Fishery reserves in the Mediterranean Sea: the Gulf of Castellammare case study

C. Pipitone*, F. Badalamenti, G. D'Anna, M. Coppola, G. Di Stefano, G. Scotti

Abstract

The effects of fisheries management based on artificial reefs and on trawl banning are explored in the Gulf of Castellammare fishery reserve by means of biological (from trammel and trawl survey) data collected during several research programs between 1990 and 2001. The artificial reefs have caused an increase of diversity but not of biomass, as suggested by the comparison between the associated fish assemblage and that of nearby sandy bottoms. The associated species however do not have any trophic relation to the boulders, except the two-banded seabream, *Diplodus vulgaris*. An overall increase of experimental trammel net yields in the artificial reef area was observed from 1990 to 1998, due mainly to pelagic species associated with the boulders. The trawl ban caused a dramatic increase of groundfish biomass in the protected area (+711% after four years, total species). Different species had different increase rates, from 2-fold for the musky octopus, *Eledone moschata* to 127-fold for the gurnard, *Lepidotrigla cavillone*. Eight and ten years after the ban started, the yields did not vary significantly in the overall area, but decreased near to (both outside and inside) the protected area, probably due to increased legal and illegal trawling. The mean size did not increase in three studied species, except for the monkfish, *Lophius budegassa*. In conclusion the Gulf of Castellammare fishery reserve is considered a positive example of marine coastal fisheries management, especially considering the effects of the trawl ban on the abundance of groundfish stocks, although the cooperation between scientists and administrative bodies is still far from optimal.

Keywords: coastal fisheries management, marine protected areas, trawl ban, artificial reefs, artisanal fisheries, Sicily.

1. Introduction

The quest for fishery management practices not tied to a traditional approach based on single-species population dynamics models, has pushed scientists and managers towards Marine Protected Areas (MPAs), considered a powerful tool for the management of coastal fisheries. The rationale behind this lies in the concept of protection (full or partial) of habitats and organisms aimed at their sustainable exploitation. Several potential effects are expected from MPAs, among others the increase of mean size and standing crop inside the protected area and the enrichment of surrounding fished grounds through egg/larval dispersal and adult spillover (Bohnsack, 1998). MPAs aimed at fisheries management have been created in

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several areas in the Mediterranean (Figure 1 for some examples of existing fishery reserves; Figure 2): no-take zones in Corsica (*cantonnements de pêche*: Meinesz *et al*., 1983), no-trawl zones in Greece (Vassilopoulou & Papaconstantinou, 1999) and Italy (Pipitone *et al*., 2000a); seasonal trawl ban in Cyprus (Garcia, 1986) and in Italy (Cau *et al*., 1993; Pranovi *et al*., 1996; Relini *et al*., 1996); artificial reefs in most countries (see Jensen *et al*., 2000). The Gulf of Castellammare (Figure 3) has acted in the last two decades as a sort of natural lab where several different management measures have been implemented, aimed at reducing the conflict between the trawl and artisanal fleets and at rebuilding the depleted groundfish stocks (Arculeo *et al*., 1990). Such measures included the deployment of artificial reefs and the creation of a no-trawl zone on about 50% of the Gulf surface (Badalamenti *et al*., 2000). No-trawl zones are particularly useful when the reduction of fishing mortality is deemed necessary for stock enhancement, and at the same time small-scale artisanal fishing is considered advantageous from the economic, social and environmental point of view (e.g., Bailey, 1997). On the other hand, artificial reefs are considered a viable method to prevent inshore trawling and to provide potential shelter and food to fishes (Bombace, 1997).

The present paper is based on already published data collected during studies carried out since 1990 at the Marine Biology Laboratory of CNR-IAMC, concerning the effects of artificial reefs and of the trawl ban on the abundance of resources. It tries at the same time to highlight the complex fishery management issues inherent to the Gulf.

