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Marine Protected Areas in the Mediterranean Sea: Objectives, Effectiveness and Monitoring

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With 1 table

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Abstract. The number of Marine Protected Areas (MPAs) is continuously increasing worldwide because of the increasing recognition of the profound effects that humans can have on marine systems. A large body of literature deals with marine reserves and their potential as conservation and management tools. In several cases, empirical evidence demonstrated that reserves can harbour greater diversity, higher abundance, and larger organisms than unprotected areas. In most cases, however, reserve design and site selection involved little scientific justification, with no direct test of most of the mechanisms assumed to work in a marine reserve. Field investigations of subtidal marine reserves are generally confounded by intrinsic ecological differences between sites investigated inside and outside reserves, by a lack of site and reserve replication, or by the absence of information about the biota before reserve establishment. This is particularly true in the Mediterranean Sea. The aim of this paper is to show that, at least in the Mediterranean basin, the effectiveness of MPAs has been rarely demonstrated because of lack of appropriate sampling designs. An MPA can be considered as a zone subjected to human impact, presumably a positive one. As a consequence, we propose the use of experimental procedures generally utilised for detecting environmental impacts.

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Problem

Over the past thirty years, Marine Protected Areas (MPAs) have become a highly advocated form of marine conservation and management all over the world (Dee Boersma & Parrish, 1999; Hixon *et al.*, 2001). The concept of MPA is being applied very differently in many countries, and includes a wide variety of management schemes. This spatially explicit approach to managing human impacts has many potential ecological and socio-economic benefits, but these are still far from being quantitatively understood (Palumbi, 2001). The siting and design of MPAs is frequently based on opportunity more than on ecological criteria and information, and evaluation of reserve effectiveness often produces equivocal and sometimes contradictory evidence about the ecological consequence of protection (Lasiak, 1999; Garcia Charton & Pérez-Ruzafa, 1999). Therefore, a large body of literature has focused on marine reserves, but our knowledge of the effects of protection remains limited (Planes *et al.*, 2000). Complex processes, such as reproduction, recruitment, dispersal and survivorship of populations have seldom been quantitatively investigated in the context of marine reserves. General understanding of these ecological processes is at a very early stage, making their application at improving reserve design and management even more challenging (Polunin & Roberts, 1993; Allison *et al.*, 1998).

One difficulty in quantifying MPA effectiveness is that reserves generally lack clearly defined objectives, or have multiple, and sometimes conflicting, objectives. Rarely is there a single reason for reserve designation. The existence of conflicting objectives (e. g. ecosystem conservation, fisheries enhancement, ecotourism) often hides strong compromise dictated by the socio-economic reality of the area (Carr, 2000). Accordingly, it is very difficult to test the efficacy of poorly defined aims of protection.

The difficulties in measuring reserve effectiveness should be overcome by appropriate sampling designs, distinguishing between the influence of management and the intrinsic natural variability of ecological systems due to factors other than protection. Comparing protected with unprotected areas should provide a better understanding of the effects of human activities in coastal marine environments, above and beyond the natural variation that is likely to exist among apparently similar habitats.

To date, 33 MPAs have been established in the Mediterranean, and there is a general interest in establishing additional networks of MPAs (Cognetti, 1993; Ramos Esplà & McNeill, 1994; Badalamenti *et al.*, 2000). The aims of this paper are to:

- provide evidence that studies evaluating the effectiveness of Mediterranean MPAs largely used sampling designs that cannot separate the effects of natural variation from those of protection;
- suggest the use of experimental designs developed for the detection of environmental impact as a tool to test the effectiveness of MPAs.

Effects of protection in Mediterranean MPAs

The lack of knowledge about the effectiveness of MPAs is particularly evident for the Mediterranean Sea, notwithstanding the increasing interest in monitoring the biological and socio-economic outcomes of protection measures (Goñi *et al.*, 1998). Studies mainly focused on rocky-littoral fish assemblages although some have centred on species assemblages associated with seagrass ecosystems (Sanchez Lizaso & Ramos Espla, 1994). Prohibiting fishing within MPAs produces an increase in abundance and biomass of target fish species, with a shift towards bigger and older individuals in previously exploited populations (Bell, 1983; Garcia Rubies & Zabala, 1990; Francour, 1991; Francour, 1994; Dufour *et al.*, 1995; Harmelin *et al.*, 1995; Goñi *et al.*, 1998). Even among target fish species, however, the pattern of greater density within MPAs is not universal, and several exceptions exist (reviewed by Boudouresque *et al.*, 1992; and Garcia Charton *et al.*, 2000). Other aspects remain unclear. Compensatory density-dependent processes, potentially involving changes in biological variables (reduced growth, increased mortality or lower reproductive success) have been rarely compared between protected *vs.* exploited areas (Macpherson *et al.*, 1997; Planes *et al.*, 2000; Sánchez Lizaso *et al.*, 2000).

