Collaboration between research institutions and MPAs contributes to *Posidonia oceanica* conservation: The Egadi Island’s experiment

Preliminary results on the collaboration between the ENEA’s Marine Environment Research Center and the Egadi Islands’ Marine Protected Area (MPA), aimed to evaluate effectiveness of artificial reefs in limiting the impact of trawling on *Posidonia oceanica* meadow at Favignana Island, are reported. The methods and parameters chosen for monitoring showed their reliability in training non-experienced personnel for data collection within the MPA. The proposed monitoring approach is of great value to the MPA interested in both gathering basic and long-term data on the health status of protected habitats and acquiring baseline information useful for the evaluation of protection and conservation actions

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Introduction

Declines in the cover of *Posidonia oceanica* (L.) Delile meadows have been recorded in many parts of the Mediterranean Sea, where the plant forms extensive meadows on rocks and sandy bottoms in clean water at a depth from less than 1 meter to over 40 meters [1]. Identified as a priority habitat type for conservation in the Habitats Directive (Dir 92/43/CEE), these meadows provide important ecological functions and services, and harbour a highly diverse community with some species of economic interest. Any decline in *P. oceanica* meadows could have serious economic implications, not only in terms of loss of biodiversity and ecosystem quality, but also of a decrease in fishing resources and an increase in coastal erosion.

Meadow declines have been attributed to several natural and anthropogenic impacts, illegal trawling fishing being one of the most important direct causes of large scale degradation of *P. oceanica*. Repeated passes of trawl gear over the seabed cause the mechanical degradation of meadows, reduce plant density and cover and this degradation changes the structure and dynamics of the associated biological assemblages. It has been reported that trawling gear can remove between 100000 and 360000 shoots/hour [2]. The slow re-growth of the plant further prolongs the impact of trawling, which sometimes can run into decades [3].

With the main objective of restoring *P. oceanica* meadows, restrictions on trawling over meadows have been reinforced in the last 15 years in Spain, Italy and France by the deployment of anti-trawling artificial

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reefs (AR) [4]. AR are heavy concrete constructions which can be armoured with extruding steel bars. These have been recognized as one of the most effective tools for integrated management and conservation of coastal resources after the establishment of Marine Protected Areas, particularly for *P. oceanica* habitat and its associated halieutic resource [5].
In order to limit the impact of trawling on the largest *P. oceanica* meadow in the Mediterranean, in 2013 the Egadi Islands' MPA authority, within the MASTER project, adopted protective measures by deploying AR within 50 m of depth in well-identified, sensitive areas. According to the Italian law, trawling is banned at depths lower than 50 m or at less than 3 nautical miles from the coastline. To measure the status and trends of meadows over time and analyze the changes of associated fish species, a long-term monitoring has been set up. Long-term monitoring is essential in any protective or recovery initiative in order to address its effectiveness [6]. Here the preliminary results on the collaboration between the ENEA's Marine Environment Research Center and the Egadi Islands' Marine Protected Area (MPA) are reported, presenting the results of the training activities (September 2012) and the preliminary results of monitoring activities carried out by the MPA divers in May-June 2013 (before the AR deployment) and February 2014. A brief discussion on the pros and cons of the methods employed is also reported.

