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Common methodology for design and execution of sound scientific monitoring of small scale fishery within and around an MPA

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1. Background and need for an integrated approach

Marine protected areas (MPAs) have been proposed as tools aiming at protecting natural populations and ecosystems, enhancing small scale fisheries, and promoting local socio-economies through sustainable development. MPAs could therefore lead to a win-win scenario where the challenges of conservation and small scale fisheries management can be resolved in parallel (Di Franco et al. 2016). However MPAs can deliver benefits only under a certain set of conditions. In order to identify these conditions it is crucial to consider small scale fisheries and fishing resources as a complex socio-ecological system (SES) that integrates both natural and human components. In this perspective, an integrated approach covering ecological, economic and social dimensions is required.

Small scale fisheries (SSFs) are in fact complex activities encompassing multiple dimensions of management of natural resources. Specifically the management of SSFs can affect the environment through the extraction of fishing resources and therefore potentially having an impact on marine ecosystems, and also the human dimensions of SSFs and fishermen through modification in fishermen incomes and a large set of social variables. Due to this multifaceted nature, successful management practices of SSFs should properly address all these aspects, and therefore it clearly emerges the need to collect relevant data concerning multiple aspects of SSFs management in order to develop and adapt sound management plans and strategies.

However until now very few studies investigated both the environmental and the human dimension of SSF management, and therefore it clearly emerges the need to fill this gap.

This document aims to provide some broad guidelines about general dimensions and specific variables that should be monitored in order to obtain crucial elements to develop a sound management of SSF within and around MPAs with the aim to reach a win-win scenario ensuring both conservation and fisheries goals. More specifically, here we describe the methodologies that we used to collect relevant data in the framework of FishMPABlue 2, in each of the 11 Pilot MPAs.

As a general recommendation it is important to stress the relevance of: 1) carrying out sound scientific studies of environmental and human aspects related to SSFs management in order to gather data about a number of relevant outcomes (e.g. MPA ecological effectiveness, MPA effect on CPUE, fishermen revenues, community empowerment, increase in social welfare) that are crucial to implement an effective management strategy of the complex social-ecological systems composed by SSFs and MPAs; 2) perform multi-year monitoring studies in order to evaluate temporal trends of assessed outcomes. In this context, it is fundamental to stress the importance of planning robust sampling strategies and designs allowing to highlight the effect of MPAs on a set of variables accounting for natural and spatial variability in the investigated system (Claudet and Guidetti 2010). It is advisable therefore that scientific studies and monitoring should be conducted in partnership between MPAs scientific or technical personnel and scientific institutions to make sure that the methods chosen, the way the monitoring is actually conducted in the field and the way data is analyzed allow proper conclusions to be drawn.

Here below we will describe some variables (and methodologies) that deserve to be investigated to understand the effect of MPAs on SSFs management accounting both for the environmental and the human dimension of the system.

2. Environmental monitoring

Here we focus on the monitoring of the fish assemblage because it is directly related to SSFs management representing the resource extracted by SSFs.

In order to assess MPAs reserve effect on fish assemblage, it is important to characterize and compare the fish assemblage among locations under different protection levels: no-take/no-access zones, buffer zones and unprotected locations outside the MPA, at multiple sites within each of these zones. The sampling design should be adapted to each MPA related to MPA zoning and peculiar features.

In the framework of FishMPABlue 2 monitoring, in order to characterize the fish assemblage, we combined two techniques (underwater visual census with strip transect and Baited Underwater Video systems) in order to collect information about a large spectrum of fish species. These techniques allow us to estimate fish density, size distribution and biomass per each species recorded.

In addition a recently developed methodology (Squidpop) was used to assess the potential effect of MPAs on predation intensity and related top-down ecological control.

1.1. Underwater visual census (UVC) – strip transect

Fish assemblages were sampled by means of underwater visual census using strip transects of 25 × 5 m (a standard surface largely used globally and in the Mediterranean Sea particularly, Harmelin-Vivien et al. 1985). In each transect the diver swims at constant speed, identifying, counting and estimating the size of all individuals within 2.5m on either side of the transect line (Fig. 1).

