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CIGESMED FOR DIVERS: A SUCCESSFUL APPROACH COMBINING SCIENCE AND CITIZEN INVOLVEMENT FOR THE MONITORING OF NW MEDITERRANEAN CORALLIGENOUS REEFS

Abstract
CIGESMED for divers is a citizen science program developed in 2016 by an international scientific team. It aimed to provide a scientifically-based simplified protocol for recreational divers to get involved in the monitoring of coralligenous reefs. Between 2016 and 2021, about 150 observations were collected by volunteer divers in and around the area of the Calanques National Park (Marseilles, France). The data collected allowed the qualitative and semi-quantitative description of the benthic communities of 27 diving sites and the assessment of some natural and anthropic pressures. Data were analysed by gathering observations over three consecutive years to get enough data to reduce the observer bias, and to allow temporal comparisons of the most frequented diving sites. It was then possible to characterise the abundance of the main taxa, as well as the pressures that occurred in this habitat. Their variation over time was also highlighted. Considering the limitations imposed by scuba diving to citizens' involvement, as well as the lack of knowledge from recreational divers and diving instructors regarding coralligenous communities, those results were only made possible because of the enthusiastic coordination of a local network. Indeed, a diving and scientific organisation (Septentrion Environnement) proposed, every year, training sessions (theory and practice) and scheduled dives dedicated to CIGESMED for divers. By encouraging a feedback flow with the participants, it promoted the long-term involvement of citizens. CIGESMED for divers has proved to be an effective tool for the long-term monitoring of coralligenous reefs, particularly for local management purposes. It has also demonstrated to be a great tool for educational and training activities.

Key-words: long-term monitoring; coralligenous reefs; pressures; citizen science; local network

Introduction
Over the past decade, the active participation of volunteer divers has greatly assisted researchers in the inventory and monitoring of marine biodiversity (Thiel *et al*., 2014) and it still continues. In the Mediterranean Sea, some notable examples of Citizen Science (CS) programs focused on marine biodiversity concern the study and monitoring of non-indigenous species (Giovos *et al*., 2019; Zenetos *et al*., 2013), vulnerable emblematic species (Bramanti *et al*., 2011), aggregates of jellyfish and other gelatinous plankton (e.g. www.jellywatch.org), fish populations (Arvanitidis *et al*., 2011), gorgonians and corals mortality and/or reproduction (e.g. Coral Alert! Observadores del Mar platform), or long-term variations in marine benthic rocky communities linked to climate change (Turicchia *et al.*, 2021).
Although a multitude of CS projects concern tropical coral reefs on a global scale, few focus on their Mediterranean counterparts: the coralligenous reefs. This is likely due to the depth at which this biocenosis usually develops, which requires more experienced

scuba divers than for observing shallow water reefs. At the same time, the complex structure and remarkable biological and functional diversity contribute significantly to the high aesthetic value of coralligenous reefs (Tribot *et al*., 2016). Thus, they are extremely popular among scuba divers and are, without a doubt, among the most valued dive sites of the Mediterranean Sea.

In the framework of CIGESMED SeasEra (ERAnet) international project, the citizen science initiative "CIGESMED for divers" was launched in 2016 in France, Greece and Turkey. A simplified scientific protocol based on observation was created and theoretical training material was provided.

This initiative was launched to involve enthusiastic divers in the study and monitoring of Mediterranean coralligenous assemblages. It also aimed to introduce citizen to the gathering of basic information regarding the spatial occurrence and the assemblage structure of coralligenous reefs, as well as it participates to the awareness concerning pressures or threats that may be encountered (Gerovasileiou *et al.*, 2016). One of the objectives of CIGESMED for divers was to provide tools for recreational divers to continue to study and monitor coralligenous reefs after the official end of the CIGESMED project (2016). Willing to make divers aware of the ecological concerns in regard to coralligenous reefs and to promote their privileged position as the first observers of environmental changes, this initiative hand over the coordination to local actors and while maintaining a context of strong collaboration with scientists.

