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DIVERS UNITED FOR THE ENVIRONMENT

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PARTNERS



www.DUEproject.org

INTRODUCTION

The Mediterranean Sea represents less than 1% of the area globally occupied by the oceans, but it is considered a hotspot (a reserve) of marine biodiversity, as it is home to about 17,000 species representing 7% of the world's biodiversity, of which between 25% and 30% are endemic Mediterranean species found nowhere else in the world. The Mediterranean Sea is one of the most densely populated and highly urbanized coastal areas, with 450 million people living along its coasts in 22 neighboring countries. In addition, it provides goods and services of fundamental importance to populations, such as: recreational activities, thus supporting the tourism industry; coastal protection; commercial and recreational fishing; and the well-being associated with different natural ecosystems. However, the Mediterranean Sea is facing several direct and indirect human threats, including overexploitation of resources, habitat loss and threats to the survival of indigenous species due to climate change and the tropicalization of the sea. Extensive conservation efforts and large-scale monitoring are needed to obtain the data needed for effective management to prevent biodiversity loss resulting from human impact and climate change. Government agencies and research institutions are often underfunded, but in some cases Citizen Science can overcome the economic limitations of data collection by involving citizens in monitoring programs while increasing their active participation in scientific research and environmental awareness.

In ecology, the term "biodiversity" is defined as the number of plant and animal species present in a place, region or ecosystem. A natural and unaltered habitat has a high degree of biodiversity because many species of plants and animals live there in ecological balance. In contrast, an unnatural or altered environment has a low degree of biodiversity because it is home to only a few species. Therefore, the level of biological diversity is an indication of the state of the environment. Monitoring is essential to understand the state of the environment and is therefore preparatory to management and conservation of natural resources. If sensitised and involved, citizens can participate in monitoring actions to help protect these habitats. In previous projects, divers and snorkelers have already demonstrated their ability to act as valid detectors of the state of health of the marine environment. The "Sea Sentinels - Divers United for the Environment" (DUE project) is an environmental monitoring programme (started in 2017) that aims to estimate the degree of biological diversity of the coastal waters of the Mediterranean. The starting point of this research are the results of our previous project "Divers for the Environment - Mediterranean underwater biodiversity project" (2002-2005). The volunteer researchers are recreational divers and snorkelers. They are asked to fill in a questionnaire in which they indicate which organisms they encountered during the dive and an approximation of their abundance.

The last three decades have seen a rapid increase in recreational diving that has prompted researchers to involve recreational divers as volunteers, taking advantage of their natural interest in marine life. Many studies use strict data collection protocols, which require intensive training and require volunteers to conduct surveys at specific sites on specific species to ensure uniform data collection. This method can reduce the attractiveness of the project, thereby reducing the number of volunteers. The DUE project uses a survey protocol based on occasional underwater observations (recreational citizen science). This method allows divers to carry out normal recreational activities and guarantees the reliability of the collected data. In our previous projects we tested the accuracy of the data collected

by the volunteers by comparing it with the data collected by one of our researchers who had dived on the same day and in the same place with at least 3 volunteers, without interfering with their activities. The average accuracy of the data was 55-60% (70% of the tests were between 50% and 90% accurate). The international scientific community has confirmed the validity of our data with the publication of the results on important international scientific journals: Ecological Applications, Biodiversity and Conservation and Frontiers in Ecology and Evolution. The diving agencies, diving schools and diving centres are the protagonists of the research by filling in the questionnaires and motivating their students to do so. The questionnaires are then sent to the University of Bologna for data processing and dissemination of results.

RESEARCH GOALS

The DUE project aims to monitor the biodiversity of the Mediterranean Sea by collaborating with volunteer divers and snorkelers. The data collected can be used by local institutions as a tool to implement conservation and safeguard measures. Moreover, the project contributes to the development of ecotourism along the Mediterranean coasts, increasing the environmental awareness of tourists.