Figure 1. Scientific diver carrying out underwater visual census in Zakynthos Marine Park.

Actual number of fish encountered are recorded up to 10 ind., whereas larger groups are recorded using categories of abundance (i.e. 11–30, 31–50, 51–200, 201–500, >500 ind.). Fish size (total length, TL) is recorded within 2 cm size classes for most of the species, and within 5 cm size classes for large-sized species (maximum size >50 cm) such as the dusky grouper *Epinephelus marginatus* and the brown meagre *Sciaena umbra*. Data about cephalopods and macro-crustaceans are recorded following the same methodology (carapace and mantel length are estimated respectively for crustacean and cephalopod).

In order to account also for the potential effect of benthic coverage on fish assemblages (and therefore be able to control it and properly estimate reserve effect) information related to habitat coverage was also recorded. Specifically, cover of algae, barren, and sediment was estimated by analyzing photos taken with a camera held orthogonally downward at a standard distance (~1 m) from the bottom (Fig. 2).

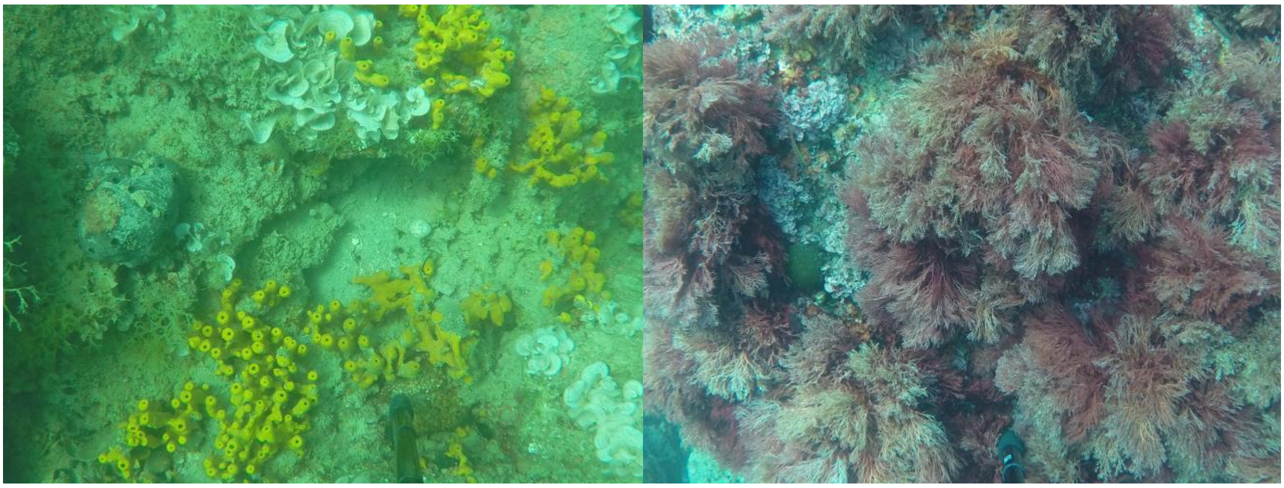

Figure 2. Examples of photos of the bottom to estimate cover of benthic organisms (on the left a photo from Strunjan, on the right a photo from Cabo de Palos).

1.2. Baited Underwater Video systems (BUVs)

Fish assemblages were surveyed by deploying standard Baited Underwater Video systems (BUVs). BUVs represent a complementary method to UVC to estimate fish abundance, diversity and size/biomass in both shallow and deep habitats. The principal advantages of such baited video sampling techniques are that they are not invasive or extractive and they might allow to record large mobile and predatory fishes, that in some instances can avoid SCUBA divers. Videos and images can be analyzed more than once by several observers, allowing repeatable and accurate measurements. Such underwater video techniques can also overcome some safety issues related to working at high depths or under adverse environmental conditions for divers (Fig.3).