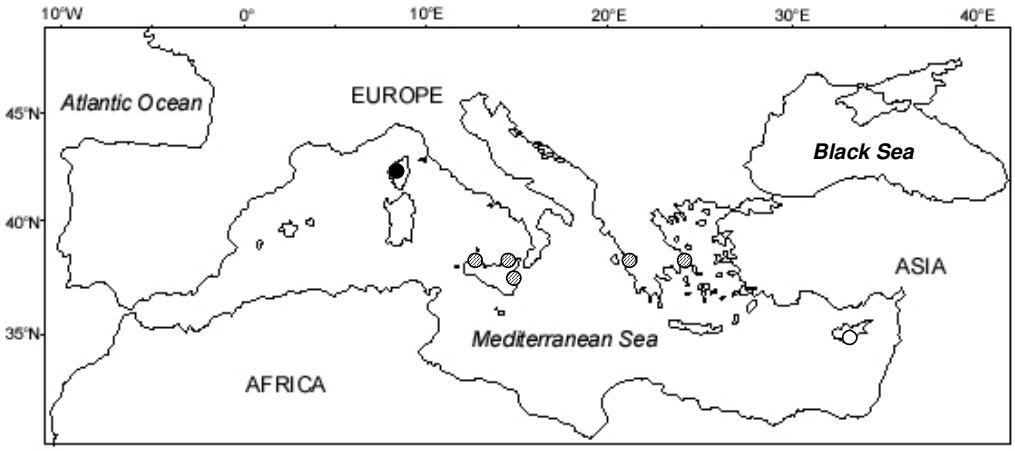

Figure 1. Some of the existing MPAs aimed at fisheries management in the Mediterranean. Black circle: no-take zones; striped circles: trawl ban zones; white circle: seasonal trawl ban.

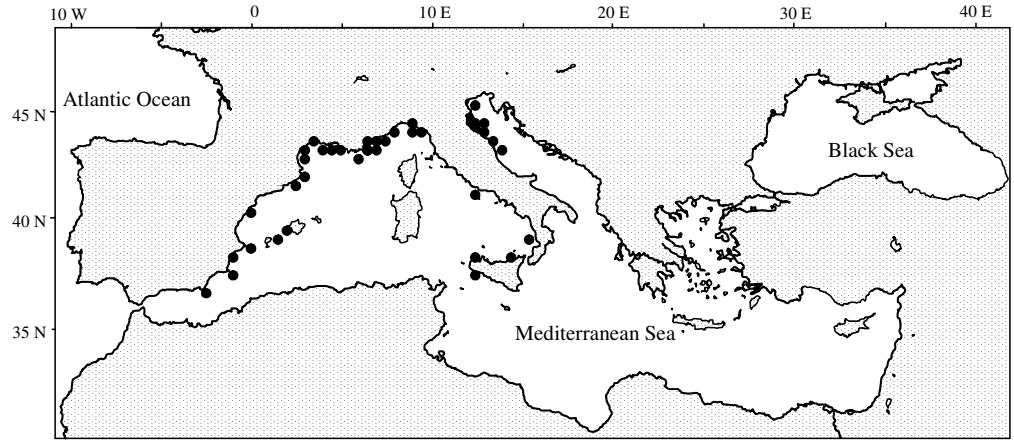

Figure 2. Artificial reef areas along the European coasts of the Mediterranean (from Jensen, 2002).