This study represents the continuation of previous monitoring programmes, with the same method of recreational citizen science, which gave excellent results and obtained international credits: 1999-2001: Mediterranean Ippocampus Mission" ([S. Goffredo, C. Piccinetti, F. Zaccanti. *Conservation Biology*, 18: 1492-1503, 2004](#)), followed by "2002-2005: Sub for the environment - Mediterranean Underwater Biodiversity Project" ([S. Goffredo, F. Pensa, P. Neri, A. Orlandi, M. Scola Gagliardi, A. Velardi, C. Piccinetti, F. Zaccanti. *Ecological Applications*, 20: 2170-2187, 2010](#)) and then from "2007-2015 "STE: Turismo subacqueo per l'ambiente" - Red Sea biodiversity monitoring program ([Branchini S., Meschini M., Covi C., Piccinetti C., Zaccanti F., Goffredo S. *PLoS ONE*, 10: e0131812, 2015](#)). These monitoring programs have been developed by the Marine Science Group (www.marinesciencegroup.org) in the Mediterranean Sea and the Red Sea and their results have been published in peer-reviewed international scientific journals.

MATERIALS AND METHODS

The questionnaire used for this monitoring program contains three sections: the first part is an informative infographic about plastics, the second part serves for the identification of the organisms detected, the third for the recording of data. The organisms examined were selected based on the following characteristics:

- ease of recognition by non-professionals;
- expected frequency: common throughout the Mediterranean.

These characteristics make this method easy to use for volunteers. The presence of waste is also recorded as an indicator of negative environmental conditions.

Volunteers are asked to fill in the survey questionnaire immediately after the end of the dive or snorkeling tour. The data are aggregated by habitat type, divided into "survey stations" (dive site where at least ten questionnaires were correctly filled in during the year) and are processed by researchers at the University of Bologna to obtain an index of marine biodiversity.

The role of diving centers, associations, diving schools and diving instructors is fundamental for the involvement of volunteers. Through a "pyramid system", prepared operators (researchers, tour leaders, divemasters and instructors) sensitize thousands of tourists and clients with briefings and assisting them during the completion of questionnaires. The students who have chosen to do their thesis internship with the Marine Science Group on the DUE project, will spend a few weeks at Italian coastal tourist facilities promoting the project and encouraging tourists to participate in the data collection. Tourists are also encouraged to participate in our project during public events, where questionnaires and information material are distributed. In order to raise awareness and involve the largest number of volunteers, local, Italian and international media are contacted for the public dissemination of the project's objectives and methods, in 2019 we reached more than [5.000.000 contacts](#). Real-time updates on research progress and relevant initiatives are published on the [project website](#), on the [Facebook page](#), on the [Instagram page](#) and sent to the volunteers by e-mail.

The Sea Sentinels project is supported by: [CONFCOMMERCIO](#) and [CONFTURISMO](#) who supported the project for 2018 and 2019; as part of this collaboration our students were hosted by several coastal tourist facilities to directly involve tourists in the project. For 2019 also the tour operator [KEL 12](#) and [NATIONAL GEOGRAPHIC EXPEDITIONS ITALIA](#) have supported the project; within this collaboration our students have been hosted in a sailing boat dedicated to the project along the Ligurian coast. [SCUBAPRO](#), one of the world's leading companies in the diving equipment sector, committed to the development of sustainable tourism as a factor of social and cultural progress, contributes to support the project. [PADI](#), the largest diving training organization in the world and supporter of environmental awareness and protection philosophies, promotes the dissemination of the project through its instructors and facilities.

RESULTS AND DISCUSSION

In 2023, 509 questionnaires (corresponding to 398 dive hours) were collected. 37% of the questionnaires were recorded by divers from our sponsoring diving agency PADI (Table 1). The involvement of several diving agencies and dive centers suggests that this monitoring program could be used as a tool to add value to recreational diving by encouraging people to dive and/or snorkel in order to collect data that will be used to check the biodiversity status of the Mediterranean Sea. Some diving schools or diving centers stood out for their contribution to data collection (Table 2). The geographical distribution of the surveys carried out covers a fairly wide area (Fig. 1), although the distribution of the surveys is rather uneven, so one of our objectives for the next few years will be to have a more homogeneous map of the areas surveyed.