Our sampling protocol for each MPA was to deploy for one-hour replicate Horizontal Baited Underwater Video systems (H-BUVs) in three locations (No-take, Buffer, Unprotected) and in two random sites within each location at a fixed habitat typology and depth range.

Each H-BUVs unit consists of a stainless steel frame having a mesh bag on one end containing a fixed amount of bait (i.e. crushing sardines to ensure greater dispersion of the plume, usually 400 gr of *Sardina pilchardus* per replicate; Harvey et al 2007), and supporting -- on the other end -- two GoPro Hero 3 high resolution (720p) stereo-video cameras located in a waterproof housing. Each H-BUVs unit is fixed by a rope to a large buoy on surface along with two small buoys in proximity of the unit. These reduce the tie-beam power from end to end and prevent the negatively buoyancy of the rope interfering with the video system.

Each BUV system was deployed at an approximate distance of 150 meters each other, to potentially avoid the estimation of the same individuals over time, particularly for sedentary species. Each replicated 1-hour video was analyzed in the lab to record standard response variables as: species identity (fish species richness), MaxN (the Maximum Number of fish of the same species observed in a given frame) and the size of each fish individual through a specific computer software. The MaxN value reduces the possibility to count different times the same fish and gives a conservative measure on the relative abundance of every species in a given 1-hour replicate (Whitmarsh et al. 2016).

Figure 3. Frames from videos of BUV deployment. In order from left to right: Cabo de Palos, Cote Bleue and Telasciča.

1.3. Squidpop

Since well-enforced MPAs boost total fish biomass particularly that of large predatory fishes, we also aimed to assess how top-down control varies in no-take, buffer, unprotected locations/sites and through time by Squidpops.

Squidpops is a novel standardized technique to assess top-down control in marine systems, being used in several habitats worldwide and considered to be a useful technique to measure variation in predation intensity among habitats, among seasons, and along environmental gradients (Duffy *et al.*, 2015). Specifically, the squidpop measures the relative feeding intensity of generalist predators and consists of a 1.3-cm diameter disk of dried squid mantle tethered to a 30-60 cm rod, which is either inserted in the sediment in soft-bottom habitats or secured to existing structures (Fig. 4a; 4b). Each replicate squidpop is scored as present or absent after 1 and 24 hours, and the data for analysis are proportions of replicate units (25 tethered rods) consumed at each time. Underwater, tethered rods are spaced by 1-2 m in single or double rows and filmed by an underwater camera for the first hour (Fig. 4c; 4d; Duffy *et al.*, 2015).