Materials and methods

AR were deployed in June 2013 in several localities chosen by the MPA authority around the Egadi Islands. Each AR unit was composed by a Technoreef® module called Stopnet, equipped with special hooks designed to trap nets and release cords or cables. Stopnet was placed in straight line running out from the coast, forming a barrier to illegal trawling activity.
An appropriate follow-up monitoring protocol to be applied by the MPA marine biologists was set up by ENEA researchers for measuring changes of both seagrass abundance parameters and associated pelagic and necto-benthic fish assemblages [7, 8, 9]. The protocol was defined to ensure an easy collection of basic data by non-experienced divers called for biannual (June and December) field activities to be performed in the same localities (GPS located), before (as reference) and after the AR deployment. Six localities around Favignana Island where chosen by the MPA authority for monitoring (Figure 1). In each locality, five sampling sites were randomly chosen along a 50 m transect parallel along the shore at 12 m depth. At each sampling site, *P. oceanica* canopy cover was visually estimated on a circle with a 5m radius. Shoot density was estimated by counting the number of shoots in six sub-quadrats (20×20 cm), randomly selected on a gridded quadrat of $1m^{-2}$. Shoot percent cover was calculated as the percentage of sub-quadrats containing *P. oceanica* shoots in a total number of 25 quadrats [10]. Along the same transect, abundance of fish species censused in the water column (hereafter called 'pelagic') and on the bottom (hereafter called 'necto-benthic') was estimated trough visual census performed by 2 divers at the same meteo conditions, and between 10 and 14 daytime. Visual census was made at a depth of 3, 6, and 12 m at the beginning and at the end of each transect and at two random, replicate points along the transect at 12 m depth. At each point, fish species abundance was evaluated, sampling a circular area (360°) with a diameter of 5 m. Hence 4 pelagic and 4 necto-benthic fish abundance was estimated. During the survey, seawater temperature (°C), visibility (m), wind direction, and current direction were recorded.
As the level of personal experience may bias the results of visual evaluation of *P. oceanica* cover and fish visual census, an intensive training was done in September 2012 by ENEA marine biologists for MPA divers, to standardize the procedures and the observers' ability to collect accurate data, before the official sampling started. For visual census of fish, underwater tablets with images of the most representative pelagic and necto-benthic species known for the area were fixed up. After a briefing on fish and *P. oceanica* counting methods, two non-experienced MPA divers were trained during a preliminary survey. Surveys were carried out in three days by two couples of divers, each formed by one MPA diver and one ENEA diver. The following dives were scheduled: Cala Rossa West (CRw) and Cala Rossa Center (CRc) the 3rd of September; Cala Rossa East (CRe) and Cala Monaci East (CMe) the 6th of September; Cala Monaci Center (CMc) and Cala

Monaci West (CMw) the 7th of September. Counting of *P. oceanica* shoots were made by one non-experienced MPA diver and one experienced ENEA diver within the same 15 replicate quadrats in each locality (Figure 2). Visual estimation of both *P. oceanica* leaf canopy cover and fish abundance was carried out in pair along the transects. Paired t-tests were used to compare the data acquired in September 2012 and analyze the differences between divers. Monitoring activities were then carried out by MPA divers in May-June 2013 (before the AR deployment) and in February 2014 (after the AR deployment).

FIGURE 1 Map of the 6 localities around Favignana Island chosen for long-term monitoring (© Google Earth)

FIGURE 2 Counting of *P. oceanica* shoots performed during training by one non-experienced MPA diver and one experienced ENEA diver within the 1 m² reference quadrat

Results

Training activity

P. oceanica shoot counts in the quadrats showed no significant differences (P>0,05) between experienced and non-experienced divers, although these latter showed tendency to underestimate the number of shoots per quadrat (Figure 3).

Data on visual estimation of *P. oceanica* canopy cover showed differences (P<0.05) between divers in the first three localities monitored, but in the following period the

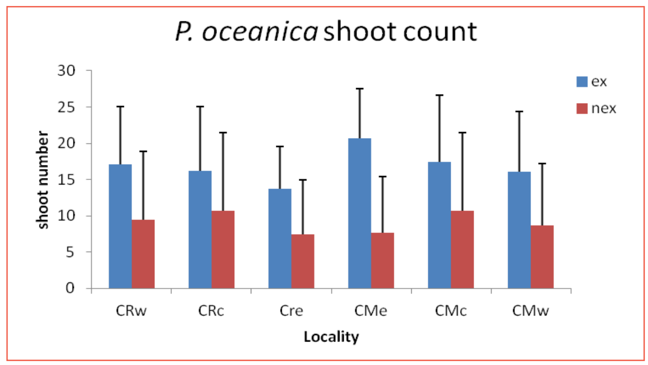

FIGURE 3 Mean number of *Posidonia oceanica* shoots counted by experienced (ex) and non-experienced (nex) divers in five replicate quadrats at each sampling locality. Standard deviations are indicated by bars

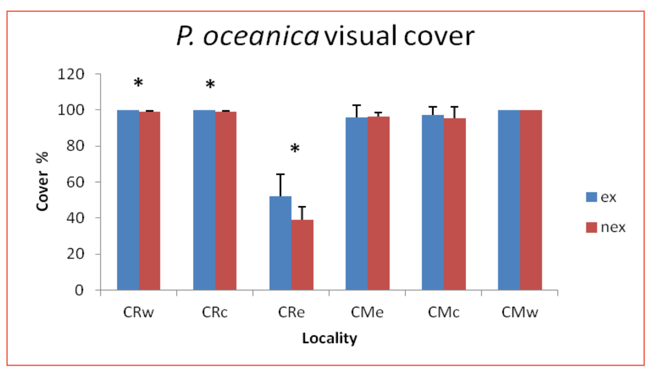

FIGURE 4 Mean percentage cover of *P. oceanica* evaluated by one experienced (ex) and one non-experienced (nex) diver in five replicates at each sampling locality. Asterisks (*) show differences (T-test for dependent samples, P<0,05) between observers. Standard deviations are indicated by bars