Outside the Mediterranean, there is some evidence of significant change in fishery yields around MPAs (Russ & Alcala, 1996). In the Mediterranean, however, it is still unclear whether the export of adults reflects an increase in population size inside the protected area and concomitant density-dependent emigration from the reserve, or simply a re-arrangement of the spatial distribution of the populations. The effects of protection on species recruitment within MPAs have proved difficult to assess (Bayle Sempere *et al.*, 1994; Planes *et al.*, 2000) and the hypothesis that MPAs serve as propagule sources for surrounding areas is still very poorly tested (Manríquez & Castilla, 2001).

The substantial spatial and temporal variations in fish populations, furthermore, have rarely been considered and explicitly incorporated into sampling schemes to evaluate reserve effects. When quantification of the natural pattern of spatio-temporal variability in populations across different locations is lacking (Garcia Charton & Pérèz Ruzafa, 1999; Garcia Charton *et al.*, 2000), it is difficult to compare protected and unprotected areas to determine what component of variation can be attributed to protection alone (Bell, 1983; Harmelin, 1990; Harmelin, 1997).

At the assemblage level, there is little evidence for effects of MPAs on diversity and/or species richness in the Mediterranean. Only few studies have explicitly examined this aspect, finding no significant differences between protected and unprotected areas (Bell, 1983; Harmelin *et al.*, 1995; Garcia Charton *et al.*, 2000).

Most information on the effects of MPAs is on fish. Few studies have addressed the effects of protection on benthic species, most data deriving from work on trophic cascades, where benthos is hypothesized to be influenced by protection through trophic interactions with carnivorous fish (Boudouresque *et al.*, 1992; Sala & Zabala, 1996; Sala, 1997; Sala *et al.*, 1998; Badalamenti *et al.*, 1999; Chemello *et al.*, 1999; Pinnegar *et al.*, 2000). Studies of trophic cascades propose that Mediterranean shallow rocky sublittoral assemblages exist in one or two states. One state is due to sea urchin (*Paracentrotus lividus* and *Arbacia lixula*) overgrazing, leading to "barrens" with low algal biomass, dominated by encrusting calcified rhodophytes. In the other state, assemblages are dominated by erect algae and have low urchin abundances (fleshy erect algae communities) (McClanahan & Sala, 1997). These alternate states have been linked to differences in fishing pressure, influencing the abundance and size structure of carnivorous fish and, thus, their impact on lower tropic levels (reviewed by Pinnegar *et al.*, 2000). For example, in the MPA of the Medes Islands (Spain), increased abundance and size of predatory fish at two sites within the reserve was accompanied by a decrease in the abundance of sea urchins, with greater cover of erect algae compared to an adjacent, unprotected area (Sala & Zabala, 1996). These results should be considered with caution because only one control site was sampled. Moreover, long-term monitoring of sea urchin populations within and outside the MPA showed high year-to-year variation, suggesting that factors other than fish predation underlie sea urchin abundances in this system (Sala *et al.*, 1998). Long-term monitoring and consideration of alternative models are thus clearly needed to determine whether trophic cascades actually influence Mediterranean rocky sublittoral assemblages.

The studies carried out at Scandola (France) (Boudouresque *et al.*, 1992; Francour, 1994) and Ustica (Italy) (Milazzo *et al.*, 2000) are the only ones that evaluated "reserve effects" on macrozoobenthic species in Mediterranean MPAs. Their conclusions, however, may be influenced by low site replication. The two reserve systems, in fact, showed opposite responses to protection. At Scandola, the large macrozoobenthos had lower abundance and species richness in the totally protected part of the reserve than in the adjacent, partially protected sites, in agreement with the trophic-cascade hypothesis that greater predator abundances within the reserve may control invertebrate populations. Conversely, at Ustica, significantly greater abundances and species richness were documented for both polychaetes and molluscs in the totally protected part of the reserve than in adjacent, partially-protected sites (Badalamenti *et al.*, 1999; Milazzo *et al.*, 2000). Also in this case, however, the authors propose a trophic cascade mechanism, with greater top predator abundances leading to lower abundances of the small fish commonly feeding on benthic molluscs and polychaetes.