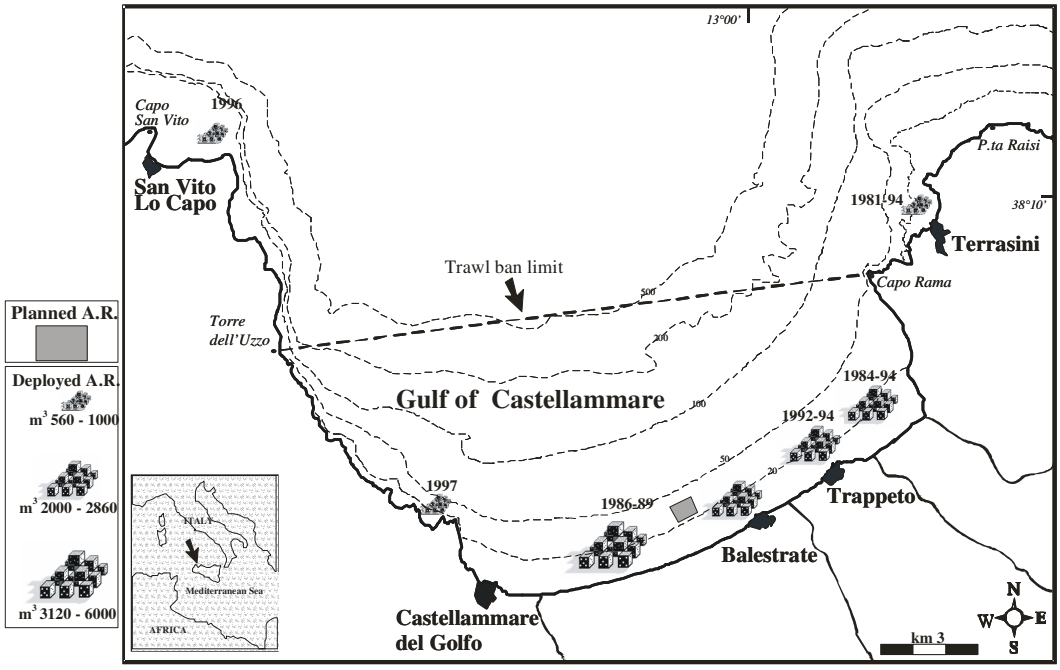

Figure 3. Map of the Gulf of Castellammare, with the trawl ban limit and the artificial reefs (A.R.).

2. Background information on the Gulf of Castellammare

The Gulf of Castellammare lies along the northwestern coast of Sicily (Figure 3). Its surface from Capo San Vito to Punta Raisi is 397 km^2 (=115 nm^2). The coast is rocky along the eastern and western sides, and sandy in the whole central part, where the outlets of a few small streams are located. The seafloor is covered to a great extent with soft bottoms; rocks and scattered small *Posidonia oceanica* meadows occur along both sides of the Gulf. There are four ports in the Gulf (from east to west): Terrasini, Trappeto, Balestrate and Castellammare. A fifth port - San Vito - can be considered out of the study area, due to its location at the farthest western corner of the Gulf and to the patterns of activity of its fishing fleet that are concentrated in areas not directly affected by the local management regime. 138 boats are registered as licensed fishing vessels in the Port Authority (Figure 4), 98 of them (71%) as artisanal vessels, 27 (20%) as purse seiners and 13 (9%) as trawlers. Most artisanal fishermen use a trammel-gillnet as their main fishing gear (Figure 5), switching to other gear on the basis of the target species available at different periods of the year. The most important seasonally active artisanal fisheries are (i) the fish fry fishery, that targets larval clupeoids in late winter-early spring, and (ii) the FAD (Fish Aggregating Device) fishery (Figure 6) that targets dolphinfish as well as other less abundant mid-size pelagic species from late summer to mid-autumn (Pipitone *et al*., 2000b).

The legal framework that regulates fishery management in the Gulf (as well as in the whole Sicily) is summarized in Table 1. The current management regime includes artificial reefs deployed over a wide area between 10 and 50 m depth, and a year-round trawl ban imposed over the continental shelf and part of the upper slope on a surface of 200 km^2 (=58 nm^2). It is noteworthy that, although the law imposed fishing restrictions and allowed the creation of an artificial reef area, there is neither an explicit definition of the Gulf of Castellammare as a "protected area", nor a body institutionally charged with monitoring the effects of management.

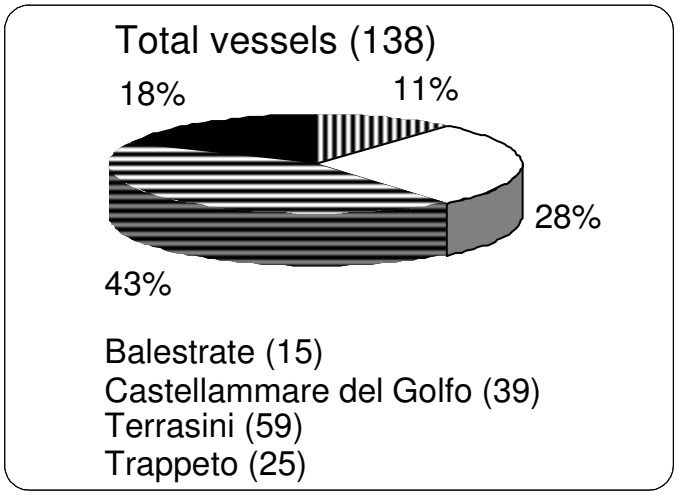

Figure 4. Distribution of total fishing vessels among the four ports in the Gulf of Castellammare.

