastal habitats by the Greek government in defining Sites of Community Importance (SCIs). For example, habitat type 1170 (reefs) includes a variety of shallow and deep habitats such as mussel beds, mixed faunal turf communities on shallow rocky reefs, communities on soft circalittoral rock, coralligenous communities, hydrothermal vents, sea mounts, vertical rock walls, overhangs, pinnacles, ridges, broken rock and boulder and cobble fields, and many more. Hence, based on the initial general guidelines for the establishment of the Natura 2000 network in the marine environment, a site with only one of these habitats and a site of equal area with all the above habitats would be of equal value for satisfying the national obligations for the Habitats Directive. In general, according to the report of IUCN, WWF, and MedPAN on the status of the MPAs in the Mediterranean Sea, very few Natura 2000 sites have been identified offshore and this is considered the most important gap in the current Natura 2000 network (Abdulla *et al.*, 2008). Classifications of marine habitats are biased in favour of shallow habitats, because of gaps in knowledge on deep-sea environments (Fraschetti *et al.*, 2008). For all these reasons, many rare or vulnerable habitats (e.g. deep-sea hydrothermal vents, cold-water coral carbonate mounds, Mediterranean coralligenous communities) are insufficiently represented in the Natura 2000 network (Salomidi *et al.*, 2012).

Furthermore, cetacean species such as the sperm whale or the short-beaked common dolphin, which are endangered at the national level (Legakis and Maragkou, 2009) and are or have been proposed as regionally endangered by IUCN and ACCOBAMS (Bearzi, 2003; Notarbartolo di Sciara and Reeves, 2006) in the Mediterranean Sea, are absent from the relevant Annex II of the Habitats Directive (species whose conservation requires the designation of special conservation areas). This absence prevents the authorities from creating marine Natura 2000 sites based on hotspots or critical areas for these species and makes the update of Annex II a conservation priority. It is worth mentioning that the Hellenic Trench (part of which is the western study area) has been adopted by the 3rd Meeting of the Parties of ACCOBAMS as the only, so far, area of special importance and proposed MPA for Mediterranean sperm whales since 2007 (Anonymous, 2007). This area constitutes the core of the sperm whale habitat in the entire eastern Mediterranean basin, and the only well known calving and nursery ground (Frantzis *et al.*, 2003) for a population which is listed as 'Endangered' by the IUCN. These characteristics make it an appropriate area for the establishment of a pelagic MPA, such as the pelagic Great Australian Bight Marine Park which has also been created mainly for marine mammal conservation (Game *et al.*, 2009).

This study provides evidence that systematic conservation planning may represent a powerful tool for the implementation of marine conservation planning in the European Seas in the context of ecosystem-based marine spatial management. In May 2011, the European Commission adopted a new strategy to halt the loss of biodiversity and ecosystem services in the EU by 2020 (European Commission, 2011). Systematic conservation planning provides a conceptual framework for the allocation of limited conservation resources to minimize the loss of biodiversity and ecosystem services (Margules and Pressey, 2000). Decision-support software applying the principles of systematic conservation planning have been widely used (e.g. Airamé *et al.*, 2003; Fernandes *et al.*, 2005) and their potential is continuously expanding (Moilanen *et al.*, 2009). Explicitly, taking into account quantitative data on the spatial distribution of biodiversity and human activities, optimization algorithms can lead to the identification of coastal and offshore priority areas for conservation with minimum cost (Ball *et al.*, 2009). The Habitats and Birds Directives and the associated guidelines for their implementation set targets and obligations, leaving the methods for the selection and management of sites to the individual Member States. Systematic conservation planning could be used to identify new priority areas for conservation complementary to the existing Natura 2000 sites or aid the zoning of the existing ones using new prioritization software, e.g. Marxan with zones (Watts *et al.*, 2009), which allows any marine area to be allocated to a specific management zone, not just reserved or unreserved. Furthermore, the combination of adaptive management and systematic conservation planning would greatly improve the effectiveness of the Natura 2000 network, by allowing revisions of boundaries of the planning region, refinement of conservation goals, and the selection of additional conservation areas when new biodiversity and/or socio-economic data are collected.

Using systematic conservation principles within the framework of European conservation policy would not reject or substitute experts' opinions but embrace them (Cowling *et al.*, 2003; Knight and Cowling, 2007; Pressey and Bottrill, 2008). Experts' opinion can be valuable throughout the planning process filling data gaps. The outcome of the prioritization analysis should be submitted to the critical eye of the expert who will be given the opportunity to comment, intervene and amend the initial plan (Fernandes *et al.*, 2005). Local stakeholders should also be involved from the start in the conservation planning procedure through consultation and consideration of socio-economic aspects (Cowling and Pressey, 2003). Then, the output of the prioritization scheme should be presented to stakeholders for plan evaluation and modification. Contemporary computational tools, such as Marxan, help the user to modify the original output providing information at every step about how much of the conservation goal is achieved. The initial outcome of the systematic analysis provides a basis on which different actors can contribute (Klein *et al.*, 2008). Furthermore, systematic conservation planning can embrace 'informed opportunism' which considers the real-world conservation opportunities and at the same time recognizes the trade-offs involved (Pressey and Bottrill, 2008). This issue is particularly important in human-dominated environments such as the European Union and its marine environment, where multiple human uses, pressures, and conservation initiatives are in conflict (Coll *et al.*, 2012).

Future systematic approaches could be applied at various spatial scales: local, national, regional (bio-geographical regions), and European. Kark *et al.* (2009) found that planning for the protection of terrestrial ecosystems in the Mediterranean Basin as a single integrated entity (fully coordinated solution) delivers a significantly more efficient conservation outcome than separate plans for each country. The same efficiency is obtained when a partly coordinated solution is generated incorporating only EU-Mediterranean countries. This may also be true for marine systems. However, in broad-scale planning schemes, the biodiversity of all bio-geographical regions of the Mediterranean Sea should be represented. In such planning schemes, multiple human uses should be considered. Spatial distributions of bio-physical data and pressures from land use (e.g. agriculture), extraction of living resources (e.g. fishing), tourism, energy infrastructure and maritime activities should be integrated into a systematic analysis facilitating ecosystem-based marine spatial management.

The Natura 2000 network, despite its drawbacks, is a good starting point towards the effective conservation of the marine ecosystems by creating coherent and representative networks of MPAs. However, to achieve this there is a strong need for substantial reform of the Natura 2000 network, both in terms of design principles and adaptive management. Designation of Natura sites has been based on a restricted number of species and a few very broad habitat types, which has actually left out a large number of endangered species and sensitive habitats. The Annexes I and II of the Habitats Directive need to be updated and expanded. Including cost considerations through a systematic conservation planning approach would enhance social acceptance and efficiency of the Natura 2000 network. Applying adaptive management principles would allow the Natura 2000 network to be flexible to revisions, based on new information, improved prioritization, and adaptation to a changing environment.

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