The average depth of greatest stay was 8.7 m, the highest survey effort was recorded in summer (99% of dives were carried out between June and September) and in late morning (the dive start time in 78.4% of dives was between 9.00 and 14.00). This sampling distribution reflects the typical pattern of recreational tourist diving activity in the Mediterranean Sea. Divers prefer summer, when the water temperature is higher, and daytime, as night dives require specific equipment and advanced training. The distribution of the environments in which the surveys were carried out is not homogeneous, in fact 52.1% of the questionnaires recorded referred to the rocky environment, 17.7% to the sandy environment and 9.4% to other environments (e.g. wrecks, diving in the blue, etc.); the same imbalance in survey effort was recorded in the previous project (Table 3).

The calculation of the marine biodiversity index was elaborated only for the rocky seabed environment, because the sandy seabed and other environments did not reach enough survey stations to allow a meaningful statistical elaboration. For the rocky environment, a total of 107 survey stations were identified, of which 1 was present in all six years of the project, 9 recorded only in 2017, 21 in 2018, 16 in 2019, 3 in 2020, 1 in 2021, 18 in 2022 and 8 in 2023. We received questionnaires from many other dive sites but could not classify them as survey stations due to the limited number of completed questionnaires (less than 10 during a year) (Table 4). The marine biodiversity index was calculated for all survey stations of the DUE project (2017-2023) and for the Sub for the Environment + DUE project (2002-2005 plus 2017-2023).

DUE PROJECT

43.9 % of the monitoring stations (47 out of 107) were found to belong to the 'medium' environmental quality class, 40% (43 stations) to be in the 'low' class, 14% (14 stations) to be in the 'good' class, 2.8% (3 stations) in the 'very low' class and finally none to be in the 'very good' class (Fig. 2).

SUB FOR THE ENVIRONMENT PROJECT + DUE

From 2002 to 2005 (sub for the environment project) and from 2017 to 2023 (DUE project), a total of 22 546 valid questionnaires were collected for the rocky environment, of which 17 377 (77.1 %) were useful questionnaires for the analyses that led to the identification of 298 stations. Most of the data collected came from the Italian coast (Fig. 3), but also from Croatia, France, Greece, Malta, Slovenia, Spain and Turkey.

56% of the stations (167 out of 298) were found to be in the 'medium' environmental quality class, 27,5% (82 stations) in the 'low' class, 11.1% (33 stations) in the 'good' class, 5.4% (16 stations) in the 'very low' class and finally none to be in the 'very good' class.

The data we have obtained so far are not sufficient to compare the current state of the Mediterranean Sea with the one obtained 20 years ago through the "Sub for the environment" project because we do not have enough survey stations in common between the two projects. We will continue to collect data to standardize the two studies and have a continuous time series of data concerning the biodiversity of the Mediterranean Sea. We must continue to monitor and protect our sea to avoid the loss of biodiversity in the coming years due to anthropogenic pressures and impacts of climate change.

CONCLUSION

This recreational monitoring allows you to collect a significant amount of data with an acceptable level of reliability because: (1) volunteers are trained and assisted during field data collection by divemasters and instructors who have previously been trained by professional researchers; (2) the method is suitable for non-professionals because an easy-to-use questionnaire is used with species easily recognizable by recreational divers. Each year the results of the project will be presented during the communication and dissemination activities. This project represents a successful case of collaboration between researchers and citizens, demonstrating that with adequate recruitment and training, the data collected by volunteers are qualitatively equivalent to those collected by professional researchers and useful for resource management. This work reinforces the importance of citizen science projects as a fundamental tool for environmental monitoring and management activities. This method could be applied in several countries by local

governments and marine managers to implement large-scale, long-term conservation and management actions necessary in a rapidly changing world where climate change and anthropogenic uses of natural resources are causing environmental changes worldwide at an unprecedented rate.

ACKNOWLEDGMENTS

A big thank you to all our volunteers who have continued and continue to support us by reporting their sightings and sharing with us their curiosities and observations about our sea!

