Assessment of marine biodiversity in a protected bay: the importance of integrated methods for a better result

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Abstract. Like other Mediterranean Marine Protected Areas, Punta Campanella MPA (Italy) is undergoing some significant changes in biodiversity. To properly understand the situation and to depict a valid baseline, several monitoring campaigns have occurred to assess biodiversity in Ieranto Bay, a special zone B of the MPA that allows the sustainable interaction between humans and nature. This work aims to analyze the different monitoring methods used and how each of them has contributed to the assessment of more than 250 species in the bay, from algae to vertebrates. The results represent a substantial biodiversity baseline of data to assess eventual changes in the future, and a valid tool to inspire and suggest management plans. The census of underwater life in this protected bay is an ongoing and constant activity and is an experience of collaborative research involving experts and volunteers supervised by the MPA staff.

Introduction

The Mediterranean Sea is a marine biodiversity hotspot, contributing to more than 7% of the world's marine biodiversity (Coll et al. 2010). In the last years, worldwide biodiversity has been decreasing at an unprecedented and alarming rate due to several human impacts (United Nations 2019). To preserve nature, many Protected Areas (PA) have been created. A PA is defined as a geographically limited area, which is designated, regulated, and managed to achieve specific conservation objectives (Dudley and Stolton 2008). It has a fundamental role in protecting species and habitats from extinction and in supporting the natural ecological processes (Naughton-Treves et al. 2005), controlling the impacts, and trying to slow down the extinction process.

More recently, Mediterranean marine habitats and their managers have had to adapt to changing environmental conditions, requiring practical efforts to keep a climate-conscious design operational and management in the global network to ensure long-term effectiveness for safeguarding biodiversity and ecosystems (Tittensor et al. 2019; Azzurro et al. 2020). Due to the importance of monitoring wildlife and ecosystems in the last few decades, a big effort is being done to assess the environmental status (Molnar et al. 2008; Meola and Webster 2019; Azzurro et al. 2019).

Ieranto Bay

Fig.1. Punta Campanella MPA map with Ieranto Bay area signalized by the black shape (left) and view of Ieranto Bay (right – photo by Francesco Rastrelli).

The Marine Protected Area (MPA) of Punta Campanella (Fig.1 – left) is located between two important gulfs, the Gulf of Naples and the Gulf of Salerno. It was established in 1997, spanning an extension of 31 km with a total area of 1539 ha. The MPA is divided into the following 8 areas with descending levels of protection: 2 red areas (zone A) just for nature with no human presence; 3 yellow areas (zone B) where regulated human presence is allowed; and 3 green areas (zone C) with a larger human presence. In the middle of this MPA, in a zone B, lies Ieranto Bay, the heart of the Punta Campanella MPA (Fig.1 – right).

Ieranto Bay is located on an internationally popular tourist route between Sorrento, Capri, and the Amalfi coast and it is a renowned diving spot, as it presents high marine biodiversity. Until the foundation of the park in 1997, it was considered the perfect place for boat tourism due to its sheltered position, with hundreds of vessels anchored every day on the seagrass meadow (*Posidonia oceanica*) (pers. obs.). Today, the bay has two special measures of conservation: 1 – professional fishing is allowed only for 8 months per year – not allowed during summertime; 2 – the entrance of motorboats is not allowed, except for authorities and authorized guided tours.

To gather information about the bay and to protect it from boating, anchoring, and illegal fishing, the Punta Campanella MPA has developed a pilot management model (Fig.2) that is composed of 3 interconnected key actions: Monitoring, Conservation, and Communication (Sgambati et al. 2020). Despite their connection with each other, monitoring is the most important action. As reported by Vierros (2004), the correct application of adaptive management strongly depends on monitoring.