data collected by non-experienced (MPA) divers were similar to those from experienced (ENEA) divers (Figure 4). Fish abundance evaluation through visual census showed no differences (P>0,05) both in the case of pelagic (Figure 5) and of necto-benthic fishes (Figure 6). Despite the high variability in counts, abundance of some necto-benthic fishes was overestimated by the non-experienced observers.

Monitoring activities

In 6 localities, the visual estimation of *P. oceanica* canopy cover of the meadow ranged between 100% (Cala Monaci W) and 42% (Cala Rossa E) in 2012, between 99% (Cala Monaci E) and 58% (Cala Rossa E) in 2013, between 98% (Cala Monaci E) and 72% (Cala Rossa E) in 2014 (Figure 7). The mean shoot number · m^{-2} of the meadow ranged between 381 (Cala Rossa E) and 540 (Cala Monaci E) in 2012, between 370 (Cala Rossa E) and 500 (Cala Rossa W) in 2013, between 337 (Cala Rossa E) and 468 (Cala Rossa C) in 2014 (Figure 8). Generally, higher values of cover % corresponded to higher shoot number · m^{-2}, as recorded at Cala Monaci E, Cala Rossa E and Cala Rossa C.

On the whole, 32 fish species were censused during the monitoring activities performed in 2012, 2013, 2014 (Table 1). Most of them (21) were those recorded on the bottom, 11 were found in the water column (see Materials and Methods).

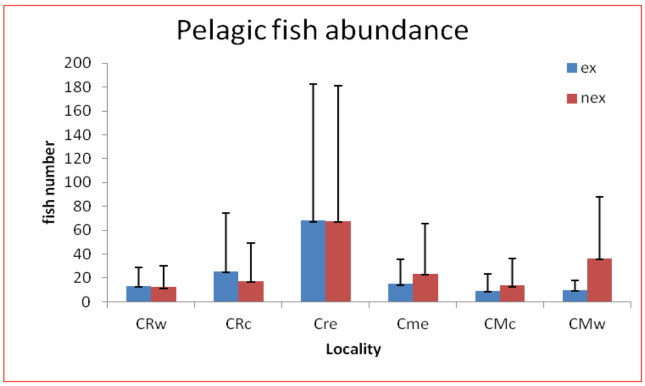

FIGURE 5 Mean pelagic fish species abundance evaluated by one experienced (ex) and one non-experienced (nex) diver in the six localities. Standard deviations are indicated by bars

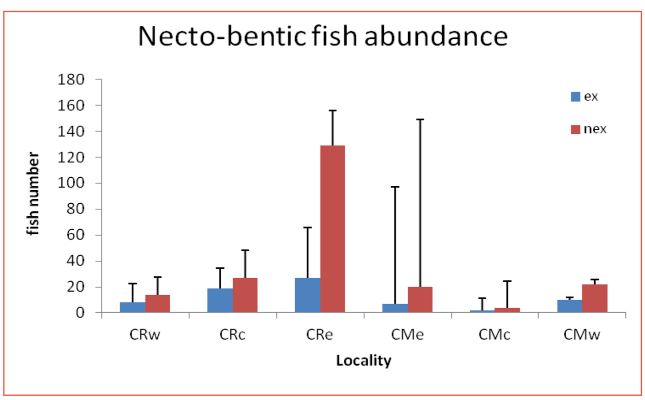

FIGURE 6 Mean necto-benthic fish species abundance evaluated by one experienced (ex) and one non-experienced (nex) diver in six localities. Standard deviations are indicated by bars

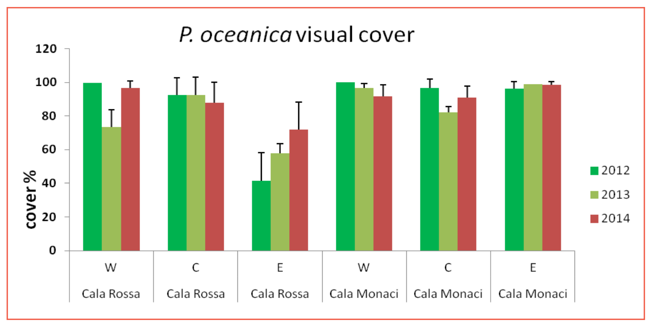

FIGURE 7 Mean percentage cover (± S.D.) of the meadow estimated in 6 localities in 2012, 2013, 2014