FIGURES AND TABLES

Table 1. Survey questionnaires registered in 2020 by different agencies. (N.S. indicates non-specified agency)

Diving agencies	Web	Filled questionnaires	%
PADI	www.padi.it	193	37,9
NADD	www.naddeurope.com	16	3,1
ESA	www.esaweb.net	11	2,2
CMAS	www.cmas.org	9	1,8
Other agencies		22	4,3
N.S.		258	50,7
Total		509	100

Table 2. Diving schools and diving centers contribution to data collection in 2020.

Diving Center-Club	City	Web	Filled questionnaires	%
SDS	Bologna (IT)	www.sdseducational.org	139	27,3
Acqua Mission	Trieste (IT)	www.acquamission.it	101	19,8
Orca Dive Club	Sta. Teresa Gallura (IT)	www.orca-diveclubs.com	74	14,5
Mare Nostrum	Ustica (IT)	www.marenostrumdiving.it	44	8,6
Moby Diving	Lampedusa (IT)	www.mobydiving.it	28	5,5
Other diving centers			108	21,4
N.S.			15	2,9
Total			509	100

Table 3. Distribution of survey effort by volunteer recreational divers, those of the previous project Sub for the Environment (2002-2005) and those of this three years of Divers United for the Environment project (2017-2020).

Year	Diving hours	Total valid questionnaires	Rocky bottom	Sandy bottom	Other environments
2002	2446	3342	2847	387	108
2003	4459	6230	5544	428	258
2004	3830	5313	4699	452	162
2005	2805	3872	3443	352	77
2017	1217	1385	1215	108	62
2018	2042	2521	1655	721	145
2019	2065	2522	1589	800	136
2020	540	668	311	306	50
2021	444	623	229	340	54
2022	1066	1385	721	283	381
2023	397	498	360	90	48

Table 4. Distribution of survey effort by volunteer recreational divers, those of these four years of Divers United for the Environment project (2017-2023), the surveys are divided in VRQ: surveys recorded, UQ: useful surveys and SQ: scattered surveys.

Region	Recorded questionnaires (VRQ)							Usable questionnaires(UQ)							Sparse questionnaires (SQ)						
	2017	2018	2019	2020	2021	2022	2023	2017	2018	2019	2020	2021	2022	2023	2017	2018	2019	2020	2021	2022	2023
Sardegna	93	250	227	121	0	50	58	37	197	190	113	0	11	25	56	53	37	8	0	39	33
Sicilia	213	212	15	0	70	92	116	129	140	11	0	57	0	78	84	72	4	0	13	92	38
Malta	3	26	41	0	0	0	0	0	0	0	0	0	0	0	3	26	41	0	0	0	0
Liguria	104	132	216	41	36	193	19	34	82	120	0	0	87	10	70	50	96	41	36	106	9
Toscana	422	368	486	109	177	94	70	306	264	401	84	141	36	58	116	104	85	25	36	58	12
Lazio	20	61	3	0	0	12	0	10	46	0	0	0	0	0	10	15	3	0	0	12	0
Campania	43	0	4	0	0	0	40	0	0	0	0	0	0	37	43	0	4	0	0	0	3
Calabria	13	0	0	0	0	45	0	0	0	0	0	0	0	32	0	13	0	0	0	0	13
Puglia	2	143	45	1	0	0	0	0	103	24	0	0	0	0	2	40	21	1	0	0	0
Abruzzo	0	24	12	0	0	0	0	0	0	0	0	0	0	0	0	24	12	0	0	0	0
Veneto	0	11	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0
Friuli - Venezia Giulia	186	106	355	5	0	0	0	184	105	346	0	0	0	0	2	1	9	5	0	0	0
Slovenia	0	0	69	0	0	0	0	0	0	69	0	0	0	0	0	0	0	0	0	0	0
Istria (Croazia)	34	163	47	9	0	21	13	19	142	27	0	0	11	10	15	21	20	9	0	10	3
Reg. litoraneo-montana (Croazia)	71	159	69	0	0	0	0	56	151	61	0	0	0	0	15	8	8	0	0	0	0
Reg. di Sebenico e Tenin (Croazia)	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Ägäis-Region (Turchia)	9	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0
Isole Baleari	0	0	0	25	0	0	0	0	0	0	10	0	0	0	0	0	0	15	0	0	0
Grecia	0	0	0	0	0	214	0	0	0	0	0	0	167	0	0	0	0	0	47	0	0
Total	5785							4152							1633						