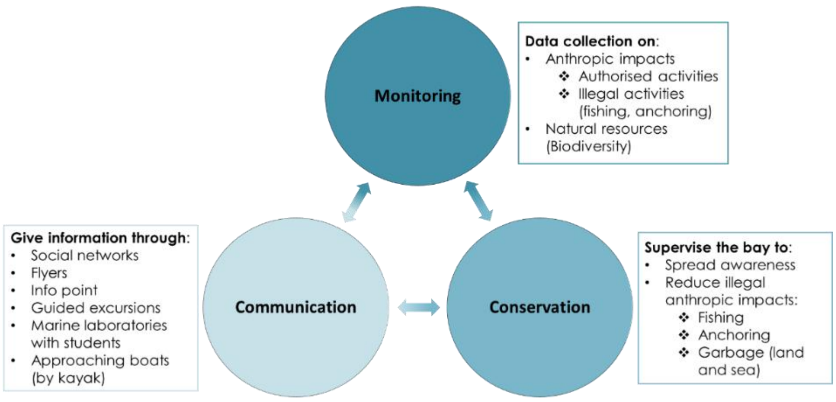

Fig.2. Punta Campanella MPA management model applied to Ieranto Bay.

Following the application of this model, the volunteers of Project M.A.R.E. (https://www.marineadventures.org/en/), an European Voluntary Service project that is funded by the European Commission through the European Solidarity Corps program and coordinated by the Punta Campanella MPA, have been running an assessment of the biodiversity in Ieranto Bay since 2015. This underwater life census is an ongoing and continuous activity and is an experience of collaborative research, involving local experts and foreign volunteers supervised by the MPA staff to explore and discover the biodiversity in the bay. These data will support future conservation plans, taking into account the challenges that conservation poses in this stretch of sea with a high population density and tourist presence.

Marine Biodiversity Assessment

According to MMMPA Supervisory Board 2016, all monitoring activities have numerous variables to consider when an assessment is being planned. Monitoring is needed to ensure the goals and objectives of the MPAs, but the methods are highly variable depending on what they measure, who performs it, and where, when, and how it occurs. They must be personalized and include good baseline data, robust indicators, and control sites.

The techniques used to run a monitoring activity can be "traditional" (e.g. visual census, video/photo sampling, genetic tools, etc.) or can be from emerging interdisciplinary fields (e.g. georeferred biocartography, genetic connectivity, biogeochemistry, etc.) (MMMPA Supervisory Board 2016). More recently, scientists have been taking advantage of citizen involvement and collaboration of sea users to collect useful scientific data (Preece 2016; Azzurro et al. 2019).

Ieranto Bay extends for approximately 51 ha with the following specific natural characteristics that provide valuable, complex, and mixed habitats:

- The presence of strong upwelling currents (De Alteris; de Ruggiero et al. 2016) – bring inorganic nutrients into surface waters, which result in some of the most productive marine ecosystems worldwide. They are important for organisms that rely on abundant phytoplankton and zooplankton food resources (e.g. sardines, anchovies, and mackerel) (Anderson and Lucas 2008);
- N-S orientation – provides different shadow-light expositions in a small area;
- A vertical underwater cliff, close to the Southern coast of the Sorrento Peninsula, located at the edge of the continental shelf (Ferrigno et al. 2018) – the cliff gives substrate to sessile organisms and shelter to organisms depending on the rocky environment;
- The presence of canyons and caves accessible with snorkeling.

Due to these characteristics, the bay has a mixture of benthic organisms (which live along the jagged coast and on the seabed covered with *Posidonia oceanica*) and pelagic organisms that are transported within the bay, with resident and occasional species.

According to Edgar et al. 2014, "global conservation targets based on area alone will not optimize protection of marine biodiversity. More emphasis is needed on better MPA design, durable management, and compliance to ensure that MPAs achieve their desired conservation value".

This work aims to build a solid biodiversity baseline of data from Ieranto Bay. Different monitoring methods are considered and evaluated based on their contribution to the overall assessment of marine biodiversity. These results are important to set a standardized protocol and apply it in other MPAs. The data collected has the important role of being the reference for future assessments, analyzing the changes that are occurring through the next years.

Methods

The performed underwater monitoring campaigns are in the framework of a long-term monitoring program started in 2012 and are based on different and complementary methods putting together standardized protocols, random punctual observations, fishermen, and citizen science records. This section focuses on the 7 different methods used during the 8 underwater monitoring campaigns realized between 2015 and 2020 (Table 1) inside the approximately 5 ha that cover the two bays: the big (A) and the small (B) bay (Fig.3).