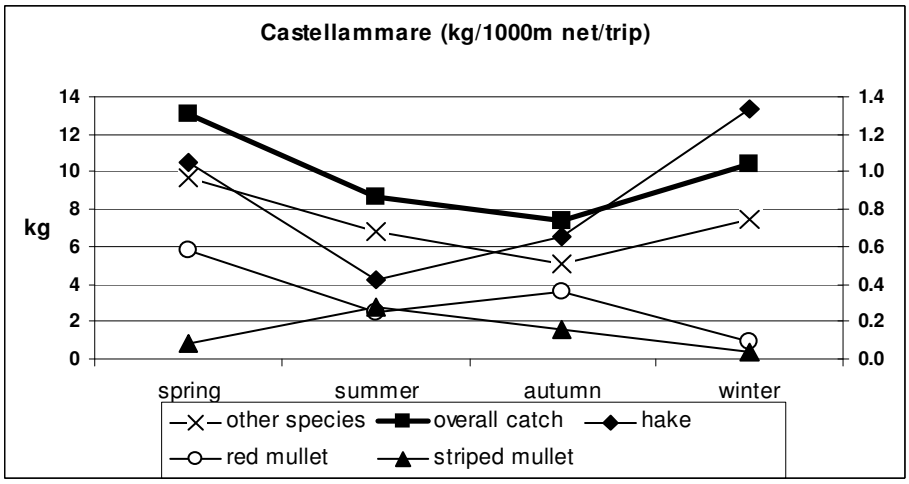

Figure 5. Landings from the Castellammare trammel-gillnet fishery, 1998-99 landings survey. Yields on the left *y* axis refer to the overall catch, while those on the right *y* axis refer to single species.

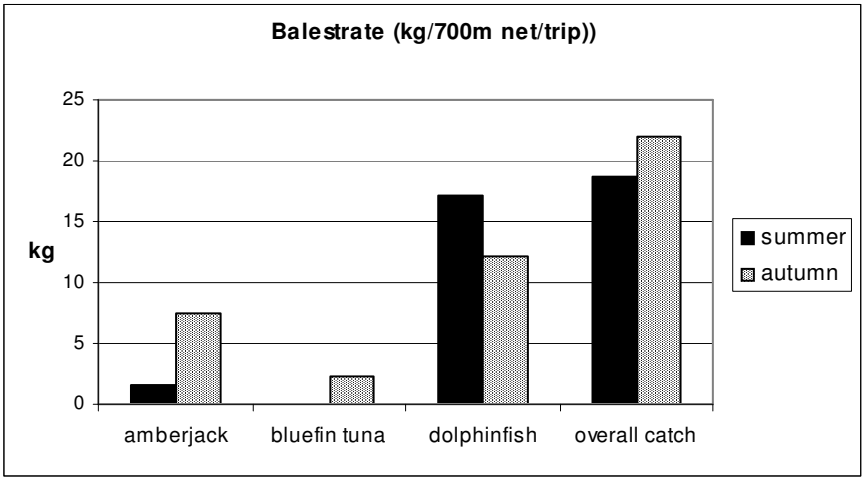

Figure 6. Landings from the Balestrate FAD fishery, 1998-99 landings survey.

Table 1. Laws that regulate fishery management in Sicily.

Act	Content	Goal
L.R. 31/1974	Measures for the enhancement of fish stocks. Institution of three Associations of local authorities (*Consortia*) in Sicily	Fish stock enhancement and protection by means of artificial reefs
L.R. 1/1980 L.R. 26/1987	General laws on fisheries in Sicily	Modernization of the fleet; reduction of trawling effort through change to a different gear; seasonal fishing ban; increase of fish and shellfish open-sea culture; measures for scientific research
L.R. 25/1990	Year-round trawling ban in three Sicilian Gulfs	Enhancement of fish stocks
L.R. 32/2000	Economic and industrial development and planning of Sicily for 2000-2006	Chapter XII concerns the fishing activities, and updates previous regulations