Experimental designs: the logic of environmental impact studies

The above overview shows that, in the Mediterranean, knowledge of the ecological effects of MPAs is largely based on studies of fish communities, providing only a partial evaluation of reserve effects. In the area of ecology dealing with fisheries, many studies lack rigorous analysis of explicitly stated hypotheses, so that conclusions are often indefensible. In contrast, experimental ecology has strongly influenced the field of environmental assessment, and considerable work has been done to improve the structure, logic, and analytical procedures for detecting environmental impacts (Green, 1979; Underwood, 1996). Monitoring programmes to determine the putative negative effects of some human activities (marinas, sewage outflows, power plants) on benthic populations and assemblages commonly use these approaches (Underwood, 1993).

A wide array of environmental impacts can be detected using the 'beyond-BACI' (Before and After Control Impact) sampling designs (Underwood, 1994). Beyond-BACI designs are based on the contrast between one or more putatively impacted sites with multiple control sites, before and after the impact occurred. Considering protection as a positive impact (Jones *et al.*, 1992; Garcia Charton & Pérèz Ruzafa, 1999), similar experimental designs can be used, comparing one or more protected area with multiple control sites, before and after MPA institution. With these procedures, the effect of protection can be identified and distinguished from variation falling in the range of natural variability. Hierarchical sampling designs, aimed at measuring spatial and temporal variability at a variety of scales, are advisable. This procedure allows the additive partitioning of variability among different scales and to identify the scale that contributes the most to the total variation. The choice of nested designs is also advisable when the spatial extent of the protected population is unknown. Sampling frequency, often arbitrarily chosen (e. g., monthly or seasonal), is important for detecting variability at different temporal scales (Underwood, 1993). In some cases, in fact, a single seasonal sampling (even if conducted at many replicate sampling locations) can generate false trends, where short-term variability can create or blur among-season differences. A more appropriate alternative is to randomly choose multiple sampling dates (the same for all locations) for each season. When estimates of spatial and temporal variance of populations are obtained at different scales, modelling procedures can be used to optimise future sampling designs so that specified effects can be detected with *a priori* defined probabilities of Type I and Type II errors (Benedetti-Cecchi, 2001).

When no data are available before the establishment of an MPA, the original BACI design should be modified so as to compare the protected and unprotected areas after MPA institution ('ACI', After Control Impact, Glasby, 1997) (see also Box 1 and Table 1). However, these designs cannot distinguish between pre-existing differences, associated for example with the siting of MPAs in areas with specific characteristics, and changes caused by the protection regime. Controls must be chosen randomly from a set of similar locations, but natural variability makes it almost impossible that any control site is truly comparable with the protected one. Furthermore, since MPAs are often chosen for their unique characteristics (e. g. species composition, habitat features), the choice of controls can be very difficult. The choice of controls, however, is crucial and deserves careful consideration, as monitoring will provide direct causal evidence only with suitable controls.

According to Underwood (1992) and Chapman *et al.* (1995), control locations must be unaffected by protection and have the same type of assemblages and similar habitat features to those of the potentially impacted area (the MPA). Furthermore, they should be chosen over a spatial scale covering the dispersal range of the sampled populations, or range from local to regional distributions when the scales of protection effects and organism dispersal are unknown. The study has to be long enough to allow separation between short-term variability and long-term trends (Menge, 1997; Garcia Charton & Pérèz Ruzafa, 1999).

The choice of the most appropriate analytical tools is still much debated. Besides the use of the Analysis of Variance and more specifically asymmetrical ANOVA, the use of multivariate approaches in environmental impact studies has been stressed by Clarke (1993) and by Clarke & Warwick (1994). Some environmental impact studies benefited from a combination of univariate and multivariate approaches (Chapman *et al.*, 1995; Roberts *et al.*, 1998), but the most appropriate analyses are largely determined by the specific predictions about reserve effects, which in turn are determined by reserve objectives (see below). The use of different analyses makes it more likely to detect effects on different components of the assemblage (Underwood & Peterson, 1988; Warwick, 1993). These two approaches can be used to complement each other, although there may be differences in the optimal allocation of sampling units required by the different designs.

In a review of 30 papers, as a subsample of the literature on reserve effects in the Mediterranean, we found that only ten papers included more than one control to test the efficacy of the protection measures (Garcia & Zabala, 1990; Francour, 1993; 1994; 1996; La Mesa & Vacchi, 1999; Macpherson *et al.*, 1997; Sala *et al.*, 1998; Vacchi *et al.*, 1998; Vigliola *et al.*, 1998; Vacchi *et al.*, 1999). In addition, a lack of "before data" is particularly evident: only in one case was monitoring conducted before the implementation of a fishing ban in the Gulf of Castellamare, Sicily (Pipitone *et al.*, 2000), but without any control site outside the protected area. The widespread use of sampling designs with inadequate or no replication in space and time likely underlies the absence of clear evidence about reserve effects.