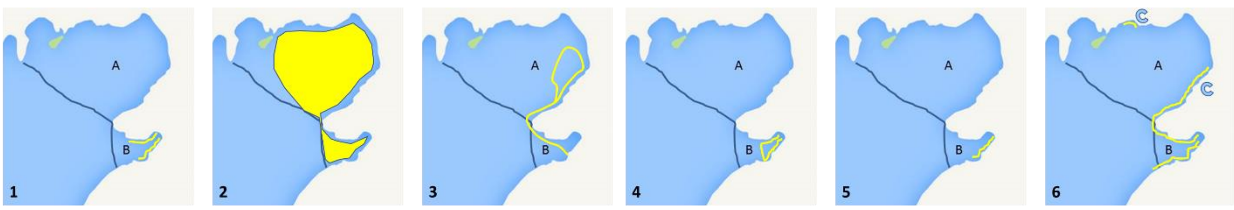

Fig.3. Maps with the transects (yellow line) performed each year for each method. A = Big bay; B = Small bay. 1 – 2015 and 2019 (Algae); 2 – 2015 (Fish) area where the 8 transects were performed; 3 – 2016 and 2017; 4 – 2018; 5 – 2019 (Animals); 6 – 2020 with the blue C representing the caves.

Table 1. Description of the 7 different methods used during the 8 underwater monitoring campaigns completed between 2015-2020. (all the methods using snorkeling took place from the surface down to a depth of 2-3 m and the ones using scuba diving down to 5 m) *the method used in 2016 is the same as in 2017. Total species (TS) = total censed species; Added species (AS) = species added to the species database in respect to the previous year and monitoring methods (new records for the study area). FVC = Fish Visual Census; BTA = BlueTeam in Action; SN = Snorkeling; SD = Scuba diving; DS = Destructive sampling; PS = Photographic sampling.

Year	*Focused group*	*Number of observers*	*Total transect (m)*	*Apparatus*	*Specifics*	*Species identification*	*Season*	*TS*	*AS*
2015	Algae	2	180	SN	-	DS	Summer	24	24
A total transect of 180 m was performed through the rocky walls of the small bay, by snorkeling, to collect samples of algae for a post-identification with microscope, id manuals, and experts.									
2015	Fish	1	100*8=800	SN	FVC	*in situ*	May + October	23	23
Eight transects of 100 m were made in 10 minutes, swimming at a constant velocity to observe the fish around the swimmer, covering a radius of 2.5 m (Azzurro et al. 2020). The fish were identified when they were observed.									
2016*	Animals	4	890	SN	BTA	*in situ*	Summer	90	71
2017	Animals	4	890	SN	BTA	*in situ*	Summer	95	30
Monitoring campaign carried out following the international activity BioBlitz (National Geographic). In the Punta Campanella MPA it has the name of BlueTeam in Action and it is done in all the area of the MPA including Ieranto Bay. The transect was performed using snorkeling and the identification of the species was done while they were observed.									
2018	Cnidaria & Porifera	1	235	SN + SD	-	PS	Summer	54	16
A total transect of 235 m was performed inside of the small bay to identify species from Cnidaria and Porifera phylum through *in situ* observations and photo identification when it was not possible to do the identification *in situ*. The photos were analyzed with id manuals and experts.									
2019	Algae	1	180	SN	-	*in situ* + DS	Summer	41	29
A total transect of 180 m was performed along the rocky walls of the small bay to identify *in situ* and collect samples for a post-identification with microscope, id manuals, and experts.									
2019	Rocky environment (Animals)	2	95	SN	12 h	*in situ* + PS	September – October	140	47
A total of 95 m was narrowly traversed through a rocky wall from the small bay in a total of 12 hours. The species identification was done *in situ* and with the analyses of photos. The photos were analyzed with id manuals and experts.									
2020	Rocky environment & Caves (Animals)	7	545	SN + SD	-	*in situ* + PS	October – February	92	9
A total of 545 m was performed in small and big bay, exploring the rocky walls and the caves. The identification was done *in situ* using specific underwater guides and the analyses of photos with id manuals and experts.									