3. Assessment of the effects of fisheries management

- *Artificial reefs*

Cubic concrete boulders, either isolated or assembled in pyramids were deployed on the sandy and muddy bottoms of the Gulf between 10 to 50 m depth from 1981 to 1998 (Figure 3) (Badalamenti *et al*., 2000). Experimental trammel net surveys and visual census surveys were carried out to assess the effectiveness of the artificial reefs as a tool for increasing the fish biomass. Moreover the benthic fauna settled on the boulders and the stomach contents of several fish species were studied to assess the trophic links between artificial reefs and associated fish species.

The artificial reefs host rocky bottom species that were absent from the original soft bottom, causing an increase of biological diversity (D'Anna *et al*., 1994, 1995). The mean value of the associated fish standing crop, as estimated in one year of observations, was 7.9 kg/pyramid (=0.07 kg/m^3). The dominant species were the damselfish, *Chromis chromis*, sparids (*Diplodus annularis*, *D. vulgaris*, *D. sargus* and *Lithognathus mormyrus*) and mullids (*Mullus barbatus* and *M. surmuletus*). Qualitative underwater observations have also revealed that bottom FADs associated with artificial reefs attract the amberjack, *Seriola dumerili* and help to keep its shoals in the area for a longer time than observed before.

The trophic studies have demonstrated that the main fish species occurring on the artificial reefs do not have any direct trophic relation with the boulders, with the exception of the two-banded seabream, *D. vulgaris* (Pepe *et al*., 1996).

The catches per unit effort (cpue) from experimental trammel net surveys conducted in the artificial reef area from 1990 to 1998 ranged between 1.4 and 3.6 kg/500m net (D'Anna *et al*., 2001). Figure 7 shows the temporal trend of cpues for pelagic, sandy bottom and rocky bottom species separately. No increment across time was observed for the two latter categories ($p>0.05$, Spearman correlation), while catches of pelagic species like bogue, *Boops boops* and horse mackerel, *Trachurus trachurus* increased ($p<0.02$).

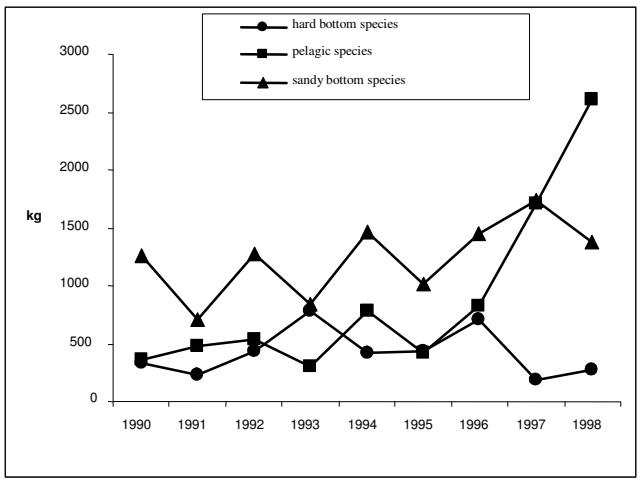

Fig. 7 - Cpue (kg/500 m net/trip, annual mean) from trammel net surveys in the artificial reefs in the Gulf of Castellammare.

- *Trawl ban*

The assessment of the effect of the trawl ban was based on the analysis of cpues from trawl surveys conducted before (1987-89) and during (1993-94, 1998-99 and 2000-01) the ban. Only spring surveys data were used, due to insufficient data from other seasons in the pre-ban period (Pipitone *et al*., 1996). The area was surveyed between -10 m and -200 m depth according to a stratified random sampling design. Figure 8 shows the cpues of the total catch expressed as kg/30min tow (mean values over the total study area). Cpues in 1993-94 increased by 711% (from 3.8 to 31.1 kg) if compared with the pre-ban period ($p<0.001$, Mann-Whitney U-test). In 1998-99 and 2000-01 cpues did not vary significantly if compared to 1993-94 (Pipitone *et al*., 2001). The ANOVA between cpues of each survey showed that (a) yields outside the protected area were always lower than inside, and (b) yields inside the protected area remained constant through time, while those outside decreased from 1998-99 to 2000-01 (Pipitone *et al*., in press).