Perspective

Mediterranean MPAs vary widely in their intrinsic, jurisdictional, management and enforcement features (Harmelin, 2000). However, a common trait is their siting in shallow rocky areas. Thus, hard bottom subtidal benthic assemblages can be the ideal target for

Box 1. Sampling design for evaluating the "reserve effects" on benthic species of hard substrates of a hypothetical MPA. The interpretation of the analysis is oversimplified. Further details can be found in Underwood (1993) and Glasby (1997). The tested hypothesis is that protection results in a change in mean abundance and/or spatial and temporal variance of a given species. The design considers a putatively impacted location (the protected area) and a number of randomly selected control locations (see text for criteria in choosing controls). Replicate sites are randomly selected at each location and replicate units are sampled within each site (the size of the sampling unit should be chosen on the basis of the size and spatial arrangement of the species studied, see Benedetti-Cecchi et al., 1996). Sampling is repeated a number of times chosen at random during the period of study. The levels of the various sources of variation (number of sampling units, sites, locations and times of sampling) will vary from study to study and should be based on considerations of optimal sampling design. The example considers that no data on the abundance of the species before the protection within and outside the MPA are available. Two different analyses of variance are performed with the collected data. First, the complete data set associated with impacted and control locations is analysed using a multifactorial model with sites nested within locations and time random and orthogonal to both sites and locations. Second, the analysis is repeated using only data of the controls. The asymmetrical components (i. e. Impact *vs.* Controls and its interaction with time) are then calculated by subtracting the sum of squares (SS) of the second analysis from those of the first analysis (Table 1). Mean squares are then calculated by dividing these SS by the appropriate number of degrees of freedom (df).

Table 1. Example of analysis of variance comparing one protected area (*P*) with control (*Cs*) locations; t = number of sampling times, l = number of locations (including the protected area), s = number of sites and n = number of replicate units.

Source of Variation	*df*	*SS*	*MS*	*F versus*	
Time = T	t-1	SS_T	MS_T		
Locations = L	l-1	SS_L	MS_L		
Cs	l-2	SS_{Cs}	MS_{Cs}	MS_{TxCs}	
P vs. Cs	1	SS_L-SS_{Cs}	$MS_{(P\ vs.\ Cs)}$		$MS_{Cs}{}^{F}$ $MS_{Residual}{}^{E}$
Sites (L) = S(L)	l(s-1)	$SS_{S(L)}$	$MS_{S(L)}$	$MS_{T\ x\ S(L)}$	
Sites (Cs) = S(Cs)	(l-1)(s-1)	$SS_{S(Cs)}$	$MS_{S(Cs)}$	$MS_{T\ x\ S(Cs)}{}^{D}$	
Sites (P) = S(P)	s-1	$SS_{S(L)}$-$SS_{S(Cs)}$	$MS_{S(P)}$	$MS_{T\ x\ S(P)}{}^{D}$	
T x L	(t-1)(l-1)	$SS_{T\ x\ L}$	$MS_{T\ x\ L}$	$MS_{T\ x\ S(L)}$	
T x Cs	(t-1)(l-2)	$SS_{T\ x\ Cs}$	$MS_{T\ x\ Cs}$	$MS_{T\ x\ S(Cs)}$	
T x P vs. Cs	t-1	$SS_{T\ x\ L}$-$SS_{T\ x\ Cs}$	$MS_{T\ x\ (P\ vs.\ Cs)}$		$MS_{T\ x\ Cs}{}^{C}$ $MS_{Residual}{}^{B}$
T x S(L)	(t-1) l(s-1)	$SS_{T\ x\ S(L)}$	$MS_{T\ x\ S(L)}$	$MS_{Residual}$	
T x S(Cs)	(t-1)(l-1)(s-1)	$SS_{T\ x\ S(Cs)}$	$MS_{T\ x\ S(Cs)}$	$MS_{Residual}{}^{A}$	
T x S(P)	(t-1)(s-1)	$SS_{T\ x\ S(L)}$-$SS_{T\ x\ S(Cs)}$	$MS_{T\ x\ S(P)}$	$MS_{Residual}{}^{A}$	
Residual	tls(n-1)	$SS_{Residual}$	$MS_{Residual}$		

