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FISH ASSEMBLAGES ACROSS THE MEDITERRANEAN SEA AND THE EFFECTS OF PROTECTION FROM FISHING

I POPOLAMENTI ITTICI NEL MEDITERRANEO E GLI EFFETTI DELLA PROTEZIONE DALL'IMPATTO DELLA PESCA

Abstract *– Several studies have assessed the effectiveness of individual marine protected areas (MPAs) in protecting fish assemblages, but regional assessments of multiple parks are scarce. Here fish surveys using visual census were done in marine parks and fished areas at 31 locations across the Mediterranean Sea. Fish species richness, diversity and biomass (especially of top predators) were higher in MPAs compared to fished areas, and community structure differed significantly between MPAs and fished areas. Results suggest that MPAs are generally effective means to protect and recover fish populations and assemblages.*

Key-words: *fish biomass, predators, marine parks, fishing impact, visual census, Mediterranean Sea.*

Introduction – Marine protected areas (MPAs) are portions of the coastline and/or sea where human activities, especially fishing, are restricted or banned (Agardy *et al.*, 2003). As fish assemblages usually include many species targeted by fishing, they are primarily expected to respond to protection within MPAs, especially those MPAs that have no-take zones (Micheli *et al.*, 2004). The evaluation of benefits on fish assemblages, e.g. in terms of increase in density, size and biomass of target fishes (Micheli *et al.*, 2004; Guidetti & Sala, 2007), can be useful to assess the ecological effectiveness of MPAs. Moreover, most target fishes are high-level predators in the food webs and their functional extinction may cause community-wide changes (Sala *et al.*, 1998; Worm *et al.*, 2006). Protection from fishing, therefore, may directly restore populations of target fishes and indirectly drive whole communities towards an unfished state (Sala *et al.*, 1998; Micheli *et al.*, 2004). Effective MPAs and, more generally, areas characterized by null/low levels of exploitation were found worldwide to host particularly high total fish biomass with a clear dominance of top predators (Friedlander & DeMartini, 2002). In the Mediterranean Sea, approximately 100 MPAs have been established (Abdulla *et al.*, 2008), making this region among those with the highest concentration of MPAs in the world. A number of Mediterranean studies assessed direct and indirect 'reserve effects' of protection (Guidetti & Sala, 2007 and references therein). Most of the 'reserve effect' assessment studies in the Mediterranean basin were carried out focusing on fish assemblages associated with rocky reefs, due to the fact that: 1) rocky reefs are the most common habitat protected within MPAs in Mediterranean; 2) previous visual census studies showed that rocky reefs host greater abundance of fish species targeted by fishing and that fish assemblages more clearly respond to protection from fishing than others (e.g., benthic assemblages). This study aims at investigating the generality of responses to protection of fish assemblages associated with shallow rocky reefs across the Mediterranean Sea, by comparing MPAs and areas open to fishing and other human uses.

Materials and methods – Fish surveys were done in late spring 2007 and 2008 at 12 MPAs and 19 fished areas across the northern Mediterranean coast (Spain, Italy, Greece, Turkey; Fig. 1).

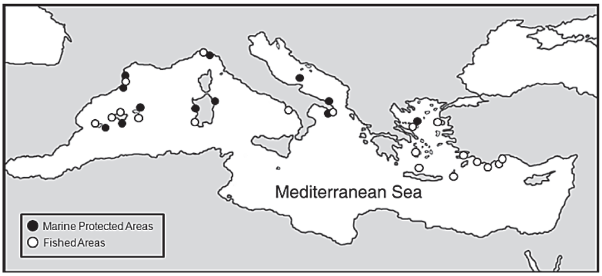

Fig. 1 - Location of Marine Protected Areas and fished areas investigated in this study.
Localizzazione delle Aree Marine Protette ed aree aperte alla pesca oggetto del presente studio.