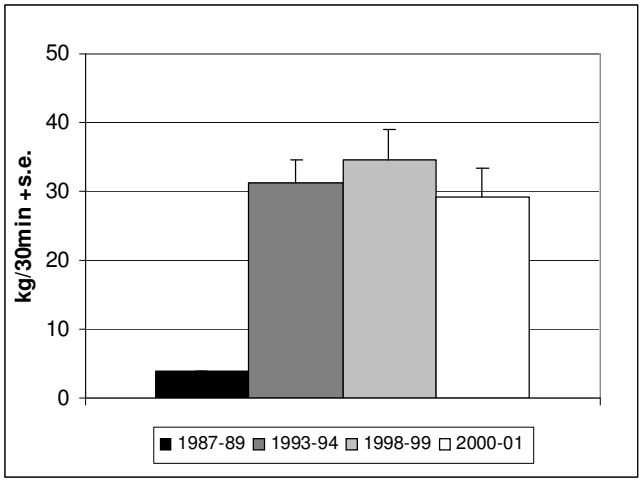

Fig. 8 - Cpue (kg/30min tow, total area, spring surveys) of total catch from trawl surveys in the Gulf of Castellammare. s.e.: standard error.

Figure 9 shows cpues (annual mean) from the trammel net surveys conducted from 1990 to 1999 at less than -30 m depth, in areas with hard and soft bottoms as well as with artificial reefs, traditionally exploited by artisanal fishermen. An increase of fish biomass across time ($p<0.001$, Spearman correlation) was observed, with a peak in 1995 due to the increase of sandy bottom species, whose cpues rose from 1.3 to 3.6 kg.

Finally, the size structure of a few species in the no-trawl area was analyzed (Badalamenti *et al*., 2002). An increase in the mean size was observed in the monkfish, *Lophius budegassa* but not in the hake, *Merluccius merluccius* and the red mullet, *M. barbatus*.

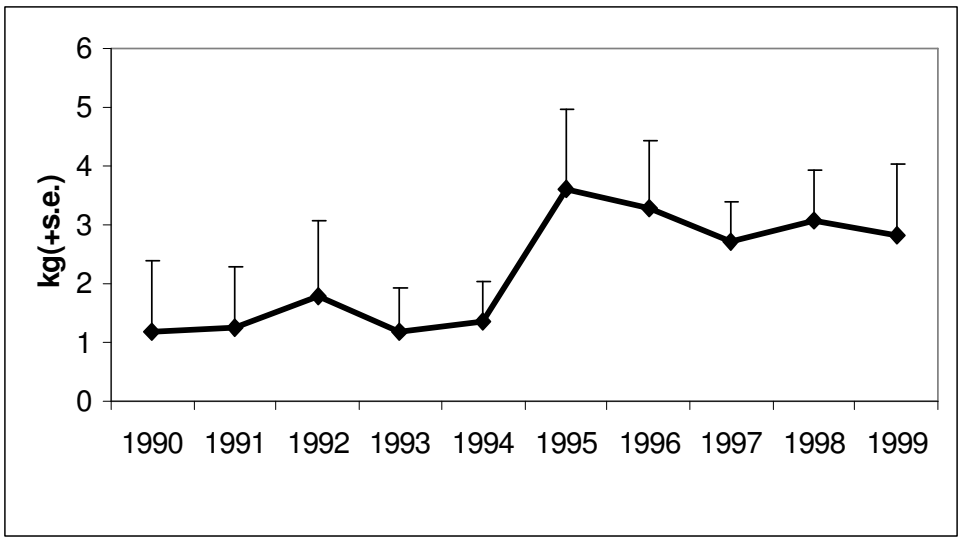

Fig. 9 - Cpue (kg/500 m net/trip, annual mean) from trammel net surveys in the total study area, Gulf of Castellammare.. s.e.: standard error.

4. Discussion

The management of coastal fisheries in the Gulf of Castellammare has developed along two main lines: (a) the deployment of artificial reefs aimed at protecting the coastal zone from trawling and at providing food and shelter to coastal fishes, and (b) the imposition of a trawl ban aimed at rebuilding the shelf groundfish stocks and at solving conflicts between the artisanal and trawl fleets.