[A] If terms *T x S(Cs)* and *T x S(P)* are both significant, or not significant, a 2-tail *F* ratio on variance components of these terms can be used to test for differences between the protected area and the controls in space x time interactions at the scale of sites. If one of these terms is significant and the other is not, then there is already evidence of differences between the protected area and the control locations.
[B] If both *T x Cs* and *T x S(L)* can be pooled or eliminated (this requires that the probability associated with these tests is > 0.25, Underwood 1997).
[C] If the term *T x Cs* cannot be pooled or eliminated.
[D] These tests are done only if there is no evidence of protection in the form of temporal interactivity at the scale of sites. If this condition is verified, and if *S(Cs)* and *S(P)* are both significant, or not significant, a 2-tail *F* ratio on variance components of these terms can be used to test for differences between the protected area and the controls in spatial variation at the scale of sites.
[E] If the terms *Cs, S(L), T x L* and *T x S(L)* can be pooled or eliminated and if there is no evidence of protection in the form of temporal interactivity at the scale of locations.
[F] If the term *Cs* cannot be pooled or eliminated and if there is no evidence of protection in the form of temporal interactivity at the scale of locations.

studying and implementing MPAs. Shallow marine assemblages (up to 10 metres depth) can be considered as good indicators of environmental changes because species living at shallow depths are particularly exposed to impacts from coastal activities and thus tend to exhibit stronger responses to human pressure than assemblages from deeper habitats. Moreover, sessile organisms can be easily monitored and manipulated, and in the last years several papers have been published on the spatio-temporal variability of Mediterranean benthic assemblages (Menconi *et al.*, 1999; Fraschetti *et al.*, 2001).

Non-destructive sampling can be conducted using visual censuses or photographic techniques. For example, Roberts *et al.* (1994) compared photographic and direct sampling by visual inspection of temperate rocky reef communities, and found that these two methods had similar efficacy. Photographic methods also provide an objective sample (the picture) that can be analysed by many researchers and stored for future reference and analyses. Furthermore, pictures can be taken also by non-specialists, a feature that makes photographic sampling particularly appropriate over broad-scales.

Conclusions

There is an urgent need to understand the importance of rigorous sampling designs in conservation. At present, the lack of detailed and scientifically defensible knowledge regarding the effects of reserves makes the evaluation of their effectiveness within the reserve very difficult, and predictions about the expected effects uncertain. Moreover, Mediterranean MPAs greatly vary in their physical and biological characteristics as well as in the socio-economic context influencing their design and management, making it unlikely that a single study design will be applicable to all these different scenarios. It is possible, however, to identify the logical structure that should guide the design and interpretation of what might be defined as experimental monitoring studies.

First, reserve goals have to be explicitly defined in order to develop specific predictions about the expected effects. Second, sampling should quantify variation in populations and assemblages and tease apart natural variability from that caused by protection. Studies should include multiple control locations, describe long-term trends, and include descriptions of the system before reserve establishment. Studying hard bottom benthic assemblages in MPAs and adjacent unprotected areas with similar characteristics may represent a rapid, cost-effective and widely applicable means of evaluating protection effects. This is a unique opportunity to investigate natural variability in marine ecosystems over broad spatial scales, potentially encompassing the whole Mediterranean basin if experimental monitoring networks are established.

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References

Allison, G. W., J. Lubchenco & M. H. Carr, 1998: Marine reserves are necessary but not sufficient for marine conservation. Ecol. Appl., **8**: 79–92.

Badalamenti, F., G. Cantone, R. Domina, N. Di Pietro, D. Catalano, E. Mollica & G. D'Anna, 1999: Primi dati sulla fauna a policheti di substrato duro dell'infralitorale fotofilo superiore dell'Isola di Ustica. Biol. Mar. Medit., **6**: 230–236.

Badalamenti, F., A. A. Ramos, E. Voultsiadou, J. L. Sanchez Lizaso, G. D'Anna, C. Pipitone, J. Mas, J. A. Ruiz Fernandez, D. Whitmarsh & S. Riggio, 2000: Cultural and socio-economic impacts of Mediterranean marine protected areas. Environ. Conserv., **27**: 110–125.

Bayle-Sempere, J. T., A. A. Ramos Esplà & J. A. García Charton, 1994: Intra-annual variability of an artificial reef fish assemblage in the marine reserve of Tabarca (Alicante, Spain, SW Mediterranean). Bull. Mar. Sci., **55**: 824–835.

Bell, J. D., 1983: Effects of depth and marine reserve fishing restrictions on the structure of a rocky reef fish assemblage in the northwestern Mediterranean Sea. J. Appl. Ecol., **20**: 357–369.

Benedetti-Cecchi, L., 2001: Beyond BACI: optimization of environmental sampling designs through monitoring and simulation. Ecol. Appl., **11**: 783–799.