2017 + 2018 + 2019 + 2020 +
2021 + 2022 + 2023

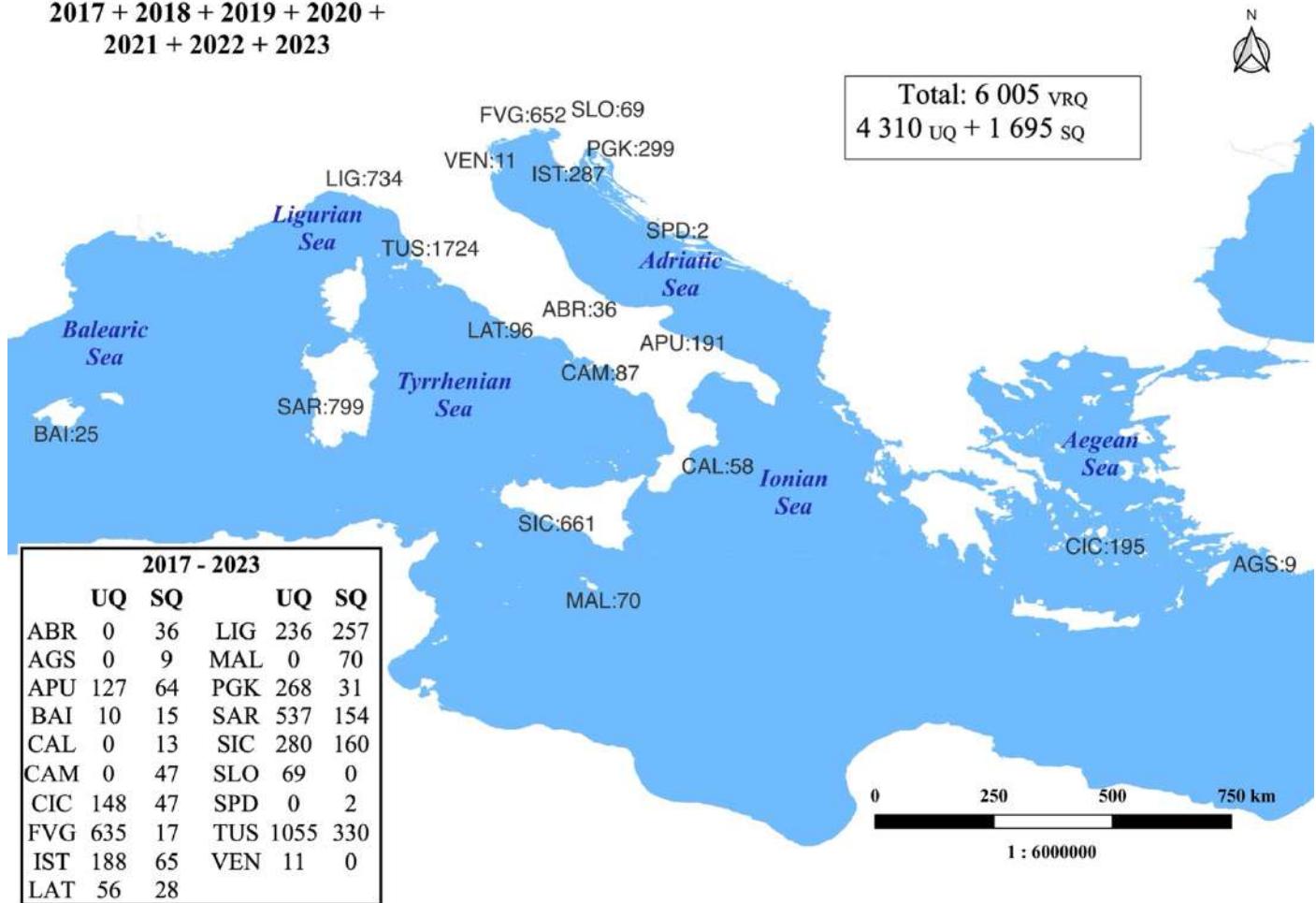


Figure 1. Geographic distribution of the survey effort performed on rocky bottom habitats over the Sea Sentinels project (2017-2023). The total number of valid recorded questionnaires (VRQ) was divided into usable questionnaires (UQ), those coming from survey stations, and sparse questionnaires (SQ), those coming from dive sites that failed to reach an annual quorum of 10 recorded questionnaires. Survey site abbreviations: ABR: Abruzzo; AGS: Agais-Region (Turkey); APU: Puglia; BAI: Balearic Islands; CAL: Calabria; CAM: Campania; FVG: Friuli-Venezia Giulia; IST: Istria (Croatia), LAT: Lazio; LIG: Liguria; MAL: Malta; PGK: Primorje-Gorski Kotar County (Croatia); SAR: Sardinia; SIC: Sicily; SLO: Slovenia; SPD: Šibenik-Knin County (Croatia); TUS: Tuscany; VEN: Veneto.