Results and Discussion

In six years of monitoring the species in Ieranto Bay, we built a database with 271 species from 11 phyla (Plantae, Annelida, Arthropoda, Bryozoa, Cnidaria, Echinodermata, Entoprocta, Mollusca, Porifera, Protista, and Chordata) and the photosampling allowed the collection of more than 1000 photos. Overall data came from different sources, being the main one the underwater monitoring campaigns (91.9%) done by the volunteers from Project M.A.R.E. between 2015 and 2020. Nevertheless, a small percentage (8.1%), but highly significant from a biological point of view (since these species would hardly be identified by the monitoring campaigns), came from the following sources:

- The constant presence of the observers in the bay, which allows for the identification of species passing there or coming in specific moments with the currents, for example (e.g. *Planes minutus* and *Velella velella*);
- The presence of fishermen during the winter throughout many years, which allows for the understanding of changes through time and the identification of species from catches at a depth that we do not usually reach (e.g. *Coryphaena hippurus* and *Euthynnus alletteratus*);
- Random observations coming from the general public in the bay and also from scuba diving groups. This second type gives information from other places and depths in the bay that we usually do not cover in the monitoring campaigns (e.g. *Caretta caretta* and *Ichthyaetus audouinii*);
- Observations coming from other events of monitoring done in the bay, for example from the monitoring campaigns of *Pinna nobilis* (e.g. *Scyliorhinus stellaris* and *Caulerpa taxifolia*).

With all data collected in these years, the species found in the bay can be divided into 3 groups (Fig.4), with Invertebrates representing more than 50% of the species (55.7%) and Vertebrates and Plantae representing together the other 50% (24.0% and 20.3%, respectively).

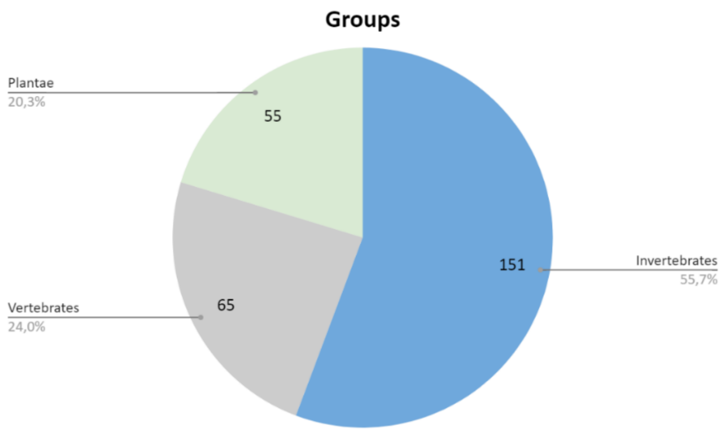

Fig.4. Group representativeness in Ieranto Bay.

These results are in line with the main characteristics of the bay, an extremely heterogeneous environment with mountains going into the sea (Ferrigno et al. 2018), and different shadow-light exposures that provide different conditions for various habitat types densely populated by invertebrates.

A close analysis of the data reveals that out of the 11 phyla (Fig.5 – left), the group Chordata (Fish) and the phyla Plantae and Mollusca represent more than 50% of the species in the bay (58%, 55%, and 41%, respectively). On the other hand, Annelida, Echinodermata, Chordata (others – birds, dolphins, and sea turtles), Chordata (Tunicata), Bryozoa, Protista, and Entoprocta represent less than 15 species each. In part, this distribution can be explained having into account some factors:

- Chordata (Fish) – the data for this group comes from one focused campaign in 2015, from fishermen and contains the most familiar species to the general public. It also is made up of species that are easier to find;
- Plantae – the data for this group comes from two focused campaigns (2015 and 2019);
- Mollusca – *per se* it is a big phylum and its common species are present within the rocky environment of Ieranto, which makes them easier to identify;
- Other groups (less than 15 species) – most unknown groups and with species that are morphologically smaller (< 5 cm), which adds the difficulty in finding them.