Benedetti-Cecchi, L., L. Airoldi, M. Abbiati, & F. Cinelli, 1996: Estimating the abundance of benthic invertebrates: a comparison of procedures and variability between observers. Mar. Ecol. Prog. Ser., **138**: 93–101.

Boersma, P. D. & J. K. Parrish, 1999: Limiting abuse: marine protected areas, a limiting solution. Ecol. Econ., **31**: 287-304.

Boudouresque, C. F., A. Caltagirone, J. R. Lefevre, V. Rico & R. Semroud, 1992: Macroozoobenthos de la Réserve Naturelle de de Scandola (Corse, Méditerranée nord-occidental). Analyse pluriannuelle de l'effet réserve. In: J. Olivier, N. Gerardin & A. Jeudy De Grissac (Eds.), Economic impacts of the Mediterranean coastal protected areas. Medpan News, Ajaccio: 15–20.

Carr, M. H., 2000: Marine Protected Areas: Challenges and opportunities for understanding and conserving coastal marine ecosystems. Environ. Conserv., **27**: 106–109.

Chapman, M. G., A. J. Underwood & G. A. Skilleter, 1995: Variability at different spatial scales between a subtidal assemblage exposed to the discharge of sewage and two control assemblages. J. Exp. Mar. Biol. Ecol., **189**: 103–122.

Chemello, R., M. Milazzo, E. Nasta, & S. Riggio, 1999: Studio della Malacofauna di alghe fotofile nella riserva marina "Isola di Ustica" (Sicilia Settentrionale). Biol. Mar. Medit., **6**: 247–249.

Clarke, K. R., 1993: Non-parametric multivariate analysis of changes in community structure. Aust. J. Ecol., **18**: 117–143.

Clarke, K. R. & R. M. Warwick, 1994: Change in marine communities: an approach to statistical analysis and interpretation. Natural Environment Research Council, Plymouth, U. K.

Cognetti, G., 1993: Transboundary marine parks in the Mediterranean. Mar. Pollut. Bull., **26**: 292–293.

Dufour, V., J. Y. Jouvenel & R. Galzin, 1995: Study of a Mediterranean reef fish assemblage. Comparisons of population distributions between depths in protected and unprotected areas over one decade. Aquat. Living Resour., **8**: 17–25.

Francour, P., 1991: The effect of protection level on a coastal fish community at Scandola, Corsica. Rev. Ecol.-Terre Vie, **46**: 65–81.

Francour, P., 1993: Ichthyofauna of the natural reserve of Scandola (Corsica, northwestern Mediterranean): Analysis of the pluriannian reserve effect. Mar. Life, **3**: 83–93.

Francour, P., 1994: Pluriannual analysis of the reserve effect on ichthyofauna in the Scandola natural reserve (Corsica, Northwestern Mediterranean). Oceanol. Acta, **17**: 309–317.

Francour, P., 1996: Ichthyofauna of *Posidonia oceanica* seagrass beds in Scandola Marine (Corsica, northwestern Mediterranean Sea): Reserve effect. J. Rech. Oceanogr., **21**: 29–34.

Fraschetti, S., C. N. Bianchi, A. Terlizzi, G. Fanelli, C. Morri & F. Boero, 2001: Spatial variability and human disturbance in shallow subtidal hard substrate assemblages: a regional approach. Mar. Ecol. Prog. Ser., **212**: 1–12.

García Charton, J. A. & A. Perez-Ruzafa, 1999: Ecological heterogeneity and the evaluation of the effects of marine reserves. Fish. Res., **42**: 1–20.

García Charton, J. A., I. D. Williams, A. Pérez Ruzafa, M. Milazzo, R. Chemello, C. Marcos, M.-S. Kitsos, A. Koukouras & S. Riggio, 2000: Evaluating the ecological effects of Mediterranean marine protected areas: habitat, scale and the natural variability of ecosystems. Environ. Conserv., **27**: 159–178.

García-Rubies, A. & M. Zabala, 1990: Effects of total fishing prohibition on the rocky fish assemblages of Medes Islands marine reserve (Northwest Mediterranean). Sci. Mar., **54**: 317–328.

Glasby, T. M., 1997: Analyzing data from post-impact studies using Asymmetrical Analyses of Variance: A case study of epibiota on marinas. Aust. J. Ecol., **22**: 448–459.

Goñi, R., A. Ramos Esplà, M. Zabala, S. Planes, A. Perez-Ruzafa, P. Francour, F. Badalamenti, N. V. C. Polunin, R. Chemello & E. Voultsiadou, 1998: Ecological effects of protection in Mediterranean marine reserves (Ecomare). In: K. G. Barthel, H. Barth, M. Bohle-Carbonell, C. Fragakis, E. Lipiatou, P. Martin, G. Ollier & M. Weydert (Eds.), Project synopses, vol. 1. Luxembourg: 139–150.