2017 + 2018 + 2019 + 2020 +
2021 + 2022 + 2023

N = 107

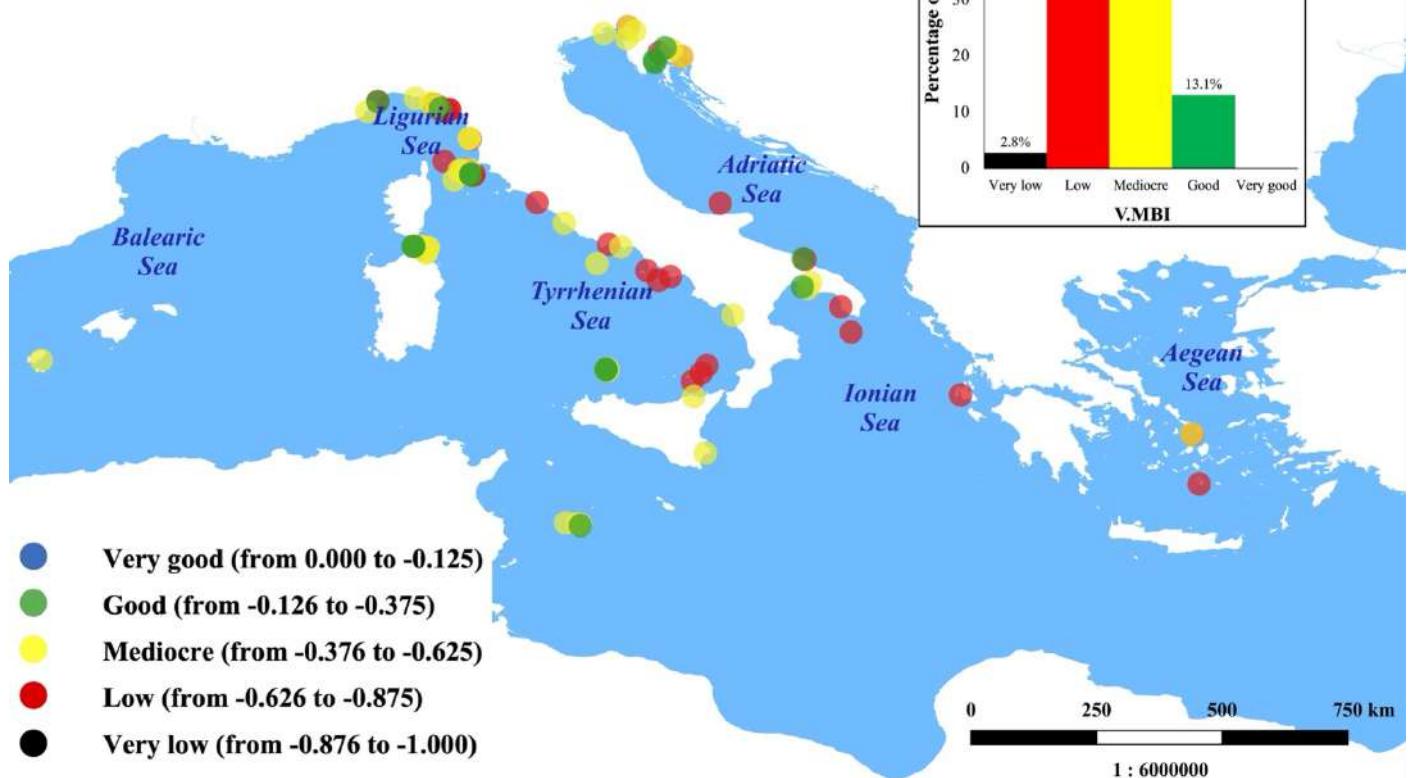


Figure 2. Environmental quality index (V.MBI) calculated for the 98 stations recorded during the 6 years of the DUE project. Most of the dive sites (54.1 %) presented an 'average' score, while none fell into the 'very good' class.