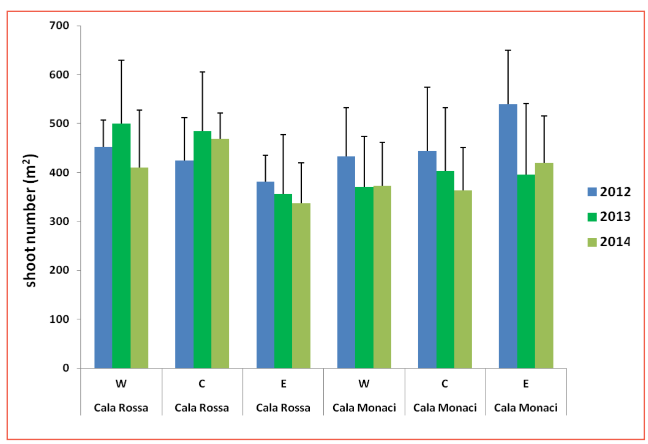

FIGURE 8 Mean shoot number· m^{-2} (± S.D.) counted in 6 localities in 2012, 2013, 2014

FAMILY/SPECIES
Atherinidae
Atherina sp.
Serranidae
**Epinephelus marginatus* (Lowe)
**Serranus cabrilla* (Linnaeus)
**Serranus scriba* (Linnaeus)
Apogonidae
**Apogon imberbis* (Linnaeus)
Carangidae
Seriola dumerilii (Risso)
Sparidae
Boops boops (Linnaeus)
Diplodus annularis (Linnaeus)
Diplodus sargus (Linnaeus)
Diplodus vulgaris (Geoffroy Saint-Hilaire)
Oblada melanura (Linnaeus)
**Sarpa salpa* (Linnaeus)
Spondyliosoma cantharus (Linnaeus)
Centracanthidae
Spicara smaris (Linnaeus)
Scienidae
**Sciaena umbra* Linnaeus
Mullidae
**Mullus surmuletus* Linnaeus
Pomacentridae
Chromis chromis (Linnaeus)
Sphyraenidae
Sphyraena viridensis Cuvier
Labridae
**Coris julis* (Linnaeus)
**Labrus merula* Linnaeus
**Labrus mixtus* Linnaeus
**Labrus viridis* Linnaeus
**Symphodus doderleini* Jordan
**Symphodus mediterraneus* (Linnaeus)
**Symphodus melanocercus* (Risso)
**Symphodus ocellatus (Forsskål)*
**Symphodus roissali* (Risso)
**Symphodus rostratus* (Bloch)
**Symphodus tinca* (Linnaeus)
**Thalassoma pavo* (Linnaeus)
**Xyrichtys novacula* (Linnaeus)
Bothidae
**Bothus podas* (Delaroche)

TABLE 1 List of 32 fish species censused in 2012, 2013, 2014. Asterisks (*) indicate necto-benthic fish species

In 2012, 29 fish species belonging to 12 families (Atherinidae, Serranidae, Apogonidae, Carangidae, Sparidae, Centracanthidae, Scienidae, Mullidae, Pomacentridae, Sphyraenidae, Labridae, Bothidae), where censused in the 6 localities (Tab. 2). The most numerous family was that of Labridae (10 species), followed by Sparidae (7 species), 3 species belonged to Serranidae, 1 of each species represented the other families. In 2013, 7 families (Atherinidae, Serranidae, Sparidae, Centracanthidae, Mullidae, Pomacentridae, Labridae) were recorded, 25 fish species in total (Table 2). The most numerous family was that of Labridae (12 species), followed by Sparidae (7 species). In 2014, the number of fish species was lower (17) when compared with the previous census (Table 2) and belonged to 6 families (Serranidae, Sparidae, Centracanthidae, Mullidae, Pomacentridae, Labridae), being Sparidae and Labridae the most represented ones (6 species).The other families were present with 2 species (Serranidae) or 1 species.