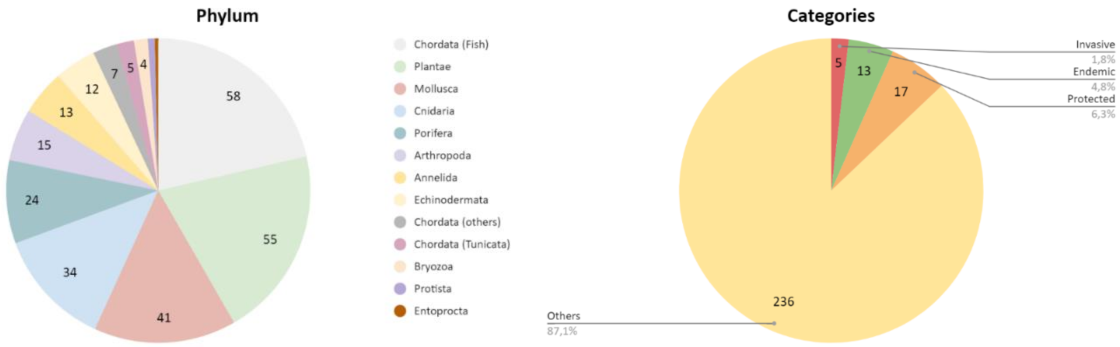

Fig.5. Distribution of Ieranto Bay species by phylum (left) and by categories (right).

From a conservation point of view, 5 invasive species (e.g. *Caulerpa taxifolia* and *Percnon gibbesi*), 13 endemic species (e.g. *Agelas oroides* and *Tripterygion melanurum*) and 17 protected species (e.g. *Luria lurida* and *Epinephelus marginatus*) were identified in the bay (see Fig.5 – right).

Focusing on the underwater monitoring campaigns, as shown in Fig.6, all new campaigns found some species not previously recorded in the database (identified as "New"), even when the same method was repeated (2016 and 2017). The method that identified the highest number of species (140) and had the second highest number of added species (47) was the one performed in 2019 – a small area (95 m) of rocky environment was explored, using snorkeling, to identify animals during September and October. The method performed in 2020 – exploration of rocky environment and caves, using snorkeling and scuba diving, to identify animals from October until February – also identified a high number of species (92) but added fewer species to the list (9).

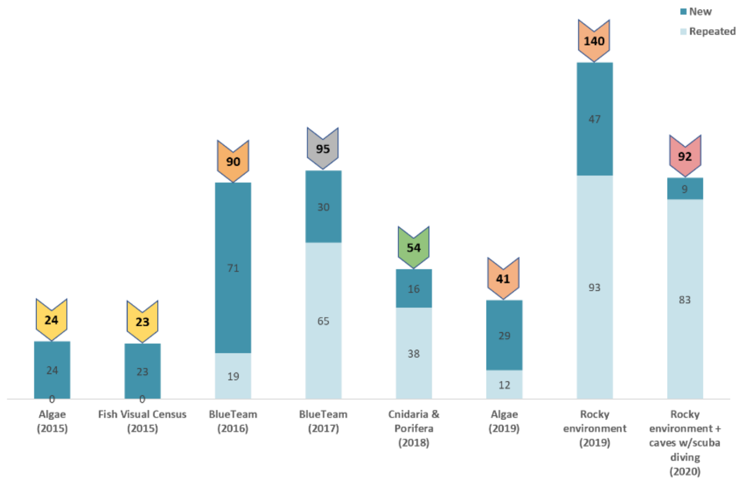

Fig.6. Contribution for the database given by each campaign. The number above the columns represents the total species identified in each campaign. "New" represents the species that appear for the first time in our database and "Repeated" the ones that were already identified in other campaigns.