Fish data were collected by using underwater visual census (UVC) at several stations within each areas (protected or fished), with three replicated UVCs at each station, for a total of 516 UCVs. Each replicate consisted of a 25 m-long and 5 m-wide transect. Along each transect, the diver swam one way (at ~10 m depth) for about 8-10 min, identifying and recording the number and size of each fish encountered (Harmelin-Vivien *et al.*, 1985). Fish wet-weight was estimated from size data by means of length-weight relationships from the available literature and existing databases (Froese & Pauly, 2009). Multivariate and univariate analyses were conducted to examine whether fish assemblage structure (i.e. taxa composition and abundances) and single variables (e.g. species richness) responded to protection. Effects of protection were analyzed on whole fish assemblages (using species×sample matrices) using three-way permutational multivariate analysis of variance (PERMANOVA) both on abundance and biomass data. The sampling design consisted of 3 factors: Protection (Pr; fixed factor with 2 levels), Area (Ar; random and orthogonal) and Station (St; random and nested in Area). Multivariate analyses were based on Bray-Curtis dissimilarity matrices and ln(x+1) transformed data. Univariate analyses on species richness, diversity, and total abundance and biomass of fish were run using t-tests to compare mean values under protected and unprotected conditions. Finally, fish taxa in terms of biomass data from both protected and fished conditions were pooled into trophic groups because fishing disproportionately targets species at higher trophic levels (Pauly *et al.*, 1998), and recovery from fishing potentially includes increased abundances or biomass of high-level predators and shifts in trophic structure (Micheli *et al.*, 2004). Each taxon was assigned to one of 4 trophic macrogroups using the information about diet in the database "FishBase" (Froese & Pauly, 2009), and in Mediterranean studies (Guidetti & Sala, 2007): 1) large apex predators (large carnivores, AP), 2) small carnivores (including piscivores and invertivores, SC), 3) herbivores (He), and 4) planktivores-detritivores (PD).

Results – Multivariate analyses (PERMANOVA tests) showed that considering total fish abundance ($P<0.01$) and even more biomass ($P<0.001$), fish assemblage structures were significantly different between MPAs and fished areas, and that a significant variability was detected at both spatial scales of areas and stations. Species richness (*t*-tests, P<0.01), diversity (*t*-tests, P<0.05) and total biomass of fish (*t*-tests, P<0.01) were significantly higher in protected than in fished conditions, while no statistical differences were found as far as fish abundance (*t*-tests, P>0.05) was concerned. In spite of a significant variability among areas (especially among MPAs), total fish biomass clearly tended to be higher in MPAs (Fig. 2).

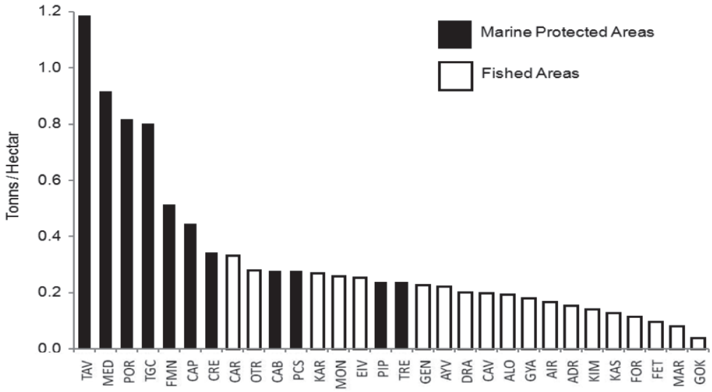

Fig. 2 - Total fish biomass in Marine Protected Areas and fished areas investigated in this study.
Biomassa ittica totale nelle Aree Marine Protette ed aree aperte alla pesca oggetto del presente studio.

Fish biomass split into the 4 trophic groups (see Methods) was different between MPAs and fished areas. At MPAs, in fact, predator fishes, especially apex predators (18.4 vs 5.5%), were far better represented than in fished areas (Fig. 3).

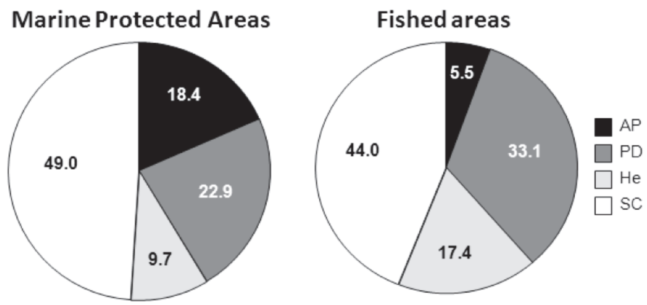

Fig. 3 - Fish biomass of different trophic groups (see Methods) in Marine Protected Areas and fished areas investigated in this study.
Biomassa ittica dei quattro differenti gruppi trofici (vedi Metodi) nelle Aree Marine Protette ed aree aperte alla pesca oggetto del presente studio.

Conclusions – The present study investigated the effects of protection by surveying fish assemblages across the Mediterranean scale. In spite of the large site-to-site variability, fish assemblage structures were found to be significantly different between MPAs and fished areas. Moreover, species richness and diversity were greater in MPAs than in fished areas. The greatest differences, however, concerned fish biomass. Not only on the whole mean fish biomass was higher in MPAs than in fished areas, but in some MPAs the values were dramatically high. In addition, in MPAs a significantly greater contribution to the total fish biomass was attributable to apex predators. These results are in agreement with the available literature from the Mediterranean Sea and elsewhere (Friedlander & DeMartini, 2002; Sandin *et al*., 2008) and stress how effective can be MPAs for recovery of fish at population and ecosystem levels.

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