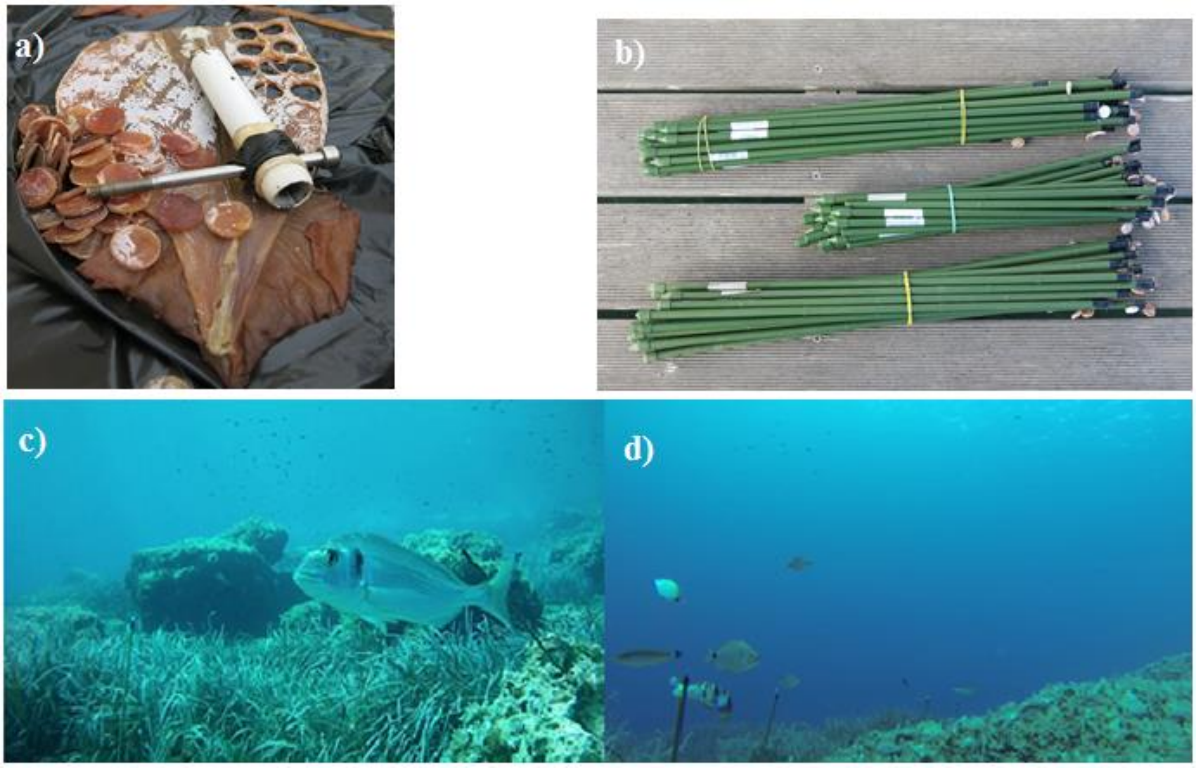

Figure 4.a) Disc of dried squid mantle b) plant stek with dry squid attached ready for sampling c-d)Frames from videos recorded during Squidpop deployments (on the left a photo from Es Freus on the right a photo from Telasciča)

3. Monitoring of human dimension (i.e. socio-economy)

In order to capture the multi-faceted nature of human dimension of small scale fisheries it is crucial to collect data concerning a relevant number of variables. These variables may encompass different domains, for instance economic, social, cultural, health and governance (and relative subdomains) as proposed by Kaplan-Hallam and Bennett 2017 (Fig. 5).