Green, R. H., 1979: Sampling design and statistical methods for environmental biologists. Wiley, Chichester; 257 pp.

Harmelin, J. G., 1990: Ichtyofaune des fonds rocheux de Méditerranée: structure du peuplement du coralligène de l'île de Port-Cros (Parc national, France). Mésogée, **50**: 23–30.

Harmelin, J. G., 1997: Structure et variabilité de l'ichtyofaune d'une zone rocheuse protégée en Mediterranée (Parc national de Port-Cros, France). P.S.Z.N. I: Mar. Ecol., **8**: 263–284.

Harmelin, J. G., 2000: Mediterranean marine protected areas: some prominent traits and promising trends. Environ. Conserv., **27** (2): 104–105.

Harmelin, J. G., F. Bachet & F. Garcia, 1995: Mediterranean marine reserves: Fish indices as tests of protection efficiency. P.S.Z.N. I: Mar. Ecol., **16**: 233–250.

Hixon, M. A., P. D. Boersma, M. L. Jr Hunter, F. Micheli, E. A. Norse, H. P. Possingham & P. V. R. Snelgrove, 2001: Ocean at risk: research priorities in marine conservation biology. In: Conservation Biology: Research Priorities for the Next Decade, M. E. Soulé & G. H. Orians (Eds.), Island Press, Washington, D. C.

Jones, G. P., R. C. Cole & C. N. Battershill, 1992: Marine reserves: do they work? In: Proceedings of the Second International Temperate Reef Symposium, 7–10 January 1992, Auckland, New Zealand, C. N. Battershill, D. R. Schiel, G. P. Jones, R. G. Creese & A. B. Macdiarmid (Eds.), NIWA Marine: 29–45.

Lasiak, T., 1999: The putative impact of exploitation on rocky infratidal macrofaunal assemblage: a multiple-area comparison. J. Mar. Biol. Assoc. UK, **79**: 23–34.

La Mesa, G. & M. Vacchi, 1999: An analysis of the coastal fish assemblage of the Ustica Island Marine Reserve (Mediterranean Sea). P.S.Z.N. I: Mar. Ecol., **20**: 147–165.

Macpherson, E., F. Biagi, P. Francour, A. Garcia-Rubies, J. G. Harmelin, M. Harmelin-Vivien, J. Y. Jouvenel, S. Planes, L. Vigliola & L. Tunesi, 1997: Mortality of juvenile fishes of the genus *Diplodus* in protected and unprotected areas in the western Mediterranean Sea. Mar. Ecol. Prog. Ser., **160**: 135–147.

Manríquez, P. H. & J. C. Castilla, 2001: Significance of marine protected areas in central Chile as seeding grounds for the gastropods *Concholepas concholepas*. Mar. Ecol. Prog. Ser., **215**: 201–211.

McClanahan, T. R. & E. Sala, 1997: A Mediterranean rocky-bottom ecosystem fisheries model. Ecol. Model., **104**: 145–164.

Menconi, M., L. Benedetti-Cecchi & F. Cinelli, 1999: Spatial and temporal variability in the distribution of algae and invertebrates on rocky shores in the northwest Mediterranean. J. Exp. Mar. Biol. Ecol., **233**: 1–23.

Menge, B. A., 1997: Detection of direct versus indirect effects, were experiments long enough? Am. Nat., **149**: 801–823.

Milazzo, M., R. Chemello, F. Badalamenti & S. Riggio, 2000: Molluscan assemblages associated with photolithic algae in the Marine Reserve of Ustica Island (Lower Tyrrhenian Sea, Italy). Ital. J. Zool., **67**: 287–295.

Palumbi, S. R., 2001: The ecology of marine protected areas. In: Marine Community Ecology, M. D. Bertness, S. D. Gaines & M. E. Hay (Eds.), Sinauer Associates, Sunderland, MA: 509–530.

Pinnegar J. K., N. V. C. Polunin, P. Francour, F. Badalamenti, R. Chemello, M. L. Harmelin-Vivien, B. Hereu, M. Milazzo, M. Zabala, G. D'Anna & C. Pipitone, 2000: Trophic cascades in benthic marine ecosystems: Lessons for fisheries and protected-area management. Environ. Conserv., **27**: 179–200.

Pipitone, C., F. Badalamenti, G. D'Anna & B. Patti, 2000: Fish biomass increase after a four-year trawl ban in the Gulf of Castellammare (NW Sicily, Mediterranean Sea). Fish. Res., **48**: 23–30.