In this context, the partnership between Septentrion Environnement, *via* its citizen science platform POLARIS (Barth, 2020), and CIGESMED for divers has proven to be coherent and fruitful since its beginnings in 2016. POLARIS has become increasingly involved in the theoretical and practical training of diver-observers. It has developed a training process that is now autonomous and operational, which has proven to be essential for the effective application of the coralligenous habitat observation protocol. Two to three dive sessions per diving season are entirely dedicated to CIGESMED for divers which enable POLARIS to collect data and monitor coralligenous reefs year after year, particularly in the Calanques National Park (Gatti & Barth, 2020).

Six years after the beginning of this program, the data collected by volunteers have provided many information about coralligenous reefs communities in Marseilles' Bay, and the long-term monitoring of the most frequented diving sites has been initiated. This study aimed to discuss the initial objectives and the implementation strategy of CIGESMED for divers. More precisely, it identified which goals have been achieved, and discussed how to improve the dissemination strategy to support coralligenous reefs monitoring elsewhere in the Mediterranean Sea.

Materials and methods

The study area included 27 dive sites in the marine side of the Calanques National Park (Marseilles, France), in the NW Mediterranean Sea. With only two exceptions from the "buffer zone" (PNCAL-A-87, -64, and -141), most of the study sites was located in the "restricted zone" of the Park.

Data collection was supported by submersible slates provided to the volunteer divers. The slates contained all the required information for the characterization and assessment of coralligenous assemblages. More precisely, was observed a) the basic topographic and abiotic features for the preliminary description of each site; (b) the semi-quantitative abundance (abundance ranks: 0 - absent; 1 - rare; 2 - common; 3 - very common) of 23 typical conspicuous species distributed throughout the whole Mediterranean; and c) the semi-

quantitative abundance (abundance ranks: 0 - absent; 1 - limited; 2 - extended) of pressures and imminent threats (see Gerovasileiou *et al.,* 2016 for more details about the protocol).
Prior to their first dive considered in this study, all volunteers have participated to a theoretical and practical training provided by POLARIS' team. After the dive, each participant shared their data *via* the POLARIS' mobile application.
After checking the validity of the data, the number of observations collected in each diving site was computed in order to highlight the most frequented dive sites, which will be selected for long-term monitoring.
Data were analysed by gathering observations over three consecutive years (T0: 2016-2018; T1: 2018-2021) to reduce the observer bias, and to ensure that long-term monitoring of the most frequently visited sites was possible.
For coralligenous assemblage characterization, species were grouped according to their higher taxonomic affinity (Algae, Porifera, Cnidaria, Bryozoa, Crustacea, Echinodermata and Osteichthyes); endangered and protected species (according to IUCN Red List and local conservation measures) where grouped as well. The average abundance of each group (taxonomic and endangered/protected) per site was calculated as the sum of the average abundance of the species in each group. The temporal comparison of the assemblage composition and of the endangered/protected species was possible only for sites that presented sufficiently high and similar number of observations in the two periods (T0 and T1). The average abundance rank of each pressure and threat was computed taking into consideration all the study sites, in order to get an overview of their overall contribution and temporal variation in the Calanques National Park.