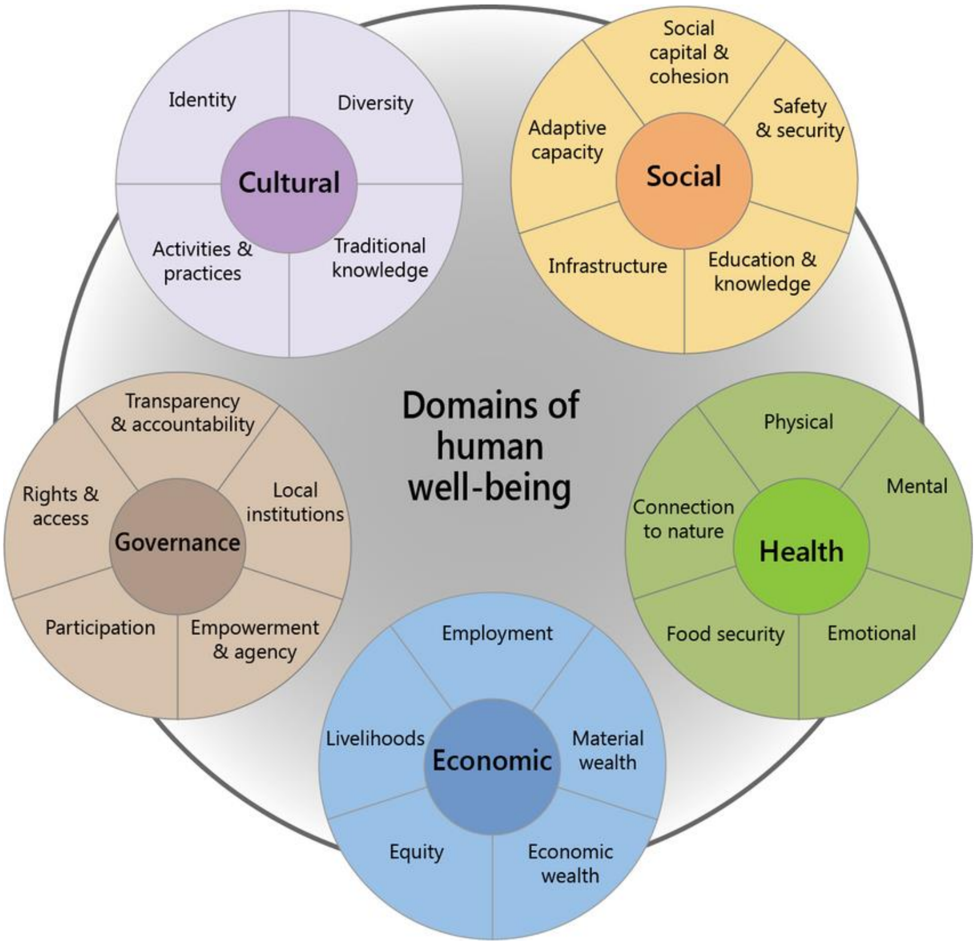

Figure 5. Domains of human well-being for social impact assessments as proposed by Kaplan-Hallam and Bennett 2017. From Kaplan-Hallam and Bennett 2017.

In FishMPABlue 2 we chose to collect data about the economic dimension of small scale fisheries in MPA by comparing the catches per unit of effort (CPUE) and the revenue per unit of effort (RPUE) obtained within the MPA with those obtained in open fishing areas outside the MPA using the same gear and approximately within the same bathymetric range and habitats.

To this end we planned to monitor a set of landings inside and outside each of the pilot MPAs. Multiple landings can be monitored at a single day, and even from a single fisherman, i.e. from a fisherman deploying 2 nonconsecutive nets in a single day (e.g. a net inside the MPA and a net outside the MPA).

For each landing monitored we collected information about: 1) catches, 2) fishing effort and 3) distance traveled to perform the fishing operation (i.e. distance between starting port and fishing site).

In addition we collected information about ex-vessel price of each species.

In order to collect information about catches, a number of different methodologies can be applied. In order to minimize sampling time in field and fish manipulation we chose to collect data using a photo-sampling methodology. Practically the operator places the catch over a flat surface (e.g. a table or the fish box to minimize manipulation) and takes one/multiple pictures where a ruler (as length reference) has to be visible and on the same plane as fishes. All the individuals have to be clearly identifiable and seen entirely (from the tip of the snout to the tail). The pictures have to contain an unique identifier of the fishing operation (i.e. a small piece of paper with a unique code) (Fig. 6, 7). This will allow, a posteriori, to assess length and wet weight of each specimen in laboratory by using a image-analysis software (e.g. ImageJ).