The following details refer to the species found each year and the methods used to identify them (see Fig.6 and 7):

- 2015 was focused on two individual groups (Plantae and Chordata [Fish]), with the destructive sampling of algae identifying 24 species and the fish visual census identifying 23 species;
- in 2016 and 2017, using the *in situ* identification, species from 10 groups were identified (Chordata [Fish] – 43% [2016] and 32% [2017], Porifera – 6% [2016] and 9% [2017], Mollusca – 16% [2016] and 17% [2017], Echinodermata – 9% [2016] and 11% [2017], Cnidaria – 11% [2016] and 13% [2017], Bryozoa – 2% [2016] and 3% [2017], Arthropoda – 8% [2016] and 7% [2017], Annelida – 3% [2016] and 6% [2017], Plantae – 1% [2016] and 1% [2017] and Chordata [Tunicata] 2016 – 1% and Protista 2017 – 1%) with approximately the same proportions;
- in 2018, photosampling through snorkeling and scuba diving focused on Cnidaria (33%) and Porifera (26%), but other 8 groups with smaller representativeness were also identified (Chordata [Fish] – 17%, Chordata [Tunicata] – 2%, Porifera – 26%, Mollusca – 2%, Echinodermata – 6%, Cnidaria – 33%, Bryozoa – 2%, Arthropoda – 6%, Annelida – 4% and Plantae – 4%);
- in 2019, the campaign focused on Plantae using *in situ* identification and destructive sampling through which 41 species were identified. The photosampling in a rocky environment further identified 9 groups with

Chordata (Fish) (23%), Mollusca (21%), Cnidaria (16%), and Porifera (15%) having the higher percentages and the remaining groups (Chordata [Tunicata] – 2%, Echinodermata – 6%, Bryozoa – 3%, Arthropoda – 7% and Annelida – 7%) with lower percentages.

- in 2020, photosampling in rocky environment and caves, through snorkeling and scuba diving, identified 11 groups with Cnidaria (22%), Chordata (Fish) (20%), and Mollusca (15%) being the most representative and (Chordata [Tunicata] – 1%, Porifera – 10%, Entoprocta – 1%, Echinodermata – 11%, Bryozoa – 1%, Arthropoda – 8%, Annelida – 5% and Plantae – 7%) making up the other organisms found.

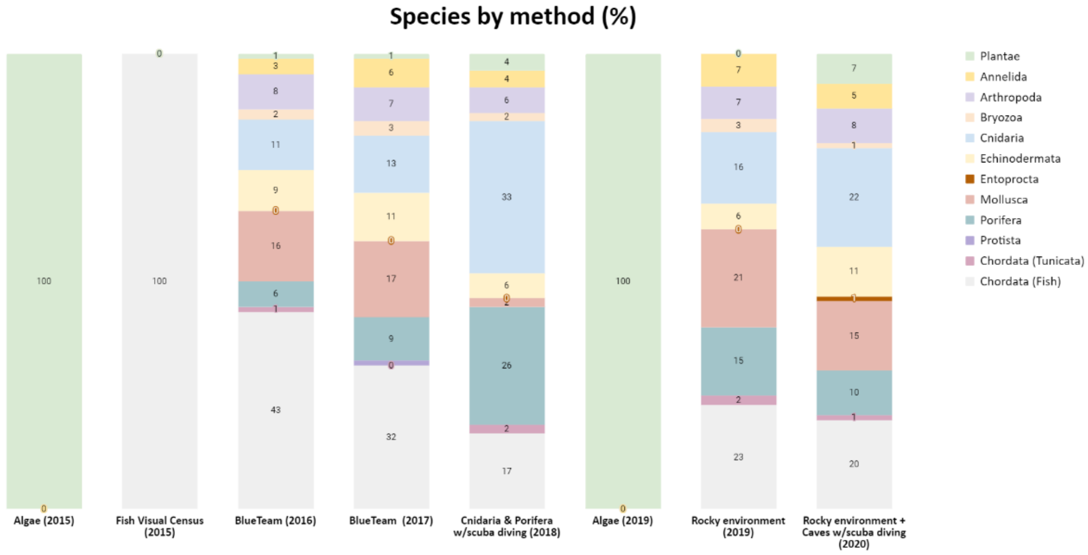

Fig.7. Distribution, in proportion, of species by each campaign completed.

It is important to highlight the different variables that are involved in these monitoring campaigns. Besides the different methods applied, there are also different observers with different experience and different focuses that change every year, and the campaigns were also done at different times of the year/seasons.

The particular and complex environment in Ieranto Bay, where we find an overlap of different organisms in the rocky ecosystems, requires the combination of different methods to have a more complete overview of all habitats and taxa.