	Cala Rossa W	Cala Rossa C	Cala Rossa E	Cala Monaci W	Cala Monaci C	Cala Monaci E	TOTAL
September 2012	6 - 9	5 - 7	5 - 8	7 - 6	5 - 7	8 - 7	29
May-June 2013	5 - 1	11 - 7	12 - 7	6 - 2	7 - 5	4 - 6	25
February 2014	6 - 5	6 - 5	6 - 6	5 - 5	6 - 2	5 - 3	17

TABLE 2 Number of necto-benthic and pelagic fish species associated to the meadow censused in 6 localities in 2012, 2013, 2014

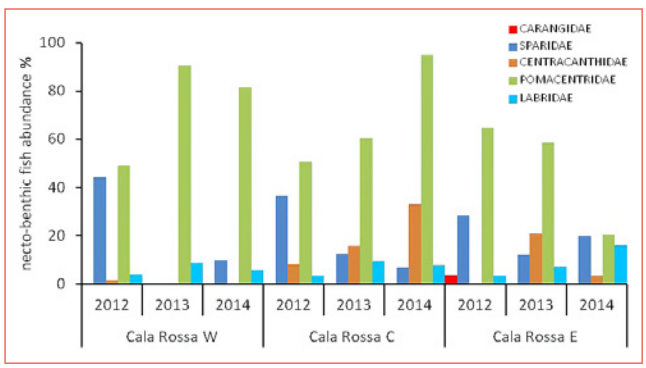

FIGURE 9 Abundance (%) of necto-benthic fish families censused at Cala Rossa W, Cala Rossa C, and Cala Rossa E in 2012, 2013, 2014

In 2012, the majority of pelagic species were Pomacentridae (94-98%), with *Chromis chromis* the most represented fish species. Differently, in 2013 no pelagic species were censused at 2 localities (Cala Rossa W, Cala Monaci W), whereas in the other localities Pomacentridae was the most abundant family, then Centracanthidae and Atherinidae. No pelagic species were seen in the column water in 2014 in all localities.
Among necto-benthic species, in 2012, 2013, 2014 Pomacentridae was the most abundant family at Cala Rossa localities (Figure 9), whereas at Cala Monaci localities many families contributed to fish assemblages. In 2013 and 2014, 3 localities of Cala Monaci displayed a different fish composition, Labridae contributing by 80% at Cala Monaci W to fish assemblages.

Conclusions

The results here reported, referring to the training activities carried out in September 2012 and the monitoring activities carried out in May-June 2013 and February 2014, have to be considered as the beginning of the ongoing long-term monitoring prefigured for at least 5 years to evaluate effectiveness of Stopnet AR in limiting the impact of trawling on *P. oceanica* meadow at Favignana Island. In February 2014, seagrass abundance parameters did not differ from those previously recorded and indicated high densities and cover such as those referred to good health meadows [5]. Differences in abundance (%) of necto-benthic fish families found during monitoring could be determined, in addition to the natural variability of fish assemblages [7], to sampling period. Performing periodic (seasonal) sampling activity is fundamental to establish the temporal distribution of fish assemblages and to estimate their quantitative variation among periods, even if the factors influencing the distribution are numerous and can apply at different scales [7].
Both the methods and parameters chosen for monitoring showed their reliability in training non-experienced personnel for data collection in MPA. One-week training for divers with a good basic knowledge on fish taxonomy and good diving skill is appropriate for a team to monitor areas of interest within the MPA. Our experience suggests that few, essential monitoring parameters can be easily collected by non-experienced divers in a few days, working at safety depths (no more than 15 metres). This approach is of great value to the MPAs interested in gathering continuous and long-term data on the health status of the protected environment and in acquiring baseline information for the evaluation of protection and conservation actions.
The proposed monitoring method should be replicated at least two times a year to gather significant and comparable data. Care should be devoted to accuracy in sampling the same site, in the same month and, at least for fish abundance evaluation, at the same hour of the day. Moreover, in order to evaluate the AR effectiveness it is mandatory that any follow-up monitoring program lasts for at least 5 years. Improving the proposed method with the collection of data on the physical-chemical water characteristics of the studied habitat could be easily achieved through the use of today's easy-to-use probes, that can be deployed by personnel onboard during dive time. Hence, the collected data can be stored in a database managed by the MPA and, if needed, shared with a scientific institution for data analysis and interpretation.
As far as we know, a first, clear indication of the 'indirect' dissuasive action performed through the AR deployment at Favignana is the 50% reduction of violations by illegal fishing trawlers recorded locally in 2014. Other management and conservation actions by the MPA and the Port authority -such as notification of illegal trawling sighting, fishing license suspension, in-the-field control, vessel position tracking control based on AIS data payment of penalty- could beneficially complement.

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