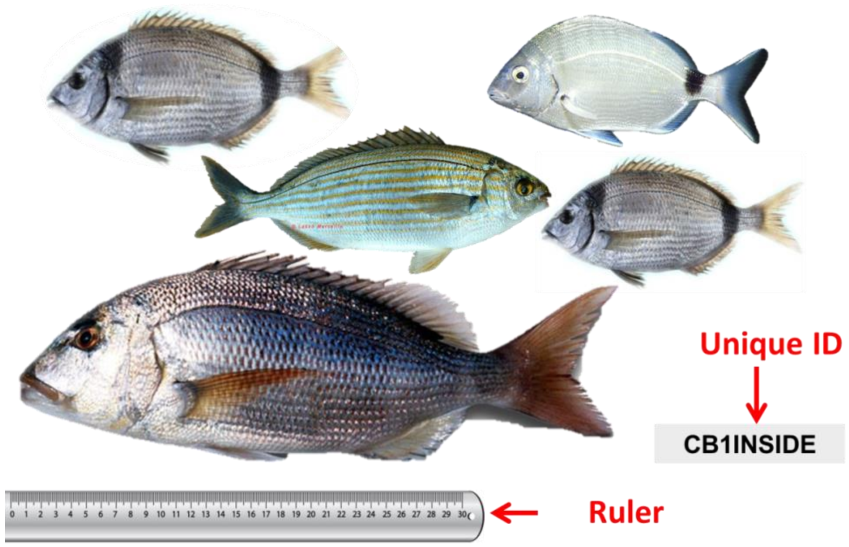

Figure 6. Exemplificative representation of how to collect data on small scale fisheries catches.

Figure 7. Picture of small scale fisheries landings taken at Zakynthos Marine Park (Greece) using photo-sampling technique (photo by Charalampos Dimitriadis).

We also developed two questionnaires to collect data about a number of other domains (and specific variables) of the human dimension. A set of relevant variables to describe the human dimension in small scale fisheries and more precisely the human well-being of small scale fishermen communities has been identified through extensive literature review and expert knowledge assessment.

Here below an exemplificative list of some of the categories, variables and potential descriptors that can be useful to describe human dimension of small scale fisheries in and around MPAs (Table 1).

Table 1. Non-exhaustive list of category, subcategory and potential descriptors of domains of human dimension of small scale fisheries.

Category	Sub-category	Description	Potential Descriptors
Economic	Employment	Employment rate and diversity within the fishermen community	1. Increasing number of people per family (or community) who work inside the MPA or whose work depends on the MPA 2. Increasing number of working activities inside the MPA e.g. pesca-tourism) or associated to it (e.g. fish and processed fish shops) 3. Sense of employment security
Social	Knowledge	Level of knowledge about the marine environment and human impacts on it	1. Increased knowledge
Governance	Participation	Fishermen participation in MPA management and decision making processes	1. Number of meeting proposed by fishermen 2. Number of fishermen participating to each meeting organized by the MPA
Governance	Empowerment and rights	Fishermen community unity and social commitment toward the MPA	1. Occurrence or number of warnings from professional fishermen on potential infractions in the MPA (e.g. warnings of illegal activities) 2. Level of collaboration in the MPA management
Cultural	Identity	Fishermen identity and identification with MPA and its goals	1. Self-definition (at individual and community level) 2. Fisherman perception about their role within the community and MPA
Cultural	Traditional practices and activities	Use or recovery of fishing community traditional practices	1. Increasing use of traditional fishing practices 2. Recovery of traditional use of resources (e.g. reintroduce and popularize traditional recipes)
Health	Emotional health	Life satisfaction and sense of personal and community safety	1. Level of life satisfaction 2. Level of happiness
Health	Connection to nature	Level of place uniqueness, level of affinity with the place and MPA contribution to this affinity	1. Sense of place 2. MPA contribution to make the place special/unique and pleasant to live and work in/around

The questionnaires have been administered to the MPA managers, and to a relevant proportion of small scale fishers within each pilot MPAs (Fig. 8).

Figure 8. Interviewing fishermen at Egadi MPA, Italy.

In order to properly administer the questionnaires it is important to consider the following best-practices:

- Avoid to select respondents basing on your personal liking. All fishermen opinions are important.
- Make the interview relaxing and enjoyable. Try to interview fishermen when they are not too busy, for example when they are mending the nets. Avoid to interview them when they are landing or selling the fish.
- The interview can be conducted in every comfortable place for fishermen, (eventually inviting them for a drink in a bar).
- Arrange with them the time and place for the interview if needed.
- Ensure confidentiality of the interview. Promise not to divulge person ID in report or documents.
- Clearly state that the interview is voluntary.
- State the importance of their participation to the interview for improving SSF conditions within the MPA.
- Keep neutrality, do not let your impressions or feelings guide the interview. Do not manipulate fishermen opinion for a convenient result.

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