Since this protected bay is part of the Mediterranean Sea, a complex region where ecological and human influences meet and strongly interact, there is a large and growing potential to impact marine biodiversity (Coll et al. 2010). Thus, it is highly important to know the present environmental status to understand and control the impacts.

With this work, we advocate for the application of the management model of the MPA because the monitoring information helps to provide a more comprehensive analysis of conservation and management initiatives to preserve biodiversity, as proposed by Coll et al. 2010.

All the work undertaken during the last 6 years also resulted in the creation of diversified disseminative and scientific materials (Fig.8, 9, 10 and 11) that help with the accurate identification of species and contribute to raising awareness of people attending the area about what can be found in the bay and how its extraordinary biodiversity can be preserved.

Fig.8. Algariums created in 2015 (A), 2019 (B) and 2020 (C).

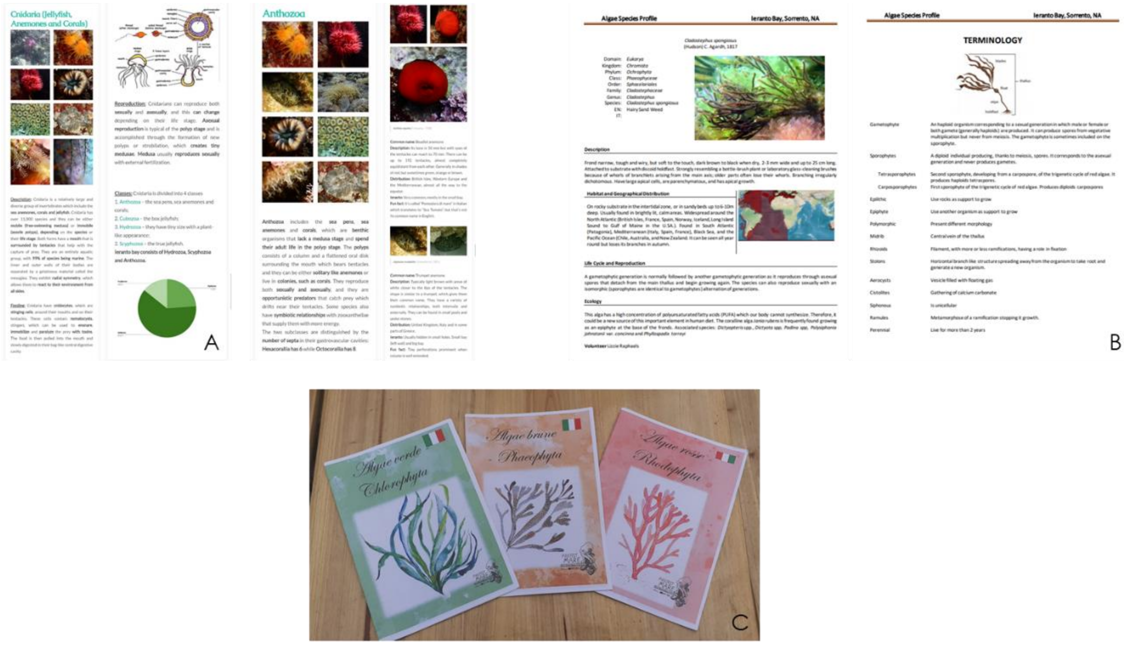

Fig.9. Species info sheets created in 2019 (A) and 2020 (B) and Algae info books (C) created in 2019.