Results

Globally, 151 observations were collected between 2016 and 2021, including about 10% of non-exploitable contributions. The observed depth range varied from 11 m to 38 m. The observations were not evenly distributed among the study sites. In most of the sites, less than 5 observations were registered over T0+T1, while only 4 study sites had more than 10 observations (PNCAL_C_106, 103, 007 and PNCAL_A_087) (Fig. 1). The site PNCAL_C_106 was the only one that accounted for more than 20 observations almost evenly distributed between T0 and T1 (12 and 15, respectively). It was therefore selected for the temporal comparison of coralligenous assemblages that follows. The coralligenous reef of PNCAL_C_106 (Les Pharillons) developed on vertical walls from 14 m to 38 m depth and were exposed to all cardinal points. The bioconstruction was discontinuously distributed over an horizontal extent of more than 20 m and have shown medium to small crevices. Whatever the depth and time, the community was dominated by Cnidaria, followed by Algae (calcareous red algae and *Peyssonnelia* spp.), Porifera, Bryozoa and Osteichthyes; Echinodermata and Crustacea which were less represented (Fig. 2a). The temporal comparison between T0 and T1 highlighted negligible changes in protected/endangered species abundance (Fig. 2b) and in the majority of taxa, with the exception of Porifera which increased their abundance rank of more than 1 unit over time (Fig. 2a).
Pressures and threats over all study sites were mostly represented by "Organisms necrosis" and "Mucilaginous aggregations" at both T0 and T1, and did not changed over time. "*Asparagopsis* spp." was the second major pressure in T0, but dramatically decreased in T1. "*Caulerpa cylindracea"*, "Fishing gear" and "Divers recklessness" contribution was less important, both showing a slight reduction over time. "Sedimentation" was also low, but lightly increased in T1. Finally, "Anchoring" and "Litter" have shown negligible abundance and temporal variation.

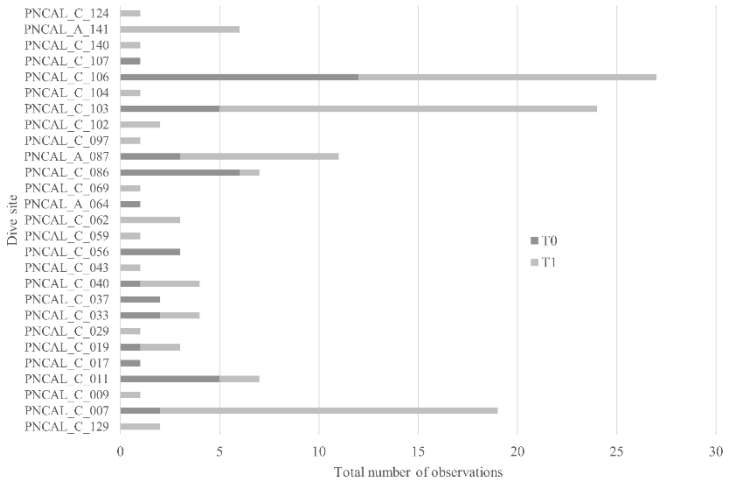

Fig. 1: Total number of observations collected in the Calanques National Park over 27 diving sites, and their distribution between T0 (dark grey) and T1 (light grey).

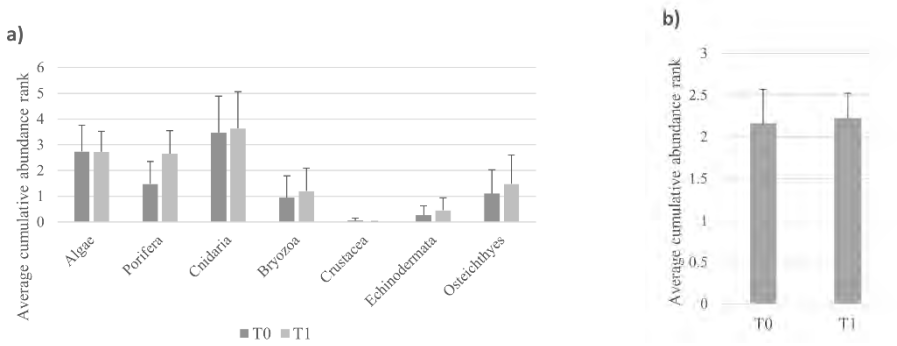

Fig. 2: Site PNCAL_C_106 (Les Pharillons) - a) Average (+SD) taxa abundance at T0 (dark grey) and T1 (light grey); b) average (+SD) abundance of protected/endangered species at T0 and T1.