Artificial reefs have led to an increase of biological diversity of the fish assemblage, if compared to the original soft bottom assemblage. This increase is due mainly to hard bottom species that probably joined the artificial reefs as adults, rather than recruiting at an early life stage (Badalamenti & D'Anna, 1997). Such hard bottom species as well as resident pelagic species seem tied to the boulders more by tigmotropic attraction and by the shelter provided by the boulders rather than by food resources, since a direct trophic link with the artificial reefs was detected only for *D. vulgaris*. Nonetheless a possible role of artificial reefs in supporting the artisanal fishery could consist in enlarging the distribution of valuable hard bottom species like the seabream, *D. sargus* that shelters among the concrete boulders and feeds in the nearby *Cymodocea nodosa* meadows (Badalamenti & D'Anna, 1997).

Unlike biological diversity, fish biomass in the artificial reef area did not increase after the deployment of the boulders. This is one of the reasons why artisanal fishermen in the Gulf have shown a less than favourable attitude towards artificial reefs, the other being that they have experienced a reduction of the overall fishable area due to the wide portion of seafloor occupied by the boulders (Pipitone *et al*., 2000b). Yet another positive role of artificial reefs - in particular those associated with bottom FADs - is their ability to maintain in place commercially important species with a seasonal occurrence, like the amberjack. This suggests a large potential for wisely planned artificial structures (Badalamenti & D'Anna, 1997). Although artificial reefs in the Gulf of Castellammare have at least partially failed in their purpose of increasing shallow water fish resources, they have successfully acted as a research tool for the study of ecological processes in the coastal zone (Bombace *et al*., 2000; Riggio *et al*., 2000). The results of research carried out to date suggest that detailed preliminary studies are needed before the planning phase, in order to assess the cost/benefit ratio of artificial reefs according to their goals.

The trawl ban in the Gulf of Castellammare has caused a dramatic increase in groundfish stock size, as suggested by the trawl surveys made four years after it started, in spite of artisanal and recreational fishing. The lack of any further significant variation of biomass from 1994 to 2001 could be explained with a steady state reached by the environment and the permitted fisheries. Yet it is not unlikely that a possible further increase of biomass has been masked by the intense trawling activity along the protected area border and by the frequent poaching occurring in the eastern part of it (Whitmarsh *et al*., 2002). The lack of any observed increase of mean size (except for the monkfish) could be due to a density dependent effect on individual growth, as observed in marine protected areas by Sanchez Lizaso *et al*. (2000) and Béné & Tewfik (2003). This could be true in particular for the red mullet, which underwent a dramatic biomass increase in the Gulf after the imposition of the trawl ban.

5. Conclusion

The Gulf of Castellammare is an interesting case of coastal fisheries management achieved through a marine protected area that includes artificial reefs and a trawl ban zone. The use of fishery reserves of this or similar type has spread worldwide in recent years, and is considered a highly promising tool for the sustainable exploitation of living resources (*e.g.*, Hall, 1998; Hastings & Botsford, 1999). Trawl bans have been applied elsewhere in the Mediterranean, as well as artificial reefs. The Castellammare case study is unique in that it includes data sets collected before and during the current management regime as well as socioeconomic data (Pipitone *et al*., 2000b), which have allowed us to assess some effects of management with more detail than in the rest of the Mediterranean (Pipitone *et al*., 2000a; Badalamenti *et al*., 2002; Whitmarsh *et al*., 2002, in press). The overall picture is made even more complex by offshore fish farming in floating cages, developed in recent years. Considering this articulated framework, it should be highlighted that, at least locally, a deep gap exists between fishery scientists and fishery managers, and that two issues stand out dramatically: (1) the management body (i.e., the Regional Council for Fisheries) does *not* manage the resources, i.e., there is no follow-up to policy decisions (e.g., closing an area to trawling); (2) the same body does not put any scientific institution in charge of monitoring the effectiveness of management and studying its effects on the resources (although the laws account for research funding). It is left to single research teams to raise funds to assess such effects. This gap needs to be filled if management has to play its expected role of assuring the sustainable exploitation of resources.

6. Acknowledgments

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