Planes, S., R. Galzin, A. Garcia Rubies, R. Goñi, J. G. Harmelin, L. Le Direach, P. Lenfant & A. Quetglas, 2000: Effects of marine protected areas on recruitment processes with special reference to Mediterranean littoral ecosystems. Environ. Conserv., **27**: 126–143.

Polunin, N. V. C. & C. M. Roberts, 1993: Greater biomass and value of target coral-reef fishes in two small Caribbean marine reserves. Mar. Ecol. Prog. Ser., **100**: 167–176.

Ramos Esplà, A. A. & S. E. Mcneill, 1994: The status of marine conservation in Spain. Ocean Coast. Manage., **24**: 125–138.

Roberts, D. E., S. R. Fitzhenry & S. J. Kennelly, 1994: Quantifying subtidal macrobenthic assemblages on hard substrata using a jump camera method. J. Exp. Mar. Biol. Ecol., **177**: 157–170.

Roberts, D. E., A. Smith, P. Ajani, & A. R. Davis, 1998: Rapid changes in encrusting marine assemblages exposed to anthropogenic point-source pollution: a 'Beyond BACI' approach. Mar. Ecol. Prog. Ser., **163**, 213–224.

Russ, G. R. & A. C. Alcala, 1996: Do marine reserves export adult fish biomass? Evidence from Apo Island, Central Philippines. Mar. Ecol. Prog. Ser., **132**: 1–9.

Sala, E., 1997: Fish predators and scavengers of the sea urchin *Paracentrotus lividus* in protected areas of the north-west Mediterranean Sea. Mar. Biol., **129**: 531–539.

Sala, E., M. Ribes, B. Hereu, M. Zabala, V. Alvà, R. Coma & J. Garrabou, 1998: Temporal variability in abundance of the sea urchins *Paracentrotus lividus* and *Arbacia lixula* in the northwestern Mediterranean: comparison between a marine reserve and an unprotected area. Mar. Ecol. Prog. Ser., **168**: 135–145.

Sala, E. & M. Zabala, 1996: Fish predation and the structure of the sea urchin *Paracentrotus lividus* populations in the NW Mediterranean. Mar. Ecol. Prog. Ser., **140**: 71–81.

Sanchez Lizaso, J. L. & A. A. Ramos Esplà, 1994: Grazing on the seagrass *Posidonia oceanica* in the marine reserve of Tabarca, Spain. Invest. Mar. Cicimar, **9**: 103–108.

Sanchez Lizaso, J. L., R. Goñi, O. Reñones, J. A. Garcia Charton, R. Galzin, J. T. Bayle, P. Sanchez Jerez, A. Pérèz Ruzafa & A. A. Ramos, 2000: Density dependence in marine protected populations: a review. Environ. Conserv., **27**: 144–158.

Underwood, A. J., 1992: Beyond BACI: the detection of environmental impact on population in the real, but variable world. J. Exp. Mar. Biol. Ecol., **161**: 145–178.

Underwood, A. J., 1993: The mechanism of spatially replicated sampling programmes to detect environmental impact in a variable world. Aust. J. Ecol., **18**: 99–116.
Underwood, A. J., 1994: On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecol. Appl., **4**: 3–15.
Underwood, A. J., 1996: Detection, interpretation, prediction and management of environmental disturbances: some roles for experimental marine ecology. J. Exp. Mar. Ecol., **200**: 1–27.
Underwood, A. J. & C.H Peterson, 1988: Towards an ecological framework for investigating pollution. Mar. Ecol. Progr. Ser., **46**: 227–234.
Vacchi, M., S. Bussotti, P. Guidetti & G. La Mesa, 1998: Study of the coastal fish assemblage in the marine reserve of the Ustica Island (Southern Tyrrhenian Sea). Ital. J. Zool., 65 Suppl.: 281–286.
Vacchi, M., S. Bussotti, P. Guidetti & G. La Mesa, 1999: Osservazioni preliminari sulle cernie della Riserva Marina di Ustica. Biol. Mar. Medit., **6**: 278–280.
Vigliola, L., M. L. Harmelin-Vivien, F. Biagi, R. Galzin, A. Garcia-Rubies, J. G. Harmelin, J. Y. Jouvenel, L. Le Direach-Boursier, E. Macpherson & L. Tunesi, 1998: Spatial and temporal patterns of settlement among sparid fishes of the genus *Diplodus* in the northwestern Mediterranean. Mar. Ecol. Prog. Ser., **168**: 45–56.
Warwick, R. M., 1993: Environmental impact on marine communities: pragmatical considerations. Aust. J. Ecol., **18**: 63–80.