2002 + 2003 + 2004 + 2005 +
 2017 + 2018 + 2019 + 2020 + 2021 + 2022 +
 2023

Total: 22 546 VRQ
 17 377 UQ + 5 169 SQ

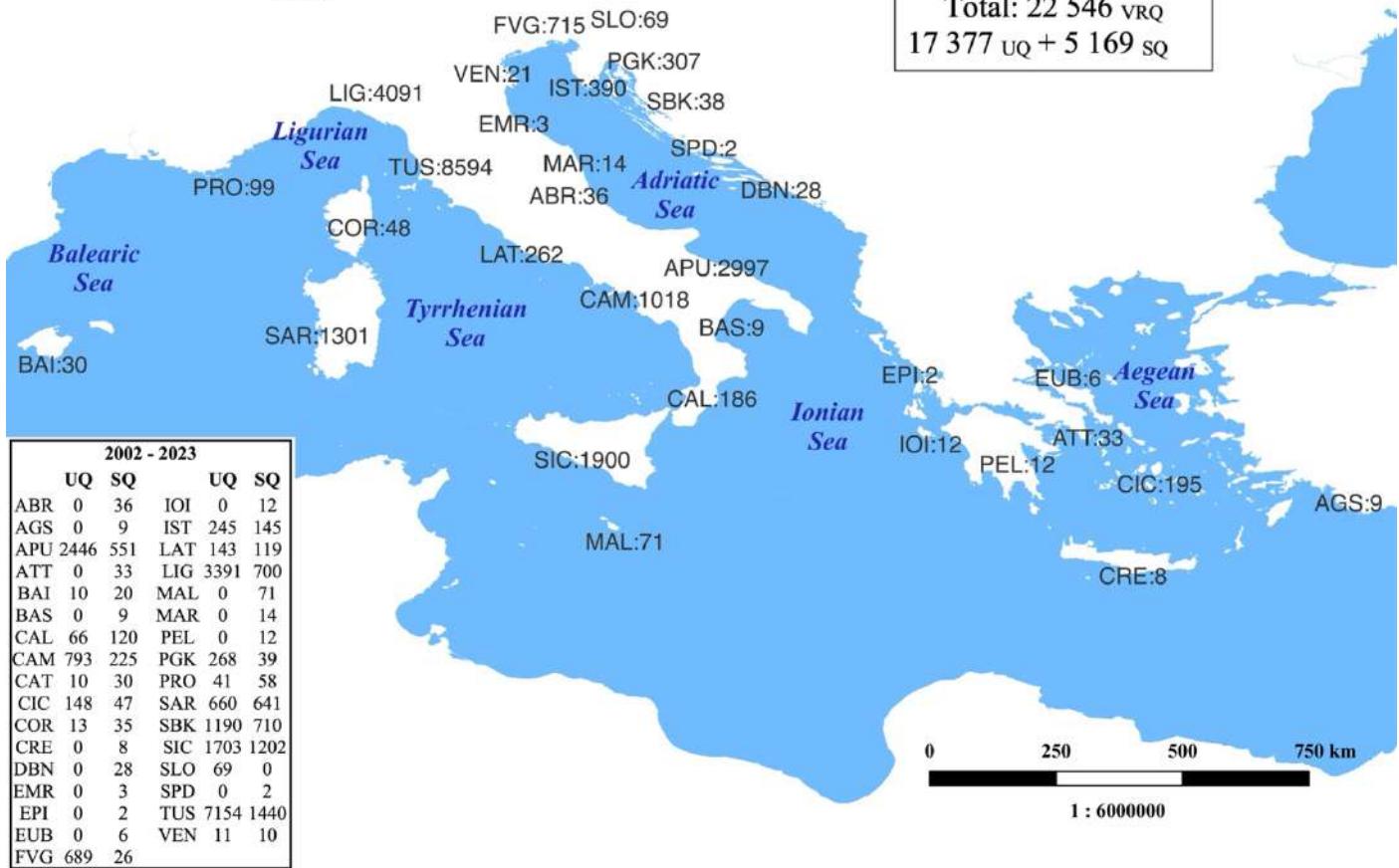


Figure 3. Geographical distribution of rock bottom questionnaires in the two projects SPA (2002-2005) and DUE (2017-2022). The total number of valid registered questionnaires (VRQ), shown in the map for each region, was divided into useful questionnaires (UQ) and discarded questionnaires (SQ). Survey site abbreviations: ABR: Abruzzo; AGS: Agais-Region (Turkey); APU: Apulia; ATT: Attica (Greece); BAI: Balearic Islands (Spain); BAS: Basilicata; CAL: Calabria; CAM: Campania; CAT: Catalonia (Spain); COR: Corsica (France); CRE: Crete (Greece); DBN: Region of Dubrovnik-Norway (Croatia); EMR: Emilia-Romagna; EPI: Epirus (Greece); EUB: Evia (Greece); FVG: Friuli-Venezia Giulia; IOI: Ionian Islands (Greece); IST: Istria (Croatia); LAT: Lazio; LIG: Liguria; MAL: Malta; MAR: Marche; PEL: Peloponnese (Greece); PGK: Primorsko-Goranska Region (Croatia); PRO: Provence (France); SAR: Sardinia; SBK: Zadaratine Region (Croatia); SIC: Sicily; SLO: Slovenia; SPD: Šibenik and Tenin Region (Croatia); TUS: Tuscany; VEN: Veneto.

2002 + 2003 + 2004 + 2005 +
 2017 + 2018 + 2019 + 2020 + 2021
 +2022 + 2023

N = 298

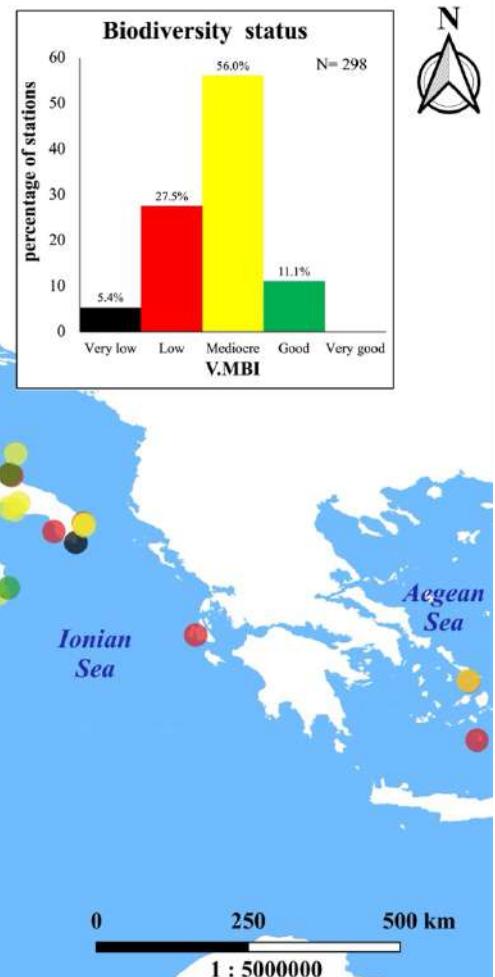


Figure 4. Environmental quality index (V.MBI) calculated for the 289 stations recorded during the 10 years of the two projects SPA (2002-2005) and DUE (2017-2022). 56.4 % of the dive sites presented an 'average' score, while only one fell into the 'very good' class.