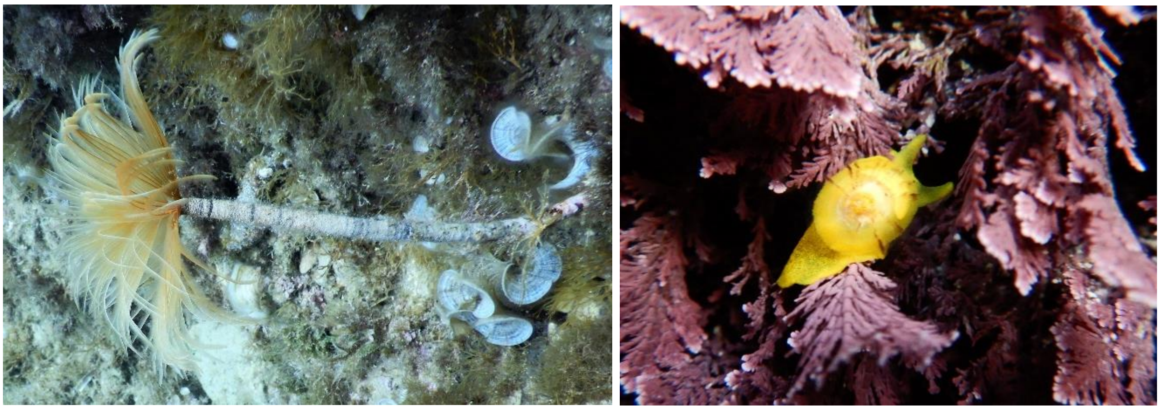

Fig.10. E.g. from photographic database: *Sabella spallanzanii* (photo by Domenico Sgambati in 2019 – left) and *Tylodina perversa* (photo by Érica Moura in 2019 – right).

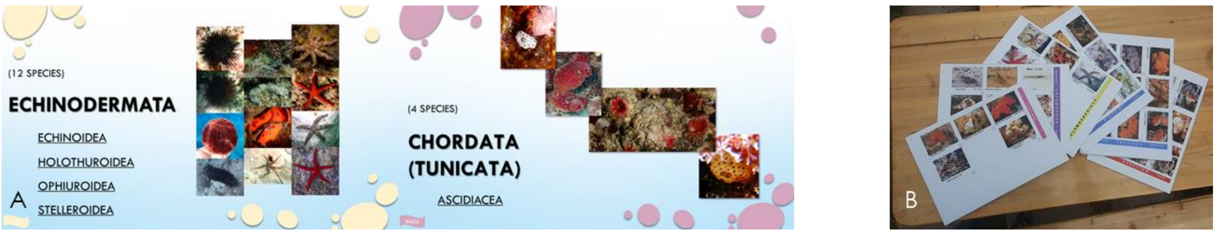

Fig.11. Species guides created in 2020: virtual and interactive guides (A) and forex underwater guides (B).

Conclusion

Similar to other MPAs (Bruno et al. 2018; D'Amen and Azzurro 2019), the Punta Campanella MPA is undergoing some significant changes in biodiversity, involving the presence of exotic species and native community shifts. To properly understand the current status of the area and to depict a valid baseline, several monitoring campaigns have been completed to assess biodiversity in Ieranto Bay, a special zone B of the MPA that allows the sustainable interaction between humans and nature.

According to Sgambati et al. 2020, the monitoring represents the central and most important action of the Punta Campanella MPA management model, as it allows for the evaluation of the different dimensions through which humans influence the sea resource, it examines the results of conservation and gives correct and updated information to the public.

Ieranto Bay allows the use of experimental tools and young volunteer involvement in marine conservation, from which efficient practices are developed and shared with other areas within the Punta Campanella MPA and with other MPAs. The results of this work represent an important biodiversity baseline of data to assess eventual changes in biodiversity in the future of the MPA, and a valid tool to suggest management plans. However, only recently was possible to put effort into the monitoring activities in this protected bay. The lack of old-time data, as the almost only old data available are the ones coming from fishermen, makes difficult the comparison between past and present data and for this reason we have the risk to incur in the shifting baseline syndrome (SBS) (Soga and Gaston 2018).

Nevertheless, the census of underwater life in this Ieranto bay is an ongoing open and constant activity, especially when looking to the future. It is an experience of collaborative research, involving experts and volunteers supervised by the MPA staff that is already planning its next steps: more data collection from citizens through the creation of a public group to share information/photos about species found in the bay, the exploration of new depths through the acquisition of an underwater drone (Barberá et al. 2012; Mallet and Pelletier 2014), and new collaborations with experts.

Monitoring is needed to ensure the goals and objectives of the MPAs are met, and it has to be individualized according to the area and its goals (MMMPA Supervisory Board 2016). It is necessary to know the status of biodiversity in a MPA to better understand the effects of future environmental pressures.

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