Discussion and conclusion

The spatial distribution of the observations highlighted a very dispersed sampling effort. Since now, no limits were imposed to the participants on the choice of diving site. However, opting for a large set of sites reduced the number of observations in a site, as the replication process was then limited. The data acquired wasn't sufficient to be analysed in a different way than descriptive purposes, or a long-term monitoring. At the same time, the results highlighted that a handful of sites were regularly frequented, because of their strategic position, protected from the prevailing winds in the area (NW and SE winds). A temporal analysis was possible in only one site: observations were carried out regularly at T0 and T1, which was not the case for the other sites. For these latest sites, it would be necessary to wait until T2 (2021-2024 data) to start a long-term monitoring. Then, from a scientific point of view, it would be useful to concentrate the dives dedicated to CIGESMED for divers (three per diving season, at Septentrion Environnement) on these few sites, in order to obtain enough data to continue monitoring. This strategy would be in agreement with the feedback received from other diving facilities that we have been trained to the protocol: most of them usually dive on the same sites (four to five at the most). It will therefore be useful to encourage them to choose a couple of sites to do CIGESMED for divers, in order to concentrate the sampling effort and obtain useful data for the long-term monitoring and statistical analyses. Nonetheless,

during autonomous dives, volunteer observers will still have the opportunity to choose the observation site. Such information will feed the participative coralligenous database even if it is scattered.

The minimal changes observed for taxa between T0 and T1 were in agreement with the general characteristics of the coralligenous biocenosis, dominated by long-lived and slow-growing organisms (Ballesteros, 2004). The positive variation observed for Porifera could be traced to an improvement in the identification of *Agelas oroides* and *Cliona* spp. Volunteer divers have often shown difficulty in identifying those species, and this has led us to particularly insist on this issue during the training sessions. The same problem was encountered for the "Sedimentation" pressure, which however remained a particularly difficult element to identify for voluntary observers.

The overview of pressures and threats indicated “Organisms necrosis” as the most abundant at both T0 and T1 (Fig. 3). In fact, as in other areas of the NW Mediterranean Sea, the populations of gorgonians in the Calanques National Park are regularly affected by episodes of necrosis due to summer heat waves (Coma *et al.,* 2009). Some “Mucilaginous aggregations” were also observed each year. This pressure causes necrosis in several taxa of ecosystem engineers and an increase in algal turf, affecting the ecological state of the coralligenous biocoenosis (Piazzi *et al.*, 2018). The participative observation of these phenomena has contributed concretely to their long-term monitoring in the area. In the meantime, recreational divers have become aware of the impact of seawater warming on their favorite playground.

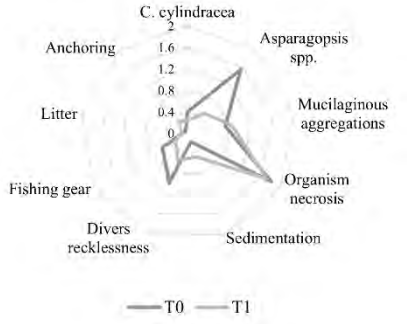

Fig. 3: Average abundance of each pressure and threat observed over all study sites at T0 (dark grey) and T1 (light grey).

CIGESMED for divers has proved to be an effective tool for the long-term monitoring of coralligenous reefs, particularly for local management purposes. It has also demonstrated to be a great tool for educational and training activities.

Considering the limitations imposed by scuba diving to citizens’ involvement, as well as the lack of knowledge from recreational divers and diving instructors regarding coralligenous communities, those results were only made possible because of the enthusiastic coordination of a local network, by the ONG Septentrion Environnement and its POLARIS platform, in constant interaction with the scientific team of CIGESMED for divers. By encouraging a feedback flow with the participants, the training sessions and the submersible slate were regularly improved and adapted according to their suggestions, reducing the observer bias and promoting the long-term involvement of citizens (Cerrano *et al.*, 2017).

CIGESMED for divers successfully took over the CIGESMED project in the monitoring of coralligenous reefs in France, as its implementation along the French Mediterranean

coasts is now encouraged by the French Biodiversity Office through the MarHa Life project (2020-2022).

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